MEDIUM VOLTAGE ELECTRICAL LINE FOR THE FEEDING OF EXTRACTION WATER PUMPS

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RESUMEN EJECUTIVO

La combinación de un clima prácticamente desértico con un incremento demográfico exponencial, derivado de una expansión económica, lleva a un incremento de la demanda de agua. Esta situación es la que se ha generado en Riad, capital de Arabia Saudí, lugar donde se enmarca este proyecto.

Con motivo de responder a esta demanda, se han buscado balsas de agua subterráneas. La más cercana a la ciudad se ha encontrado a 70km de ahí.

La compañía suministradora de agua ha pedido el diseño de una instalación para la explotación de ésta. Como toda industria, necesita de suministro eléctrico para su funcionamiento. Ahí es donde entra en acción este proyecto.

Para dar respuesta a esta necesidad energética, se ha ideado una instalación que consta de siete líneas aéreas de media tensión que se situarán sobre la balsa de agua subterránea de manera uniforme para alimentar a las bombas de extracción. Es necesario destacar que, dado que la compañía suministradora de agua será la propietaria de la instalación, han prevalecido sus peticiones por encima de optimizaciones técnicas, consecuencia de ello es que el diseño se realice a 33kV.

Este proyecto se centra en la descripción, diseño y cálculo de una de las siete líneas. Además, explica detalladamente como se realiza la alimentación de los pozos a través de una transición de la línea aérea hasta el transformador correspondiente. Estas líneas son alimentadas desde una subestación transformadora.

Por otro lado, explica el diseño de una línea subterránea que es necesaria para llevar suministro eléctrico desde la subestación transformadora hasta la planta de tratamiento de aguas.

La normativa que se ha tenido que usar es la saudita, la normativa SEC. Por petición del cliente también se ha utilizado otra normativa más restrictiva del país, la normativa Aramco. En aspectos técnicos en los que hubiese un vacío en la regulación, como por ejemplo en el sistema de puesta a tierra, se han utilizado las normas internacionales de la IEEE.

Cabe destacar que uno de los factores determinantes a la hora del diseño y que ha marcado la originalidad del proyecto han sido las condiciones ambientales. Al encontrarse en una zona prácticamente desértica con temperaturas tan elevadas se ha necesitado prever el funcionamiento de cada equipo ante condiciones extremas.

Línea Aérea

La línea aérea tendrá una longitud de 13km y alimentará a 13 puntos de extracción de agua. Su nivel de tensión es de 33kV. La capacidad de transporte, dado que cada bomba consume 390kW, es de 5070 MW. Aún eso, debido al futuro mallado de la línea, se ha realizado el diseño para una posible potencia de 13MW (252A).

Se ha decidido usar un cable tipo MERLIN con capacidad máxima de transporte de 519A. La elección del conductor se debe, en primer lugar, a la normativa. La normativa existente en Arabia, marca que los dos únicos posibles conductores a usar son el QUAIL (276A) y el MERLIN (519A). En segundo lugar, aunque parece posible el uso del primer cable, dadas las condiciones climatológicas de la instalación, el fabricante elegido, Bahra Cables, mantiene que hay una reducción de la capacidad a 241A y 396A respectivamente.

Los apoyos elegidos son los normalizados por la normativa saudita. Serán apoyos tubulares de acero alternativamente de 13 y 14 metros de altura dependiendo de las necesidades del terreno. El cálculo de éstos se ha realizado a partir del software PLS-POLE® verificando el cumplimiento de las especificaciones. Hay que tener en cuenta, que dado que el propietario de la línea es el propietario del terreno no ha surgido ninguna complicación a la hora de elegir el camino menos desfavorable de la traza. Además, cabe añadir que la instalación se enmarca en una llanura desértica, por lo que el perfil del terreno ha sido prácticamente plano.

Respecto a las cimentaciones se han calculado con el software Caisson®. Debido al tipo de apoyo usado, se han realizado cimentaciones monobloque con hormigón H150.

Los aisladores escogidos han sido rígidos y verticales de porcelana, siendo su línea de fuga de 1320 mm cumplimentando los niveles básicos de seguridad eléctrica. La unión del conductor al aislador será a través de una cinta de neopreno.

Finalmente mencionar que el sistema de puesta a tierra elegido consta de una pica de cobre de metro y medio de longitud y de 14 mm de diámetro unido a un anillo de cobre que rodea la cimentación de 95mm^2 de diámetro para aguantar las condiciones térmicas posibles derivadas de un cortocircuito.

El presupuesto de construcción de esta línea es de 414.363,35 €.

Transición Aéreo-Subterránea

Los pozos son alimentados desde las líneas aéreas. Ha sido necesario diseñar una transición desde ésta hasta el transformador. Las transiciones sólo se darán en apoyos de 14 metros, con su cimentación y su diseño mecánico correspondiente según lo detallado en la parte de la línea aérea.

Para la protección contra las posibles sobreintensidades se ha instalado un seccionador con capacidad de corte de 8kA. Como elemento de protección contra sobretensiones se ha elegido una autoválvula proveyendo de un nivel de aislamiento de 156kV al transformador.

La interfaz entre el conductor aéreo y el cable subterráneo es un terminal. Dado que el cable subterráneo elegido es tripolar, será necesario el uso de terminales tripolares en vez de unipolares.

El cable será de cobre de sección de 185 mm^2 tripolar con aislamiento extruido de XLPE. En su descenso por el apoyo, irá, en un primer lugar al aire, a una altura de 2m, se protegerán bajo un tubo de PVC para impedir su contacto directo. Finalmente, su instalación subterránea será directamente enterrado en zanja.

El presupuesto de construcción de esta instalación, contando con los 13 pozos, es de 195.059,47 €.

Línea Subterránea

La línea subterránea tendrá una longitud de 297 m y su capacidad de transporte es de 25MVA (437A)

El cable elegido será de cobre, unipolar, de sección 500 mm^2 con aislamiento extruido de XLPE. Aunque aparentemente la capacidad de conducción del cable es de 680 A, dadas las condiciones de la instalación se reduce a 528 A. Aunque se pensase que el cable elegido está sobredimensionado, el siguiente cable de sección menor que éste, normalizado es de 240 mm^2, y dadas las condiciones de la instalación, su capacidad se reduce a 341 A.

La instalación será enterrada bajo tubo. El conexionado de las pantallas de los conductores se realizará con el sistema solid bonded.

El presupuesto de construcción de esta instalación es de 130.463,71 €.

EXECUTIVE SUMMARY

The combination of a desert climate with a demographic increase, due to an economic expansion, leads to an increase of the water demand. This situation has been given at Riyadh, Saudi Arabia's capital, where this project is located.

In response to this demand, underground water reservoirs have been searched. The nearest founded is 70km away from the city.

The water company supplier has request the design of a facility for the operation of it. As any industry, it needs of electric supply for its working. That is the point where this project enters.

In order to respond to this energetic demand, it has been thought up a facility which consist of seven medium voltage overhead lines which will be located over the underground water reservoirs to feed the extraction pumps. It is needed to highlight that, as the water supplier company is the owner of the facility, their requests have prevailed over the possible technical optimization, example of this is the given voltage as 33kV.

This project focusses its attention on the description, design and calculation of one of the seven lines. Moreover, it explains how is made the well feeding through a transition between the overhead line till the corresponding transformer. These lines are fed from a transformation substation.

Also, this projects describes the design of an underground line which is necessary for the electric supply of the water treatment plan.

The regulation which has been taken into account is the Saudi's, the SEC regulation. As a client request, other local specification has been bear in mind, the Aramco. Where a specification gap has been found, IEEE international regulation has been used.

It should be emphasized that, one of the decisive factors in order to design and which has originally marked this project is its ambient conditions. As it is located on a desert site with extreme temperatures, it has been needed to test the correct operation of each equipment under these working conditions.

Overhead Line

The length of the overhead line will be 13km and it will feed 13 water extraction points. Its voltage level will be 33 kV. Its transport capacity, as the pump consumes 390kW, is 5070W. Nevertheless, due to a future gridding, the design has been done for 13MW (252A).

It has been decided the use of the MERLIN conductor with a maximum transport capacity of 519A. This election is due to, firstly, the regulation. The existent Arabic regulation stands that the only two possible conductors for medium voltage are the QUAIL (276A) and the MERLIN. Secondly, eventhough the use of the second conductor may seem possible, due to the climate conditions of the facility, the conductor manufacturer, Bahara Cables, specifies that it exists a reduction of the capacity till 241A and 396A respectively.

The elected poles are the ones normalized by the Saudi's specification. They will be octagonal steel poles of 13 or 14 m high alternatively, depending of the need of the ground. For its calculation it has been used the PLS-POLE® software, verifying the fulfillment of the requirements. It must be bared in mind that, as the owner of the facility is the owner of the site, there has not been any problem when the trace of the line has been elected. Moreover, as the location of the facility is on a desert plain, the profile of the line is mainly flat.

Regarding the foundation, they have been also calculated by the software Caisson®. Due to the type of pole used, the made foundations are single block with H150 concrete.

The chosen insulators have been rigid and vertical porcelain being its creapage distance 1320mm in order to fulfill the basic safety insulation requirements. The join between the insulator and the conductor will be made by a neoprene top tie.

Finally, mention that the earthing system will be composed by a copper lance of 1,5 m long join to a copper bare conductor of 95 mm^2 in order to stand the thermal conditions giver as a consequence of a shortcircuit.

The construction budget for the line is 414.363,35 €.

Overhead-Underground Transition

The wells are fed from the overhead lines. It has been need to design a transition between them till the transformer. The transitions will only occur on the 14m poles, its foundation and its mechanical design is the one explained on the overhead line section.

In order to protect the transformer from overloads, a fuse cut-out with 8kA as current capacity has been installed. Moreover, for the protection over overvoltage, a surge arrester has been also installed, providing 156kV as insulation level for the transformer.

The interface between the overhead conductor and the insulated cable is a terminal. As the underground conductor elected is three-cored, it has been needed the use of three-core terminals instead of single-core ones.

For the installation of these elements it is necessary the use of two additional crossarms. There will perpendicular to the insulator crossarm. One of them will contain the fuse cut-outs and the other one the surge arresters. It is important to note that, for the connection order, it goes firstly the cut out and afterwards the surge arrester.

The cable will be three-cored copper 185 mm^2 with XLPE extruded insulation. On its lowering through the pole, firstly it will go in open, secondly, at two meters from the ground, it will be protected by a PVC tube in order to prevent from its direct contact. Finally, its underground installation will be directly buried.

The construction budget for the facility, counting with the 13 extraction points, is 195.059,47 €.

Underground Line

The underground line will be 297 m long and its transportation capacity will be of 25 MVA (437 A)

The elected cable is one core, copper conductor 500mm^2 conductor with XLPE extruded insulation. Eventhough it may seem that the conduction capacity of the conductor is 680A, due to the climate condition it is reduced till 528A. Although it may be thought that this capacity exceeds from the one needed, the following conductor which is normalized is 240mm^2 and under the installation facility, its capacity is reduced till 341A.

The installation will be buried on a tube. The connection of the screens will be done following the solid bonded system.

The construction budget for this facility is 130.463,71 €.

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INTRODUCTION

1. MOTIVATION

I would rather begin this Project by introducing the main reasons which led me to its realisation.

To decide which degree I wanted to be enrolled in was a tough decision for me. I am a curious person and if something makes a difference on me is the desire I have for learning new things, but engineering had something special: the creative capacity. We are able to analyse, build and give answers and solutions on a practical and a functional way to needs. This is synonymous of improving tangibly the live quality and the wellness of the people.

In order to choose specialization, I had no doubt, the electrical was the one for me. The electric energy is on a big boom, this is due to the fact that is the cleanest, fast and efficient way to transport energy. Moreover, is the only type of energy which nowadays permits at home to have access to other type of energy such as heat and also other type of services, from the refrigerator till the hairdryer. It is functional and it is starting to be considered as a first necessity good, because its multifaceted uses that may have.

The truth is, that when the moment of choosing project came, I took into account the decision factor I always take when important decisions arrive which is people. After reading each offered project I thought, where are the people on it? Am I increasing their live quality? That is why I chose this one, due to the huge social impact it has.

Therefore, this project fits me to a tee on my approach to my future professional career. It responds to a social essential necessity: the water. Thanks to the engineering, and mostly, to the electricity, this scarce and basic good can be satisfied on the Arabic Kingdom. Building a set of high voltage lines in order to provide water to a population is a functional and practical solution to an increasing problem at Riyadh.

This is only one example of the multiple solutions that engineering offers to people. I wanted to culminate my underdegree education by a challenge like this one, which answers to one of my basic and principal moral convictions, building up a world a little bit more human, making use of the resources it provides us and trying to distribute them with equity.

2. AIM AND ADMINISTRATIVE SITUATION

The main objective of this section is to explain the different aspects that complies the electric supply facility, the contract conditions and the different specifications that shall provide the requirements of the technical conditions and guarantees.

The contractor has demand the electric system of the facility as the construction of the infrastructure to distribute power from SEC substation at Wasia area to feed:

- The well field
- The water treatment plant
- The pumping station
- The transmission pipelines

This complies the contection to SEC substation, the switchgear, the underground/overhead transmision lines to the water treatment plants, the pumping station and transmission pipelines, and the overhead transmission lines, conections to the feeding transformers of the submersible pumps, connection to the feeding transfromers of the valves. The regulation that applies at Saudi Arabia is the SEC standard. The owner of the facility will be the National Water Company, which it will be in charge of its operation and maintenance.

3. BACKGROUND AND OBJECTIVE OF THE FACILITY

This project is contextualised on the Middle East Region, to be more precise, 70km east of Riyadh, the capital of Saudi Arabia.

This country has had an impressive economic development along the last year. This idea can be perfectly appreciated analysing the data given by the IMF:

Year	GDP increase (%)	GDP (thousands of millions of dollars)	GDP per capita (dollars)	CPI Inflation (%)	Public Debt/GDP (%)	Current account/ GDP (%)
2015	4,26	770,57	24.970,33	3,53	2,35	15,00
2014	4,39	746,82	24.684,74	3,58	2,79	17,6
2013	3,57	718,47	24.246,47	3,76	3,27	19,33
2012	5,13	711,05	24.523,92	2,86	3,70	23,16
2011	8,57	669,51	23.599,11	3,75	5,40	23,69

Table 1: Arabia Saudi last few years macroeconomic data

The strong economic development has led to an exponential demographical rise of the country. The following table and graphic reveal the historical data of the population.

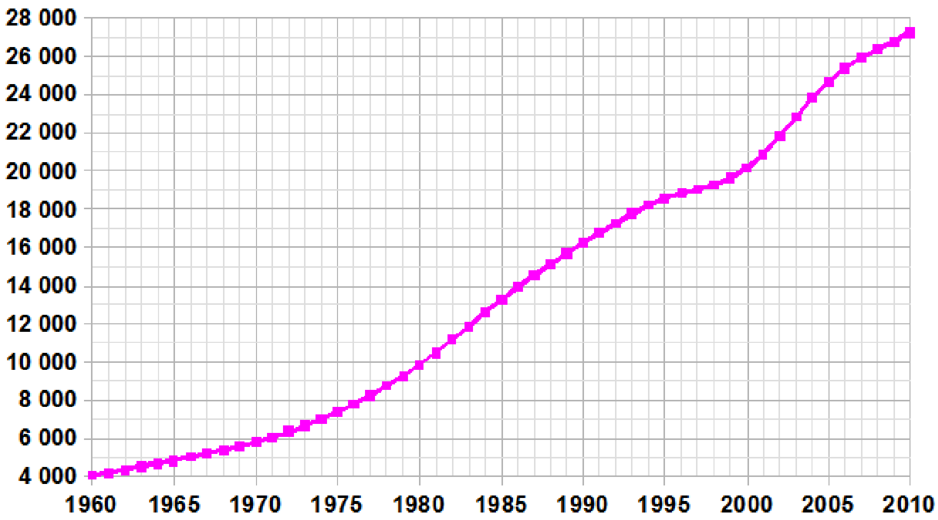


Figure 1: Saudi's demographic growth

Year	1960	1970	1980	1990	2000	2010	2015
Population	4,041,000	5,772,000	9,801,000	16,139,000	20,045,000	27,448,000	31,540,000
±%	+29.5%	+42.8%	+69.8%	+64.7%	+24.2%	+36.9%	+14.9%

Table 2 Saudi Arabian Historical Population Data

At the Arabic Kingdom the desert climate is extreme. This it can be revealed at the following climograph:

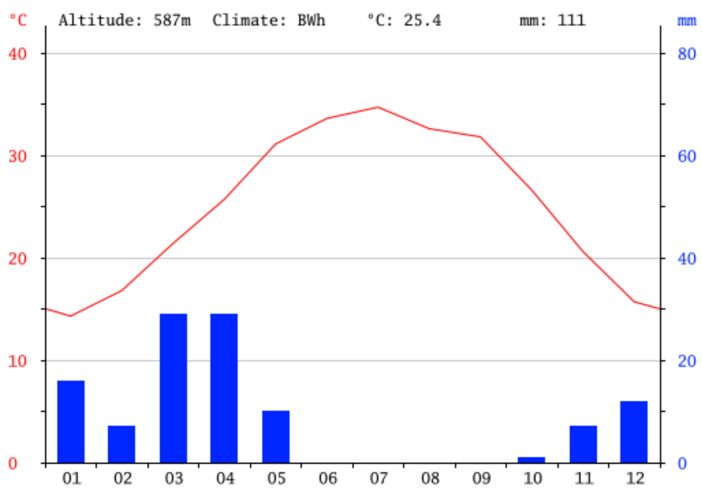


Figure 2: Saudi Arabian climograph

Summing together the two facts mentioned above, the water has turned to be an extremely scarce resource at the country. The National Water Company (NWC), the entity in charge of providing drinking water to the Saudis, has set up a new enterprise, Wasia. Wasia has been intrusted to operate an underground water reservoir founded 70 km east away from Riyadh (it is thought to be one of the Pleistocene water stores) which can supply the excess of water demanded along two years.

400.000 m^3 per day can be extracted from the massive water reservoir, which will be treated on the water plants providing daily the 300.000 m^3 of safe water which is the deficit expected at the capital on the following two years.

The supplier company has nowadays a treatment water plant 15 km southwest away from the founded area, on the Kharais road, it is intended to increase the capacity of this facility.

For the water extraction from the phreatic level till the surface it will be need different wells with pump stations. They will be uniformly distributed over the field. Moreover, for the transportation of the extracted water from the reservoir till the plant it will also be required a pumping system and a pipeline infrastructure to canalise it.

Due to the location of the water reservoir and the magnitude of the facility, it is easy to conclude that an important lack of electricity may exist.

The facility consists of a well field, a water treatment plan, water reservoirs and a pump station. The well field complies drilling wells, each of them will have a submersible pump which will extract the water and will transport it till the surface by riser pipes. It will also have a pipeline network in order to transport the extracted water to the treatment plant. This water will need the use of valves to be transported. Finally, after the water is treated it is need to transport it to the reservoirs. Therefore, a pump station and transmission pipelines are needed on the nearby of the WTP.

The entry point of the electrical power for these facilities will be the SEC substation. This substation is located 10 km away from the beginning of the undergrounded water area.

From the substation till the pumping station the electrical power will be transported by an underground line, moreover, from the substation till the WTP another underground line will transport the electric power.

On the other hand, the electrical power from the substation till the well field and till the reservoirs will be transmitted by overhead lines.

The site plan of the project is the following:

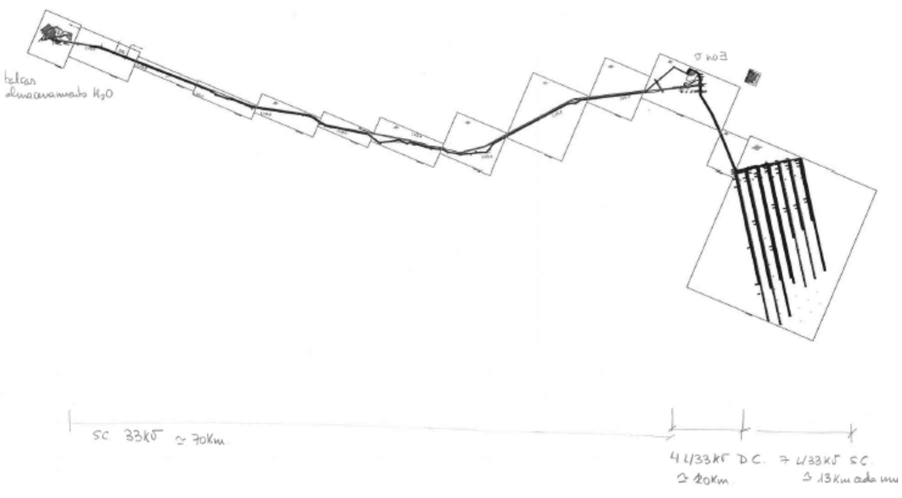


Image 1 Sketch of the Top view of the Facility

4. GENERAL CHARACTERISTICS OF THE INSTALATION

4.1 GENERAL CHARACTERISTICS OF THE LINES

The characteristics that will be insightfully explained below have been precisely specified by the contractor.

- SEC substation – Water Reservoirs line

  The line that goes from the SEC substation till the water reservoirs, which are located on the suburbs of the Riyadh city has the following characteristics:

GENERAL	
System	Three-Phase Alternating current
Nominal Voltage	33 kV
Highest Voltage of the network	36 kV
Frequency	60 Hz
Total Length	70.000 m
Origin	SEC Substation
End	Water Reservoirs
TYPE of ELECTRIC LINE	OVERHEAD
Number of circuits	1
Configuration	Horizontal configuration
Number of phase conductors	3
Maximum transport power	22,63 MVA / circuit

Table 3 Characteristics line ST-Water Reservoir

- SEC substation – Well Field

  As it has been said before, the substation is 10 km away from the well field, but afterwards, the electric power has to be transmitted to the pumps located at each well. Therefore, this transmission will be done using two type of configuration. The first one, which goes from the substation till the arrival at the well field will be shaped by four parallel double circuit lines. Afterwards, each of the circuit of each line will conform a single circuit line which will cover approximately 13 linear km of the water area. This single circuit lines will have uniformly distributed transitions to each of the pumps.

  The four lines that go from the SEC substation till the well field will have the following characteristics:

GENERAL	
System	Three-Phase Alternating current
Nominal Voltage	33 kV
Highest Voltage of the network	36 kV
Frequency	60 Hz
Total Length	10.000 m
Origin	SEC Substation
End	Well Field
TYPE of ELECTRIC LINE	OVERHEAD
Number of circuits	2 x 4
Configuration	Double flag configuration

Number of phase conductors per circuit	3
Maximum transport power	22,63 MVA / circuit x 8

Table 4 Characteristics line ST-Well Field

Once the power has arrived at the well field it will be uniformly distributed by seven parallel single circuit lines that will cover the area. It has to be taken into account that one of the circuits coming from the double circuit line will not follow a single circuit line, because it is left as a reserve, for future needs.

The seven lines mention above will have the following main characteristics:

GENERAL	
System	Three-Phase Alternating current
Nominal Voltage	33 kV
Highest Voltage of the network	36 kV
Frequency	60 Hz
Total Length	Between 13.000 and 17.000 m (aprox.)
Origin	Well Field
End	Water Well Pump
TYPE of ELECTRIC LINE	OVERHEAD
Number of circuits	1 x 7
Configuration	Horizontal configuration
Number of phase conductors	3
Maximum transport power	22,63 MVA / circuit x 7

Table 5 Characteristics line Well Field-Water Well Pump

Note that as seven lines of this type will cover this trail, the length of the line will vary between 13 or 17 km. In addition, as at every kilometre a subtraction pump will be found, the power will decrease as the track is trailed.

- SEC substation – Transformers for Water Treatment Plant (WTP) [LOT 4]

GENERAL	
System	Three-Phase Alternating current
Nominal Voltage	33 kV
Highest Voltage of the network	36 kV
Frequency	60 Hz
Total Length	297 m
Origin	SEC substation
End	WTP
TYPE of ELECTRIC LINE	UNDERGROUND
Number of circuits	1
Configuration	Flat formation
Number of phase conductors	3
Maximum transport power	25 MVA / circuit

Table 6 Characteristics line ST-WTP

- SEC substation – Transformers for Pumping Station [LOT 5]

GENERAL	
System	Three-Phase Alternating current
Nominal Voltage	33 kV

Highest Voltage of the network	36 kV
Frequency	60 Hz
Total Length	145 m
Origin	SEC substation
End	Pumping Station
TYPE of ELECTRIC LINE	UNDERGROUND
Number of circuits	2
Configuration	Trefoil formation
Number of phase conductors	3
Maximum transport power	25 MVA / circuit

Table 7 Characteristic line ST-Pumping Station

4.2 OWNER OF THE FACILITY AND LOCATION

The owner of the facility and of the terrain of this Project is Wasia Enterprise, therefore non-amicable settlement or expropriation shall be made.

As it has been said before the facility is located 70km east of Riyahd city and 15km of the existing WTP/PS Wasia. It will be parallel to the actual Khrais Road.

Overview of the affected site:

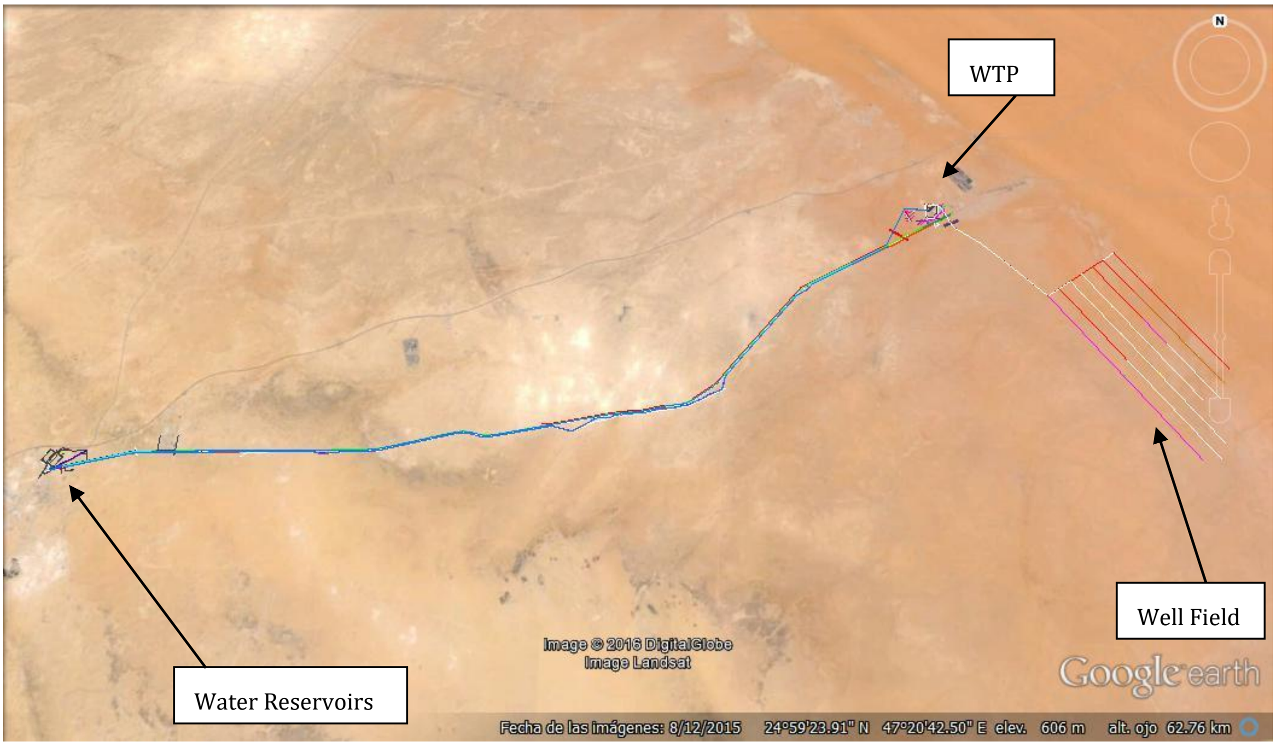


Image 2: Site Plan

4.3 STUDY PARTS

As it can be appreciated, the project described above has a magnitude that cannot be contemplated by a degree thesis. Therefore, this degree thesis will focus on three main parts, the ones that have been thought that will increase the knowledge of the line engineering.

The first one is the study of one of the single circuit line that goes throw the exploited area. The line chosen is Line 1.

The second one is the feeding from the single circuit line to the transformer before the pump and the well, as any transformer is the same as the others, only one design will be explained.

The third part will be an underground line, the underground line chosen is the one that links SEC substation to the Water Treatment Plant (LOT4).

SPECIFICATION DOCUMENT

The main goal of this Specification Document is to name the technical standards this project must follow in order to implement it. Most of them correspond to the Saudi Arabian Regulation, nevertheless when a legal vacuum has been met, international standards have been applied.

OVERHEAD LINE

01-SDMS-01 rev01	Specifications for general requirements for all equipment / material
10-SDMS-01 rev00	Specifications for 13.8&33kV overhead line conductors (ACSR/AW type)
15-SDMS-01 rev00	Specification for overhead line porcelain insulators
20-SDMS-01 rev02	Specifications for Octagonal steel poles for distribution lines
20-SDMS-02 rev01	Specifications for overhead line accessories
SAES – P – 107	Overhead distribution system. Saudi Aramco Engineering standard.
01-SDMS-01 rev00	Construction standard for overhead lines
IEEE C2 2007	National Electrical Safety Code (2007)

EARTHING SYSTEM

01-SDMS-01 rev01	Specifications for general requirements for all equipment / material
01-SDMS-01 rev00	Construction standard for overhead lines
IEC 60909-3	Short-circuit currents in three-phase AC systems - Part 3: Currents during two separate simultaneous line-to-earth short circuits and partial short-circuit currents flowing through earth
IEC 60909-0	Short-circuit currents in three-phase A.C. systems - Part 0: Calculation of currents
IEC TS 60479-1	Effects of current on human beings and livestock - Part 1: General aspects
IEC TR 61201	Extra-low voltage (ELV) - Limit values.
IEC GUIDE 104	The preparation of safety publications and the use of basic safety publications and group safety publications.
IEEE 142	Recommended Practice for Grounding of Industrial and Commercial Power Systems.
IEEE 81	Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System
IEEE 1410	Guide for Improving the Lightning Performance of Electric Power Overhead Distribution Lines

IEC 61024	Protection of structures against lightning

WELL TRANSFORMER FEEDING

01-SDMS-01 rev01	Specifications for general requirements for all equipment/material
10-SDMS-01 rev00	Specifications for 13,8&33KV overhead line conductors (ACSR/AW type)
11-SDMS-03 rev02	Specifications for XLPE insulated power cables for rated voltages form 15kV up to 36kV (Um)
15-SDMS-01 rev00	Specification for overhead line porcelain insulators
20-SDMS-01 rev02	Specifications for octagonal steel poles
20-SDMS-02 rev01	Specifications for overhead line accessories
34-SDMS-01 rev 00	Specifications for MV dropout fuse cut outs
35-SDMS-01 rev00	Specifications for metal oxide surge arresters
01-SDMS-01 rev00	Construction standard for overhead lines

UNDERGROUND LINE

01-SDMS-01 rev01	Specifications for general requirements for all equipment/material
11-SDMS-03 rev 02	Specifications for XLPE insulated power cables for rated voltage for 15kV up to 36kV (Um)
01-SDMS-01 rev01	Specifications for general requirements for all equipment / material
IEC 60502 Part 2	Cables for rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)
Bahra Cables	Medium Voltage Power Cables

ELEMENTS OF ELECTRIC LINES

CHAPTER I: OVERHEAD LINE'S ELEMENTS

1. INTRODCUTION

This section will describe the process of design of an electric line. In order to start designing the first thing to know are the basic features of the line, these are: the type of current, the disposition, the technology of the conductor, and the voltage level.

The type of current can be direct (DC) or alternating current (AC). Up to now, most of the electrical lines built have been AC lines, nevertheless it has been proved that AC is more economic only to a critical distance, 800 km (approximately). In order to use DC lines, it is need a converter station AC/DC at the generation point and another DC/AC, as the consumers are AC, this stations are very expensive, therefore there is a compromise between distance and cost between alternating and direct current. As the line studying is a 13 km long line, the type of current chosen is alternating current.

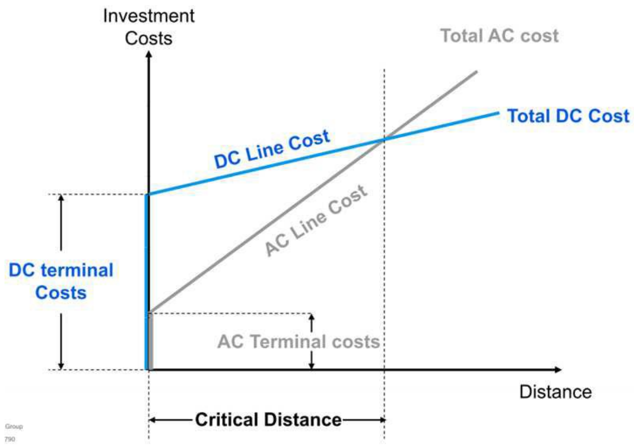


Figure 3: Relation Cost Between AC and DC lines

The disposition chosen is overhead line. In order to choose the disposition is important to take into account the following different factors. While describing the different factors it will be easy to notice why the overhead disposition is the best one for this facility:

- *Costs:* As the overhead technology has been more developed, the cost of the overhead lines is cheaper than the cost of undergrounded lines for long distances.
- *Security of the Electric System:* When a short circuit occurs or any operation maintenance is needed, as it is visible, is easy to operate on it, leading to a more efficient and secure system.
- *Visual Impact:* The visual impact of the underground lines is almost null, as it cannot be seen, while on the overhead line is complete. This is one of the main reasons why at urban sites, any electric transmission is done by underground connections. As the site where is located the facility is over the desert, non-visual impact is applied.
- *Occupation and Cost of the site:* As the owner of the land is the contractor of the overhead line, this has not been a determinant fact.
- *Environment Effects:* The underground line provides far less environmental damage than the overhead lines. The underground line does not need the quantity

of cut down trees than the overhead ones. Moreover, the overhead line implies difficulties on the bird fauna of the region, due to possible collisions between the bird and the earth wire. As the area of the facility is a dessert, non-cut down tree is needed, also, as the line voltage is medium voltage, non-earth wire is installed.

The technology of the conductor is a direct consequence of the disposition chosen. The overhead lines lead to bare conductors instead of the insulated conductors. The conductors of the overhead lines do not need of insulated materials as the air acts like an insulator due to its electric strength.

Finally, the last fact to be chosen is the voltage level. As the electric power is mathematically defined as:

$$P = U \cdot I$$

Therefore, in order to transport the same power, a higher voltage, lower current, and consequently cheaper wire. In the Saudi Arabian specification 01-SDMS-01, Rev. 01 it is determined the different voltage levels than can be used at the electrical installations, which are:

- 33 kV
- 13,8 kV
- 380V
- 220V

Hence, the voltage level chosen is 33kV.

Thus, the main features of the line will be:

Type of Current	Alternating Current
Disposition	Overhead line
Conductor's Technology	Bare Conductor
Voltage Level	33 kV

Table 8 Main Characteristics of Line 1

Once these characteristics have been decided, it is high time to analyse the different elements that will be used, which are:

- Conductor
- Insulators
- Poles
- Accessories
- Foundations
- Earthing system

2. CONDUCTOR

The conductor is the element which is in charge of the transmission of the electric current along the line, therefore, the electrical characteristics of it are essential to the line design.

Nevertheless, not only the electric features shall be taken into account, but also the mechanical ones. As the conductor will be stringed between two poles it is important to make note of its mechanical strength. Thus, there will be a compromise between electrical and mechanical materials when the line design shall be made.

2.1 ELECTRICAL ASPECTS

Regarding the electrical aspects, any line has its fundamental electric constants, which are: resistance, inductance, capacitance and conductance.

The resistance is known as the opposition that any material offers to the current passing through. It is the main cause of power losses, which are known as the Joule's effect.

Mathematically, the Joule's effect is defined as:

$$P = R \cdot I^2$$

Where:

- P: Loss Power (W)
- R: Resistance (Ω)
- I: Electric Current (A)

According to the last expression, in order to reduce power losses, it shall be necessary to reduce either the current or the resistance. As the current cannot be reduced because is determined by the power demanded the only way of reducing the losses is reducing resistance.

The resistance of a conductor is mathematically defined as:

$$R = \rho \cdot \frac{L}{S}$$

Where:

- R: Resistance (Ω)
- L: Length of the wire (m)
- S: Section of the wire (mm^2)
- ρ: resistivity of the material $\left(\frac{\Omega \cdot mm^2}{m}\right)$

The resistance of a conductor is directly proportional to the length of it, as it will be the length that the electrons must travel. It is important to note that this length it is slightly bigger than the length of the line as the conductors are not solid but twisted.

The section of the wire has an inverse relation with the resistance as the bigger the section the more distance the electrons have to flow. The section is directly determined by the current that needs to be transmitted. Moreover, something similar to what happens with the length happens with the section, as the cable is twisted, the real area is smaller than the theoretical one, thus, the resistance is slightly bigger.

The resistivity it is the opposition that any material offers to the current pass throw per unit of length and per unit of surface at a certain temperature. Hence, the resistivity depends on the material and on the ambient temperature. This is mathematically expressed as:

$$\rho_{\theta} = \rho_{20º} \cdot (1 + \alpha(\theta - 20))$$

Where:

- ρ_{θ}: resistivity of the material at the working condition temperature $\left(\frac{\Omega \cdot mm^2}{m}\right)$
- $\rho_{20º}$: resistivity of the material at 20ºC $\left(\frac{\Omega \cdot mm^2}{m}\right)$
- α: thermal coefficient of the resistivity $\left(\frac{1}{ºC}\right)$
- θ: Working condition temperature (ºC)

As the length and the section cannot vary due to the specifications of the line, the only way of reducing the resistance of a conductor is choosing a conductor which its resistivity at 20ºC it is small.

The most common conductors used at the overhead lines are made of aluminium and copper. Its characteristics are:

Material	COPPER	ALUMINIUM	Relation Copper/Aluminium
Resistivity $\left(\frac{\Omega \cdot mm^2}{m}\right)$	0,0176	0,026	0,68
Density $\left(\frac{kg}{m^3}\right)$	8,9	2,7	3,29
Mechanical Strength $\left(\frac{N}{mm^2}\right)$	427	165	2,59
Price $\left(\frac{€}{kg}\right)$	4,15	1,38	3

Table 9 Characteristics of Conductor Materials

As it can be revealed by the data, the copper has a lower resistivity than the aluminium but it is 3,29 heavier. Also the mechanical strength is better, but the price is three times higher. Hence, a compromise exists between the electrical and the mechanical features of the conductor, and between electrical and economic benefits.

As the economic aspect is the most important in order to choose the conductor, the aluminium cable is elected. Nevertheless, the lack of mechanical properties must be supplied. The use of a combination of aluminium and steel complete this deficiency. It exists different ways to make this combination.

- ACSR: Aluminium Conductor Steel Reinforced:
- ACSR/AW: Aluminium Conductor Steel Reinforced Alumoweld
- AACSR: Alluminium Alloy Conductor Steel Reinforced

ACSR: Aluminium Conductor Steel Reinforced

These conductors are made of different wires of aluminium and galvanized steel. They are cored in different concentrical layers, putting the steel reinforced wires on the centre while the aluminium wires are put next to the periphery.

The galvanized steel can usually be made of 1, 7 or 19 wires. The diameter of the steel wire can be the same as the one of the aluminium wire or different.

Thus, varying the proportion between steel and aluminium it can be achieved the exact characteristics demanded as the aluminium increases the electric conductivity while the steel increases the mechanical strength.

ACSR/AW: Aluminium Conductor Steel Reinforced Alumoweld

This type of conductor follows the same idea as the ACSR but it improves its technique. The main difference is that the steel wires are covered with aluminium. Hence, it has the same mechanical strength but better conductivity.

It also reduces the possibility of corrosion inside, between the different wires of the conductor when the characteristics of the ambient are aggressive. Moreover, it weights between 3% and 6% less than its equivalents in ACSR.

It is the most commonly used type of conductor nowadays.

AACSR: Alluminium Alloy Conductor Steel Reinforced

The main difference between the AACSR and the ACSR is that the composition is not aluminium and steel wires but aluminium alloy and steel wires. The aluminium alloy increases the ultimate elongation, therefore this type of conductor it is ideal for long spans.

The types of conductors allowed by SEC regulations are specified on the 10-SDMS-01 specification, which are:

TYPE OF CONDUCTOR	Area (mm^2)	Overall Diameter (mm)	Strand Diameter		AMPACITY* (A)
			Al (mm)	Al-Clad(mm)	
MERLIN/AW	170,5	11,35	3,472	3,472	519
QUAIL/AW	67,44	11,34	3,782	3,782	276

Table 10 Conductors allowed by the SEC specification

*Note that this ampacity does not take into account the correction factors that shall be borne in mind due to the ambient conditions.

The reason why the steel it is placed on the core of the conductor is the skin effect. The uniform distribution along the surface of the conductor only takes place on direct current.

The skin effect is due to the different variation the magnetic field has along the section, being bigger on the centre. Thus, the current tend to circulate on the outskirts of the conductor. This effect increases with the frequency.

As there is a reduction of the effective section of the wire, the resistance is bigger. This is mathematically modelled by the following formula:

$$R_{AC} = R_{DC\ 20^{o}C} \cdot (1 + \alpha(\theta - 20)) \cdot (1 + \Upsilon_s)$$

Where:

- R_{AC} (Ω): Resistance of the conductor operating at its ambient condition with alternating current
- $R_{DC20ºC}$ (Ω): Resistance of the conductor operating at 20ºC with direct current
- α: thermal coefficient of the resistivity $\left(\frac{1}{ºC}\right)$
- θ: Working condition temperature (ºC)
- Υ_S: skin effect corrector coefficient (it is obtained empirically, it depends mainly on the frequency and on the geometric structure of the conductor)

2.2 MECHANICAL ASPECTS

The conductor shall be laid in between two structures (lattice towers or poles), which are of different height and weight. The horizontal distance between two structures is called span. The stringing of the conductor will shape a curve which is called catenary and the distance between the lowest point of the curve and the straight line which joins the two structures is called sag.

The mechanical calculation of the conductor has two main objectives:

- Determine the mechanical stress of the conductor so the conductor is not submitted to worse conditions than its mechanical limits, leaving a security coefficient.

- Determine the maximum sags, in order to know which shall be the height and the distance between the structures.

Therefore, the cable has to have three essential characteristics:

- Flexible
- Elastic
- Expandable

In order to increase the flexibility of the conductor the conductors are not made solidly by a unique wire but different wires shape them. The way the wires are disposed is helicoidally twisted. Eventhough, as it has been said before, the helicoidally twist increase the resistance of the conductor, it provides the needed flexibility for the overhead lines. If they were solid, it will be physically impossible to make its transportation, the stringing, etc.

As it have been said before, the conductor chosen could be either Quail or Merlin shall be bimetallic, due to the presence of aluminium and steel, thus, its mechanic properties will be a combination of the two metals depending on its proportion.

Modulus of Elasticity (E):

$$E = \frac{E_S \cdot S_S + E_A \cdot E_S}{S}$$

Linear expansion coefficient (α):

$$\alpha = \frac{E_S \cdot S_S \cdot \alpha_S + E_A \cdot S_S \cdot \alpha_A}{E_S \cdot S_S + E_A \cdot S_A}$$

The modulus of elasticity and the linear expansion coefficient of the steel and of the aluminium is the following:

Material	Modulus of Elasticity (GPa)	Linear Expansion Coefficient $\left(\frac{10^{-6}}{ºC}\right)$
STEEL	210	12
ALUMINIUM	70	23

Table 11 Mechanical Properties of the Aluminium and of the Steel

Thus, the mechanical characteristics of the conductor Quail and Merlin shall be in between those values.

Conductor	Number of Wires	Modulus of Elasticity (GPa)	Linear Expansion Coefficient $\left(\frac{10^{-6}}{ºC}\right)$
QUAIL	1St+6Al	84	18,9
MERLIN	1St+18Al	70,74	21,2

Table 12 Mechanical Properties of the Proposed Conductors

Note: This is general data; each manufacturer will use a type of steel or a type of aluminium that will might defer slightly with the data proposed at this two tables.

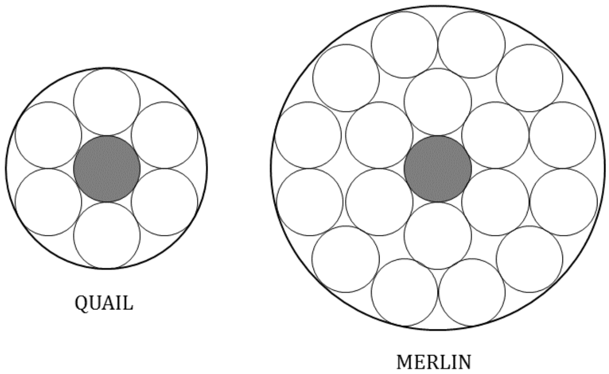


Image 3 Quail and Merlin Section

3. INSULATORS

The insulators are the elements in charge of joining the conductors to the towers and maintaining the tower isolated from the conductor during service conditions and during overvoltage situations.

Thus, they must stand not only the loads generated as a consequence of overvoltage situations but also the different mechanical loads that the conductor transmits to the pole. Hence they must fulfil electrical and mechanical requirements.

3.1 INSULATOR CHARACTERISTICS

Perforation Voltage: Is the voltage level at which the mass of the insulator is drilled by the electric arc. When this occurs, the isolation turns to be completely useless as there does not exist any possibility of regeneration. Hence, a high perforation voltage is always recommended.

Flashover Voltage: Is the voltage level at which the electric arc is generated passing through the air following the shortest distance between phase and earth, which is the surface of the insulator. Thus, a high flashover voltage is always searched.

Mechanical Resistance: To stand the different efforts demanded by the conductor.

Thermal Variation Resistance: As the insulators are outdoor installed, its material shall stand the different oscillation of the temperature without losing its isolating properties.

Lack of aging: During its useful life, it is sought a non-loss of the isolating properties.

Mixed Resistance: The insulator shall resist combined electric, thermal and mechanical efforts.

3.2 ELECTRICAL DESIGN

For the electrical design, they are two factors that must be taken into account: the different types of overvoltage and the pollution level.

3.1.1 Types of Overvoltage

When the voltage of the line reaches any value beyond the highest peak of the nominal voltage of the system it is considered as an overvoltage.

The overvoltage is a temporary phenomenon, the parameters that shall be taken into account are:

- Peak Value
- Oscillation Frequency
- Duration

The highest operating voltage considered when the nominal system voltage is 33kV is 36kV, beyond this value, any tension is considered overvoltage.

The classification of the overvoltage can be either according the lasting time, the origin or the type of transitory. The common way of classifying is according to the origin.

Temporary Overvoltage

Overvoltage between phases or earth and phase, at a similar system frequency. Its duration is relatively long (t ≥1ms) and it is not damped.

The origin of it can be:

- Earth Fault: Causes Phase-Earth overvoltage on the healthy phases
- Sudden load loss: Causes Phase-Earth, Phase-Phase and Longitudinal overvoltage
- Ferroresonance: Causes Phase-Earth, Phase-Phase and overvoltage
- Synchronization: Causes Longitudinal overvoltage

Earth fault: It essentially depends on the neutral arrangement

$$U_{PEAK} = k \cdot \frac{\sqrt{2}}{\sqrt{3}} \cdot U_{PP}$$

Where:

- U_{PEAK}: Overvoltage Value (V)
- U_{PP}: Phase to Phase Value (V)

- k: Earth Fault Factor (-)

NEUTRAL ARRANGEMENT	k
Connected solidly to earth	1,4
Not connected solidly to earth	1,7
Isolated	1,9

Table 13 Earth Fault Factor

Sudden load loss: It occurs when all of a sudden a big consumer is disconnected of the line, it causes overvoltage at the end of the line.

Ferroresonance: It occurs when saturable inductive loads comply an enclosed circuit with a capacitive part of the system. It is usual:

- Inductive transformers with a capacitive Thèvenin equivalent phase to earth on grids which have isolated neutral as neutral arrangement.
- Capacitive transformers due to the interaction of its internal capacities with the harmony inductance.
- Power transformers feed by isolated cables after the opening of one or two phases.

Synchronization: When two non-synchronized grids have an open switch in between, appears between the contacts a potential difference. The worst case is when the two tensions are on opponent phases.

Slow Forefront Overvoltage

This temporary overvoltage it is highly damped, its peak value is around 4 times the nominal system voltage and its duration is short (t∈ (10μs, 10ms)). The frequency of the wave is between 2 and 10 kHz.

Its origin is the operation of a switch, its opening or closing causes a modification on the state and on the configuration of the network leading to transit phenomena.

Usually three types of operations are done: connection and auto-reclosing of a line; fault elimination and operation with inductive and capacitive loads.

Fast Forefront Overvoltage

This temporary overvoltage is damped. Its peak value is more than 4 times the nominal system value and its duration is extremely short ($t \leq 10$ µs). Its origin is the atmospheric discharge.

The impact of the thunderbolt can be located on an earth conductor, on the tower or on the nearby of the line.

Earth conductor atmospheric discharge: Two waves are generated. The current value of them is the half of the intensity of the thunderbolt. These waves travel on opposite directions toward the poles. On the poles, part of this current is goes directly to earth and another part causes the arc arcing. The arc arcing helps to the flow of that part of the current.

Tower atmospheric discharge: Most of the thunderbolt is conducted directly to earth. Nevertheless, as the intensity of the thunderbolt is extremely high, the arc arcing is generated, causing the flow of part of the current of the thunderbolt throw the line.

Nearby atmospheric discharge: Causes the flashover of the insulators, this means that some of the components of the insulators which normally has no tension start to be connected.

3.1.2 Pollution Level

The pollution level is essential when electing the insulators. Depending on the ambient conditions, the quantity of dust that can be posed on the surface of the insulator can vary. If too many dust is located on the surface, part of the current which is transported by the conductors can deviate itself throw the dust and finally arrive to the pole. This is because the isolating properties of the insulator are much different to the ones the dust provides, therefore, the auto-cleaning of the insulator (set by the shape of it) depends directly on this value.

The contamination level for this project is:

- Equivalent Salt Deposit Density (ESDD) in a period of any six: 0.3 to 0.5 mg/cm^2
- Average hydrogen sulphide in the atmosphere: 40 mg/m^3 (0.03 ppm)
- Soil salinity: 0 to 140 g/m^3 (0 to 100000 ppm)

3.1.3 Type of discharges

Sometimes, eventhough the pollution level and the types of overloads are taken into account, the current can make a discharge flowing from the conductor to the pole. The reasons why this may happen are the following:

Material Conductivity: The current flows throw the insulator mass. In order to avoid this, the material used are the ones who have a despicable leakage current.

Superficial Conductivity: The current flows over the insulator surface due to a conductivity increase. This increase is caused by the posed of dust or by the humidity. This conductivity is highly reduced by choosing the adequate insulator profile.

Insulator Mass Perforation: It is almost impossible to maintain the dielectric uniformity along the whole mass of the material, thus, it exists the risk of the material perforation, this risk increases when the thickness is big. Hence, the insulators are usually made by pieces of small thickness.

Disruptive Discharge Through Air: The current flows through the air when the dielectric rigidity is not enough to avoid the discharge. This happens under raining or high humidity conditions due to the air ionization. In order to avoid this type of discharge, the length of the insulator is increased, needing therefore, a bigger voltage to produce the electric arc through air.

As it can be noticed, the only type of discharge that leaves the insulator completely useless is the perforation discharge. A new element has been design to prevent from this type of discharges, this elements are called dischargers.

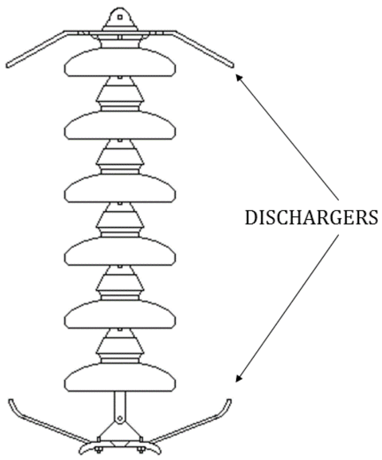


Image 4Dischargers

3.3 MECHANICAL DESIGN

The insulators shall have mechanical characteristics which stand the different loads the conductor will transmit to the pole.

These loads depend on the disposition the insulator is installed, it can be suspension set or tension set.

Tension set: The loads of the conductor are stood by the insulator.

Image 5 Tension Set Insulators

Suspension set: The loads of the insulator are lower than on the tension set and are obtained by the equilibrium equations.

Image 6 Suspension Set Insulators

Most of the insulators manufacturers have normalized loads stands of the insulators.

3.4 TYPES OF INSULATORS

The insulators can be classified either according the insulator material (glass, porcelain or polymeric) or either according the way of shaping the insulator (cap and pin or long rod)

3.4.1 Material Classification

Porcelain Insulators

The porcelain is composed by quartz and kaolin. It is manufactured by moulding with a thermal drying treatment. Afterwards, it is covered by a silicate layer. The insulator passes through another thermal treatment at 1300ºC in order to obtain a heated glaze.

The aim of the glaze is to increase the mechanical resistance of the material and to hinder the pose of dust or humidity on the surface.

As cons, the porcelain is a non-hydrophobic material, it will wet itself when raining conditions may occur. Therefore, this type of insulator need of cleaning maintenance. In addition, in case of impact, the internal damage of the material is hardly seen.

Glass Insulators

The glass is made by a mix of silicic acid and oxides (calcium oxide, sodium oxide, barium oxide, aluminium oxide…). It is manufactured by casting moulding. Afterwards a tempering is done. The objective of this tempering is to increase the mechanical and thermal variation resistance of the material, which is obtained by sudden cooling.

As cons, this type of material is also non-hydrophobic, hence a cleaning maintenance shall be done. As pros, in case of impact is easy to know where the damage is.

Polymeric Insulators

This type of insulator is made of a nucleus of glass fibre which are axially aligned and are imbued on resin. The nucleus is all over covered with silicone gum.

This type of insulator has been achieved due to the search of better insulation materials at highly polluted places. Also, as the material is hydrophobic, non-cleaning maintenance is demanded.

3.4.2 Shape Classification

Cap and Pin Insulators

Usually porcelain and glass insulators are shaped with a cap and pin structure.

- Standard Insulator: most common, they are used at low polluted areas.

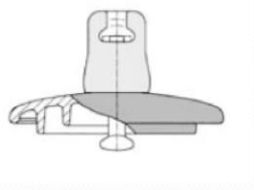


Image 7 Standard Insulator

- Antipollution Insulator: Ideal for medium or high polluted areas. As the creepage distance is increased, the reducing the risk of superficial conduction instead of increasing the length of the insulator.

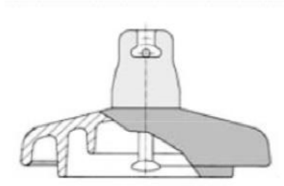


Image 8 Antipollution Insulator

- Aerodynamic Insulator: Recommended at desert zones, the lack of ribs makes easier the self-cleaning due to the wind action. Also, it makes more difficult the pose of dust over the surface of the disc.

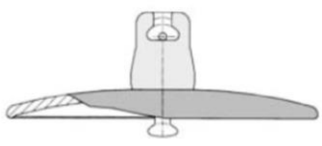


Image 9 Aerodynamic Insulator

- Spherical Insulator: As the aerodynamic insulator, the lack of ribs and its shape makes easier the self-cleaning due to the raining and wind action. Also, it makes more difficult the pose of dust over the surface of the disc.

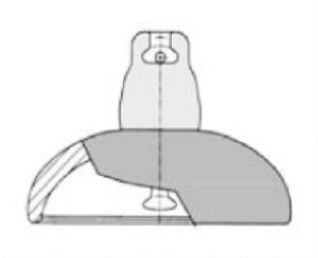


Image 10 Spherical Insulator

Long Rod Insulators

Usually the polymeric insulators are shaped with the long rod structure.

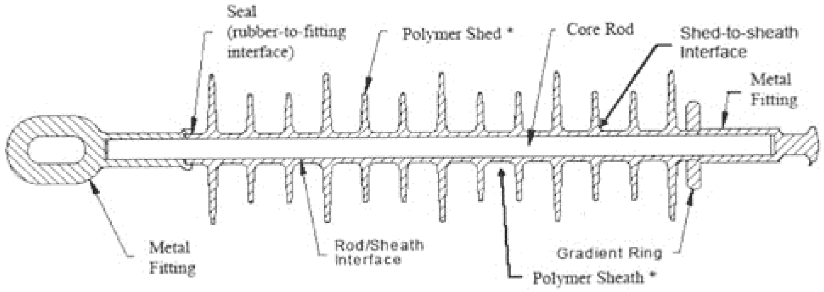


Image 11 Long Road Insulator

The SEC regulation only allows the use of porcelain or polymeric long rod insulators.

4. POLES

The supports are the elements in charge of sustaining through the insulator the conductor of the overhead line, maintaining them at the necessary height over the surface and providing the mechanical resistance of the set.

4.1 CLASSIFICATION

The towers may be classified according its material, its geometry; the type of insulator set or the relative position with the line.

<u>According to the material</u>

The supports may be made of:

- Wood: Only used at low voltage facilities and nowadays is rarely used
- Concrete: Used at low or medium voltage facilities
- Steel: Used at medium and high voltage facilities. There are two types of steel tower:
  - Lattice Tower
  - Tubular Poles

    As the Arabic Specification does not contemplate the possibility of using lattice towers the type of support chosen will be tubular poles.

<u>According to the geometry</u>

The parameters that define the geometry of the tower are:

- Number of circuits
- Conductors Disposition
- Mass Distance (Un)
- Height due to the sag

<u>According the insulator set</u>

- Suspension Support: The suspension towers are the ones who have suspension insulator sets

- Tension Support: The tension towers are the ones who have tension insulator sets

- Stain Support: The strain towers are special points of the line with tension sets which are in charge of providing a "fixed point" on the line, this means that non-longitudinal efforts due to the conductors will be transmitted through it.

- Terminal Support: The terminal towers are the ones in charge of sustaining in one unique longitudinal direction the efforts of the conductors. They are critical supports due to the force disequilibrium into they are submitted.

<u>According the relative position with the line</u>

- Intermediate Support: Suspension or tension support used on a straight path of the line.
- Angle Support: Suspension or tension tower used in an angle of the line's path.

4.2 CONFIGURATION

According to the pole's head, it does exist different conductor dispositions.

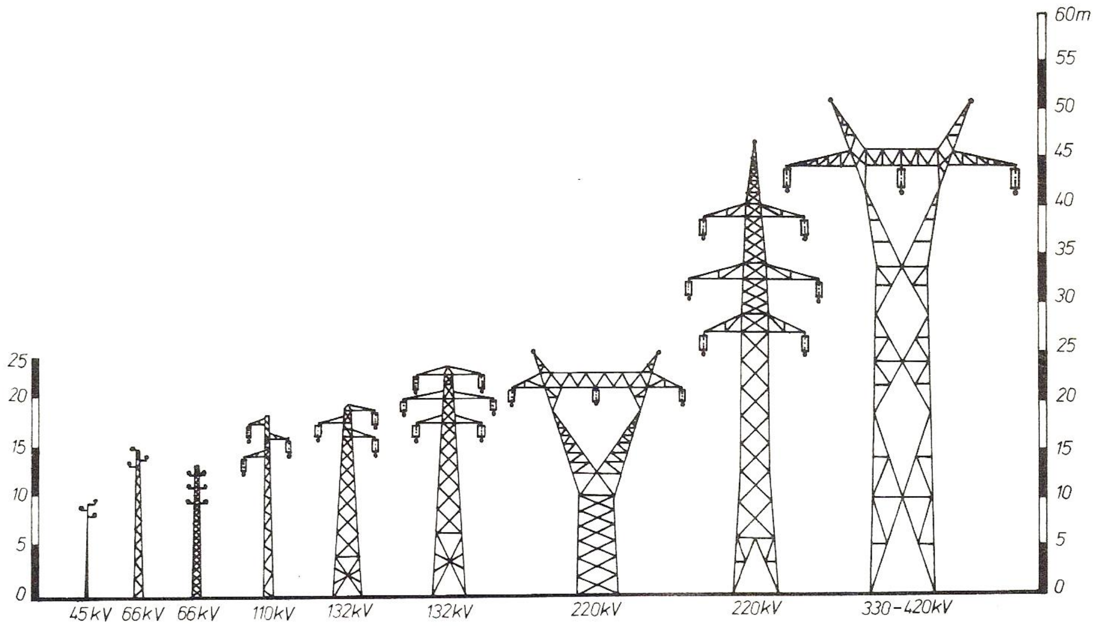


Image 12 Pole's Configuration

In order to choose a type of pole configuration two things must be taken into account:

- *Height of the pole*: The height of the pole is directly related with the forces that must stand the support. If the height increase, the loads increase and therefore, the foundation.
- *ROW [Right of way]:* The right of way is the space of the site which is covered by the poles head. If the head is wider the ROW will be bigger and therefore, the renting that shall be paid to the owner of the land will be higher.

As it can be notice, it does exist a compromise between the height and the ROW. Usually, at urban sites high poles are used while wide poles are used at mountain sites.

Note that a minimum distance between the conductor phases must be constant at the same voltage level due to electric safety reasons.

The common configurations for medium voltage simple circuit are:

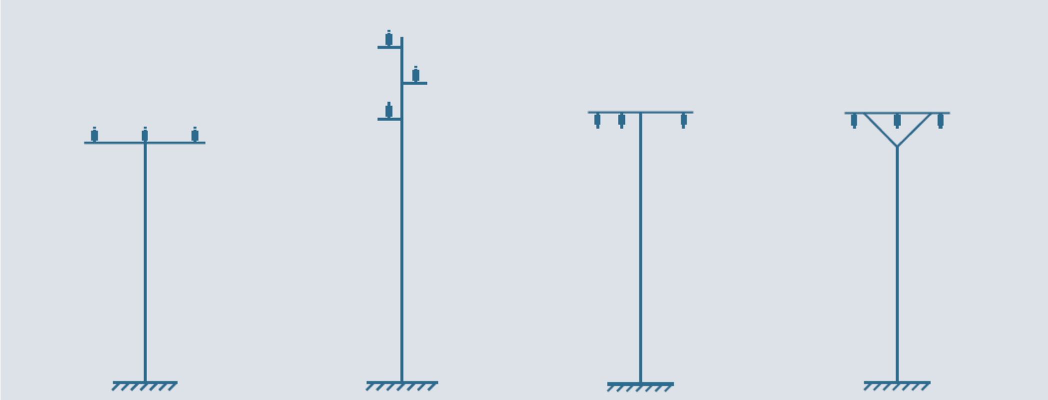


Image 13 MV Pole Configuration

4.3 POLE STABILITY

The poles can be self-supporting support or guyed support.

Guyed Support

The guyed support is a support whose stability is ensured by stays. Therefore, the foundations do not need to be as deep or as resistant as the ones on the self-supporting supports. Consequently, this type of supports is much cheaper.

Nevertheless, the stays cover more space, thus the ROW of the line increases. If the price of the land at that point is high, the price increases considerably. Thus, this types of poles are only used at places where no transit may exist.

Self-Supporting Support

The self-supporting support is a type of tower whose stability is intrinsic, this means it does not depend on external elements such as stays. Eventhough the foundation is more expensive they are commonly used.

5. FOUNDATIONS

The supports of the line transmit their loads to the ground throw the foundations.

The selection of foundation types and the design is determined by the:

- Loads resulting from the tower design
- Soil conditions on the site
- Accessibility to the line route
- Availability of machinery

According to the configuration of the foundation, it exists two main types of foundation: block foundation and separate footing foundations.

Block Foundation

The block foundation consists of a single block of concrete, into which the leg of the support or anchor bolts are embedded.

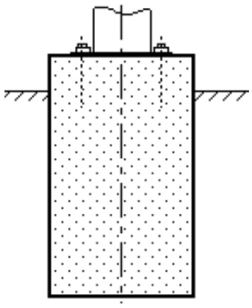


Image 14 Block Foundation

This type of foundation is usually used on small lattice tower supports or in poles. The calculation for this configuration considers the mainly the buckling torque and the stability is given by the ground reactions which depends on the compressibility coefficient of the ground.

The design is done for the worst load configuration on the support. The bucking torque is limited by the angle that the foundation may rotated. It is commonly used the limitation of:

$$\tan\alpha < 0{,}01$$

Nevertheless, as one of the main goals is to make a robust design, a security coefficient is used, normally 1,2 or 1,5.

Separate Footing Foundations

The separate footing foundations consists of four concrete blocks made of a solid concrete mass which have been specifically designed to withstand the loads transmitted from the pole in order to distribute them throw each leg.

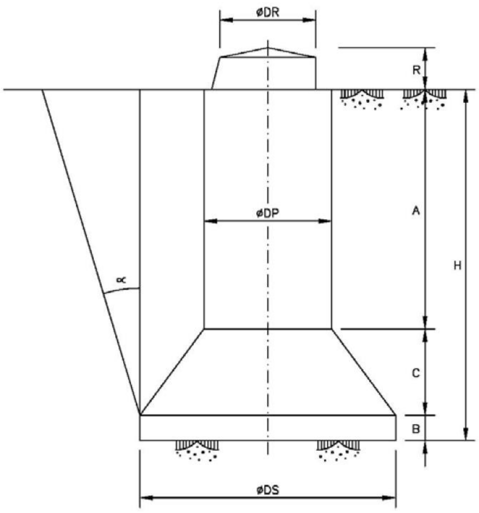


Image 15 Separate Footing Foundations

It is commonly used on the lattice towers which are located on sites in where the ground has not optimal conditions, this is to said, the type of soil is not sound rock.

The calculation for this type of configuration takes into account the booting torque, compression loads and also the adherence between the pad and the anchor.

In order to verify the opposition of the foundation versus booting, it is need to calculate the forces which may work against it, which are the own weight of the pad and the weight of the earth cone which may be dragged when the concrete is teared out.

It is commonly considered as booting angle 30º for normal soil and 20º for loose soil. As on the block foundations, a security coefficient of 1,2 or 1,5 is considered in order to make a more robust design.

So as to ensure the working of the block under compression loads, every force on the base pad it is calculated. This loads are: own weight of the pad, weight of the soil and the compression load applied by the support. These compression forces divided by the area of the whole foundation configuration shall not be greater than the admissible capacity of the soil.

Finally, it is checked the adherence between the pad and the anchor. When the concrete is working under compression, it is considered that have of this load is absorbed by the adherence between the anchor and the pad and the other half by the anchor bolts due to the shearing stress generated by the join of the anchor and its cap.

Nevertheless, if the soil characteristics are sound rock or mixed rock, the configuration of the foundations benefits from it. For the mixed rock, a combination between concrete and bolts is used in order to achieve the stability conditions. As for the sound rock ground, no concrete is used, only bolts.

6. ANCHORS

Any element, which serves for fastening insulator sets to the support and to the conductor, is named as anchor.

The bolts, nuts, screws and other pieces which compose this group of elements may have acute edges, and due to the electric field effect, on those, the potential is high. This leads to undesirable effect, which is necessary to avoid by a meticulous design.

Chain Anchors

These anchors are submitted to the same mechanical efforts that the ones on the insulators, therefore, its ultimate load must be concordant with theirs.

Span Anchors

Are the ones located over the conductor. (Clamps or fittings)

CHAPTER I: UNDERGROUND LINE’S ELEMENTS

1. CONDUCTOR

The conductor is the main element of the underground lines. Its main characteristic is that the wire is insulated, as the ground is not an insulation material but a conductor one.

They can be classified by:

Voltage:

- Low Voltage: U≤1kV
- Medium Voltage: 1kV ≤U≤30kV
- High Voltage: 30kV ≤U≤132kV
- Extreme High Voltage: U≥220kV

Number of phases:

- Single core: each phase constitutes one conductor
- Three core: one conductor constitutes the three phases under the same shield

Insulation:

- Lapped: An insulated is a tape of the material covers the conductor. The tape can be made of common paper or propylene laminated paper (PPLP)
- Extruded: The insulation can be made of:
  - PVC: polyvinyl chloride
  - EPR: Ethylene-Propylene Rubber
  - PE: Polyethylene
  - XLPE: Cross Linked Polyethylene

The main parts of the conductor are:

- Its conductive material
- The insulation
- Semiconductive layer
- Screen Shield
- Armouring
- Sheathing

On the following image it can clearly be seen the enunciated parts:

Image 16 Underground Conductor

1.1 CONDUCTOR

The conductor has an electric function, which is the main one, and is transporting the demanded current on service and overloaded conditions and during shortcuts. But also it has a mechanic function, which is, standing the efforts while its being stinging.

The main characteristics which must be searched on a conductor are: having good conductivity and an external regular surface. The two materials which qualify this features are: copper high heating tempering or aluminium of more than 99,5% of purity.

As it has been explained at the overhead line conductor's section, in order to transport the most quantity of power and having the lowest quantity of losses possible.

The resistance of a conductor is mathematically defined as:

$$R = \rho \cdot \frac{L}{S}$$

Being:

- R: Resistance (Ω)
- L: Length of the wire (m)
- S: Section of the wire (mm^2)
- ρ: resistivity of the material $\left(\frac{\Omega \cdot mm^2}{m}\right)$

The resistance for the underground conductor not only depends on the temperature but also on the skin effect and on the proximity effect. The two last ones are caused by the alternating current.

The skin effect is caused due to the variation of the magnetic field along the conductor section. This causes a non-uniformed distribution of the magnetic flow. As this, there will exists a higher current density at the periphery than on the centre of the conductor. This phenomenon increases with the section of the wire.

The effect of the proximity is a consequence of the closeness of other current wire, which may be other phase conductors or other strands from the proper conductor. The proximity causes induced currents on both wires. When the distance between phases is small in relation with its own diameter, the current tends to flow on the proximity conductor phases.

Therefore, the resistance can be it can be expressed as:

$$R_{AC\,\theta} = R_{DC\,20ºC} \cdot (1 + \alpha(\theta - 20) + \gamma_S + \gamma_P)$$

Where:

- $R_{AC\theta}$: Resistance of the conductor at the temperature θ with alternating current
- $R_{DC20ºC}$: Resistance of the conductor at 20ºC with direct current
- Θ: temperature of the working conditions of the conductor
- Υ_S: Skin effect coefficient

- Υ_P: Proximity effect coefficient

So to reduce the resistance, it will be necessary to minimize the skin effect and the proximity effect. In practice, the skin proximity effect is smaller than the skin effect.

As the skin effect is directly related with the distance, it decreases rapidly when the cables are separated. When the distance between two phases of one same circuit or between two different circuit is bigger than eight times the external diameter of the conductor, the skin effect is considered negligible.

In order to reduce the skin effect, enamelling fibres are incorporated to the conductor. These isolate conductor fibres. This type of procedure it is only used for conductor bigger or equal to 1600mm^2.

It exists two type of conductors' design: stranded conductor which may be with round or with compacted strands and the Milliken conductors.

The round stranded conductor are made of different layers located helicoidally, each layer on de inverse direction of the contiguous one. The reason why the distribution is inverse helicoidally is avoiding the permanent contact between the same conductor fibres in order to reduce the proximity effect.

Due to the permanent electric contact of low resistivity between the fibres, the skin and proximity effect, they have the same working performance as a solid conductor.

The Milken conductors are constituted by different conductors with sectorial section, proportionating a cylindrical shape to the group. This type of conductor is usually used for lines which require high transport capacity.

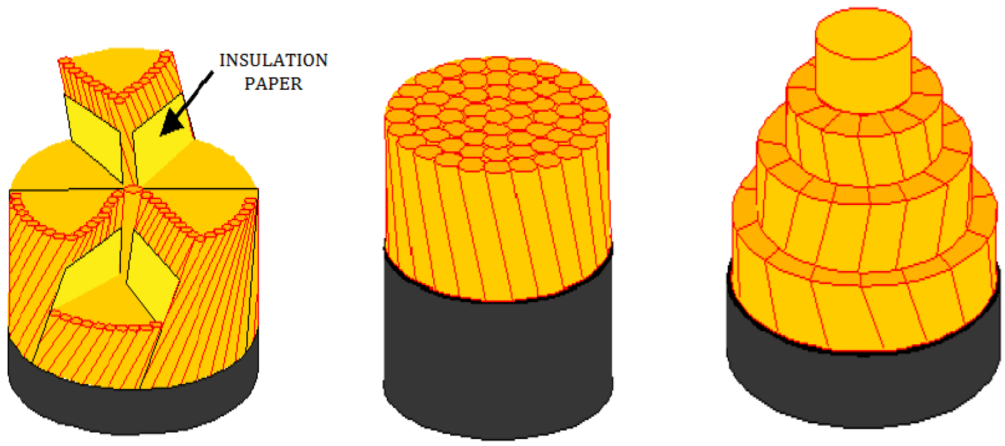


Image 17Example of Milliken Conductors

It is important to note that, as on the overhead lines, the maximum ampacity of the conductor depends on the temperature of the working conditions of the wire. Nevertheless, this temperature, for underground cables depend on multiple elements: conditions:

- Ground Temperature
- Thermal Resistivity of the ground
- Depth of the installation
- Influence of nearby circuits
- Disposition of the wires
- Type of installation

Therefore, each manufacturer has its own derating factors which are directly related with the installation conditions. The product between these derating factors and the nominal current of the conductor for the service conditions specified by de supplier shall give the maximum ampacity for the facility.

1.2 INSULATION

It exists two types of insulation: lapped or extruded.

The lapped insulation is made of thin layers of paper. This paper is made of cellulose impregnated fibres. They are impregnated of synthetic alkybenzene oil. Two designs are used: oil filled or mass impregnated. On the first ones, the oils flows throw the conductor drenching the paper while the second the oil its limited to the insulation paper layers.

This type of insulation has developed a new type of insulation paper which is the propylene laminated paper commonly known as PPLP. The key of this type of insulation is the use of consecutive layers of paper, propylene, paper. Therefore, this type of insulation combines the benefits of the tradicional paper insulation plus the electric and dielectric properties of the synthetic insulation. Nevertheless, the price is still expensive, and the consequence is that they are not widely used.

The extruded insulation is the one that has been widespread, specially, the use of XLPE as insulation material. The key of this material is the chemical process called reticulation. This process increases the thermal resistance to deformation. Before, and still for reduced voltages, other materials such as PE, EPR or PVC were used.

The main advantage of the extruded insulation from the lapped one is the non-need of installation and maintenance of hydraulic circuits for the recirculation of the oil.

The main feature of the insulation is its electric strength. The insulation can be submitted to an electric field lower to its electric strength. If not, it will lose its insulation properties letting the current flow throw it causing an electric fault.

The electric strength is measured in kV/cm, therefore, the thickness is also a key factor which provides the maximum standing electric field.

The insulation causes losses of the power which is being transported, they are called dielectric losses.

$$P_{DIELECTRIC} = 2 \cdot \pi \cdot C \cdot U_0^2 \cdot \tan(\delta) \cdot 10^{-6} \left[\frac{W}{km \cdot phase}\right]$$

Being:

- C: Capacitance to neutral [μF/km]

- U_O: Voltage between phase and earth [V]
- tan δ: Dielectric power factor

The dielectric losses from XLPE insulated conductors are less than the ones on the lapped insulated conductors.

The disadvantage of the extruded insulation is the humidity entrance or the impurity. Both reduce its electric strength and may cause defects on the insulation. The existence of humidity and a strong electric field causes a phenomenon called treeing, which leads to also to fault on the insulation.

The risk of using lapped insulation is the loss of its impregnation due to the lack of oil. This lack can be a consequence of seal or leaks. Not having enough oil leads to a reduction of the electric strength.

Eventhough the electric feature is the most important characteristic of an insulation, the chemical (humidity resistance, oxidation, etc.), physical (thermal resistance) and mechanical (bend radius, etc.) properties must be taken into account.

1.3 SEMICONDUCTIVE LAYER

It exists two different semiconductive layer: the internal, between the conductor and the insulation; and the external, between the insulation and the screen. They both have the same function.

The layers are made of a thin XLPE film mixed with other semiconductive products. They are located over the conductor surface or under the screen shield in order to provide a smooth surface. The main goal is to obtain a homogeneous electric field avoiding its concentration on particular points.

Also it reduces gradually the electric field from a conductive material till an isolating material.

Moreover, it assures the total contact between with the insulation, avoiding the presence of air in between the two layers, which may cause the ionization of it, altering the properties of the insulation material.

1.4 SCREEN SHIELD

The screen shield is a metallic element, which is located between the external semiconductive layer and the armouring.

Its principal functions are:

- Cancel the electric field outside the wire, thus, the electric field at the insulation is radial.
- Acting as a conductor for: the capacitive currents throw the insulation caused by the dielectric losses; the inductive currents due to the closeness of other conductors and for the zero-sequence current when a shortcircuit may occur.

Therefore, it is highly important to connect correctly the screen shield to the earthing system.

- Providing mechanical protection for the external aggressions.
- Depending on the design, some of the electric shields provide also seal for the water entrance.

The shields can be classified as sealing or non-sealing.

There are two main types of sealing shields. The first one is made of extruded lead tubes. They provide a resistance to corrosion and high electric resistance, this means low losses may exist on the joins to the earthing system. The main problem is its conductive capacity, thus, it does not work correctly when a shortcircuit occurs. Also, its weight and the prices is high. It is generally used for mass impregnated lapped insulation cables.

The second type is made of aluminium films longitudinally welded. They are lighter and they provide a very good conduction for the current during shortcircuits. It does not have a good electric resistance, due to that, it is need a special connection with the earthing system. The main disadvantage of this shield is the price, as no many manufacturers produce them. They are used on high voltage XLPE insulated wires.

The non-sealing shields are made of copper or aluminium fibres. They are light constructions with a high capacity to stand upon shortcircuits. They also need special connections with the earthing system that may allow humidity entrance. Thus, when this type of shield is used, normally, radial or longitudinal barriers of other materials are used.

1.5 ARMOURING

The armouring is made of different wires of galvanized steel. It provides an additional mechanical resistance. It is used when the stringing efforts are bigger than the mechanical failure load.

1.6 SHEATHING

This external cover provides mechanical as well as electrical insulation.

Mechanically, it provides protections against corrosion, external aggressions during the stringing and the operation and against humidity.

Electrically, it insulates the shield from the ground.

The material which is widespread used is the polyvinyl chloride, commonly known as PVC.

2. EARTHING SYSTEMS

The earthing system of the underground lines are design in order to avoid the inductive voltage on the shields and limiting the overvoltage on the terminals. The permanent presence of inductive voltage causes the permanent flow of inductive currents throw the shield leading to a shield warming and consequently to a reduction of the conduction capacity.

1.1 SINGLE POINT CONNECTION

The single point connection connects the three shields of each phase conductor together to a unique point being the other three terminals connected to dischargers.

As no close circuit exists, no longitudinal inductive current flow through the shields, avoiding its warming and therefore avoiding the reduction of the transportation capacity of the line.

This type of connection is used for short underground lines.

1.2 CROSS-BONDING CONNECTION

The cross-bonding connection consist of interrupting the shields and transposing the connection of them. The goal of this interruption and transposition is neutralizing the inductive voltage on the three sections. The two ends of the lines are connected to the earthing system. To achieve an exact cancellation of the inductive voltages it is also needed to transpose the phase conductors.

This type of connection is generally used on long underground lines.

3. ACCESSORIES

3.1 TERMINAL

The function of the terminal is connecting the ending of the conductor to the electric network.

The elements of the terminal are:

- Stress-cone
- Insulating Fluid
- External Insulator
- Voltage Deflector
- Overhead Connection

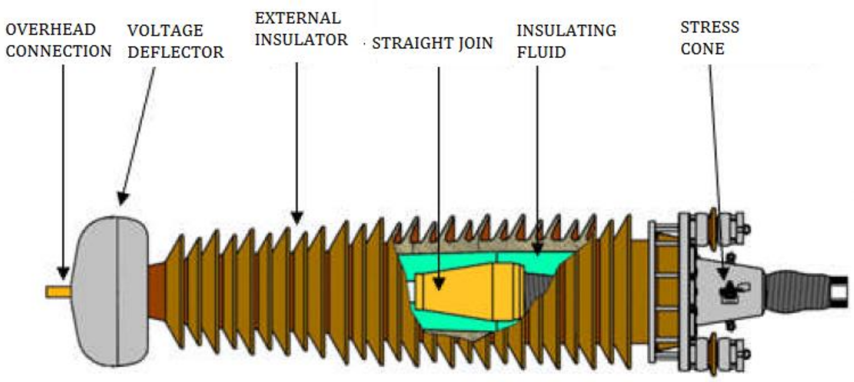


Image 18Terminal's Parts

The stress cone distributes the electric field. When the underground conductor reaches the terminal, its semiconductive external layer is ripped out. Therefore, the stress cone must conduct the electric field to pass throw the terminal. Thus, the construction of the stress cone must be extremely precise, if not, partial dischargers may occur.

The terminal is contained on an empty insulator, the external insulator, which may be polymeric or porcelain. The porcelain insulators are much heavier and when any internal malfunction occurs they may explode. On the other hand, the polymeric insulator do not explode avoiding damage on nearby elements.

The insulating fluid is in charge of providing a homogeneous environment between the stress cone and the internal insulator hollow. The fluid must have a high electric strength, it must stand the maximum serviced temperature without altering its own properties and may be compatible with every element of the terminal.

The two types of fluid commonly used are SF6 gas or synthetic oils. The oil is not under pressure although it is flammable while the SF6 it is not flammable but needs of a pressure system as the level/pressure of the gas must be control in order to avoid the explosion or any leak of the gas.

Depending on the location of its installation the terminal can be classified as external or internal. The external must be design bearing in mind the ambient conditions such as humidity, pollution or salinity.

CHAPTER III: TRANSITION'S ELEMENTS

1. SURGE ARESSTER

The surge arresters are elements aimed to limited the danger overvoltage protecting the rest of the switchgear. They are always connected between phase and earth.

They work as non-linear voltage-dependent resistors. Under service conditions, their resistance is extremely high, thus only leak current may flow through them. But when an overvoltage occurs, their resistance turns practically to zero, leading the associated overcurrent to earth.

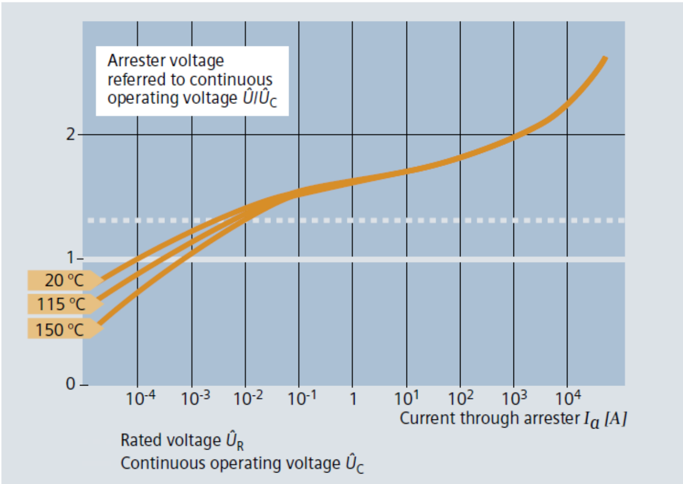


Figure 4 Current/voltage characteristics of a non-linear MO arrester

It exists two types of surge-arresters: silicon carbide (SiC) or metallic oxides (ZnO). The first ones have been replaced by the second ones due to their better properties.

They are composed by a column of active element constituted by one or various units disposed one over the other and electrically, connected in series. Each unit of active elements is embraced on a porcelain, glass or epoxy polymeric cover hermetically closed. As to avoid the explosion of the cover possible caused by an internal malfunction of the surge arrester, they are proved by a pressure limiter.

The surge arrester is equipped an earthing terminal and with a discharger counter.

The main characteristics of a surge arrester is:

- Continuous Operating Voltage(U_C): Maximum voltage RMS that can be applied permanently.
- Nominal Voltage (U_R): Maximum overvoltage RMS withstood during 10s at 60ºC and after dissipating a determine quantity of energy.
- Residual Voltage (U_P): Peak voltage value, that appears between the terminals during the discharge. Its value depends on the shape and the magnitude of the discharging current.
- Capacity Over Transient Overvoltage(TOVs): Maximum RMS withstood voltage during a particular time (U_R<TOVc(10s)) It represents the withstanding capacity from an energetic point of view.

- Nominal Discharge Current: Peak current impulse value of fast forefront overvoltage of 8/20ms. They are standardized values.

	Nominal Discharge Current				
Nominal Voltage	1,5kA	2,5 kA	5 kA	10 kA	20 kA
$U_R \leq 3kV$					
$3kV \leq U_R \leq 29kV$					
$29kV \leq U_R \leq 132kV$					
$132kV \leq U_R \leq kV$					

Table 14 Standardized Nominal Discharge Currents

- Type of Discharger: It exists five types of discharges depending on the dissipation of the discharge energy.
  - I_N:10 kA: Class 1,2 and 3
  - I_N:20kA: Class 4 and 5

The selection criteria are:

1.

$$U_C \geq \frac{U_S}{\sqrt{3}}$$

Being:

- U_S: Nominal operation voltage; for our case 33kV

2.

$$TOV_C(10s) \geq k \cdot \frac{U_s}{\sqrt{3}} \cdot \left(\frac{T_t}{10}\right)^{0,02}$$

Being:

- U_S: Nominal operation voltage; for our case 33kV
- k: Earth Fault Factor (-)

NEUTRAL ARRANGEMENT	k
Connected solidly to earth	1,4
Not connected solidly to earth	1,7
Isolated	1,9

Table 13 Earth Fault Factor

- Tt: Clearance earth fault time

3.

$$U_{BIL} \geq 1{,}2U_P$$

Being:

- U_{BIL}: Basic insulation level of the protected equipment

It is important to note, that, due to the mobile wave, the voltage of the protected equipment is bigger than the residual voltage. The nearer the surge arrester is from the equipment, the bigger is the protection.

The maximum distance between the surge arrester and the protected equipment is:

$$L = \frac{U_{BIL} - U_P}{2S} \cdot V$$

Being:

- L: Maximum Distance (m)
- U_{BIL}: Basic insulation level of the protected equipment (kV)
- Up: Residual Voltage (kV)
- S: Slope of the overvoltage wave (1 000 kV/µs)
- V: wave's propagation speed (m/µs)
  - Overhead line: 300 m/µs approx.
  - Underground line: 150 m/µs approx.

	5kA	10 kA			20kA	
Nominal Voltage		Class 1	Class 2	Class 3	Class 4	Class 5
$U_S \leq 66$ kV						
66kV $\leq U_S \leq$220 kV						
220 kV $\leq U_S \leq$380 kV						
$U_S \geq$ 380 kV						

Table 15 Usual Values of the Nominal Discharge Current

2. CUT OUT

A cut out is an element which protects from shortcircuit currents and overloads. Therefore, it has a safety function.

The circuits which must isolate the cut out should not have any current flow. It must manoeuvre under no-load operation. It is an operation element, it isolates the protected circuit in order to be manipulated by any operation staff.

The disconnection process shall always be:

- Disconnection of the principal switch of the nearby substation
- Disconnection of the cut out

For extreme conditions the cut out is set with a fuse, which is the type used for the regarding facility.

OVERHEAD LINE

CHAPTER I: CONDUCTOR CALCULUS

1. MECHANICAL CALCULATION OF CONDUCTORS LINE 1

This section contains the mechanical calculation of the conductors for the overhead line 1 that will be constructed.

The main objectives of the mechanical calculation of the conductor are:

- To determine the mechanical stress drivers in all the conductors for all the design hypothesis such as temperatures and overloads of wind. The maximum load of a conductor is an important factor for the design of the poles. It will determine the level of mechanical security of the line.
- Obtaining the sag for each span at different design hypothesis determines the height of the poles, so we can fulfil the requirements of the SEC rules regarding the minimum vertical distances between conductors and other external objects.

The characteristics of the line and the calculation hypothesis shall be described at the following subsections.

1.1 MECHANICAL CALCULATION OF THE CONDUCTOR

The projected line is a simple circuit line, in which its conductors are MERLIN ACSR/AW, being its principal characteristics:

TYPE OF WIRE	MERLIN ACSR/AW
Overall diameter of bare conductor(approx.)	17,35 mm
Aluminium area	170,22 mm^2
Steel Area	9,457 mm^2
Total cross-sectional area of the conductor	197,7 mm^2
Ultimate breaking load of the conductor	3929 kg
Rated sensible strength	3877 kg
Equivalent modulus of elasticity	6428 kg/ mm^2
Resistance of conductor per km at reference temperature 75ºC	0,2036 Ω/km
Composition (Al + Ac)	18 x 3,47 + 1 x 3,47
Weight of conductor per km	530 kg/km
Equivalent coefficient for linear expansion per ºC	21 x 10^{-6} $ºC^{-1}$

Table 16 Conductor Characteristics

The hypothesis for which it has been designed the conductor is the maximum traction hypothesis. This hypothesis stands that maximum tension that the conductor may suffer at the worst possible scenario shall be always lower or equal to the elastic limit of the conductor.

The elastic limit stablishes the maximum traction load for the conductors. In order to have a more robust design, a security coefficient is chosen. Therefore, the ultimate braking load of the conductor shall always be 3 times bigger than the maximum possible traction.

$$SC_{CONDUCTOR} \geq \frac{\text{Ultimate Breaking Load}}{\text{Elastic Limit}}$$

Due to temperature changes, the conductor expands or contracts. This causes variations in the loads and in the sag. As the expansion is linear, it will follow the rule mention below:

$$L_O = L_1 \cdot (1 + \alpha t)$$

Where:

- L_0: Length of the wire at 0ºC (m)
- L_1: Length of the wire at the temperature t_1(8m)
- α: Coefficient for linear expansion per ºC (ºC^{-1})
- t: considered temperature (ºC)

Consequently, to get to know the length variation of a wire between two points at different temperatures:

$$L_1 - L_2 = L_0 \alpha \cdot (t_1 + t_2)$$

The elongation of a wire is not only caused by a variation on the temperature, but also by subjecting the wire to a certain load. This elongation to the law of Hooke. If we denominate Ɛ to the elastic elongation produced by one kg on a driver of a meter length and a square millimetre of section, we will obtain that the elongation produced by a load over the conductor of Length Lo and section S is:

$$L_1 = L_o \cdot \left(1 + \varepsilon \cdot \frac{T_1}{S}\right)$$

Consequently, the length variation of a wire between two points subjected at different loads follow the equation mentioned below:

$$L_1 - L_2 = \varepsilon \cdot L_O \cdot \frac{T_1 - T_2}{S}$$

Being E (elasticity modulus) equal to 1/ε:

$$L_1 - L_2 = L_O \cdot \frac{T_1 - T_2}{ES}$$

The changing conditions equation takes into account the two elongation types and the vertical loads of the conductor due to its weight. Furthermore, the changing equation relates two states or situations of the overhead line. If all parameters of a state or initial condition (1) are known, it can be known by using the equation the parameters of other arbitrary state or final or condition (2).

It is defined as:

$$a_r \cdot \alpha \cdot (t_2 - t_1) + a_r \cdot \frac{T_2 - T_1}{E \cdot S} = \frac{a_r^3}{24} \cdot \left(\frac{P_2^2}{T_2^2} - \frac{P_1^2}{T_1^2}\right)$$

In a more operative way it can be define by a third grade equation in T_2.

$$T_2^2 \cdot \left[T_2 - \left(k - \alpha \cdot (t_2 - t_1)\right)\right] = \frac{a_r^2 \cdot E \cdot S \cdot P_2^2}{24}$$

Being k the following:

$$k = T_1 - \frac{a_r^2 \cdot E \cdot S \cdot P_1^2}{24 \cdot T_1^2}$$

Where:

- a: Length of the ruling (m)
- T_1: traction or horizontal mechanical force on the conductor or earth wire at initial conditions (kg)
- T_2: traction or horizontal mechanical force on the conductor or earth wire at final conditions (kg)
- P_1: load over the conductor or earth wire due to wind overload in the considered initial conditions. Usually it is expressed by the overload coefficient (q_1) and the weight of the conductor (w) in kg/m:

$$P_1 = \frac{q_1}{w}$$

- P_2: load over the conductor or earth wire due to wind overload in the considered final conditions. Usually it is expressed by the overload coefficient (q_2) and the weight of the conductor (w) in kg/m:

$$P_2 = \frac{q_2}{w}$$

- k: constant obtained by knowing the initial conditions
- α: coefficient for linear expansion per ºC of the conductor or earth wire
- E: modulus of elasticity (kg/mm^2)

- S: Area of the conductor or earth wire (mm^2)
- t_1: considered initial temperature (ºC)
- t_2: considered final temperature (ºC)

The changing conditions equation it is usually applied between the initial and the final point of a ruling span.

The ruling span is defined as the behaviour of the horizontal component of the mechanical traction of the conductor in a section kept between two tension supports. A section conformed of i spans of length ai can be define as:

$$a_r = \sqrt{\frac{\sum_i a_i^3}{\sum_i a_i}}$$

On the other hand, the sag for the i span of each section shall be calculated by the use of the following equation:

$$f_i = \frac{P_i \cdot a_i^2}{8 \cdot T} = \frac{w \cdot q_i \cdot a_i^2}{8 \cdot T}$$

Where T correspond to the horizontal component of the load of the section in kg.

1.2 RULING SPANS. SECTIONS SUMMARY

The line 1 is defined by the following different sections:

Structure Number	X Easting (m)	Y Northing (m)	Centreline Z Elevation (m)	Ahead Span (m)	Line Angle (gr.) (*)	Structure Description	Structure Pole Used	Colour Code (Number of bands)
L1 - 001	763174,106	2771921,01	525,12	90,22	0	OC14D	Terminal	Yellow(2)
L1 - 002	763225,984	2771847,2	525,47	90,22	0	OC14S	Intermediate	Yellow(1)
L1 - 003	763277,865	2771773,38	526,07	90,22	0	OC13S	Intermediate	Red (1)
L1 - 004	763329,743	2771699,57	526,39	90,22	0	OC14S	Intermediate	Yellow(1)
L1 - 005	763381,62	2771625,76	527,01	89,01	0	OC13S	Intermediate	Red (1)
L1 - 006	763432,859	2771552,97	527,15	90	0	OC14S	Intermediate	Yellow(1)
L1 - 007	763484,713	2771479,26	527,53	90	0	OC13S	Intermediate	Red (1)
L1 - 008	763535,483	2771406,91	526,5	90	0	OC13S	Intermediate	Red (1)
L1 - 009	763588,116	2771332,08	526,12	90,01	0	OC14S	Intermediate	Yellow(1)
L1 - 010	763639,821	2771258,4	525,75	90	0	OC13S	Intermediate	Red (1)
L1 - 011	763691,575	2771184,76	525,73	89,99	0	OC14S	Intermediate	Yellow(1)
L1 - 012	763743,319	2771111,14	525,32	90	0	OC14S	Intermediate	Yellow(1)

L1 - 013	763795,07	2771037,51	525,24	63,46	0	OC13S	Intermediate	Red (1)
L1 - 014	763831,653	2770985,66	525,43	50,07	-0,6133	OC14D	Terminal	Yellow(2)
L1 - 015	763860,849	2770944,98	525,45	46,48	0	OC13S	Intermediate	Red (1)
L1 - 016	763887,818	2770907,12	525,05	89,99	0	OC13S	Intermediate	Red (1)
L1 - 017	763940,424	2770834,11	524,75	89,99	0	OC14S	Intermediate	Yellow(1)
L1 - 018	763992,897	2770761	524,63	90,01	0	OC13S	Intermediate	Red (1)
L1 - 019	764045,381	2770687,87	524,67	90,22	0	OC14S	Intermediate	Yellow(1)
L1 - 020	764097,986	2770614,58	524,76	90,11	0	OC13S	Intermediate	Red (1)
L1 - 021	764150,565	2770540,76	524,59	89,99	0	OC14S	Intermediate	Yellow(1)
L1 - 022	764202,757	2770468,01	524,45	89,99	0	OC13S	Intermediate	Red (1)
L1 - 023	764255,007	2770394,68	523,91	89,95	0	OC14S	Intermediate	Yellow(1)
L1 - 024	764307,92	2770322,08	523,61	83	0	OC13S	Intermediate	Red (1)
L1 - 025	764356,318	2770254,64	523,07	90	0	OC14S	Intermediate	Yellow(1)
L1 - 026	764408,799	2770181,52	522,48	65,12	0	OC13S	Intermediate	Red (1)
L1 - 027	764446,767	2770128,62	522,2	66,02	0	OC13S	Intermediate	Red (1)
L1 - 028	764485,12	2770074,89	522,13	60,03	0,9403	OC14D	Terminal	Yellow (2)
L1 - 029	764519,372	2770025,59	522,35	85,77	0	OC13S	Intermediate	Red (1)
L1 - 030	764568,378	2769955,2	522,19	90,23	0	OC13S	Intermediate	Red (1)
L1 - 031	764619,863	2769881,1	522,03	90,06	0	OC14S	Intermediate	Yellow(1)
L1 - 032	764671,286	2769807,17	522,39	49,84	0	OC13S	Intermediate	Red (1)
L1 - 033	764699,742	2769766,25	522,44	43,97	0	OC13S	Intermediate	Red (1)
L1 - 034	764724,847	2769730,16	522,63	86,31	0	OC13S	Intermediate	Red (1)
L1 - 035	764774,126	2769659,29	522,66	89,87	0	OC13S	Intermediate	Red (1)
L1 - 036	764825,445	2769585,52	522,71	90,1	0	OC14S	Intermediate	Yellow(1)
L1 - 037	764876,893	2769511,55	523,24	89,95	0	OC13S	Intermediate	Red (1)
L1 - 038	764928,256	2769437,7	523,77	90,11	0	OC14S	Intermediate	Yellow(1)
L1 - 039	764979,708	2769363,72	524,33	88,03	0	OC14S	Intermediate	Yellow(1)
L1 - 040	765029,973	2769291,45	524,93	86,92	0	OC13S	Intermediate	Red (1)
L1 - 041	765079,602	2769220,09	524,93	85,06	0	OC13S	Intermediate	Red (1)
L1 - 042	765128,095	2769150,21	524,73	88,26	0,4274	OC14D	Terminal	Yellow (2)
L1 - 043	765177,989	2769077,41	524,91	89,79	0	OC13S	Intermediate	Red (1)
L1 - 044	765228,745	2769003,34	525,37	89,79	0	OC14S	Intermediate	Yellow(1)
L1 - 045	765279,501	2768929,28	526,22	89,79	0	OC13S	Intermediate	Red (1)
L1 - 046	765330,258	2768855,21	527,21	89,79	0	OC14S	Intermediate	Yellow(1)
L1 - 047	765381,014	2768781,15	527,43	89,79	0	OC13S	Intermediate	Red (1)
L1 - 048	765431,77	2768707,08	526,89	89,79	0	OC14S	Intermediate	Yellow(1)
L1 - 049	765482,527	2768633,02	526,37	89,79	0	OC13S	Intermediate	Red (1)
L1 - 050	765533,283	2768558,95	525,99	89,79	0	OC14S	Intermediate	Yellow(1)
L1 - 051	765584,039	2768484,89	525,49	89,79	0	OC13S	Intermediate	Red (1)
L1 - 052	765634,796	2768410,83	525,18	89,79	0	OC14S	Intermediate	Yellow(1)

L1 - 053	765685,552	2768336,76	525,13	89,79	0	OC14S	Intermediate	Yellow(1)
L1 - 054	765736,308	2768262,7	525,07	73,53	0	OC13S	Intermediate	Red (1)
L1 - 055	765777,965	2768202,1	525,09	90	-0,6073	OC14D	Terminal	Yellow (2)
L1 - 056	765829,546	2768128,34	524,99	90	0	OC13S	Intermediate	Red (1)
L1 - 057	765881,127	2768054,58	524,54	90	0	OC14S	Intermediate	Yellow(1)
L1 - 058	765932,708	2767980,83	524,3	89,63	0	OC13S	Intermediate	Red (1)
L1 - 059	765984,074	2767907,38	523,65	89,79	0	OC13S	Intermediate	Red (1)
L1 - 060	766035,534	2767833,79	522,95	89,79	0	OC14S	Intermediate	Yellow(1)
L1 - 061	766086,994	2767760,21	522,74	89,79	0	OC13S	Intermediate	Red (1)
L1 - 062	766138,454	2767686,62	522,63	89,79	0	OC14S	Intermediate	Yellow(1)
L1 - 063	766189,914	2767613,04	522,53	89,79	0	OC14S	Intermediate	Yellow(1)
L1 - 064	766241,374	2767539,45	522,57	89,79	0	OC13S	Intermediate	Red (1)
L1 - 065	766292,835	2767465,87	523,12	89,79	0	OC13S	Intermediate	Red (1)
L1 - 066	766344,295	2767392,29	523,41	89,9	0	OC14S	Intermediate	Yellow(1)
L1 - 067	766395,815	2767318,62	523,24	54,85	0	OC13S	Intermediate	Red (1)
L1 - 068	766427,382	2767273,76	523,16	89,8	-0,9	OC14D	Terminal	Yellow (2)
L1 - 069	766479,908	2767200,92	523,06	89,8	0	OC13S	Intermediate	Red (1)
L1 - 070	766532,433	2767128,09	522,93	89,8	0	OC14S	Intermediate	Yellow(1)
L1 - 071	766584,959	2767055,25	523,68	89,8	0	OC13S	Intermediate	Red (1)
L1 - 072	766637,487	2766982,41	524,48	89,97	0	OC13S	Intermediate	Red (1)
L1 - 073	766690,112	2766909,44	525,15	89,79	0	OC14S	Intermediate	Yellow(1)
L1 - 074	766742,631	2766836,61	525,37	89,79	0	OC13S	Intermediate	Red (1)
L1 - 075	766795,151	2766763,78	525,4	89,8	0	OC14S	Intermediate	Yellow(1)
L1 - 076	766847,674	2766690,94	525,5	89,75	0	OC13S	Intermediate	Red (1)
L1 - 077	766900,169	2766618,15	525,46	89,84	0	OC14S	Intermediate	Yellow(1)
L1 - 078	766952,72	2766545,28	525,51	89,8	0	OC13S	Intermediate	Red (1)
L1 - 079	767005,243	2766472,45	525,45	89,8	0	OC14S	Intermediate	Yellow(1)
L1 - 080	767057,766	2766399,61	525,42	46,08	0	OC13S	Intermediate	Red (1)
L1 - 081	767084,526	2766362,09	525,52	89,85	0,5706	OC14D	Terminal	Yellow (2)
L1 - 082	767136,412	2766288,73	525,48	89,76	0	OC13S	Intermediate	Red (1)
L1 - 083	767188,245	2766215,45	525,41	89,76	0	OC14S	Intermediate	Yellow(1)
L1 - 084	767240,077	2766142,17	525,38	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 085	767291,919	2766068,87	525,34	89,78	0	OC13S	Intermediate	Red (1)
L1 - 086	767343,761	2765995,57	524,34	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 087	767395,603	2765922,27	524,91	89,78	0	OC13S	Intermediate	Red (1)
L1 - 088	767447,445	2765848,98	524,67	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 089	767499,287	2765775,68	524,56	89,78	0	OC13S	Intermediate	Red (1)
L1 - 090	767551,128	2765702,38	524,51	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 091	767602,97	2765629,09	524,32	89,78	0	OC13S	Intermediate	Red (1)
L1 - 092	767654,812	2765555,79	523,56	89,78	0	OC14S	Intermediate	Yellow(1)

L1 - 093	767706,654	2765482,49	523,28	37,41	0	OC13S	Intermediate	Red (1)
L1 - 094	767728,256	2765451,95	523,26	89,72	0,1922	OC14D	Terminal	Yellow (2)
L1 - 095	767779,845	2765378,55	523,36	89,45	0	OC13S	Intermediate	Red (1)
L1 - 096	767831,25	2765305,35	523,41	90,19	0	OC14S	Intermediate	Yellow(1)
L1 - 097	767883,229	2765231,64	523,44	89,74	0	OC13S	Intermediate	Red (1)
L1 - 098	767934,802	2765158,19	523,52	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 099	767986,425	2765084,74	523,59	89,78	0	OC13S	Intermediate	Red (1)
L1 - 100	768038,048	2765011,29	523,61	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 101	768089,672	2764937,84	523,84	89,78	0	OC13S	Intermediate	Red (1)
L1 - 102	768141,295	2764864,39	523,93	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 103	768192,918	2764790,94	524,22	89,78	0	OC13S	Intermediate	Red (1)
L1 - 104	768244,541	2764717,48	524,25	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 105	768296,164	2764644,03	524,29	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 106	768347,787	2764570,58	524,06	52,65	0	OC13S	Intermediate	Red (1)
L1 - 107	768377,967	2764527,44	523,84	89,78	-0,0026	OC14D	Terminal	Yellow (2)
L1 - 108	768429,54	2764453,96	523,62	89,78	0	OC13S	Intermediate	Red (1)
L1 - 109	768481,163	2764380,5	522,8	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 110	768532,788	2764307,05	522,54	89,78	0	OC13S	Intermediate	Red (1)
L1 - 111	768584,412	2764233,6	522,55	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 112	768636,038	2764160,14	522,58	89,78	0	OC13S	Intermediate	Red (1)
L1 - 113	768687,664	2764086,69	522,64	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 114	768739,289	2764013,24	522,23	89,78	0	OC13S	Intermediate	Red (1)
L1 - 115	768790,915	2763939,78	521,98	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 116	768842,541	2763866,32	522,39	89,78	0	OC13S	Intermediate	Red (1)
L1 - 117	768894,167	2763792,87	522,33	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 118	768945,793	2763719,41	522,13	89,75	0	OC13S	Intermediate	Red (1)
L1 - 119	768997,455	2763646,02	522,12	52,65	0	OC14S	Intermediate	Yellow(1)
L1 - 120	769027,726	2763602,95	522,06	89,8	-0,0053	OC14D	Terminal	Yellow (2)
L1 - 121	769079,453	2763529,54	521,87	89,78	0	OC13S	Intermediate	Red (1)
L1 - 122	769131,079	2763456,08	521,84	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 123	769182,704	2763382,63	521,79	89,78	0	OC13S	Intermediate	Red (1)
L1 - 124	769234,329	2763309,17	521,56	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 125	769285,954	2763235,71	521,51	89,78	0	OC13S	Intermediate	Red (1)
L1 - 126	769337,579	2763162,26	521,46	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 127	769389,204	2763088,8	521,28	89,78	0	OC13S	Intermediate	Red (1)
L1 - 128	769440,83	2763015,35	521,14	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 129	769492,455	2762941,89	521	89,78	0	OC13S	Intermediate	Red (1)
L1 - 130	769544,08	2762868,43	520,97	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 131	769595,705	2762794,98	520,73	89,78	0	OC13S	Intermediate	Red (1)
L1 - 132	769647,33	2762721,52	520,46	52,58	0	OC14S	Intermediate	Yellow(1)

L1 - 133	769677,565	2762678,5	520,4	89,81	0,0118	OC14D	Terminal	Yellow (2)
L1 - 134	769729,204	2762605,03	520,3	89,78	0	OC13S	Intermediate	Red (1)
L1 - 135	769780,829	2762531,57	520,18	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 136	769832,455	2762458,12	519,96	89,78	0	OC13S	Intermediate	Red (1)
L1 - 137	769884,081	2762384,66	519,99	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 138	769935,706	2762311,21	519,85	89,78	0	OC13S	Intermediate	Red (1)
L1 - 139	769987,332	2762237,75	520,03	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 140	770038,958	2762164,3	520,64	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 141	770090,583	2762090,84	520,54	89,78	0	OC13S	Intermediate	Red (1)
L1 - 142	770142,209	2762017,38	520,89	89,78	0	OC13S	Intermediate	Red (1)
L1 - 143	770193,835	2761943,93	521,1	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 144	770245,46	2761870,47	521,15	89,78	0	OC13S	Intermediate	Red (1)
L1 - 145	770296,999	2761796,96	521,93	52,61	0	OC14S	Intermediate	Yellow(1)
L1 - 146	770327,251	2761753,91	522,72	89,78	-0,0056	OC14D	Terminal	Yellow (2)
L1 - 147	770378,876	2761680,45	523,19	89,78	0	OC13S	Intermediate	Red (1)
L1 - 148	770430,501	2761607	523,13	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 149	770482,126	2761533,54	523,07	89,78	0	OC13S	Intermediate	Red (1)
L1 - 150	770533,752	2761460,09	523,04	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 151	770585,377	2761386,63	522,86	89,78	0	OC13S	Intermediate	Red (1)
L1 - 152	770637,002	2761313,18	522,65	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 153	770688,627	2761239,72	522,38	89,78	0	OC13S	Intermediate	Red (1)
L1 - 154	770740,252	2761166,26	522,27	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 155	770791,877	2761092,81	522,29	89,78	0	OC13S	Intermediate	Red (1)
L1 - 156	770843,502	2761019,35	522,41	89,78	0	OC14S	Intermediate	Yellow(1)
L1 - 157	770895,128	2760945,9	522,44	89,78	0	OC13S	Intermediate	Red (1)
L1 - 158	770946,753	2760872,44	522,6	52,58	0	OC14S	Intermediate	Yellow(1)
L1 - 159	770976,988	2760829,42	522,75		0	OC14D	Terminal	Yellow (2)

Table 17 Ruling Spans

(*) Angles under 1,2gr are considered worthless. The behaviour of the efforts over the pole is as the intermediate ones.

Drawing from the stablished initial conditions, and knowing the equations for the stress and sags calculation as well as the mechanical characteristic of the conductor, the sag and the tension at the different ruling spans of the overhead line for the different hypothesis. Overhead line design shall be based on the following environmental conditions:

- Minimum temperature: -5°C
- Maximum temperature: 55°C
- Temperature of exposed surface due to the solar radiation:75ºC
- Wind speed (50 yr.): 160 km/h

*No ice overload has been taken into account due to the climatological conditions of the facility.

Vertical clearances above grade for desert installations of conductors, including service drops, messengers, and guys shall be minimum 8.5 m at final unloaded sag, no wind, and 50°C ambient temperature.

Horizontal loading for line post insulators shall not exceed 2.2 kN for initial sag at the minimum temperature, and wind loading of 430 Pa.

The rated strength of a composite conductor shall be taken as the sum of the strengths of the aluminium and aluminium-clad steel components

The breaking strength of the composite conductor shall not be less than 95% of the rated strength.

1.3 STRINGING CHART

Span From Str.	Span To Str.	Temp. (deg C)	Ruling Span (m)	Span Length (m)	Mid Span Sag (m)	Catenary (m)	Horz. Tension (N)	Wave Time (Sec)
L1 - 001	L1 - 014	15	88,72	40	0,15	1334,44	7112,17	2,1
L1 - 001	L1 - 014	25	88,72	40	0,18	1094,01	5830,72	2,32
L1 - 001	L1 - 014	35	88,72	40	0,22	908,04	4839,56	2,54
L1 - 001	L1 - 014	45	88,72	40	0,26	773,98	4125,06	2,75
L1 - 001	L1 - 014	15	88,72	50	0,23	1334,44	7112,17	2,62
L1 - 001	L1 - 014	25	88,72	50	0,29	1094,01	5830,72	2,9
L1 - 001	L1 - 014	35	88,72	50	0,34	908,04	4839,56	3,18
L1 - 001	L1 - 014	45	88,72	50	0,4	773,98	4125,06	3,44
L1 - 001	L1 - 014	15	88,72	60	0,34	1334,44	7112,17	3,15
L1 - 001	L1 - 014	25	88,72	60	0,41	1094,01	5830,72	3,47
L1 - 001	L1 - 014	35	88,72	60	0,5	908,04	4839,56	3,81
L1 - 001	L1 - 014	45	88,72	60	0,58	773,98	4125,06	4,13
L1 - 001	L1 - 014	15	88,72	70	0,46	1334,44	7112,17	3,67
L1 - 001	L1 - 014	25	88,72	70	0,56	1094,01	5830,72	4,05
L1 - 001	L1 - 014	35	88,72	70	0,67	908,04	4839,56	4,45
L1 - 001	L1 - 014	45	88,72	70	0,79	773,98	4125,06	4,82
L1 - 001	L1 - 014	15	88,72	80	0,6	1334,44	7112,17	4,19
L1 - 001	L1 - 014	25	88,72	80	0,73	1094,01	5830,72	4,63
L1 - 001	L1 - 014	35	88,72	80	0,88	908,04	4839,56	5,09
L1 - 001	L1 - 014	45	88,72	80	1,03	773,98	4125,06	5,51
L1 - 001	L1 - 014	15	88,72	90	0,76	1334,44	7112,17	4,72
L1 - 001	L1 - 014	25	88,72	90	0,93	1094,01	5830,72	5,21
L1 - 001	L1 - 014	35	88,72	90	1,12	908,04	4839,56	5,72
L1 - 001	L1 - 014	45	88,72	90	1,31	773,98	4125,06	6,2

L1 - 014	L1 - 028	15	84,1	40	0,14	1398,31	7452,54	2,05
L1 - 014	L1 - 028	25	84,1	40	0,18	1135,25	6050,56	2,27
L1 - 014	L1 - 028	35	84,1	40	0,22	929,38	4953,32	2,51
L1 - 014	L1 - 028	45	84,1	40	0,26	780,76	4161,2	2,74
L1 - 014	L1 - 028	15	84,1	50	0,22	1398,31	7452,54	2,56
L1 - 014	L1 - 028	25	84,1	50	0,28	1135,25	6050,56	2,84
L1 - 014	L1 - 028	35	84,1	50	0,34	929,38	4953,32	3,14
L1 - 014	L1 - 028	45	84,1	50	0,4	780,76	4161,2	3,43
L1 - 014	L1 - 028	15	84,1	60	0,32	1398,31	7452,54	3,07
L1 - 014	L1 - 028	25	84,1	60	0,4	1135,25	6050,56	3,41
L1 - 014	L1 - 028	35	84,1	60	0,48	929,38	4953,32	3,77
L1 - 014	L1 - 028	45	84,1	60	0,58	780,76	4161,2	4,11
L1 - 014	L1 - 028	15	84,1	70	0,44	1398,31	7452,54	3,59
L1 - 014	L1 - 028	25	84,1	70	0,54	1135,25	6050,56	3,98
L1 - 014	L1 - 028	35	84,1	70	0,66	929,38	4953,32	4,4
L1 - 014	L1 - 028	45	84,1	70	0,78	780,76	4161,2	4,8
L1 - 014	L1 - 028	15	84,1	80	0,57	1398,31	7452,54	4,1
L1 - 014	L1 - 028	25	84,1	80	0,7	1135,25	6050,56	4,55
L1 - 014	L1 - 028	35	84,1	80	0,86	929,38	4953,32	5,03
L1 - 014	L1 - 028	45	84,1	80	1,02	780,76	4161,2	5,48
L1 - 014	L1 - 028	15	84,1	90	0,72	1398,31	7452,54	4,61
L1 - 014	L1 - 028	25	84,1	90	0,89	1135,25	6050,56	5,12
L1 - 014	L1 - 028	35	84,1	90	1,09	929,38	4953,32	5,65
L1 - 014	L1 - 028	45	84,1	90	1,3	780,76	4161,2	6,17
L1 - 028	L1 - 042	45	84,46	30	0,14	779,07	4152,23	2,06
L1 - 028	L1 - 042	15	84,46	40	0,14	1392,25	7420,27	2,05
L1 - 028	L1 - 042	25	84,46	40	0,18	1128,93	6016,84	2,28
L1 - 028	L1 - 042	35	84,46	40	0,22	926,11	4935,87	2,52
L1 - 028	L1 - 042	45	84,46	40	0,26	779,07	4152,23	2,74
L1 - 028	L1 - 042	15	84,46	50	0,22	1392,25	7420,27	2,57
L1 - 028	L1 - 042	25	84,46	50	0,28	1128,93	6016,84	2,85
L1 - 028	L1 - 042	35	84,46	50	0,34	926,11	4935,87	3,15
L1 - 028	L1 - 042	45	84,46	50	0,4	779,07	4152,23	3,43
L1 - 028	L1 - 042	15	84,46	60	0,32	1392,25	7420,27	3,08
L1 - 028	L1 - 042	25	84,46	60	0,4	1128,93	6016,84	3,42
L1 - 028	L1 - 042	35	84,46	60	0,49	926,11	4935,87	3,78
L1 - 028	L1 - 042	45	84,46	60	0,58	779,07	4152,23	4,12
L1 - 028	L1 - 042	15	84,46	70	0,44	1392,25	7420,27	3,59
L1 - 028	L1 - 042	25	84,46	70	0,54	1128,93	6016,84	3,99
L1 - 028	L1 - 042	35	84,46	70	0,66	926,11	4935,87	4,41
L1 - 028	L1 - 042	45	84,46	70	0,79	779,07	4152,23	4,8
L1 - 028	L1 - 042	15	84,46	80	0,57	1392,25	7420,27	4,11
L1 - 028	L1 - 042	25	84,46	80	0,71	1128,93	6016,84	4,56

L1 - 028	L1 - 042	35	84,46	80	0,86	926,11	4935,87	5,04
L1 - 028	L1 - 042	45	84,46	80	1,03	779,07	4152,23	5,49
L1 - 028	L1 - 042	15	84,46	90	0,73	1392,25	7420,27	4,62
L1 - 028	L1 - 042	25	84,46	90	0,9	1128,93	6016,84	5,13
L1 - 028	L1 - 042	35	84,46	90	1,09	926,11	4935,87	5,66
L1 - 028	L1 - 042	45	84,46	90	1,3	779,07	4152,23	6,18
L1 - 042	L1 - 055	15	88,71	40	0,15	1334,44	7112,17	2,1
L1 - 042	L1 - 055	25	88,71	40	0,18	1094,01	5830,72	2,32
L1 - 042	L1 - 055	35	88,71	40	0,22	908,04	4839,56	2,54
L1 - 042	L1 - 055	45	88,71	40	0,26	773,98	4125,06	2,75
L1 - 042	L1 - 055	15	88,71	50	0,23	1334,44	7112,17	2,62
L1 - 042	L1 - 055	25	88,71	50	0,29	1094,01	5830,72	2,9
L1 - 042	L1 - 055	35	88,71	50	0,34	908,04	4839,56	3,18
L1 - 042	L1 - 055	45	88,71	50	0,4	773,98	4125,06	3,44
L1 - 042	L1 - 055	15	88,71	60	0,34	1334,44	7112,17	3,15
L1 - 042	L1 - 055	25	88,71	60	0,41	1094,01	5830,72	3,47
L1 - 042	L1 - 055	35	88,71	60	0,5	908,04	4839,56	3,81
L1 - 042	L1 - 055	45	88,71	60	0,58	773,98	4125,06	4,13
L1 - 042	L1 - 055	15	88,71	70	0,46	1334,44	7112,17	3,67
L1 - 042	L1 - 055	25	88,71	70	0,56	1094,01	5830,72	4,05
L1 - 042	L1 - 055	35	88,71	70	0,67	908,04	4839,56	4,45
L1 - 042	L1 - 055	45	88,71	70	0,79	773,98	4125,06	4,82
L1 - 042	L1 - 055	15	88,71	80	0,6	1334,44	7112,17	4,19
L1 - 042	L1 - 055	25	88,71	80	0,73	1094,01	5830,72	4,63
L1 - 042	L1 - 055	35	88,71	80	0,88	908,04	4839,56	5,09
L1 - 042	L1 - 055	45	88,71	80	1,03	773,98	4125,06	5,51
L1 - 042	L1 - 055	15	88,71	90	0,76	1334,44	7112,17	4,72
L1 - 042	L1 - 055	25	88,71	90	0,93	1094,01	5830,72	5,21
L1 - 042	L1 - 055	35	88,71	90	1,12	908,04	4839,56	5,72
L1 - 042	L1 - 055	45	88,71	90	1,31	773,98	4125,06	6,2
L1 - 055	L1 - 068	15	88,46	40	0,15	1337,5	7128,45	2,09
L1 - 055	L1 - 068	25	88,46	40	0,18	1094,01	5830,73	2,32
L1 - 055	L1 - 068	35	88,46	40	0,22	908,86	4843,95	2,54
L1 - 055	L1 - 068	45	88,46	40	0,26	773,98	4125,08	2,75
L1 - 055	L1 - 068	15	88,46	50	0,23	1337,5	7128,45	2,62
L1 - 055	L1 - 068	25	88,46	50	0,29	1094,01	5830,73	2,9
L1 - 055	L1 - 068	35	88,46	50	0,34	908,86	4843,95	3,18
L1 - 055	L1 - 068	45	88,46	50	0,4	773,98	4125,08	3,44
L1 - 055	L1 - 068	15	88,46	60	0,34	1337,5	7128,45	3,14
L1 - 055	L1 - 068	25	88,46	60	0,41	1094,01	5830,73	3,47
L1 - 055	L1 - 068	35	88,46	60	0,5	908,86	4843,95	3,81
L1 - 055	L1 - 068	45	88,46	60	0,58	773,98	4125,08	4,13
L1 - 055	L1 - 068	15	88,46	70	0,46	1337,5	7128,45	3,67

L1 - 055	L1 - 068	25	88,46	70	0,56	1094,01	5830,73	4,05
L1 - 055	L1 - 068	35	88,46	70	0,67	908,86	4843,95	4,45
L1 - 055	L1 - 068	45	88,46	70	0,79	773,98	4125,08	4,82
L1 - 055	L1 - 068	15	88,46	80	0,6	1337,5	7128,45	4,19
L1 - 055	L1 - 068	25	88,46	80	0,73	1094,01	5830,73	4,63
L1 - 055	L1 - 068	35	88,46	80	0,88	908,86	4843,95	5,08
L1 - 055	L1 - 068	45	88,46	80	1,03	773,98	4125,08	5,51
L1 - 055	L1 - 068	15	88,46	90	0,76	1337,5	7128,45	4,71
L1 - 055	L1 - 068	25	88,46	90	0,93	1094,01	5830,73	5,21
L1 - 055	L1 - 068	35	88,46	90	1,11	908,86	4843,95	5,72
L1 - 055	L1 - 068	45	88,46	90	1,31	773,98	4125,08	6,2
L1 - 068	L1 - 081	15	88,44	40	0,15	1340,55	7144,72	2,09
L1 - 068	L1 - 081	25	88,44	40	0,18	1095,6	5839,2	2,31
L1 - 068	L1 - 081	35	88,44	40	0,22	909,68	4848,32	2,54
L1 - 068	L1 - 081	45	88,44	40	0,26	774,82	4129,56	2,75
L1 - 068	L1 - 081	15	88,44	50	0,23	1340,55	7144,72	2,62
L1 - 068	L1 - 081	25	88,44	50	0,29	1095,6	5839,2	2,89
L1 - 068	L1 - 081	35	88,44	50	0,34	909,68	4848,32	3,18
L1 - 068	L1 - 081	45	88,44	50	0,4	774,82	4129,56	3,44
L1 - 068	L1 - 081	15	88,44	60	0,34	1340,55	7144,72	3,14
L1 - 068	L1 - 081	25	88,44	60	0,41	1095,6	5839,2	3,47
L1 - 068	L1 - 081	35	88,44	60	0,49	909,68	4848,32	3,81
L1 - 068	L1 - 081	45	88,44	60	0,58	774,82	4129,56	4,13
L1 - 068	L1 - 081	15	88,44	70	0,46	1340,55	7144,72	3,66
L1 - 068	L1 - 081	25	88,44	70	0,56	1095,6	5839,2	4,05
L1 - 068	L1 - 081	35	88,44	70	0,67	909,68	4848,32	4,45
L1 - 068	L1 - 081	45	88,44	70	0,79	774,82	4129,56	4,82
L1 - 068	L1 - 081	15	88,44	80	0,6	1340,55	7144,72	4,18
L1 - 068	L1 - 081	25	88,44	80	0,73	1095,6	5839,2	4,63
L1 - 068	L1 - 081	35	88,44	80	0,88	909,68	4848,32	5,08
L1 - 068	L1 - 081	45	88,44	80	1,03	774,82	4129,56	5,51
L1 - 068	L1 - 081	15	88,44	90	0,76	1340,55	7144,72	4,71
L1 - 068	L1 - 081	25	88,44	90	0,92	1095,6	5839,2	5,21
L1 - 068	L1 - 081	35	88,44	90	1,11	909,68	4848,32	5,72
L1 - 068	L1 - 081	45	88,44	90	1,31	774,82	4129,56	6,19
L1 - 081	L1 - 094	15	88,52	40	0,15	1337,5	7128,45	2,09
L1 - 081	L1 - 094	25	88,52	40	0,18	1094,01	5830,73	2,32
L1 - 081	L1 - 094	35	88,52	40	0,22	908,86	4843,94	2,54
L1 - 081	L1 - 094	45	88,52	40	0,26	773,98	4125,08	2,75
L1 - 081	L1 - 094	15	88,52	50	0,23	1337,5	7128,45	2,62
L1 - 081	L1 - 094	25	88,52	50	0,29	1094,01	5830,73	2,9
L1 - 081	L1 - 094	35	88,52	50	0,34	908,86	4843,94	3,18
L1 - 081	L1 - 094	45	88,52	50	0,4	773,98	4125,08	3,44

L1 - 081	L1 - 094	15	88,52	60	0,34	1337,5	7128,45	3,14
L1 - 081	L1 - 094	25	88,52	60	0,41	1094,01	5830,73	3,47
L1 - 081	L1 - 094	35	88,52	60	0,5	908,86	4843,94	3,81
L1 - 081	L1 - 094	45	88,52	60	0,58	773,98	4125,08	4,13
L1 - 081	L1 - 094	15	88,52	70	0,46	1337,5	7128,45	3,67
L1 - 081	L1 - 094	25	88,52	70	0,56	1094,01	5830,73	4,05
L1 - 081	L1 - 094	35	88,52	70	0,67	908,86	4843,94	4,45
L1 - 081	L1 - 094	45	88,52	70	0,79	773,98	4125,08	4,82
L1 - 081	L1 - 094	15	88,52	80	0,6	1337,5	7128,45	4,19
L1 - 081	L1 - 094	25	88,52	80	0,73	1094,01	5830,73	4,63
L1 - 081	L1 - 094	35	88,52	80	0,88	908,86	4843,94	5,08
L1 - 081	L1 - 094	45	88,52	80	1,03	773,98	4125,08	5,51
L1 - 081	L1 - 094	15	88,52	90	0,76	1337,5	7128,45	4,71
L1 - 081	L1 - 094	25	88,52	90	0,93	1094,01	5830,73	5,21
L1 - 081	L1 - 094	35	88,52	90	1,11	908,86	4843,94	5,72
L1 - 081	L1 - 094	45	88,52	90	1,31	773,98	4125,08	6,2
L1 - 094	L1 - 107	15	88,39	40	0,15	1340,55	7144,72	2,09
L1 - 094	L1 - 107	25	88,39	40	0,18	1097,19	5847,67	2,31
L1 - 094	L1 - 107	35	88,39	40	0,22	909,68	4848,32	2,54
L1 - 094	L1 - 107	45	88,39	40	0,26	774,82	4129,57	2,75
L1 - 094	L1 - 107	15	88,39	50	0,23	1340,55	7144,72	2,62
L1 - 094	L1 - 107	25	88,39	50	0,28	1097,19	5847,67	2,89
L1 - 094	L1 - 107	35	88,39	50	0,34	909,68	4848,32	3,18
L1 - 094	L1 - 107	45	88,39	50	0,4	774,82	4129,57	3,44
L1 - 094	L1 - 107	15	88,39	60	0,34	1340,55	7144,72	3,14
L1 - 094	L1 - 107	25	88,39	60	0,41	1097,19	5847,67	3,47
L1 - 094	L1 - 107	35	88,39	60	0,49	909,68	4848,32	3,81
L1 - 094	L1 - 107	45	88,39	60	0,58	774,82	4129,57	4,13
L1 - 094	L1 - 107	15	88,39	70	0,46	1340,55	7144,72	3,66
L1 - 094	L1 - 107	25	88,39	70	0,56	1097,19	5847,67	4,05
L1 - 094	L1 - 107	35	88,39	70	0,67	909,68	4848,32	4,45
L1 - 094	L1 - 107	45	88,39	70	0,79	774,82	4129,57	4,82
L1 - 094	L1 - 107	15	88,39	80	0,6	1340,55	7144,72	4,18
L1 - 094	L1 - 107	25	88,39	80	0,73	1097,19	5847,67	4,63
L1 - 094	L1 - 107	35	88,39	80	0,88	909,68	4848,32	5,08
L1 - 094	L1 - 107	45	88,39	80	1,03	774,82	4129,57	5,51
L1 - 094	L1 - 107	15	88,39	90	0,76	1340,55	7144,72	4,71
L1 - 094	L1 - 107	25	88,39	90	0,92	1097,19	5847,67	5,2
L1 - 094	L1 - 107	35	88,39	90	1,11	909,68	4848,32	5,72
L1 - 094	L1 - 107	45	88,39	90	1,31	774,82	4129,57	6,19
L1 - 107	L1 - 120	15	88,39	40	0,15	1340,55	7144,72	2,09
L1 - 107	L1 - 120	25	88,39	40	0,18	1097,19	5847,67	2,31
L1 - 107	L1 - 120	35	88,39	40	0,22	909,68	4848,32	2,54

L1 - 107	L1 - 120	45	88,39	40	0,26	774,82	4129,57	2,75
L1 - 107	L1 - 120	15	88,39	50	0,23	1340,55	7144,72	2,62
L1 - 107	L1 - 120	25	88,39	50	0,28	1097,19	5847,67	2,89
L1 - 107	L1 - 120	35	88,39	50	0,34	909,68	4848,32	3,18
L1 - 107	L1 - 120	45	88,39	50	0,4	774,82	4129,57	3,44
L1 - 107	L1 - 120	15	88,39	60	0,34	1340,55	7144,72	3,14
L1 - 107	L1 - 120	25	88,39	60	0,41	1097,19	5847,67	3,47
L1 - 107	L1 - 120	35	88,39	60	0,49	909,68	4848,32	3,81
L1 - 107	L1 - 120	45	88,39	60	0,58	774,82	4129,57	4,13
L1 - 107	L1 - 120	15	88,39	70	0,46	1340,55	7144,72	3,66
L1 - 107	L1 - 120	25	88,39	70	0,56	1097,19	5847,67	4,05
L1 - 107	L1 - 120	35	88,39	70	0,67	909,68	4848,32	4,45
L1 - 107	L1 - 120	45	88,39	70	0,79	774,82	4129,57	4,82
L1 - 107	L1 - 120	15	88,39	80	0,6	1340,55	7144,72	4,18
L1 - 107	L1 - 120	25	88,39	80	0,73	1097,19	5847,67	4,63
L1 - 107	L1 - 120	35	88,39	80	0,88	909,68	4848,32	5,08
L1 - 107	L1 - 120	45	88,39	80	1,03	774,82	4129,57	5,51
L1 - 107	L1 - 120	15	88,39	90	0,76	1340,55	7144,72	4,71
L1 - 107	L1 - 120	25	88,39	90	0,92	1097,19	5847,67	5,2
L1 - 107	L1 - 120	35	88,39	90	1,11	909,68	4848,32	5,72
L1 - 107	L1 - 120	45	88,39	90	1,31	774,82	4129,57	6,19
L1 - 120	L1 - 133	15	88,4	40	0,15	1340,55	7144,72	2,09
L1 - 120	L1 - 133	25	88,4	40	0,18	1097,19	5847,67	2,31
L1 - 120	L1 - 133	35	88,4	40	0,22	909,68	4848,32	2,54
L1 - 120	L1 - 133	45	88,4	40	0,26	774,82	4129,56	2,75
L1 - 120	L1 - 133	15	88,4	50	0,23	1340,55	7144,72	2,62
L1 - 120	L1 - 133	25	88,4	50	0,28	1097,19	5847,67	2,89
L1 - 120	L1 - 133	35	88,4	50	0,34	909,68	4848,32	3,18
L1 - 120	L1 - 133	45	88,4	50	0,4	774,82	4129,56	3,44
L1 - 120	L1 - 133	15	88,4	60	0,34	1340,55	7144,72	3,14
L1 - 120	L1 - 133	25	88,4	60	0,41	1097,19	5847,67	3,47
L1 - 120	L1 - 133	35	88,4	60	0,49	909,68	4848,32	3,81
L1 - 120	L1 - 133	45	88,4	60	0,58	774,82	4129,56	4,13
L1 - 120	L1 - 133	15	88,4	70	0,46	1340,55	7144,72	3,66
L1 - 120	L1 - 133	25	88,4	70	0,56	1097,19	5847,67	4,05
L1 - 120	L1 - 133	35	88,4	70	0,67	909,68	4848,32	4,45
L1 - 120	L1 - 133	45	88,4	70	0,79	774,82	4129,56	4,82
L1 - 120	L1 - 133	15	88,4	80	0,6	1340,55	7144,72	4,18
L1 - 120	L1 - 133	25	88,4	80	0,73	1097,19	5847,67	4,63
L1 - 120	L1 - 133	35	88,4	80	0,88	909,68	4848,32	5,08
L1 - 120	L1 - 133	45	88,4	80	1,03	774,82	4129,56	5,51
L1 - 120	L1 - 133	15	88,4	90	0,76	1340,55	7144,72	4,71
L1 - 120	L1 - 133	25	88,4	90	0,92	1097,19	5847,67	5,2

L1 - 120	L1 - 133	35	88,4	90	1,11	909,68	4848,32	5,72
L1 - 120	L1 - 133	45	88,4	90	1,31	774,82	4129,56	6,19
L1 - 133	L1 - 146	15	88,39	40	0,15	1340,55	7144,72	2,09
L1 - 133	L1 - 146	25	88,39	40	0,18	1097,19	5847,67	2,31
L1 - 133	L1 - 146	35	88,39	40	0,22	909,68	4848,32	2,54
L1 - 133	L1 - 146	45	88,39	40	0,26	774,82	4129,57	2,75
L1 - 133	L1 - 146	15	88,39	50	0,23	1340,55	7144,72	2,62
L1 - 133	L1 - 146	25	88,39	50	0,28	1097,19	5847,67	2,89
L1 - 133	L1 - 146	35	88,39	50	0,34	909,68	4848,32	3,18
L1 - 133	L1 - 146	45	88,39	50	0,4	774,82	4129,57	3,44
L1 - 133	L1 - 146	15	88,39	60	0,34	1340,55	7144,72	3,14
L1 - 133	L1 - 146	25	88,39	60	0,41	1097,19	5847,67	3,47
L1 - 133	L1 - 146	35	88,39	60	0,49	909,68	4848,32	3,81
L1 - 133	L1 - 146	45	88,39	60	0,58	774,82	4129,57	4,13
L1 - 133	L1 - 146	15	88,39	70	0,46	1340,55	7144,72	3,66
L1 - 133	L1 - 146	25	88,39	70	0,56	1097,19	5847,67	4,05
L1 - 133	L1 - 146	35	88,39	70	0,67	909,68	4848,32	4,45
L1 - 133	L1 - 146	45	88,39	70	0,79	774,82	4129,57	4,82
L1 - 133	L1 - 146	15	88,39	80	0,6	1340,55	7144,72	4,18
L1 - 133	L1 - 146	25	88,39	80	0,73	1097,19	5847,67	4,63
L1 - 133	L1 - 146	35	88,39	80	0,88	909,68	4848,32	5,08
L1 - 133	L1 - 146	45	88,39	80	1,03	774,82	4129,57	5,51
L1 - 133	L1 - 146	15	88,39	90	0,76	1340,55	7144,72	4,71
L1 - 133	L1 - 146	25	88,39	90	0,92	1097,19	5847,67	5,2
L1 - 133	L1 - 146	35	88,39	90	1,11	909,68	4848,32	5,72
L1 - 133	L1 - 146	45	88,39	90	1,31	774,82	4129,57	6,19
L1 - 146	L1 - 159	15	88,39	40	0,15	1342,08	7152,85	2,09
L1 - 146	L1 - 159	25	88,39	40	0,18	1098,78	5856,14	2,31
L1 - 146	L1 - 159	35	88,39	40	0,22	911,32	4857,06	2,54
L1 - 146	L1 - 159	45	88,39	40	0,26	775,66	4134,04	2,75
L1 - 146	L1 - 159	15	88,39	50	0,23	1342,08	7152,85	2,61
L1 - 146	L1 - 159	25	88,39	50	0,28	1098,78	5856,14	2,89
L1 - 146	L1 - 159	35	88,39	50	0,34	911,32	4857,06	3,17
L1 - 146	L1 - 159	45	88,39	50	0,4	775,66	4134,04	3,44
L1 - 146	L1 - 159	15	88,39	60	0,34	1342,08	7152,85	3,14
L1 - 146	L1 - 159	25	88,39	60	0,41	1098,78	5856,14	3,47
L1 - 146	L1 - 159	35	88,39	60	0,49	911,32	4857,06	3,81
L1 - 146	L1 - 159	45	88,39	60	0,58	775,66	4134,04	4,13
L1 - 146	L1 - 159	15	88,39	70	0,46	1342,08	7152,85	3,66
L1 - 146	L1 - 159	25	88,39	70	0,56	1098,78	5856,14	4,04
L1 - 146	L1 - 159	35	88,39	70	0,67	911,32	4857,06	4,44
L1 - 146	L1 - 159	45	88,39	70	0,79	775,66	4134,04	4,81
L1 - 146	L1 - 159	15	88,39	80	0,6	1342,08	7152,85	4,18

L1 - 146	L1 - 159	25	88,39	80	0,73	1098,78	5856,14	4,62
L1 - 146	L1 - 159	35	88,39	80	0,88	911,32	4857,06	5,08
L1 - 146	L1 - 159	45	88,39	80	1,03	775,66	4134,04	5,5
L1 - 146	L1 - 159	15	88,39	90	0,75	1342,08	7152,85	4,71
L1 - 146	L1 - 159	25	88,39	90	0,92	1098,78	5856,14	5,2
L1 - 146	L1 - 159	35	88,39	90	1,11	911,32	4857,06	5,71
L1 - 146	L1 - 159	45	88,39	90	1,31	775,66	4134,04	6,19

Table 18 Stringing Chart

2. ELECTRICAL CALCULATIONS OF THE OVERHEAD LINE

This section contains the electrical calculations from the overhead line of the project execution.

2.1 CURRENT CAPACITY

The maximum current density for aluminium conductors on the steady state for 60Hz alternating current (δ_L) is different from the maximum current for the aluminium-steel conductors. It exists a reduction of the current transport capacity due to the steel's conductivity. The reduction is defined by coefficient "k":

$$\delta_{LA} = \delta_L \cdot k \left(\frac{A}{mm^2}\right)$$

For the wire used at the project, MERLIN/AW, the current density and the withstand current are:

TYPE OF WIRE	MERLIN/AW
Area of Aluminium wires	336,4 mm^2
Aluminium Area	170,22 mm^2
Alumoweld Area	9,457 mm^2
Total Cross-Sectional Area	179,7 mm^2
Overall Diameter	17,35 mm
Composition	18+1
Aluminium wire Diameter	18x3,47 mm
Alumoweld wire Diameter	1x3,47 mm
Resistance at 75ºC	0,2036 Ω/km
δ_{LA}	1.542 A/mm^2
I admisible at 45ºC	396A (*)
Coefficient for linear expansion per ºC	21 x 10^{-6} ºC^{-1}

Table 19 Merlin Characteristics

(*) Ampacity is calculated:

- wind speed: 0.6m/s
- intensity of solar radiation: 900
- solar absorption coefficient: 0.5
- emissivity: 0.6

The maximum power per three-phase circuit at 33kV which can be transported is:

$$S = n \cdot \sqrt{3} \cdot U \cdot I = 1 \cdot \sqrt{3} \cdot 33 \cdot 396 = 22{,}63MVA$$

2.2 ELECTRIC PARAMETERS

An overhead line is an electrical circuit formed by several conductors (one or more per phase), separated by the air and with a distance to ground. Electrically, it can be defined as a circuit.

In this circuit there are some features along the conductors that produce a voltage drop. These values are called longitudinal features (the resistance(R) and inductance(X)), which conform the impedance of the line (Z=R+jX).

In this circuit there are also some characteristics that along line produce a leak or current shunt. These values are called cross features (conductance (G) and capacity (B)), which conform the admittance of the line (Y=G+jB).

These four: resistance, inductance, conductance and capacity values are known as basic electrical constant an overhead line. The fundamental constants from a power line are the parameters that determine its ability to fulfil its role as a component of an electrical network.

The equivalent circuit is defined as:

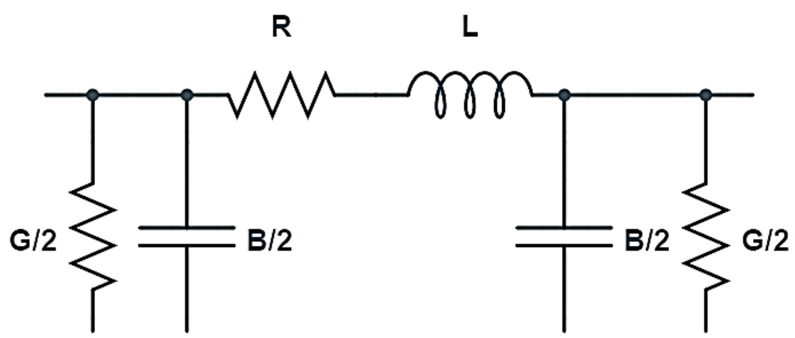


Image 19 Equivalent Circuit

2.2.1 Characteristic impedance and power

Regarding the longitudinal features, as it has been said before, they stablish relation between the voltage at the beginning and at the end of the line. Thus, the relation between the current is stablished by the impedance. It has special attention if the current is variable during the time, although it is modelled for the steady state of it.

The resistance of a conductor is defined as:

$$R = \rho \cdot \frac{L}{S}$$

Being:

- L: the length of the conductor
- S: the total area of the conductor
- ρ: the resistivity of the conductor.

The resistivity is defined as the opposition that offers a type of material to the passing of an electric current per unit of length and unit of surface. Not only depends on the type of material but also on the ambient temperature. The behaviour of the resistance in relation to the temperature is linear and responds to the following expression:

$$\rho_{\theta} = \rho_{20ºC} + \rho_{20ºC} \cdot \alpha \cdot (\theta - 20)$$

Where:

- ρθ: the resistivity of the material at a temperature θ
- ρ20ºC: the resistivity of the material at a 20ºC
- α: coefficient for linear expansion per ºC (ºC-1)
- θ: Temperature at which we want to calculate the resistivity

The resistance at the temperature of service (75ºC) is one of the parameters which are given at the technical data of the conductor. As we have mention in the table above, the Resistance at 75ºC is 0, 2036 Ω/km.

The most important consequence of the existence of a resistor in an electrical circuit are joule losses which are define by the Joule's law:

$$P = R \cdot I^2$$

Being:

- P: the power losses
- R: the resistance of the conductor
- I: the current passing through the conductor

As for the inductance, it is define as a consequence of the Faraday's law. When a sinusoidal alternating current pass through a conductor, an electromotive force (emf) is generated, and it is proportional to the frequency of the wave. This is due to the variation of the magnetic flux. Faraday's law expresses this in a mathematical way:

$$\text{emf} = \frac{\partial \Phi}{\partial t} = L \frac{\partial i}{\partial t}$$

Being:

- emf: the electromotive force, which has the same value as the voltage drop
- Φ: magnetic flux
- i: alternating current
- t: time
- L: autoinductive coefficient

As a consequence of the Faraday Law, the autoinductive coefficient can be define as:

$$L = \frac{\Phi}{i}$$

This autoinductive coefficient depends on the dimension of the conductor and the disposition of the different phase-conductor, this expression is the result summing the effects that of the integration of the magnetic field generated by each conductor.

$$L_K = \left[0{,}5 + 4{,}6 \cdot \log\left(\frac{DMG}{RMG}\right)\right] \cdot 10^{-4}$$

Being:

- L_K: autoinductive coefficient per km [F/km]
- DMG: Medium geometric distance between the phase conductors

$$DMG = \sqrt[3]{d_{12} \cdot d_{13} \cdot d_{23}}$$

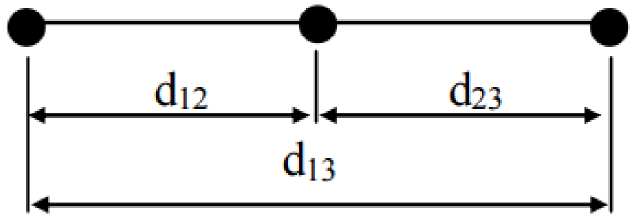


Image 20 Phase Distance

This DMG is defined by the crossarm of our pole:

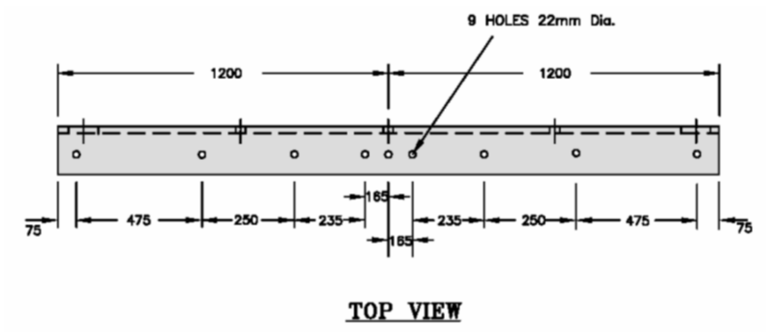


Image 21 Crossarm Top View

- d_{12}: 1125mm
- d_{23}: 1125mm
- d_{13}: 2250mm

The result is:

$$DMG = 147{,}7789cm$$

- RMG: medium geometric distance between the conductors of a phase. This has a different value from the radius of the conductor when the configuration of the system is not simplex. In our case, as being a simple circuit, it has the same value.

$$\mathrm{RMG} = \mathrm{R} = 0{,}6584\mathrm{cm}$$

As a consequence:

$$\mathrm{L_K} = 11{,}31318 \cdot 10^{-4} \frac{\mathrm{H}}{\mathrm{km}}$$

The inductance, X, when de alternating frequency is constant (60Hz) can define as:

$$\mathrm{X} = \mathrm{L} \cdot \omega$$

Thus, the inductance per km is

$$\mathrm{X_K} = \mathrm{L_K} \cdot \omega$$

In which:

- ω is the current pulsation (2 π f)
- f is the grid frequency 60Hz
- L_K is the self-inductive coefficient in H/km calculated above

To sum up, the impedance is conformed as:

$$\mathrm{Z_k} = \mathrm{R_K} + \mathrm{jX_K} \left(\frac{\Omega}{\mathrm{km}}\right)$$

Where:

- R_K is the resistance per km, which in this case is:

R_K= 0,204 Ω/km

- X_K is the self-inductive reactance per km is define by the following expression:

L_K=0,427 Ω/km

As a result, it can be said that the total impedance of the overhead line per km is:

$$\mathrm{Z_k} = 0{,}204 + \mathrm{j}\ 0{,}427 \left(\frac{\Omega}{\mathrm{km}}\right)$$

Bearing in mind the length of the line 1 is 13,56km, therefore, the total impedance of the line is:

$$\mathrm{Z} = \mathrm{Z_K} \cdot \mathrm{L_T} = (0{,}204 + \mathrm{j}\ 0{,}427) \cdot 13{,}56 = (2{,}762 + \mathrm{j}5{,}785)\ \Omega$$

2.2.2 Characteristics of the admittance. Transport Capacitance

In this circuit there are also some characteristics that along the line produce a leak or current shunt. These values are called cross features (conductance and capacity), which conform the admittance of the line.

The conductors of an overhead line, isolated from each other and from the ground are, from the electrical point of view can be modelled as capacitors, as they are at different voltage, they take an electrical charge that depends on the relative values of such potentials.

By integrating the electric potential difference between the conductors and the ground and between the different phase conductors, and afterwards summing them as parallel capacitors it can be obtained the following expression.

$$C_K = \frac{24{,}2}{\log\left(\frac{DMG}{RMG}\right)} \cdot 10^{-9} \left(\frac{F}{km}\right)$$

This parameter depends also on the distances between the phase conductors and the radius of the conductors.

The result is:

$$C_K = 10{,}293 \cdot 10^{-9} \, \frac{F}{km}$$

The susceptance is defined by the equation below. This definition can only be applied on the frequency steady state, this means that no significant variation on the frequency may occur.

$$B_K = C_K \cdot \omega = 10{,}293 \cdot 10^{-9} \cdot 377 = 3{,}880 \cdot 10^{-6} \, \frac{S}{km}$$

The line capacity is an important parameter since it generates and accumulates reactive power system. The variations of the reactive power help the system to control the voltage level demanded.

The fourth feature that determines our equivalent circuit of the line is the conductance.

Because the isolation of lines is not perfect, there is a leakage current between the active elements (conductors) and the passive. The main source of conductance is this current leakage through the insulators. Because the isolator, although they are note perfect are very precise constructed elements, its value is very small and therefore commonly neglected. Thus is considered G_K=0.

To sum up, the admittance of the overhead line per kilometre is:

$$Y_K = G_K + jB_K = j38{,}804 \cdot 10^{-7} \, \frac{S}{km}$$

As the length of the line 1 is 12,56km, thus, the total admittance is:

$$Y = Y_K \cdot L_T = j38{,}804 \cdot 10^{-7} \cdot 13{,}562 = j5{,}262 \cdot 10^{-5} S$$

2.2.3 Parameters from the Equivalent in Π

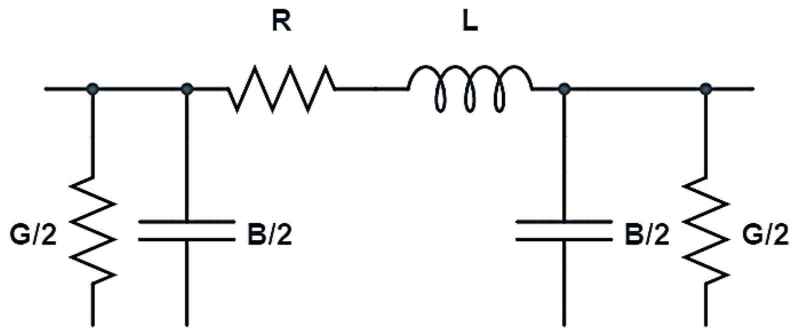


Image 22 Equivalent Circuit

This circuit, as any existing circuit, follows the first and the second Kirchhoff's Laws. The Kirchhoff's First Law, stands the principle of conservation of electric charge, implies that at any node (junction) in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out. The Kirchhoff's Second Law, stands the principle of conservation of energy, implies that the directed sum of the electrical potential differences (voltage) around any closed network is zero.

By using this two laws and the Ohm's Law, it can be determined the current and the voltage at any point of the circuit, although the points that affect at the electrical calculation are the initial and the final point. Due to this, there are defined four constants, which conform the two-terminal-pair network, which are the consequence of operating this circuit by using the laws mentioned above and makes any electrical calculations much clear.

The two-terminal-pair network is characterized by four complex parameters A, B and C D. A and D are dimensionless, B's dimension is Ω and the C's dimension is Ω^{-1} .This four constants relate the initial and the final point of the circuit in a matricidal way:

$$\begin{bmatrix} V_I \\ I_I \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} V_K \\ I_K \end{bmatrix}$$

- V_I: Voltage at the beginning of the line
- I_I: Current at the beginning of the line
- V_K. Voltage at the end of the line
- I_K: Current at the end of the line

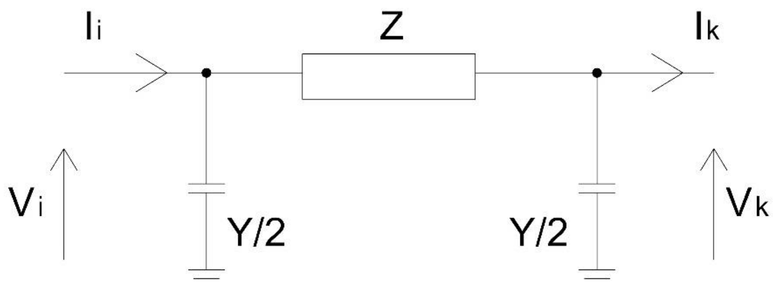


Image 23 Current and Voltage Circuit

These four constants vary their definition depending on the length of the line. The length of the line determines the circuit model it must be used. Due to the length of the line it is ought to be used the "short line" model, which stands for lines up to 80km long. Thus, the general constants are defined as:

$$A = D = \frac{Z \cdot Y}{2} + 1 = 0{,}99950 + 0{,}00024j$$

$$B = Z = (5{,}01314 + 10{,}50322j)\Omega$$

$$C = Y \cdot \left(\frac{Z \cdot Y}{4} + 1\right) = (-1{,}14408 \cdot 10^{-8} + 0{,}000096j)\frac{1}{\Omega}$$

$$\begin{bmatrix} V_i \\ I_i \end{bmatrix} = \begin{bmatrix} 0{,}99984 + 0{,}00007j & 2{,}76112 + 5{,}78493j \\ -1{,}91153 \cdot 10^{-8} + 0{,}00005j & 0{,}99984 + 0{,}00007j \end{bmatrix} \cdot \begin{bmatrix} V_K \\ I_K \end{bmatrix}$$

2.3 VOLTAGE DROP AND POWER LOSS

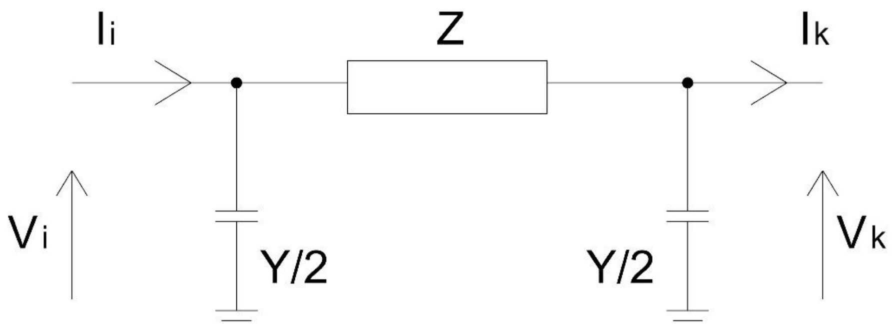


Image 24 Current and Voltage Circuit

The current at the end of the line and the voltage are the beginning of the line is data already known because of the characteristics of the project.

Due to the data of the pump, it is assumed cos(α) = cos (phi) = 0,9.

Data sheet

ANDRITZ

Pump type SU12-190/6/U/ MS-T + 4HSM14/390/2FT

Motor									
1	Manufacturer	ANDRITZ Ritz		Size		14 inch	Type		4HSM14/390/2FT
2	Execution	Rewindable 14 inch (SM14 - Zincfree Bronze - PE2+PA)							
3	Nominal voltage	V	4160	Nominal current	A	68	Enclosure		IP 68
4	Frequency	Hz	60	Efficiency	%	89,0	Type of protection		--
5	Nominal power	kW	390	cos phi		0,90	Explosion protection		--
6	No. of poles		2	Starting method		Direct	Noise level Lpfa	dB	
7	Speed	1/min	3545	Winding wire / Insulation class		PE2+PA / Class Y	Materials:	Zincfree bronze end Shield	
8	Temperature control	2 x PT 100 sensors (metallic type) sealed in probe						Duplex SS 1.4462 sahft end	
9	Power cable	20 m single core round, 4x1x16 sqmm						SS stator	
10	Control cable	20m 3 core cable 2,5 sqmm							
11	Remarks	45C° water temperture - Heat exchanger 3,0 sqm max O.D. = 346 mm							

$$V_I = 33\ \text{kV}$$

$$I_K = \frac{13 \cdot 390}{\sqrt{3} \cdot 33} \cdot 0{,}9 + j\frac{13 \cdot 390}{\sqrt{3} \cdot 33} \cdot 0{,}436 = 79{,}832 - j38{,}664\ \text{A}$$

It is considered that at the end of the line, at the last well, the voltage is exactly 33kV.

The voltage at the end of the line and the current at the beginning will be calculated by using the general constants in the matricidal way. Consequently, it will be obtained the following equations that will lead to the value of V_K and I_I:

$$V_K = \frac{V_I - B \cdot I_K}{A} = 32{,}561 - j0{,}357\ \text{kV}$$

$$I_I = C \cdot V_K + D \cdot I_K = 79{,}841 - j36{,}939\ \text{A}$$

This leads to a voltage drop of:

$$\Delta U(\%) = \frac{|V_I| - |V_K|}{|V_I|} \cdot 100 = 1{,}325\%$$

Consquently, the active power loss will be:

$$S_I = \sqrt{3} \cdot V_I \cdot I_I = (4{,}563 - j2{,}111)\ \text{MVA}$$

$$S_K = \sqrt{3} \cdot V_K \cdot I_K = (4{,}478 - j2{,}230)\ \text{MVA}$$

$$\Delta S = S_I - S_K = (85{,}202 + j118{,}618)\ \text{kVA}$$

$$\Delta P(\%) = \frac{P_I - P_K}{P_I} \cdot 100 = 1{,}867\%$$

Being:

- S_I: electric power at the beginning of the line
- S_K: electric power at the end of the line
- ΔS: electric power loses

NOTE: S is a complex number, its real part stands for the active power (W) while its complex stands for the reactive power (VAR) (S=P+jQ)

2.4 TRANSVERSAL ELECTRIC FIELD AND SUPERFICIAL FIELD AT CONDUCTORS. CORONA.

Corona losses occur in the conductors when the voltage gradient on the conductor surface is greater than the electric strength of the air. This "breakage" of the strength of the air generates heat, light, audible noise and radio interference, to sum up, energy losses in the line that must evaluated. Nevertheless, as the corona losses are very small comparing to the losses caused by the joules effect, they can be negligible.

It is need to check how the conductors respond to corona. Firstly, it is need to know which is the critical breakdown voltage, at which corona starts to show up. It has to be verified that the critical breakdown voltage is always higher than the maximum voltage of the network (36kV).

The critical breakdown voltage is calculated by the F.W.Peek's law. This law, which is empirical, determines with high accuracy with which voltage the corona starts to appear. For the simple phases (our case) is given by:

$$U_c = 84 \cdot m_c \cdot \delta \cdot m_t \cdot r \cdot \log\left(\frac{DMG}{RMG}\right)$$

Being:

- U_C: Critical Breakdown voltage (U correspond to voltage, and c to critical)
- m_C: Roughness coefficient of the conductor. This coefficient must be between 0,83 and 0,87 for bundle assembled aerial cable. For this project, it is considered a coefficient value of 0,84.
- m_t: Meteorological coefficient, which takes to account the humidity effect at the breakdown voltage. For hummed weather it will take the value of 0,8, as for dry weather (case which applies for this project) it will take 1.
- r: conductor radius in cm (r=0,6584 cm)
- RMG: medium geometric distance between the conductors of a phase (RMG=r=0,6584 cm)
- DMG: Medium geometric distance between the phase conductors. (DMG=69,295cm)
- δ: Air density corrector factor. It depends on the height above the sea and the temperature. It is directly proportional to the barometric pressure and inversely proportional to the absolute air temperature. It is determined by the following expression:

$$\delta = \frac{3{,}9252 \cdot h}{273 + T}$$

Where:

- T: Maximum temperature corresponding to the point altitude in ºC. (55ºC)

- h: Barometric pressure in cm of mercury column at the average height of the line. This pressure depends on the altitude of the considered point, it is commonly used the Halley formula to determine it:

$$\log(h) = \log(69{,}9) - \frac{y}{18{,}336} \rightarrow h = 10^{\log(69{,}9) - \frac{y}{18{,}336}}$$

Being "y" the height above the sea in m. The different results from the formula are tabulated below:

HALLEY'S LAW RESULTS	
Altitude above sea level (m) **y**	**Atmospheric pressure in centimeters of mercury (cm Hg)** **h**
0	76
100	75,1
200	74,2
300	73,3
400	72,4
500	71,6
600	70,7
700	69,9
800	69
900	68,2
1000	67,4

Table 20 Halley's Law Results

Being "y" 612m, the corresponding altitude over the sea level corresponding to Ryad altitude the following results can be obtained:

$$\delta = \frac{3{,}921 \cdot h}{273 + t} = \frac{3{,}921 \cdot 70{,}7}{273 + 55} = 0{,}8452$$

$$U_c = 84 \cdot m_c \cdot \delta \cdot m_t \cdot r \cdot \log\left(\frac{DMG}{RMG}\right) = 84 \cdot 0{,}84 \cdot 0{,}8452 \cdot 1 \cdot 0{,}6584 \cdot \log\left(\frac{147{,}7798}{0{,}6584}\right)$$

$$U_c = 93{,}06 kV_{RMS}$$

At the nominal working conditions of the facility, the maximum rms voltage will be 36kV, which will be lower than the critical breakdown voltage. As a conclusion, it can be assured that no corona effects will affect the facility.

2.5 CONCLUSION

The electrical magnitudes of the line will be:

Voltage at the beginning of the line	33kV
Voltage at the end of the line	30,99kV
Voltage drop	6,084%
Current at the beginning of the line	226,20A
Current at the end of the line	227,44A

Active power at the beginning of the line	13MW
Active power at the end of the line	11,707MW
Power loss	8,6927%

Table 21 Summary of the Electrical Magnitudes

The electrical parameters of the line:

Total Resistance	5,0131Ω
Total Inductance	10,5032Ω
Total Capacity	25,3438·10-8F
Total Conductance	0

Table 22 Summary of the Electrical Parameters

On one hand, it can be revealed that the conductor MERLIN/AW stands perfectly the electrical conditions demanded by this project, as its maximum admissible current (396A) is bigger than the current at the beginning of the line (224A). On the other hand, this conductor does not cause corona effect. To sum up, it can be assured that the conductor MERLIN/AW suits perfectly for the facility.

CHAPTER II: POLE CALCULUS

1. TYPES OF POLES AND ITS FUNCTION

The poles which are going to be used are octagonal galvanized steel poles.

The standardized steel poles are tapered octagonal and hot dip galvanized with top cap, bearing plate, earthing nut, colour making and pre-drilled holes, including all drilling, cutting and welding. The minimum average thickness of coating shall be 0.086 mm, equivalent to 610 g/m^2. The standardize lengths for the poles are 12,13,14 and 15 m.

Each pole shall be provided with 80 mm x 80 mm nameplate riveted to the shaft at the location specified in applicable drawing. Nameplate shall include, but not limited to the following information:

- Pole Type
- Pole Ultimate Load
- Pole Dimension (A/F Top/Bottom/Thickness)
- Pole Weight
- Manufacturer's Name or trademark, place and year of manufacturing
- Identification Pole

Bolts, nuts and locknuts for top cap, bearing plate and earthing nut shall be steel Grade 4.6 and shall be hot-dipped galvanized with minimum average coating thickness of 0.053 mm, equivalent to 381 g/m^2.

Steel pole shall be provided with M12 earthing nut at the location specified in applicable drawing. Hot-dipped galvanized M12 x 30 mm long hexagonal bolt with washer shall be screwed on to the earthing nut.

Steel poles shall be provided with detachable top cap and base bearing plate. Flat bar with drilled and tapped hole to suit M12 bolt shall be welded to the top and bottom of the pole for attaching the top cap and base bearing plate, respectively. Hot-dipped galvanized M12 x 30 hexagonal bolts and washers shall be provided for attaching the top cap and base plate.

The following tolerances shall apply:

- +/-0.5 % for overall length
- +/- 5 mm for A/F diameter
- +/- 2 mm for centre-to-centre distance between holes
- +/- 0.5 mm for diameter of pre-drilled holes

Different types of poles used at this project and its characteristics are:

POLE TYPE	OC13S
Length	13 m
Top A/F diameter	155 mm
Bottom A/F diameter	410 mm
Shaft thickness	4 mm

Pole ultimate load	1530 kg
Total Wight (after galvanization)	390 kg
Standard designation/grade of steel material for shaft	EN10027-15355
Shaft Weight	377 kg
Minimum coating weight of hot-dip galvanizing of pole shaft	610 g/m^3
Buried Depth	2000 mm
Crossarm Location From Top	50 mm
Colour Code	Red

Table 23 Pole OC13S Characteristics

POLE TYPE	OC14S
Length	14 m
Top A/F diameter	155 mm
Bottom A/F diameter	430 mm
Shaft thickness	4 mm
Pole ultimate load	1564 kg
Standard designation/grade of steel material for shaft	EN10027-15355
Shaft Weight	420 kg
Minimum coating weight of hot-dip galvanizing of pole shaft	610 g/m^3
Buried Depth	2000 mm
Crossarm Location From Top	50 mm
Colour Code	Yellow (1)

Table 24 Pole OC14S Characteristics

POLE TYPE	OC14D
Length	14 m
Top A/F diameter	155 mm
Bottom A/F diameter	600 mm
Shaft thickness	4 mm
Pole ultimate load	2431 kg
Total Wight (after galvanization)	586 kg
Standard designation/grade of steel material for shaft	EN10027-15355
Shaft Weight	377 kg
Minimum coating weight of hot-dip galvanizing of pole shaft	610 g/m^3
Buried Depth	2000 mm
Crossarm Location From Top	50/1250/2450 mm
Colour Code	Yellow (2)

Table 25 Pole OC14D Characteristics

2. POLES'S GEOMETRY

The three types of poles are designed for a simple circuit in horizontal dispositions for line polymeric post insulators.

The galvanized steel poles shall be in a single piece of required length.

Their crossarms sectional shapes shall be tapered octagonal and conform to dimensions given in the tables and drawings of the specification 20-SDMS-01. To have an overview an image of the drawings is attached.

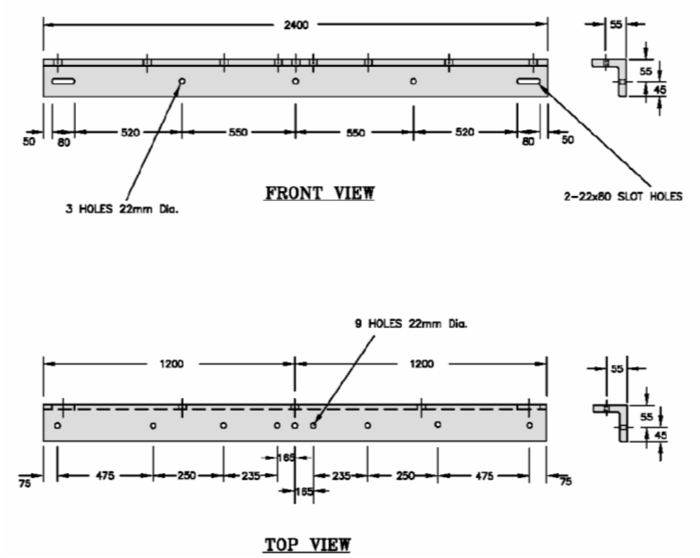


Image 25 Crossarms Sections

The technical data of the crossarm given by the vendor is the following:

DESCRIPTION	CROSSARM
Manufacturer's Drawing No.	ABI/TP/OS-410
Shape of Steel Material	L100x100x12THK
Standard Designation/Grade of Steel	ASTM A3E ORIG
Minimum Yield Stress of Steel Material	250 N/mm^2
Dimensions	L100x100x12x240 LG (mm)
Galvanize Coating Weight, g/m^2	610
Component Machine Bolts Galvanize Coating Weight	381 g/m^2
Component Cotter Keys	Stainless Steel

Table 26 Crossarm Technical Data

The crossarm of the pole is attached to the pole shaft by a brace set. The brace is attached to the crossarm by the two holes 550mm away from the edge of the crossarm, one on the left-hand side and the other on the right-hand side.

To have an overview of the brace set an image of the drawings is attached:

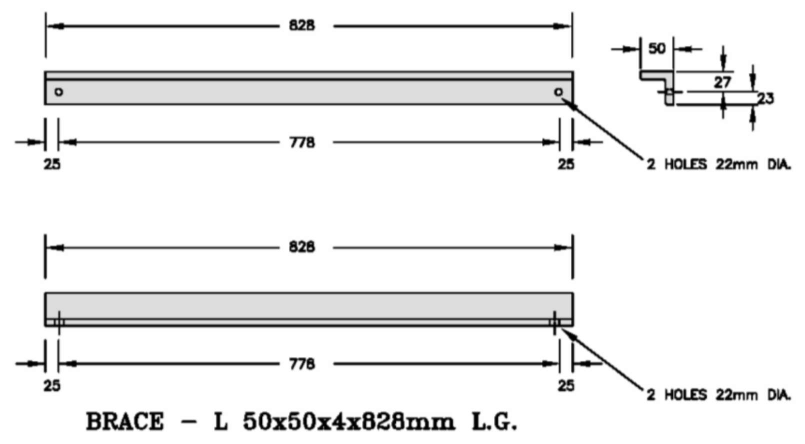


Image 26 Brace Set

Both, the crossarm and the brace set shall fulfil the requirements of the specification 20-SDMS-02. This means that, the steel material shall have a minimum yield strength of 250 N/mm2 and shall be hot-dipped galvanized in accordance with the requirement of 01-SDMS-01 with the minimum average coating thickness of 0.086 mm (equivalent to 610 g/m^2).

Also, the tolerance that must comply:

- +/- 2 mm for center-to-center distance between holes
- +/- 0.5 mm for diameter of pre-drilled holes

The poles will be buried 2 meters depth, and attached to the ground by the foundation with the use of the bearing plate. The foundation will be block foundation and will be widely explained in the apart "Calculation of Foundations".

The poles OC13S, OC14S will actuate as intermediate poles with non-deviation angle, while the OC14D will actuate as a terminal pole. The terminal poles will be located at every water-extraction point (well).

2.1 SURGE PROTECTION. WIRE DISPOSITION.

For this calculation it is important to take into account the isokeraunic level, which is 10 storms per year and bear in mind that the average rainfall per year is 150 mm. Thus, not surge protection may by installed at the overhead line, non-specification is concern about this factor.

Although, according to the SAES-P-107 surge arresters shall be installed at distribution transformer installations and aerial-to-underground cable termination points. Surge arresters shall be of the distribution class, metal-oxide, gapless type rated 27 kV arrester rating.

The grounding electrode for surge arresters shall be minimum 16 mm diameter by 3 m local copper or copper clad ground rod(s) driven along the centre line of the circuit. The ground rod(s) shall also be bonded to the plant or substation ground grid if located within 15 m of the rod. The resistance to ground of the surge arrester ground shall not exceed 25 Ω.

The minimum arrester-to-arrester clearance is given by the SAES-P-107 specification, in which it says that at this voltage level is 710 mm.

2.2. CLEARANCE BETWEEN PHASE CONDUCTORS. PHASE-TO-EARTH CLEARANCE AND HEIGTH.

2.1.1 Clearance between phase conductors.

Considering the oscillations that the wires might have due to the wind, the distance between the conductors is obtained by the following equation:

$$D = K \cdot \sqrt{F} + K' \cdot D_{PP}$$

Being:

- D: distance between the phase-conductors in meters. (1,125m - distance shown at the crossarm image)
- K: Oscillation coefficient, which depends on the wind velocity. (0,65-oscillation angle due to the wind is between 40º and 65º)
- K': Coefficient which depends on the nominal voltage of the overhead line (0,75)
- F: Maximum sag for the calculation hypothesis explained at the document "Mechanical Calculation" (1,31m)
- Dpp: Minimum isolation distance in the air to prevent the disruptive discharge between phase conductors when there is overvoltage. (0,4m)

$$D = 1{,}125 \ \geq K \cdot \sqrt{F} + K' \cdot D_{PP} = 0{,}65 \cdot \sqrt{1{,}31} + 0{,}75 \cdot 0{,}4 = 1{,}04$$

The clearance between phase conductors is bigger than the minimum required to provide electric safety.

The position of the conductors is flat configuration, on the insulators of the crossarm.

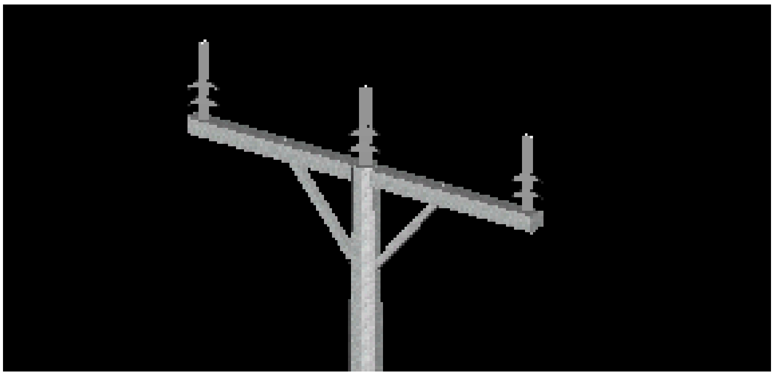


Image 27 Conductor Position at the Crossarm

2.1.1 Phase-To-Earth Clearance

The distance between the conductors and its accessories on voltage and the poles won't be smaller to the distance indicated on the table below. It depends on the highest voltage of the line.

Nominal Voltage (kV)	Highest voltage (kV)	Del (m)
33	36	0.35m

Table 27 Distance between Phase Conductors

2.1.3 Distance between conductors and ground

The ground clearance taken into account in this project have been:

- Above normal ground/Pipe lines: 6,7m
- Above roads/Wadi; 7m

3. CALCULATION HYPOTHESIS.

Poles are designed to withstand the worst possible combination of simultaneous loading:

- Lateral loads consisting of wind forces on conductors corresponding to wind spans, wind force on insulators, wind force on pole and maximum conductor tension.
- Vertical loads consisting of pole self-weight, weights of conductors, insulators, cross-arm, additional equipment, lineman and compressive force due to reaction of stays wherever applicable.

The maximum design unit stress shall not exceed the minimum yield stress as stated in this specification for the particular application and types of loads, including overload capacity factors.

The design parameters used for the calculation of the poles are the ones shown at the following table:

Description		12m, 13m, 14m and 15m
Span	Basic Wind Weight	100 m 110 m 150 m
Wind Pressure	On Pole On Conductors at 10ºC	1200 N/m^2 600 N/m^2
Factor of Safety	Vertical Loads Transverse Loads Longitudinal Loads Ultimate Load Conductor Minimum Breaking Strength	1.5 1.5 1.5 1.5 3.0

Planting Depth (m)		2.0
Type of Structure	Unstayed	Intermediate (0-5º)
	Stayed	Light Angle (6-15º)
		Med. Angle (16-60º)
	Stayed Stayed Stayed	Heavy Angle (61-90º)
	Stayed	Section
		Terminal
	Unstayed	Self-Support (90º)
Allowable Deflection at Pole Top		5% of exposed length
Conductors	Phase	170 mm^2 ACSR/AW (Merlin) in horizontal configuration 70 mm^2 ACSR/AW (Quail) for Branch
	Earth Wire	70 mm^2 ACSR/AW (Quail) below crossarm
Stay Wires	Minimum Breaking Load	101 kN
	Max. Tension	90 % of Min. Breaking Load
	Minimum Angle to the Pole	37º
Temperature	Minimum Maximum	-2ºC +80ºC

Table 28 Pole's Design Parameters

4. CALCULATION METHOD

4.1 GENERAL CONSIDERATIONS

The mechanical calculation of the poles has been done taking to account the loads and the overloads specified on the table above with the security coefficients required.

The whole study has been done regarding the conductor is Merlin AW conductor, over a medium span, bearing in mind wind over the poles and conductors (160km/h). The overload caused by ice has not been considered because of the climate conditions of the overhead line.

According to this specification, and the electrical conditions that the wire must meet due to the current it is going to stand, we have chosen the MERLIN wire. Thus, this wire stands the mechanical efforts that it will be exposed to.

4.2 CALCULATIONS AND JUSTIFICATION OF THE POLES

The design and the sizing of the poles has been made through a software - PLSCadd® and PLSPole® - which implements matricidal calculation on the linear behaviour modelling mathematically the spacing structures.

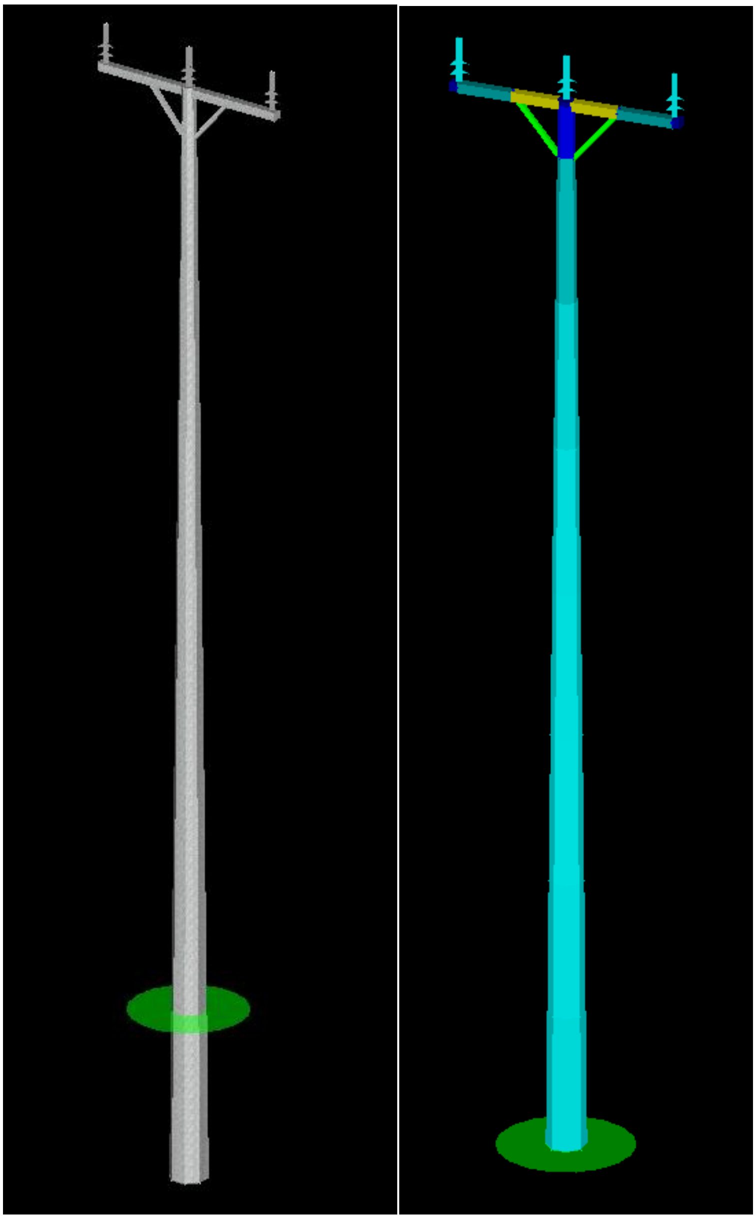
The calculations hypothesis and the security coefficients applied are the ones explained above.

For each type of pole OC13S, OC14S and OC14D there has been done the calculation for the different hypothesis. The calculation has been done taking to account the most unfavourable situation. For each type of pole, there are specifications of the stress that can be transmitted from each conductor to the pole through the crossarm. Over this, it can be built the load tree and compare it to the standing efforts, over this, it can be justified the disposition elected for the pole and its adequacy.

The loads are referenced in relation with the principal axes of the pole according the vertical transversal or longitudinal disposition regarding the line trace.

Below can be consulted the different results obtained for the different hypothesis obtained by the mentioned above software.

OC13S



Project Name: OC13S

PLS-POLE Version 13.31

Successfully performed linear analysis

1. Analysis Results:

Maximum element usage is 86.32% for X-Arm "XARM1" in load case "RULE 250B NA-,I NA-"

Maximum insulator usage is 41.18% for Post "F1" in load case "RULE 250B NA+,I NA+"

Summary of Joint Support Reactions For All Load Cases:

Load Case	Joint Label	Long. Force (kN)	Tran. Force (kN)	Vert. Force (kN)	Shear Force (kN)	Tran. Moment (kN-m)	Long. Moment (kN-m)	Bending Moment (kN-m)	Vert. Moment (kN-m)	Found. Usage %
RULE 250B NA+,I NA+	oc13s:g	0.00	-6.18	-8.22	6.18	70.78	0.00	70.78	0.00	0.00
RULE 250B NA-,I NA-	oc13s:g	-0.00	6.18	-8.22	6.18	-70.78	-0.00	70.78	-0.00	0.00
RULE 250B Uplift NA+,I NA+	oc13s:g	0.00	-6.18	-5.48	6.18	70.78	0.00	70.78	0.00	0.00
RULE 250B Uplift NA-,I NA-	oc13s:g	-0.00	6.18	-5.48	6.18	-70.78	-0.00	70.78	-0.00	0.00
RULE 250C NA+,I NA+	oc13s:g	-0.01	-7.18	-5.48	7.18	64.96	-0.06	64.96	0.00	0.00
RULE 250C NA-,I NA-	oc13s:g	-0.01	7.18	-5.48	7.18	-64.96	-0.06	64.96	0.00	0.00
RULE 277 Insulators NA+,I NA+	oc13s:g	-0.00	-2.47	-5.48	2.47	28.31	-0.00	28.31	-0.00	0.00
RULE 277 Insulators NA-,I NA-	oc13s:g	-0.00	2.47	-5.48	2.47	-28.31	-0.00	28.31	-0.00	0.00
Uplift,I NA+	oc13s:g	-0.00	-0.00	-5.48	0.00	-0.00	-0.00	0.00	-0.00	0.00
RULE 261A (wind towards 0),I Max	oc13s:g	-0.00	2.58	-3.08	2.58	-12.27	-0.00	12.27	0.00	0.00

Summary of Tip Deflections For All Load Cases:

Note: positive tip load results in positive deflection

Load Case	Joint Label	Long. Defl. (cm)	Tran. Defl. (cm)	Vert. Defl. (cm)	Resultant Defl. (cm)	Long. Rot. (deg)	Tran. Rot. (deg)	Twist (deg)
RULE 250B NA+,I NA+	oc13s:t	0.00	31.92	-0.01	31.92	0.00	-3.37	0.00
RULE 250B NA-,I NA-	oc13s:t	-0.00	-31.92	-0.01	31.92	-0.00	3.37	-0.00
RULE 250B Uplift NA+,I NA+	oc13s:t	0.00	31.92	-0.01	31.92	0.00	-3.37	0.00
RULE 250B Uplift NA-,I NA-	oc13s:t	-0.00	-31.92	-0.01	31.92	-0.00	3.37	-0.00
RULE 250C NA+,I NA+	oc13s:t	0.02	26.96	-0.01	26.96	0.00	-2.76	-0.00
RULE 250C NA-,I NA-	oc13s:t	0.02	-26.96	-0.01	26.96	0.00	2.76	-0.00
RULE 277 Insulators NA+,I NA+	oc13s:t	-0.00	12.77	-0.01	12.77	-0.00	-1.35	-0.00
RULE 277 Insulators NA-,I NA-	oc13s:t	-0.00	-12.77	-0.01	12.77	-0.00	1.35	-0.00
Uplift,I NA+	oc13s:t	-0.00	-0.00	-0.01	0.01	-0.00	0.00	-0.00

RULE 261A (wind towards 0),I Max oc13s:t 0.00 -3.20 -0.00 3.20 0.00 0.25 -0.00

Tubes Summary:

Pole Label	Tube Num.	Weight (N)	Load Case	Maximum Usage %	Resultant Moment (kN-m)
oc13s	1	3694	RULE 250B NA-,I NA-	45.69	44.20

2. Overall summary for all load cases - Usage = Maximum Stress / Allowable Stress

Summary of Steel Pole Usages:

Steel Pole Label	Maximum Usage %	Load Case	Segment Number	Weight (N)
oc13s	45.69	RULE 250B NA-,I NA-	7	3693.9

Summary of X-Arm Usages:

X-Arm Label	Maximum Usage %	Load Case	Segment Number	Weight (N)
XARM1	86.32	RULE 250B NA-,I NA-	3	174.6

Summary of Brace Usages:

Brace Label	Maximum Usage %	Load Case	Weight (N)
BR1	74.92	RULE 250B NA-,I NA-	0.0
BR2	74.92	RULE 250B NA+,I NA+	0.0

3. Maximum Stress Summary for Each Load Case

Summary of Maximum Usages by Load Case:

Load Case	Maximum Usage %	Element Label	Element Type
RULE 250B NA+,I NA+	86.32	XARM1	X-Arm
RULE 250B NA-,I NA-	86.32	XARM1	X-Arm

RULE 250B Uplift NA+,I NA+	76.25	XARM1	X-Arm
RULE 250B Uplift NA-,I NA-	76.25	XARM1	X-Arm
RULE 250C NA+,I NA+	61.90	XARM1	X-Arm
RULE 250C NA-,I NA-	61.90	XARM1	X-Arm
RULE 277 Insulators NA+,I NA+	0.00	oc13s	Steel Pole
RULE 277 Insulators NA-,I NA-	0.00	oc13s	Steel Pole
Uplift,I NA+	24.91	BR1	Brace
RULE 261A (wind towards 0),I Max	7.58	oc13s	Steel Pole

Summary of Steel Pole Usages by Load Case:

Load Case	Maximum Usage %	Steel Pole Label	Segment Number
RULE 250B NA+,I NA+	45.69	oc13s	7
RULE 250B NA-,I NA-	45.69	oc13s	7
RULE 250B Uplift NA+,I NA+	45.53	oc13s	7
RULE 250B Uplift NA-,I NA-	45.53	oc13s	7
RULE 250C NA+,I NA+	39.57	oc13s	9
RULE 250C NA-,I NA-	39.57	oc13s	9
RULE 277 Insulators NA+,I NA+	0.00	oc13s	1
RULE 277 Insulators NA-,I NA-	0.00	oc13s	1
Uplift,I NA+	0.37	oc13s	3
RULE 261A (wind towards 0),I Max	7.58	oc13s	9

Summary of X-Arm Usages by Load Case:

Load Case	Maximum Usage %	X-Arm Label	Segment Number
RULE 250B NA+,I NA+	86.32	XARM1	4
RULE 250B NA-,I NA-	86.32	XARM1	3
RULE 250B Uplift NA+,I NA+	76.25	XARM1	4
RULE 250B Uplift NA-,I NA-	76.25	XARM1	3
RULE 250C NA+,I NA+	61.90	XARM1	4
RULE 250C NA-,I NA-	61.90	XARM1	3
RULE 277 Insulators NA+,I NA+	0.00	XARM1	1
RULE 277 Insulators NA-,I NA-	0.00	XARM1	1
Uplift,I NA+	20.15	XARM1	3

RULE 261A (wind towards 0),I Max	1.02	XARM1	4

Summary of Brace Usages by Load Case:

Load Case	Maximum Usage %	Brace Label
RULE 250B NA+,I NA+	74.92	BR2
RULE 250B NA-,I NA-	74.92	BR1
RULE 250B Uplift NA+,I NA+	62.47	BR2
RULE 250B Uplift NA-,I NA-	62.47	BR1
RULE 250C NA+,I NA+	52.86	BR2
RULE 250C NA-,I NA-	52.86	BR1
RULE 277 Insulators NA+,I NA+	0.00	BR1
RULE 277 Insulators NA-,I NA-	0.00	BR1
Uplift,I NA+	24.91	BR1
RULE 261A (wind towards 0),I Max	1.26	BR1

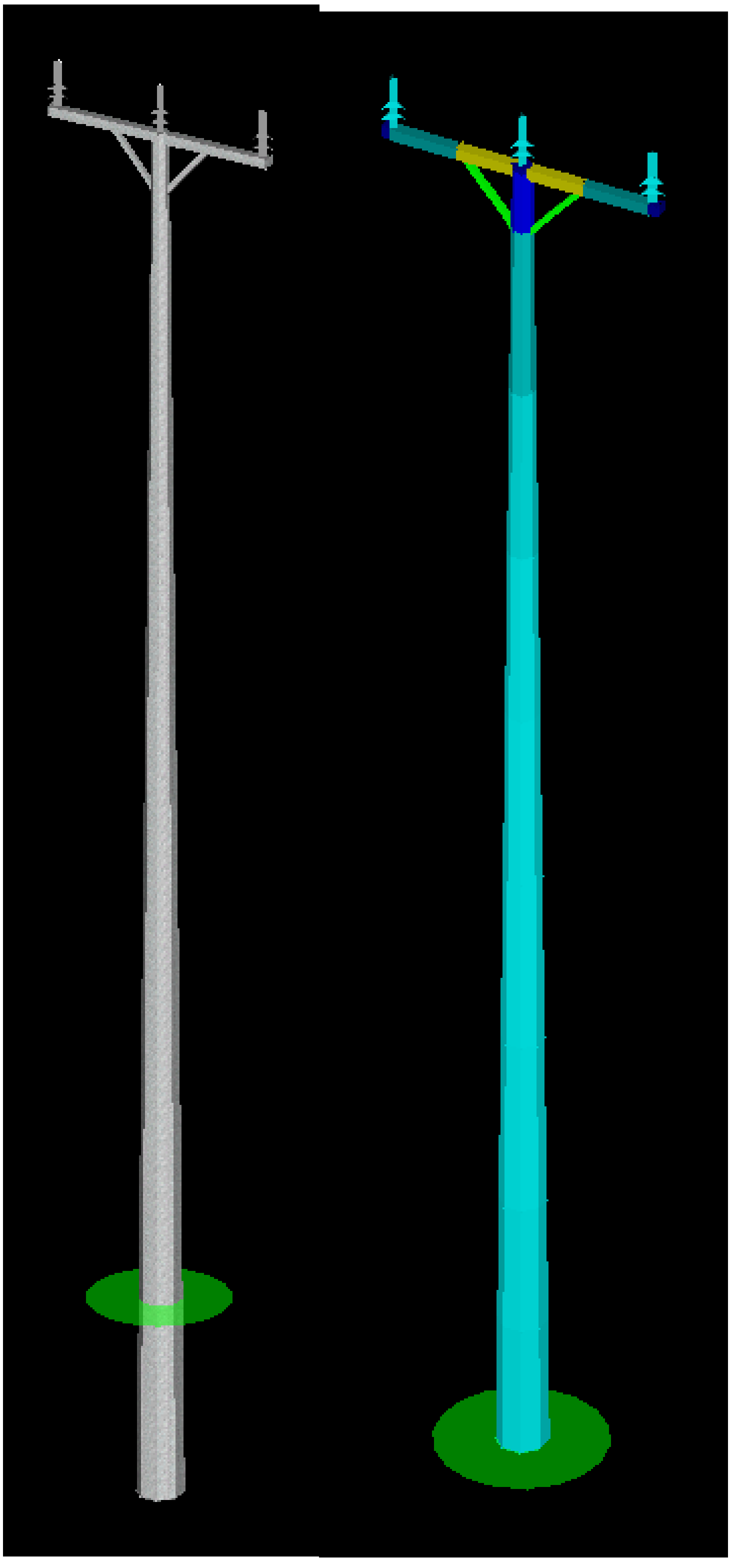
Summary of Insulator Usages:

Insulator Label	Insulator Type	Maximum Usage %	Load Case	Weight (N)
F1	Post	41.18	RULE 250B NA+,I NA+	200.0
F2	Post	41.18	RULE 250B NA+,I NA+	200.0
F3	Post	41.18	RULE 250B NA+,I NA+	200.0

4. Weight of structure (N):

Weight of X-Arms:	174.6
Weight of Steel Poles:	3693.9
Weight of Posts:	600.0
Total:	4468.5

OC14S



Project Name: OC14S

PLS-POLE Version 13.31

Successfully performed linear analysis

1. Analysis Results:

Maximum element usage is 86.32% for X-Arm "XARM1" in load case "RULE 250B NA-,I NA-"

Maximum insulator usage is 41.18% for Post "F1" in load case "RULE 250B NA+,I NA+"

Summary of Joint Support Reactions For All Load Cases:

Load Case	Joint Label	Long. Force (kN)	Tran. Force (kN)	Vert. Force (kN)	Shear Force (kN)	Tran. Moment (kN-m)	Long. Moment (kN-m)	Bending Moment (kN-m)	Vert. Moment (kN-m)	Found. Usage %
RULE 250B NA+,I NA+	oc13s:g	-0.00	-6.18	-8.80	6.18	76.96	-0.00	76.96	-0.00	0.00
RULE 250B NA-,I NA-	oc13s:g	-0.00	6.18	-8.80	6.18	-76.96	-0.00	76.96	-0.00	0.00
RULE 250B Uplift NA+,I NA+	oc13s:g	0.00	-6.18	-5.86	6.18	76.96	0.00	76.96	0.00	0.00
RULE 250B Uplift NA-,I NA-	oc13s:g	-0.00	6.18	-5.86	6.18	-76.96	-0.00	76.96	-0.00	0.00
RULE 250C NA+,I NA+	oc13s:g	-0.01	-7.55	-5.86	7.55	72.47	-0.08	72.47	0.00	0.00
RULE 250C NA-,I NA-	oc13s:g	-0.01	7.55	-5.86	7.55	-72.47	-0.08	72.47	0.00	0.00
RULE 277 Insulators NA+,I NA+	oc13s:g	-0.00	-2.47	-5.86	2.47	30.78	-0.00	30.78	-0.00	0.00
RULE 277 Insulators NA-,I NA-	oc13s:g	-0.00	2.47	-5.86	2.47	-30.78	-0.00	30.78	-0.00	0.00
Uplift,I NA+	oc13s:g	-0.00	-0.00	-5.86	0.00	0.00	-0.00	0.00	-0.00	0.00
RULE 261A (wind towards 0),I Max	oc13s:g	-0.00	2.95	-3.47	2.95	-15.19	-0.00	15.19	0.00	0.00

Summary of Tip Deflections For All Load Cases:

Note: positive tip load results in positive deflection

Load Case	Joint Label	Long. Defl. (cm)	Tran. Defl. (cm)	Vert. Defl. (cm)	Resultant Defl. (cm)	Long. Rot. (deg)	Tran. Rot. (deg)	Twist (deg)
RULE 250B NA+,I NA+	oc13s:t	0.00	36.38	-0.01	36.38	0.00	-3.59	0.00
RULE 250B NA-,I NA-	oc13s:t	-0.00	-36.38	-0.01	36.38	-0.00	3.59	-0.00
RULE 250B Uplift NA+,I NA+	oc13s:t	0.00	36.38	-0.01	36.38	0.00	-3.59	0.00
RULE 250B Uplift NA-,I NA-	oc13s:t	-0.00	-36.38	-0.01	36.38	-0.00	3.59	-0.00
RULE 250C NA+,I NA+	oc13s:t	0.02	31.15	-0.01	31.15	0.00	-2.97	-0.00
RULE 250C NA-,I NA-	oc13s:t	0.02	-31.15	-0.01	31.15	0.00	2.97	-0.00
RULE 277 Insulators NA+,I NA+	oc13s:t	-0.00	14.55	-0.01	14.55	-0.00	-1.44	-0.00
RULE 277 Insulators NA-,I NA-	oc13s:t	-0.00	-14.55	-0.01	14.55	-0.00	1.44	-0.00

Uplift,I NA+	oc13s:t	-0.00	0.00	-0.01	0.01	-0.00	-0.00	-0.00
RULE 261A (wind towards 0),I Max	oc13s:t	0.00	-4.07	-0.00	4.07	0.00	0.30	-0.00

Tubes Summary:

Pole Label	Tube Num.	Weight (N)	Load Case	Maximum Usage %	Resultant Moment (kN-m)
oc13s	1	4121	RULE 250B NA+,I NA+	45.63	44.20

2. Overall summary for all load cases - Usage = Maximum Stress / Allowable Stress

Summary of Steel Pole Usages:

Steel Pole Label	Maximum Usage %	Load Case	Segment Number	Weight (N)
oc13s	45.63	RULE 250B NA+,I NA+	7	4120.8

Summary of X-Arm Usages:

X-Arm Label	Maximum Usage %	Load Case	Segment Number	Weight (N)
XARM1	86.32	RULE 250B NA-,I NA-	3	174.6

Summary of Brace Usages:

Brace Label	Maximum Usage %	Load Case	Weight (N)
BR1	74.92	RULE 250B NA-,I NA-	0.0
BR2	74.92	RULE 250B NA+,I NA+	0.0

3. Maximum Stress Summary for Each Load Case

Summary of Maximum Usages by Load Case:

Load Case	Maximum Usage %	Element Label	Element Type

RULE 250B NA+,I NA+	86.32	XARM1	X-Arm
RULE 250B NA-,I NA-	86.32	XARM1	X-Arm
RULE 250B Uplift NA+,I NA+	76.25	XARM1	X-Arm
RULE 250B Uplift NA-,I NA-	76.25	XARM1	X-Arm
RULE 250C NA+,I NA+	61.90	XARM1	X-Arm
RULE 250C NA-,I NA-	61.90	XARM1	X-Arm
RULE 277 Insulators NA+,I NA+	0.00	oc13s	Steel Pole
RULE 277 Insulators NA-,I NA-	0.00	oc13s	Steel Pole
Uplift,I NA+	24.91	BR1	Brace
RULE 261A (wind towards 0),I Max	8.45	oc13s	Steel Pole

Summary of Steel Pole Usages by Load Case:

Load Case	Maximum Usage %	Steel Pole Label	Segment Number
RULE 250B NA+,I NA+	45.63	oc13s	7
RULE 250B NA-,I NA-	45.63	oc13s	7
RULE 250B Uplift NA+,I NA+	45.47	oc13s	7
RULE 250B Uplift NA-,I NA-	45.47	oc13s	7
RULE 250C NA+,I NA+	39.77	oc13s	10
RULE 250C NA-,I NA-	39.77	oc13s	10
RULE 277 Insulators NA+,I NA+	0.00	oc13s	1
RULE 277 Insulators NA-,I NA-	0.00	oc13s	1
Uplift,I NA+	0.37	oc13s	3
RULE 261A (wind towards 0),I Max	8.45	oc13s	10

Summary of X-Arm Usages by Load Case:

Load Case	Maximum Usage %	X-Arm Label	Segment Number
RULE 250B NA+,I NA+	86.32	XARM1	4
RULE 250B NA-,I NA-	86.32	XARM1	3
RULE 250B Uplift NA+,I NA+	76.25	XARM1	4
RULE 250B Uplift NA-,I NA-	76.25	XARM1	3
RULE 250C NA+,I NA+	61.90	XARM1	4
RULE 250C NA-,I NA-	61.90	XARM1	3
RULE 277 Insulators NA+,I NA+	0.00	XARM1	1
RULE 277 Insulators NA-,I NA-	0.00	XARM1	1

Uplift,I NA+	20.14	XARM1	3
RULE 261A (wind towards 0),I Max	1.02	XARM1	3

Summary of Brace Usages by Load Case:

Load Case	Maximum Usage %	Brace Label
RULE 250B NA+,I NA+	74.92	BR2
RULE 250B NA-,I NA-	74.92	BR1
RULE 250B Uplift NA+,I NA+	62.46	BR2
RULE 250B Uplift NA-,I NA-	62.46	BR1
RULE 250C NA+,I NA+	52.86	BR2
RULE 250C NA-,I NA-	52.86	BR1
RULE 277 Insulators NA+,I NA+	0.00	BR1
RULE 277 Insulators NA-,I NA-	0.00	BR1
Uplift,I NA+	24.91	BR1
RULE 261A (wind towards 0),I Max	1.26	BR1

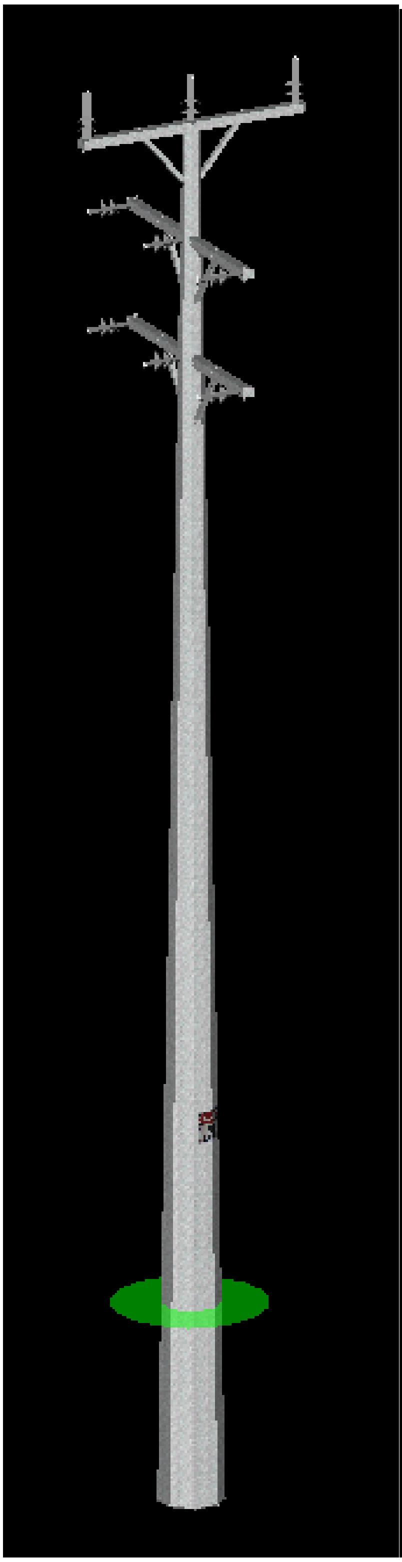
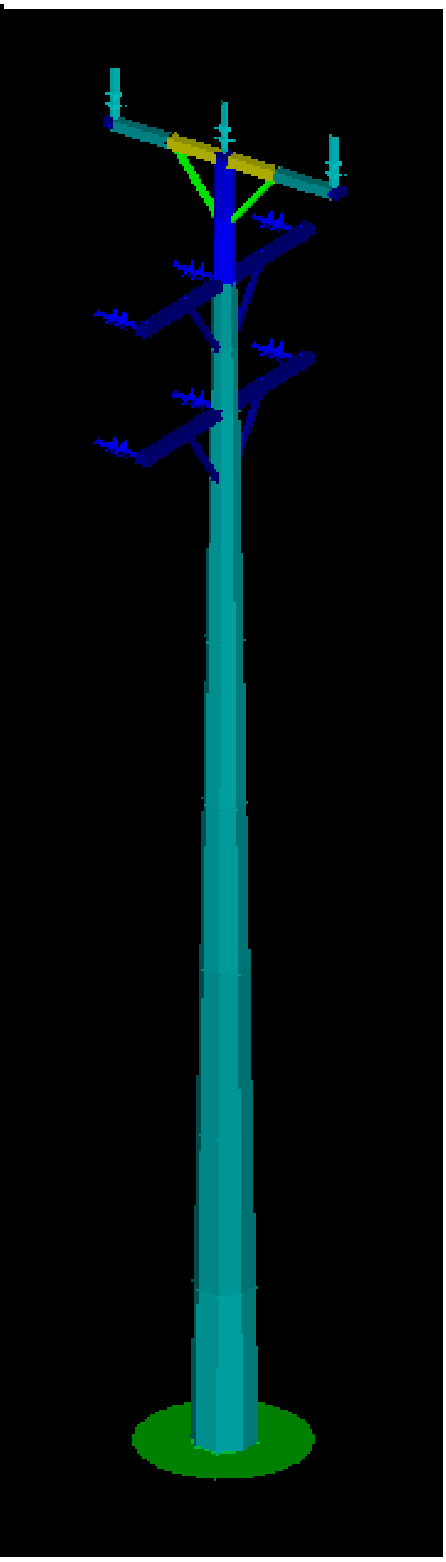
Summary of Insulator Usages:

Insulator Label	Insulator Type	Maximum Usage %	Load Case	Weight (N)
F1	Post	41.18	RULE 250B NA+,I NA+	200.0
F2	Post	41.18	RULE 250B NA+,I NA+	200.0
F3	Post	41.18	RULE 250B NA+,I NA+	200.0

4. Weight of structure (N):

Weight of X-Arms:	174.6
Weight of Steel Poles:	4120.8
Weight of Posts:	600.0
Total:	4895.4

OC14D

Project Name: OC14D

PLS-POLE Version 13.31

Successfully performed linear analysis

1. Analysis Results:

Maximum element usage is 85.88% for X-Arm "XARM1" in load case "RULE 250B NA-,I NA-"

Maximum insulator usage is 41.18% for Post "F1" in load case "RULE 250B NA+,I NA+"

Summary of Joint Support Reactions For All Load Cases:

Load Case	Joint Label	Long. Force (kN)	Tran. Force (kN)	Vert. Force (kN)	Shear Force (kN)	Tran. Moment (kN-m)	Long. Moment (kN-m)	Bending Moment (kN-m)	Vert. Moment (kN-m)	Found. Usage %
RULE 250B NA+,I NA+	oc14d:g	0.00	-6.18	-10.66	6.18	76.96	0.00	76.96	-0.00	0.00
RULE 250B NA-,I NA-	oc14d:g	-0.00	6.18	-10.66	6.18	-76.96	-0.00	76.96	0.00	0.00
RULE 250B Uplift NA+,I NA+	oc14d:g	0.00	-6.18	-7.11	6.18	76.96	0.00	76.96	-0.00	0.00
RULE 250B Uplift NA-,I NA-	oc14d:g	-0.00	6.18	-7.11	6.18	-76.96	-0.00	76.96	0.00	0.00
RULE 250C NA+,I NA+	oc14d:g	-0.02	-8.34	-7.11	8.34	75.64	-0.09	75.64	-0.00	0.00
RULE 250C NA-,I NA-	oc14d:g	-0.02	8.34	-7.11	8.34	-75.64	-0.09	75.64	0.00	0.00
RULE 277 Insulators NA+,I NA+	oc14d:g	0.00	-2.47	-7.11	2.47	30.78	0.00	30.78	-0.00	0.00
RULE 277 Insulators NA-,I NA-	oc14d:g	-0.00	2.47	-7.11	2.47	-30.78	0.00	30.78	0.00	0.00
Uplift,I NA+	oc14d:g	0.00	-0.00	-7.11	0.00	-0.00	0.00	0.00	-0.00	0.00
RULE 261A (wind towards 0),I Max	oc14d:g	-0.00	3.74	-4.71	3.74	-18.35	0.00	18.35	0.00	0.00

Summary of Tip Deflections For All Load Cases:

Note: positive tip load results in positive deflection

Load Case	Joint Label	Long. Defl. (cm)	Tran. Defl. (cm)	Vert. Defl. (cm)	Resultant Defl. (cm)	Long. Rot. (deg)	Tran. Rot. (deg)	Twist (deg)
RULE 250B NA+,I NA+	oc14d:t	-0.00	17.06	-0.01	17.06	-0.00	-1.93	-0.00
RULE 250B NA-,I NA-	oc14d:t	-0.00	-17.06	-0.01	17.06	-0.00	1.93	0.00
RULE 250B Uplift NA+,I NA+	oc14d:t	-0.00	17.06	-0.01	17.06	-0.00	-1.93	-0.00
RULE 250B Uplift NA-,I NA-	oc14d:t	-0.00	-17.06	-0.01	17.06	-0.00	1.93	0.00
RULE 250C NA+,I NA+	oc14d:t	0.01	14.75	-0.01	14.75	0.00	-1.59	-0.00
RULE 250C NA-,I NA-	oc14d:t	0.01	-14.75	-0.01	14.75	0.00	1.59	0.00
RULE 277 Insulators NA+,I NA+	oc14d:t	-0.00	6.82	-0.01	6.82	-0.00	-0.77	-0.00
RULE 277 Insulators NA-,I NA-	oc14d:t	-0.00	-6.82	-0.01	6.82	-0.00	0.77	0.00
Uplift,I NA+	oc14d:t	-0.00	-0.00	-0.01	0.01	-0.00	0.00	-0.00
RULE 261A (wind towards 0),I Max	oc14d:t	-0.00	-2.06	-0.00	2.06	-0.00	0.15	0.00

Tubes Summary:

Pole Label	Tube Num.	Weight (N)	Load Case	Maximum Usage %	Resultant Moment (kN-m)
oc14d	1	5335	RULE 250B NA-,I NA-	29.32	30.78

2. Overall summary for all load cases - Usage = Maximum Stress / Allowable Stress

Summary of Steel Pole Usages:

Steel Pole Label	Maximum Usage %	Load Case	Segment Number	Weight (N)
oc14d	29.32	RULE 250B NA-,I NA-	8	5334.9

Summary of X-Arm Usages:

X-Arm Label	Maximum Usage %	Load Case	Segment Number	Weight (N)
XARM1	85.88	RULE 250B NA-,I NA-	3	174.6
XARM2	1.35	RULE 250B NA+,I NA+	3	174.6
XARM3	1.30	RULE 250B NA+,I NA+	3	174.6

Summary of Brace Usages:

Brace Label	Maximum Usage %	Load Case	Weight (N)
BR1	74.72	RULE 250B NA-,I NA-	0.0
BR2	74.72	RULE 250B NA+,I NA+	0.0
BR21	1.82	RULE 250B NA+,I NA+	0.0
BR22	1.82	RULE 250B NA-,I NA-	0.0
BR31	1.80	RULE 250B NA+,I NA+	0.0
BR32	1.80	RULE 250B NA+,I NA+	0.0

3. Maximum Stress Summary for Each Load Case

Summary of Maximum Usages by Load Case:

Load Case	Maximum Usage %	Element Label	Element Type
RULE 250B NA+,I NA+	85.88	XARM1	X-Arm
RULE 250B NA-,I NA-	85.88	XARM1	X-Arm
RULE 250B Uplift NA+,I NA+	75.88	XARM1	X-Arm
RULE 250B Uplift NA-,I NA-	75.88	XARM1	X-Arm
RULE 250C NA+,I NA+	61.59	XARM1	X-Arm
RULE 250C NA-,I NA-	61.59	XARM1	X-Arm
RULE 277 Insulators NA+,I NA+	0.00	oc14d	Steel Pole
RULE 277 Insulators NA-,I NA-	0.00	oc14d	Steel Pole
Uplift,I NA+	24.86	BR1	Brace
RULE 261A (wind towards 0),I Max	7.03	oc14d	Steel Pole

Summary of Steel Pole Usages by Load Case:

Load Case	Maximum Usage %	Steel Pole Label	Segment Number
RULE 250B NA+,I NA+	29.32	oc14d	8
RULE 250B NA-,I NA-	29.32	oc14d	8
RULE 250B Uplift NA+,I NA+	29.17	oc14d	8
RULE 250B Uplift NA-,I NA-	29.17	oc14d	8
RULE 250C NA+,I NA+	28.38	oc14d	12
RULE 250C NA-,I NA-	28.38	oc14d	12
RULE 277 Insulators NA+,I NA+	0.00	oc14d	1
RULE 277 Insulators NA-,I NA-	0.00	oc14d	1
Uplift,I NA+	0.35	oc14d	12
RULE 261A (wind towards 0),I Max	7.03	oc14d	12

Summary of X-Arm Usages by Load Case:

Load Case	Maximum Usage %	X-Arm Label	Segment Number
RULE 250B NA+,I NA+	85.88	XARM1	4
RULE 250B NA-,I NA-	85.88	XARM1	3
RULE 250B Uplift NA+,I NA+	75.88	XARM1	4

RULE 250B Uplift NA-,I NA-	75.88	XARM1	3
RULE 250C NA+,I NA+	61.59	XARM1	4
RULE 250C NA-,I NA-	61.59	XARM1	3
RULE 277 Insulators NA+,I NA+	0.00	XARM1	1
RULE 277 Insulators NA-,I NA-	0.00	XARM1	1
Uplift,I NA+	20.01	XARM1	3
RULE 261A (wind towards 0),I Max	1.02	XARM1	3

Summary of Brace Usages by Load Case:

Load Case	Maximum Usage %	Brace Label
RULE 250B NA+,I NA+	74.72	BR2
RULE 250B NA-,I NA-	74.72	BR1
RULE 250B Uplift NA+,I NA+	62.29	BR2
RULE 250B Uplift NA-,I NA-	62.29	BR1
RULE 250C NA+,I NA+	52.72	BR2
RULE 250C NA-,I NA-	52.72	BR1
RULE 277 Insulators NA+,I NA+	0.00	BR1
RULE 277 Insulators NA-,I NA-	0.00	BR1
Uplift,I NA+	24.86	BR1
RULE 261A (wind towards 0),I Max	1.26	BR1

Summary of Insulator Usages:

Insulator Label	Insulator Type	Maximum Usage %	Load Case	Weight (N)
F1	Post	41.18	RULE 250B NA+,I NA+	200.0
F2	Post	41.18	RULE 250B NA+,I NA+	200.0
F3	Post	41.18	RULE 250B NA+,I NA+	200.0
F21	Post	0.00	RULE 250B NA+,I NA+	200.0
F22	Post	0.00	RULE 250B NA+,I NA+	200.0
F23	Post	0.00	RULE 250B NA+,I NA+	200.0
F31	Post	0.00	RULE 250B NA+,I NA+	200.0
F32	Post	0.00	RULE 250B NA+,I NA+	200.0
F33	Post	0.00	RULE 250B NA+,I NA+	200.0

4. Weight of structure (N):

Weight of X-Arms:	523.8
Weight of Steel Poles:	5334.9
Weight of Posts:	1800.0
Total:	7658.8

CHAPTER III: FOUNDATIONS

2. INTRODUCTION

This section contains the calculation of the foundations of the poles of the line 1 for the Execution.

The characteristics of the line and the calculation hypothesis are the ones described below.

The type of foundation used for octagonal poles is block foundation, which is a foundation consisting of a single block of concrete, into which the support is embedded.

After reviewing the geotechnical study of the ground, we are considering the most unfavourable conditions in desert:

TYPE OF GROUND	NORMAL - LOOSE
Density (N./m³)	25000
CU (Pa)	15000
Natural Slope Angle	45º
Density (N./m³)	25000

Table 29 Foundations Conditions

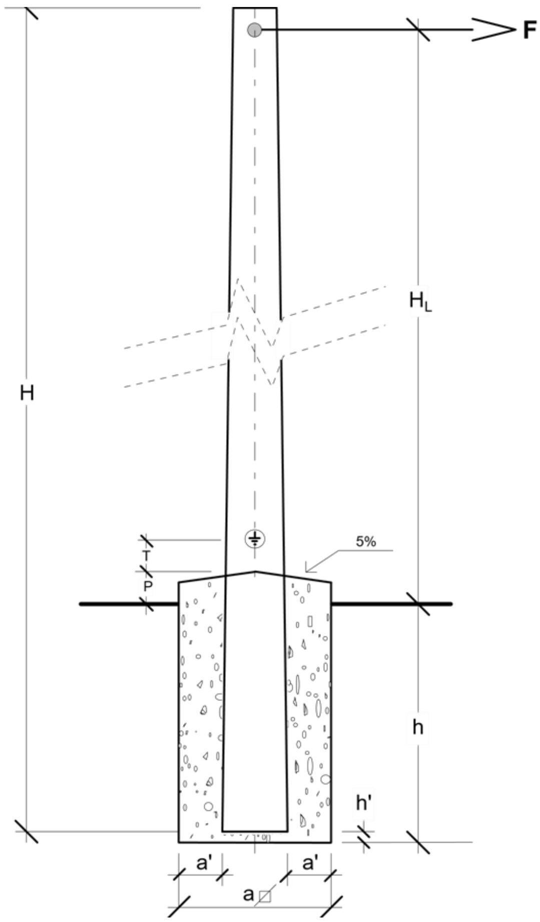


Image 28 Foundation Sketch

The characteristics of the materials used for block foundation is concrete type 150.

The calculation hypothesis applied is that the rotation angle is lower than the angle which its tangent is smaller than 0,01 (0,573º).

In order to make the sizing the block foundation, the following conditions will be required:

- The geometry shall be a cylinder with circle section
- The maximum rotation angle of the concrete shall be the one which its tangent is equal to 0,01 (tan α =0,01).
- Over the concrete base block shall be built a stand which, in its upper part shall have conical shape. Thus it can do correctly the rain or sand gutter function, with an approximate 5% slope and with a height bigger or equal to 10cm counting from the earth line till the vertex. The corresponding concrete volume for this stand shall be included on the total volume of the base block.

The block foundation design will respond in general terms to the one of the above image.

The calculation of block foundation is based on the Sulzberger method, which bears in mind the following:

- The compressibility of the ground is proportional to its depth. It increases in a linear way, and at the surface is null.
- The base block rotates over an axis situated at 2/3 of its depth and ¼ of the wall from itself.
- Confronting the founding deformations to the ground deformations, the first ones are negligible.

The following image represents the stress and reactions diagram:

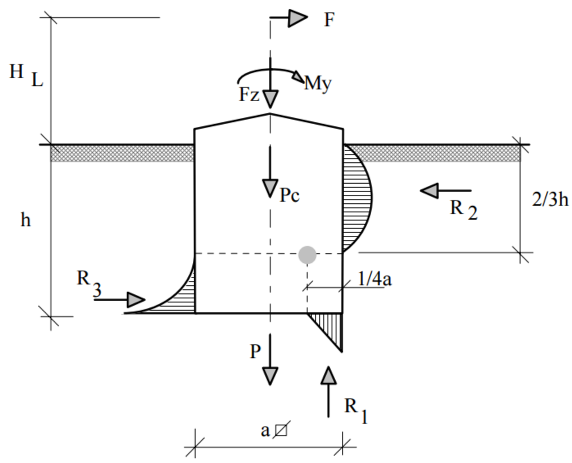


Image 29Foundation Forces and Torques

The differet calculation hypothesis are the ones mentioned below:

a. Buckling Torque

$$M_V = F \cdot \left(H_L + \frac{2h}{3}\right) \ \text{(mkp)}$$

Being:

- F = Normal stress of the pole plus the wind load over the pole reduced at the point of calculation (kp)
- H_L = Height of the pole from the F application point till the earth line. (m)
- h = Depth of the foundation (m)

b. Stabilizer Torque

$$M_e = M_1 + M_2$$

The stabilizer torque is the sum of the lateral (M1) and the vertical (M2) actions of the ground.

Regarding the lateral actions:

$$M_1 = \frac{a \cdot h^3}{36} \cdot C'_h \cdot \tan\alpha = 139 \cdot C_h \cdot a \cdot h^4$$

Regarding the vertical actions:

$$M_2 = P \cdot a \cdot \left[0{,}5 - \frac{2}{3}\sqrt{\frac{P}{2 \cdot a^2 \cdot C'_h \cdot \tan\alpha}}\right] = P \cdot a \cdot \left[0{,}5 - \frac{2}{3}\sqrt{\frac{P}{2 \cdot a^3 \cdot C_h \cdot h \cdot \tan\alpha}}\right] \quad (mkp)$$

Being:

- a = width or length of the foundation (m)
- h = depth of the foundation (m)
- P = Weight of the mass block, the pole, the vertical loads (kp)
- C'_h = Compressibility coefficient of the ground at h meters depth ($Kp/cm.cm^2$)
- C_h = Compressibility coefficient of the ground at 2 meters depth ($kp/m.m^2$)
- tan α = 0,01 maximum deviation angle of the base block

c. Stability condition

The foundation design shall comply the stability condition which is based on the grounding horizontal reactions (Deep foundations). Therefor the stability condition is conditioned in a way such tan (α) shall be lower or equal to 0,001.

Hence, it shall comply:

$M_V \leq M_1 + M_2$ For tan (α) ≤ 0,01

To make the foundation more secure, the foundation must comply;

$M{\cdot}M_V \leq 1$ For tan (α) ≤ 0,01

Thus, we will obtain a security coefficient:

$$C.S. = \frac{M_e}{M_v} = \frac{M_1 + M_2}{M_v} = 1 + \frac{M_2}{M_v} \geq 1{,}2$$

The dimension of our block foundation is a cylinder of 2m depth (h) and 1m diameter base (a), for OC13S, OC14S and OC14D pole.

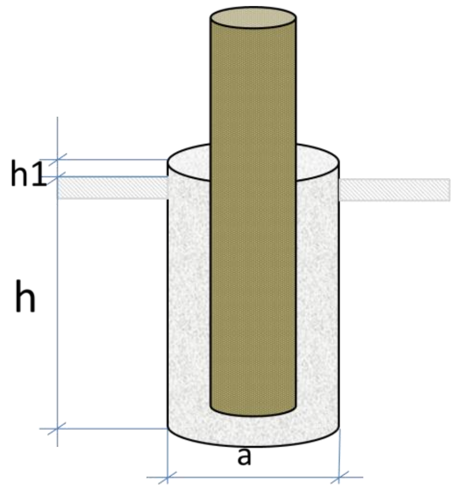


Image 30 Final Foundation Skecth

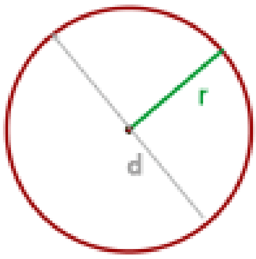


Image 31 Top View Foundation Sketch

Where:

- h = 2m
- h1 = 0,1m
- a = d = 1m

Up until this fact we have calculated the reactions on each pole and we have implemented the corresponding security coefficient (increasing of the loads), with the software, and here they are the results.

3. CALCULATIONS

OC13S

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CAISSON Version 13.00

Project Title: Foundation OC13S

Calculation Method: Full 8CD
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Pier Properties

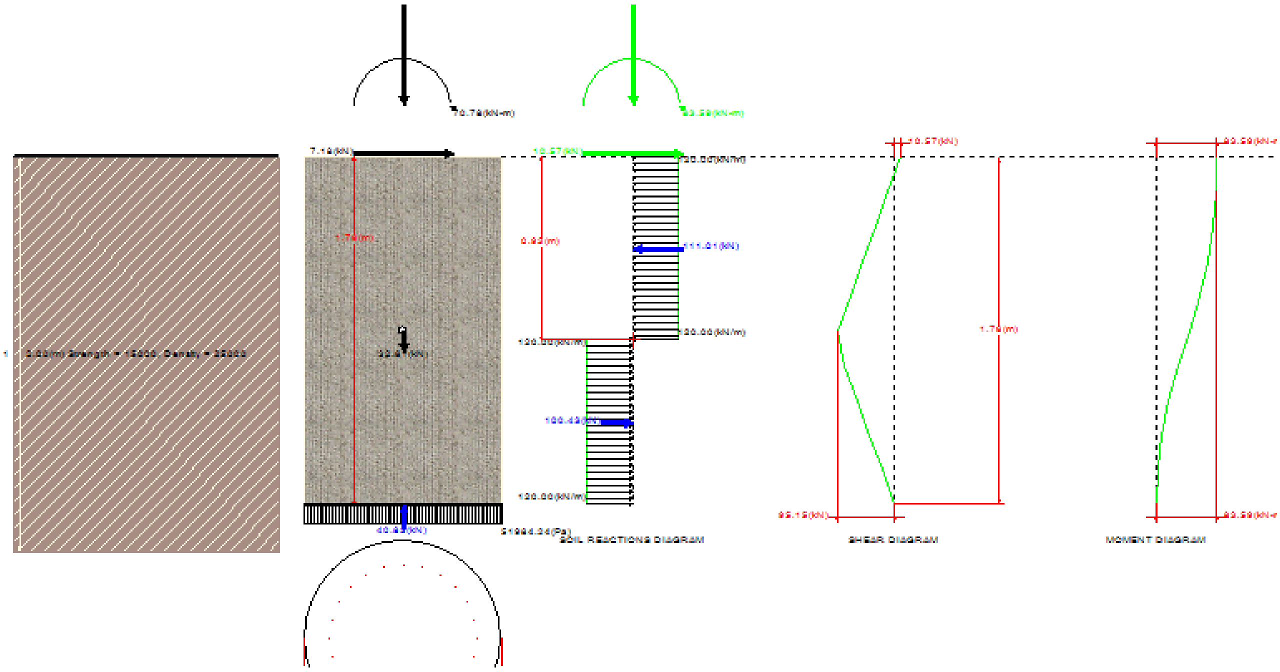
Diameter	Distance of Top of Pier above Ground	Concrete Strength	Steel Yield Strength
(m)	(m)	(MPa)	(MPa)
1.00	0.00	14.71	355.00

Soil Properties

Layer	Type	Thickness	Depth at Top of Layer	Density	CU	KP	PHI
		(m)	(m)	(N/m^3)	(Pa)		(deg)
1	Clay	2.00	0.00	25000.0	15000.0		

Design (Factored) Loads at Top of Pier

Moment	Axial Load	Shear Load	Additional Safety Factor Against Soil Failure
(kN-m)	(kN)	(kN)	
70.8	8.2	7.18	1.00



Calculated Pier Properties

Length	Weight	Pressure Due To Axial Load	Pressure Due To Weight	Total End-Bearing Pressure
(m)	(kN)	(Pa)	(Pa)	(Pa)
1.762	32.608	10466.0	41518.2	51984.2

Ultimate Resisting Forces Along Pier

Type	Distance of Top of Layer to Top of Pier (m)	Thickness (m)	Density (N/m^3)	CU (Pa)	Force (kN)	Arm (m)
Clay	0.00	0.93	25000.0	15000.0	111.01	0.46
Clay	0.93	0.84	25000.0	15000.0	-100.43	1.34

Shear and Moments Along Pier

Distance below Top of Pier (m)	Shear (kN)	Moment (kN-m)	Shear (kN)	Moment (kN-m)
0.00	10.6	83.6	10.6	83.6
0.18	-10.6	83.6	-10.6	83.6
0.35	-31.7	79.9	-31.7	79.9
0.53	-52.9	72.4	-52.9	72.4
0.70	-74.0	61.2	-74.0	61.2
0.88	-95.1	46.3	-95.1	46.3
1.06	-84.6	29.8	-84.6	29.8
1.23	-63.4	16.8	-63.4	16.8
1.41	-42.3	7.5	-42.3	7.5
1.59	-21.1	1.9	-21.1	1.9
1.76	0.0	0.0	0.0	0.0

OC14S

CAISSON Version 13.00

Project Title: Foundation OC14S

Calculation Method: Full 8CD

Pier Properties

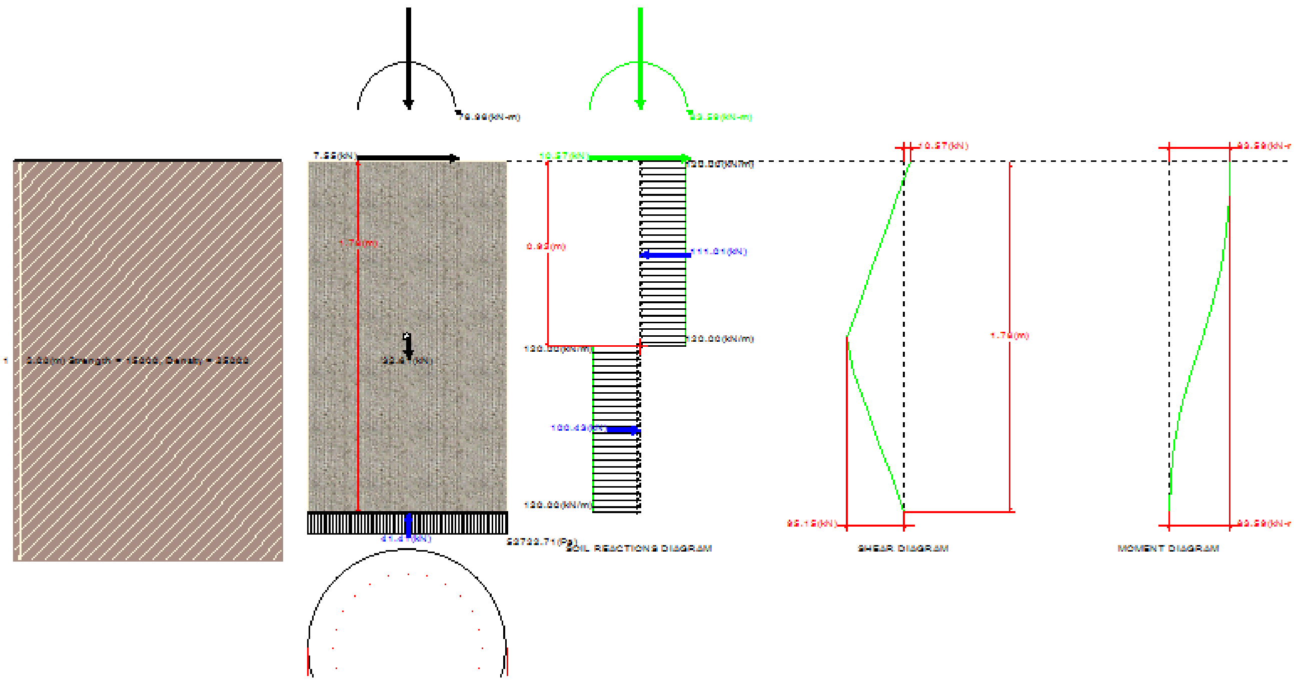
Diameter (m)	Distance of Top of Pier above Ground (m)	Concrete Strength (MPa)	Steel Yield Strength (MPa)
1.00	0.00	14.71	355.00

Soil Properties

Layer	Type	Thickness (m)	Depth at Top of Layer (m)	Density (N/m^3)	CU (Pa)	KP	PHI (deg)
1	Clay	2.00	0.00	25000.0	15000.0		

Design (Factored) Loads at Top of Pier

Moment (kN-m)	Axial Load (kN)	Shear Load (kN)	Additional Safety Factor Against Soil Failure
77.0	8.8	7.55	1.00



Calculated Pier Properties

Length	Weight	Pressure Due To Axial Load	Pressure Due To Weight	Total End-Bearing Pressure
(m)	(kN)	(Pa)	(Pa)	(Pa)
1.762	32.608	11204.5	41518.2	52722.7

Ultimate Resisting Forces Along Pier

Type	Distance of Top of Layer to Top of Pier	Thickness	Density	CU	Force	Arm
	(m)	(m)	(N/m^3)	(Pa)	(kN)	(m)
Clay	0.00	0.93	25000.0	15000.0	111.01	0.46
Clay	0.93	0.84	25000.0	15000.0	-100.43	1.34

Shear and Moments Along Pier

Distance below Top of Pier (m)	Shear (kN)	Moment (kN-m)	Shear (kN)	Moment (kN-m)
0.00	10.6	83.6	10.6	83.6
0.18	-10.6	83.6	-10.6	83.6
0.35	-31.7	79.9	-31.7	79.9
0.53	-52.9	72.4	-52.9	72.4
0.70	-74.0	61.2	-74.0	61.2
0.88	-95.1	46.3	-95.1	46.3
1.06	-84.6	29.8	-84.6	29.8
1.23	-63.4	16.8	-63.4	16.8
1.41	-42.3	7.5	-42.3	7.5
1.59	-21.1	1.9	-21.1	1.9
1.76	0.0	0.0	0.0	0.0

OC14D

CAISSON Version 13.00

Project Title: Foundation OC14D

Calculation Method: Full 8CD

Pier Properties

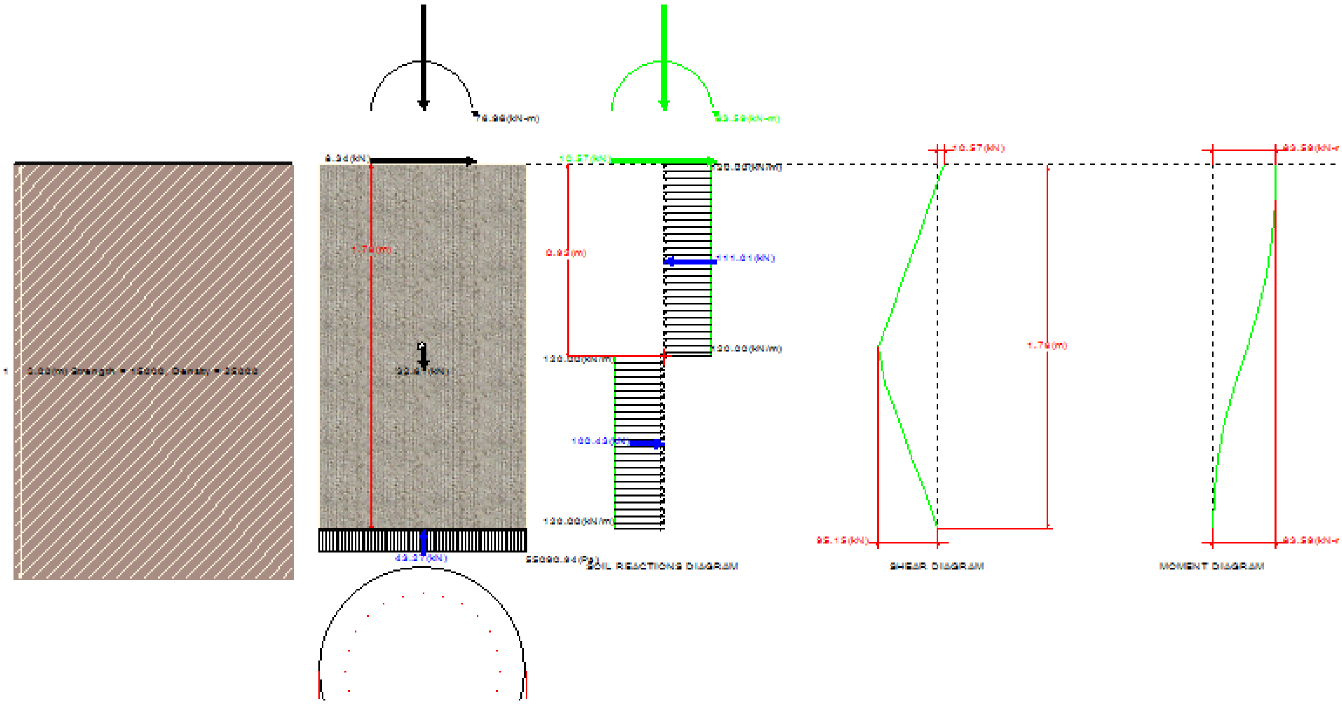
Diameter (m)	Distance of Top of Pier above Ground (m)	Concrete Strength (MPa)	Steel Yield Strength (MPa)
1.00	0.00	14.71	355.00

Soil Properties

Layer	Type	Thickness (m)	Depth at Top of Layer (m)	Density (N/m^3)	CU (Pa)	KP	PHI (deg)
1	Clay	2.00	0.00	25000.0	15000.0		

Design (Factored) Loads at Top of Pier

Moment (kN-m)	Axial Load (kN)	Shear Load (kN)	Additional Safety Factor Against Soil Failure
77.0	10.7	8.34	1.00



Calculated Pier Properties

Length	Weight	Pressure Due To Axial Load	Pressure Due To Weight	Total End-Bearing Pressure
(m)	(kN)	(Pa)	(Pa)	(Pa)
1.762	32.608	13572.7	41518.2	55090.9

Ultimate Resisting Forces Along Pier

Type	Distance of Top of Layer to Top of Pier	Thickness	Density	CU	Force	Arm
	(m)	(m)	(N/m^3)	(Pa)	(kN)	(m)
Clay	0.00	0.93	25000.0	15000.0	111.01	0.46
Clay	0.93	0.84	25000.0	15000.0	-100.43	1.34

Shear and Moments Along Pier

Distance below Top of Pier (m)	Shear (kN)	Moment (kN-m)	Shear (kN)	Moment (kN-m)
0.00	10.6	83.6	10.6	83.6
0.18	-10.6	83.6	-10.6	83.6
0.35	-31.7	79.9	-31.7	79.9
0.53	-52.9	72.4	-52.9	72.4
0.70	-74.0	61.2	-74.0	61.2
0.88	-95.1	46.3	-95.1	46.3
1.06	-84.6	29.8	-84.6	29.8
1.23	-63.4	16.8	-63.4	16.8
1.41	-42.3	7.5	-42.3	7.5
1.59	-21.1	1.9	-21.1	1.9
1.76	0.0	0.0	0.0	0.0

The software recommends a depth of the foundation of 1,762m for all the poles, because of all them are working under the same conditions.

As we are digging 2m depth foundations, they are valid for the installation.

CHAPTER IV: INSULATION JUSTIFICATION

The insulators have the function of mechanically fasten the conductors keeping them isolated from ground (support) under normal conditions (33kV) and in the case of the maximum expected surge (36kV).

They must withstand the mechanical load transmitted from the conductor to the pole through them. Moreover, they have to withstand the power surges to which they are subjected.

The characteristics of the line and the isolation chosen is based on the normalized isolation standards and explained in the following paragraphs.

According to the 01-SDMS-01 specification, the Basic Level of Insulation (BIL) shall be 170kV peak and the power frequency withstand shall be 70kV rms one minute duration.

Due to the service conditions of the 33KV facility such as, the maximum relative humidity (100%), the contamination level [Equivalent Salt Deposit Density (ESDD) in a period of any six (0.3 to 0.5 mg/cm2) and average hydrogen sulphide in the atmosphere (40 Mg/m3 (0.03 ppm))] and the average rainfall per year (150 mm) and the maximum wind velocity (160 km/h), we have chosen polymeric insulators.

According to the 15-SDMS-01 the complete porcelain insulators shall be made of good commercial grade wet process porcelain.

The entire exposed porcelain surface of the insulators shall be standard glazed and shall be in brown color. The entire porcelain surface shall be smooth and free of imperfections.

The glazing of the porcelain shall be of A-Type to minimize radio interference (RIV) and corona discharge voltage.

Metal parts shall be made of a good commercial grade of malleable iron, ductile iron or steel, galvanized in accordance with specification 01-SDMS-01.

Portland cement shall be used as the bonding agent and for filling the gap between the porcelain and the metal parts. It must have high compressive strength to maintain the cantilever strength ratings of the insulators specified in the technical data schedule.

Sulfur based cements are not acceptable.

For this line we have chosen line post insulators. Regarding its construction, the insulator shall fulfil the following requirements in order to maintain its insulation capacity whatever the ambient conditions may be.

The hardware shall be cemented on the porcelain with load distribution evenly throughout the porcelain. Before cementing, the hardware surface in contact with the cement shall be coated with bituminous compound.

The contours of the metal and porcelain parts shall be such as to eliminate areas of high electrical stress concentrations.

The insulator shall be of puncture proof porcelain constructions.

The insulator surface shall be shaped and spaced for effective natural cleaning and effective use of leakage distance for desert conditions.

The insulator shall be radio interference free at operating voltage.

Finally, all ferrous components except those made of stainless steel shall be galvanized.

The technical (mechanical and electrical) characteristics of the insulator:

NORMALIZED TYPE	LINE POST INSULATOR
Nominal System Voltage (kV)	33
Insulating Material	Porcelain
Colour of Insulator	Brown Glazed
Tie Top Radius (mm)	25
Side Tie Radius (mm)	25
Neck Diameter (mm)	73
Shed Diameter (mm)	<185
Minimum Creepage (mm/kV)	40
Total Creepage Distance (mm)	1320
Dry Arcing Distance (mm)	438
Cantilever Strength (kN)	12.5
Flash Overvoltage Power Frequency (dry) (kV)	175
Withstand Voltage Power Frequency (dry) (peak) (kV)	160
Maximum R.I Value at Test Voltage of 44kV(μV)	200
Stud Size	M20
Complete With Studs	Short Stud

Table 30 Insulation Characteristics

As for the mounting of the line post insulator:

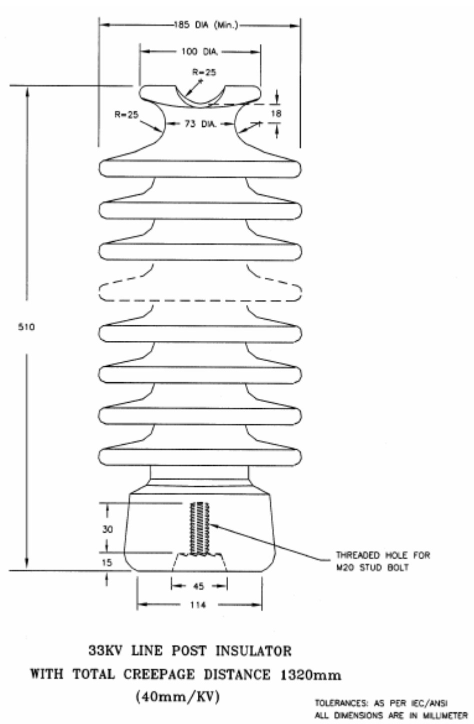


Image 32 Insulator Sketch

In order to fit the porcelain line post insulator properly, the line post insulator bottom and the stud shall be serrated to lock the stud against loosening due to line vibration as shown in sketches.

The stud for the line post insulator shall be hot- dip galvanized in accordance with appropriate industry standard and complete with nuts and washers for steel crossarm mounting.

Eventhough there is an existing document which contains the drawings, we attach an image of the insulator's plan for a general idea.

Regarding the electrical criteria for the design, we have to bear in mind the electrical stresses to which they may be subjected, which are the values mentioned above at the technical data table: highest voltage, flash overvoltage power frequency, withstand voltage power frequency, maximum R.I value at test voltage of 44kV.

According to SAES-P-107 security standards for this tension level, the minimum clearance between conductors and between arresters must be 710mm.

Also, the distance between the conductors and their accessories in tension and the poles will shall not be lower to Del, with a minimum distance of 0.2 m. It will also be checked the distances between the loose bridge and the mass.

NOMINAL VOLTAGE(kV)	HIGHEST VOLTAGE (kV)	Del (m)	Minimums (m)
33	36	0.42	0.75

Table 31 Insulation Distances

Being:

- Del: Minimum insulated distance in the air specified for preventing a disruptive discharge between phase conductors and objects at earth voltage in fast or slow front over-tension. Del can be internal (distance between the conductor and the pole) as well as external (distance between the conductor and another obstacle)

- Dpp: Minimum insulated distance in the air specified for preventing a disruptive discharge between phase conductors during fast or slow front over-voltage. It is an internal distance.

With this level of insulation, this type of insulators and respecting the distance mentioned above we can affirm that eventhough the insulators may be polluted, or the atmospheric conditions adverse, the line will be perfectly isolated.

Regarding the mechanical aspects, the insulators shall not be loaded in excess of 40% of their rated ultimate strength, according to SAES-P-107 security standards. The worst working conditions are at the tension sets, where the biggest traction load is produced, when electrical overload occurs.

CHAPTER V: ACCESSORIES

On one hand, to attach the insulator to the pole is needed a machine bolt and a nut. Due to the specifications demanded at the 20-SDMS-02 and at the 15-SDMS-01, the machine bolt will be a M20 bolt. On the other hand, to attach the conductor to the insulator it is needed a preformed line top tie, its requirements are specified at the 20-SDMS-02 and we will define its characteristic after.

For all the accessories used at the overhead line, it is required to have an equivalent with minimum yield strength of 250 Newton per sq. millimetre. Also, they shall be hot-dipped galvanized in accordance with the requirement of 01-SDMS-01 with the minimum average coating thickness of 0.086 mm (equivalent to 610 g/m^2).

Regarding the bolts, we have to take into account that each bolt should be provided with 1 nut, 2 flat washers and one spring washer.

Bolts and nuts have to be made of hot-rolled steel which has been produced by the open hearth, basic oxygen or electric furnace process and which is of a grade and quality suitable to meet the requirements of this specification.

Machine bolts shall be high strength Grade 8.8.

After galvanizing, the bolts and nuts shall be free from burrs, seams, laps and irregular surfaces that affect serviceability.

The top of the bolt head or nut shall be flat and the edges shall be chamfered or rounded. The thread end of the bolts shall be chamfered or rounded. Moreover, their head shall be regular hexagonal.

The thread and threaded hole of nut shall match the thread of the bolt. The external threaded portion of all bolts shall, after galvanizing, be in such condition that nuts tapped will fit the galvanized bolt so that the nut can run the entire length of the thread without the use of tools.

All galvanized steel bolts shall be marked with the property class symbol and with the manufacturer's identification symbol. For machine bolts, markings shall be located on the top of the head and may be raised or recessed. When raised, markings shall project not less than 0.10 mm for 12 mm and smaller bolts, and 0.20 mm for 16 mm and larger bolts above the surface of the head.

The last requirement is regarding the length of the machine bolt. Due to the characteristics of the facility, the length of the bolt shall be between 235 and 255 mm long.

Eventhough there is an existing document which contains the drawings, we attach an image of the machine bolt's plan for an overview.

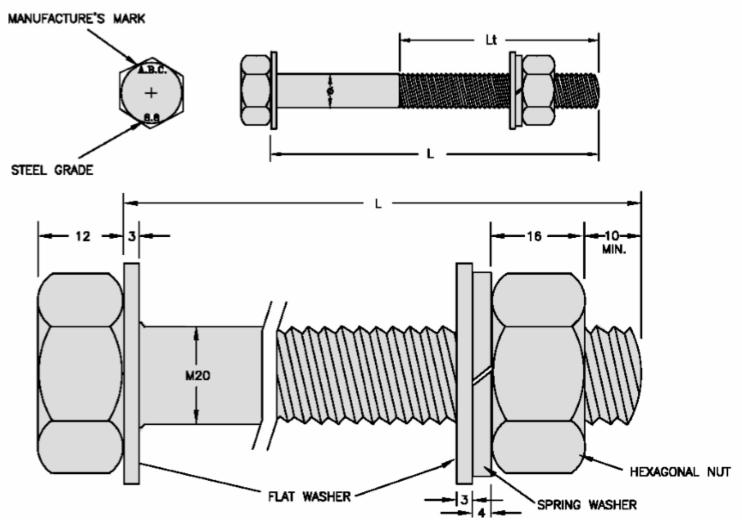


Image 33 Bolt Skecth

As for the preformed line top tie, shall be made of aluminium alloy material compatible with the ACSR/AW conductors to which they will be applied.

Due to its function as a hardware fitting, its dimensions, strength ratings and overall design shall be compatible with the applicable conductors and other related fabricated metal shapes and plates.

The lay direction of preformed helical rods shall be the same as that of the outer layer of the conductor to which it is applied.

The preformed ties shall be provided with identification label showing the manufacturer's catalogue number, insulator details and conductor diameter range.

Is technical characteristics shall be:

- Material → Aluminium coated steel wire
- Rod diameter → 3mm
- Number of strands → 2
- Length → 730mm
- Colour code → white
- Material of the pad → neoprene

Eventhough there is an existing document which contains the drawings, we attach an image of the preformed line top tie's plan for an overview.

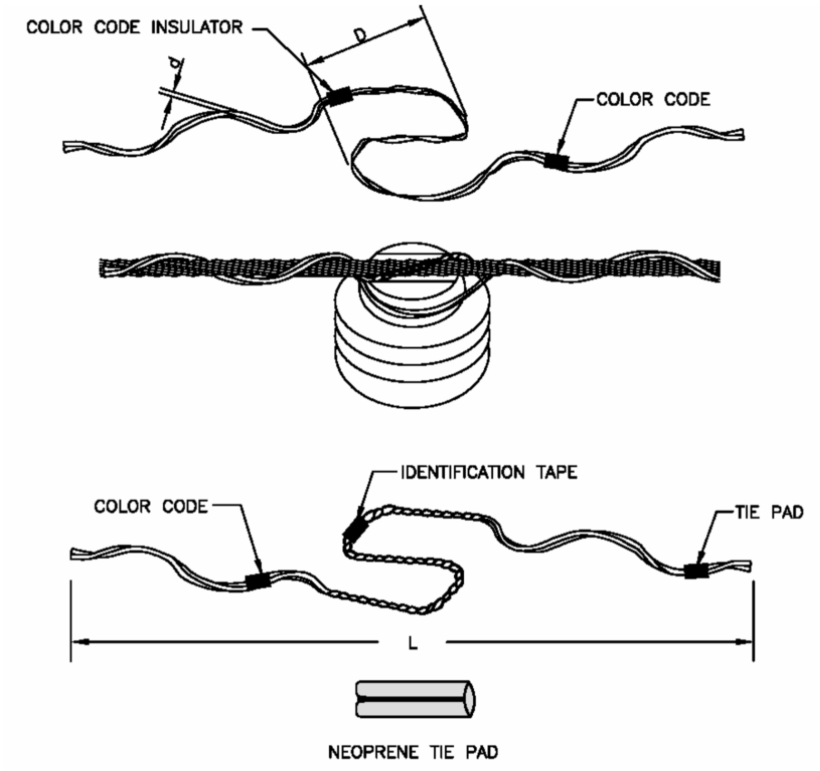


Image 34 Top Tie Skecth

CHAPTER VI: EARTHING SYSTEM

1. INTRODUCTION

The main objective of this document is to stablish and justify the design of the earthing which shall be used at the different overhead lines regarding this project. It will detailed explained firstly the design criteria, secondly its installation and finally the test which shall comply in order to be efficient at any circumstances, maintaining the step and touch voltage in between the limits. Therefore, the design guarantees the safety of the nearby people and will comply the requirements specified at SCDS-01.

2. DESIGN CRITERIA

The designed earthing system has been thought bearing in mind it shall fulfil the following requirements in order to satisfy the safety.

1. Bear the mechanical efforts and the corrosion.
2. From a thermal point, stand the greatest short circuit current determined on the calculus
3. Guarantee the people safety regarding the voltage that will appear while an earth fault may exist.
4. Protect from damaging the equipment and the materials and therefore ensure the liability of the line.

These requirements depend essentially on:

- Neutral arranging of the system:
    - Solidly grounded
    - Low resistance
- Type of pole
    - Frequented pole
    - Non-frequented pole
- Pole material
    - Conductor material
    - Non-conductor material

Our facility is considered with the following characteristics:

- The neutral arrangement shall be solidly grounded according to what is specified at the point 5.3 of SEC 01-SDMS-01.
- The type of pole considered is a non-frequented pole.
- As the pole is made of steel, it is a conductor material.

3. ELEMENTS

The earthing system shall be composed by one or more earth electrodes buried and by the earthing line which may be connect them to the elements that must be earth connected.

The earthing electrode material, the design and the dimensions, its colocation along the ground and the number used have been chosen in order to guarantee a touch voltage under the permissible limits.

The earth electrode chosen for these overhead lines with non-frequented poles, guarantees an earth resistance sufficiently lower which assures the actuation of the different electrical protection in case of earth fault.

3.1 EARTH ELECTRODE

The disposition of the earth electrodes shall be the following:

- Horizontal earth electrodes composed by buried copper plain wire of $50mm^2$ section disposed as perimeter loops.
- Vertical coppered steel lance earthing of 14mm diameter and 1,5m length that may be composed by joined elements.

3.2 INSTALLATION OF THE HORIZONTAL EARTH ELECTRODES

The earth electrode shall be buried at a depth between 0,5m and 1m in order to guarantee a mechanical protection for the system.

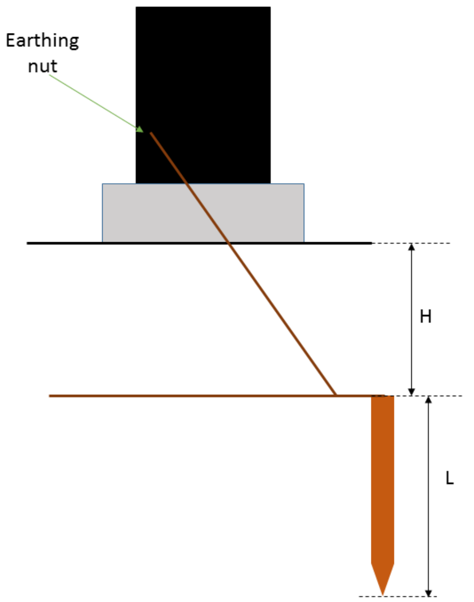
They may be located at the bottom of a perimeter trench to the concrete foundation, the distance between shall be 1m. This space will be filled by rammed earth thus there will no direct contact between concrete and electrode.

3.3 INSTALLATION OF THE VERTICAL EARTHING LANCE

The vertical lances advantage the fact that the ground resistivity decreases with the depth as the temperature is lower and the humidity higher.

The top part of the lance shall be always under the ground level and at the corresponding depth due to the chosen electrode.

Sketch of the installation



H= 0,7 m
L= 1,5 m
D= 1 m
d= 14mm

Image 35 Earthing Front Sketch

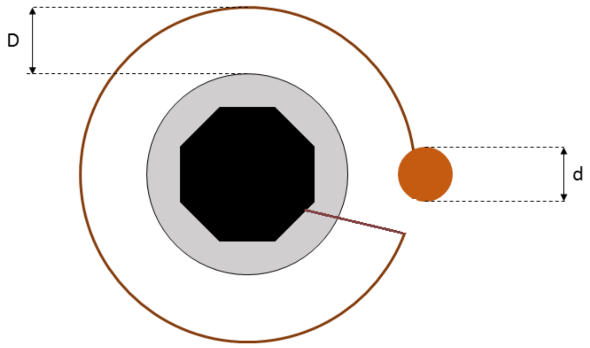


Image 36 Earthing Top Sketch

3.4 JOIN OF THE EARTH ELECTRODES

The joins used to connect the conductor elements of earth net to the earthing electrodes shall stand an electrical conduction and a mechanical and thermal stresses same as the electrodes.

They shall be corrosion resistant and shall not be liable to produce galvanic couple.

3.5 CONNECTION OF THE POLES TO EARTH

As the used poles are Steel poles and therefore they are made of a conductor material consequently each of them shall be earth connected.

The ground connexion shall be done by an earthing nut specified on the 20-SDMS-0 depending on the type of pole located at the bottom of the pole. Its position is specified at the plan of each pole such as it is shown on the right-hand sketch.

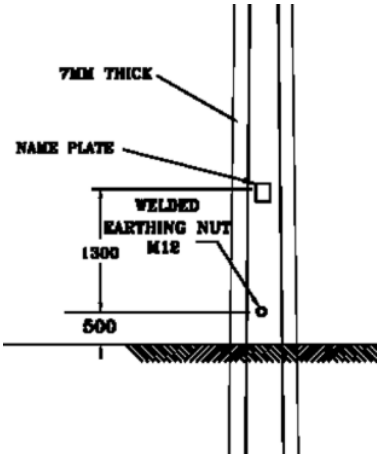


Image 37 Connection between Earthing System and Pole

4. EARTHING SYSTEM DESIGN AT INDUSTRIAL FREQUENCY

The design parameters are:

- Fault current value
- Duration of the fault
- Ground resistivity

These parameters depend essentially on the neutral arrangement of the system, which in our case is solidly grounded.

Due to the characteristics of the ground given in the 01-SDMS-01 such as:

- Soil condition – General: Corrosive. Widespread salt deposits
- Ground water table level: Varies from deep to very near the surface
- Soil pH: 7.0 – 8.5
- Salt concentrations (typical): 0 – 10 %
  - Sulphates (SO3), by weight: 0 – 5 %
  - Chlorides (as NaCl), by weight
- Soil salinity: 0 to 140 g/m^3
- Average rainfall per year: 150 mm

It has been taken into account a ground resistivity of 150 Ωm

4.1 DESIGN REGARDING THE CORROSION AND THE MECHANICAL RESISTANCE

The earth electrodes that have direct contact with the ground (plain wires and copper steel lance) shall be design to stand the corrosion (chemical or biological impact, oxidation, generation of electrolytic couple, electrolysis, etc.) Moreover, they shall stand not only the mechanical stresses during its installation but also the ones that may occur during normal service conditions.

4.2 DESIGN REGARDING THE THERMAL RESISTANCE

The short time temperature rises in a ground conductor determines the required conductor size as a function of conductor current. Therefore, the thermal resistance depends directly on the maximum earth fault and on the time fault.

4.2.1 Calculation of the earth fault current

The calculation of the section of the earth electrodes depends on the value of the fault current and its duration. Hence, they will have a section that allows them to stand the fault current lasting twice more than the line protection time without any dangerous heating.

The earth fault current is defined as:

$$I_f = 3 \cdot |I_o|$$

Where:

$$I_O = \frac{E}{3 \cdot R_f + (R_1 + R_2 + R_O) + j \cdot (X_1 + X_2 + X_O)}$$

- I_O: symmetrical rms value of the zero sequence fault current [A]
- E: phase to-neutral voltage [V]
- R_f: estimated resistance of the fault (it is normally assumed 0) [Ω]
- R_1+jX_1: positive sequence equivalent impedance [Ω]
- R_2+jX_2: negative sequence equivalent impedance [Ω]
- R_O+jX_O: zero sequence equivalent impedance[Ω]

NOTE: the equation expressed above is detailed explained at the specification IEEE Std 80-2000 Equation 67.

In order to calculate the positive, negative and zero sequence equivalent impedance it is used the method explained on the annex C of the IEEE Std 80-2000.

$$Z_1 = Z_2 = r_a + jx_a + jx_d$$

$$Z_o = r_a + r_e + jx_a + jx_e - 2 \cdot jx_d$$

Where:

$$x_d = 0{,}2794 \cdot \log\left(\frac{1}{GMR}\right) = 0{,}465 \frac{\Omega}{mi}$$

$$r_e = 0{,}00477 \cdot f = 0{,}0477 \cdot 60 = 0{,}286\frac{\Omega}{mi}$$

$$x_e = 0{,}00695 \cdot f \cdot \log\left(4{,}6655 \cdot 10^6 \cdot \frac{\rho_s}{f}\right) = 2{,}962\frac{\Omega}{mi}$$

Being:

- GMR: geometric mean distance between the phase conductors in [0,022 ft]
- r_a: ac resistance of the conductor at frequency f [0,328 Ω/mi]
- x_a: inductive reactance of the conductor at frequency f [0,686 Ω/mi]
- f: frequency [60 Hz]
- ρ_S: soil resistivity [150 Ωm]

$$Z_1 = r_a + jx_a + jx_d = 0{,}328 + j0{,}686 + j0{,}465 = (0{,}328 + j1{,}152)\frac{\Omega}{mi}$$

$$Z_o = r_a + r_e + jx_a + jx_e - 2 \cdot jx_d = 0{,}328 + 0{,}286 + j0{,}686 + j2{,}962 - 2j \cdot (0{,}465)$$
$$= (0{,}614 + j2{,}717)\frac{\Omega}{mi}$$

Taking as an example a medium point of the line such as 7km (4,350miles)

Therefore:

$$I_f = 3 \cdot \left| \frac{\frac{33 \cdot 10^3}{\sqrt{3}}}{3 \cdot 0 + [(0{,}328 + 0{,}328 + 0{,}614) + j \cdot (1{,}152 + 1{,}152 + 2{,}717)] \cdot 4{,}350} \right| = 2{,}54kA$$

For 33kV, the 01-SDMS-01 specifies that the maximum short-circuit current that may exist for 1 second is 25kA.

4.2.2 Calculation of the conductor size

According to the Equation 37 of the IEE 80-2000:

$$I = A_{mm^2} \cdot \sqrt{\left(\frac{TCAP \cdot 10^{-4}}{t_c \alpha_r \rho_r}\right) \ln\left(\frac{K_o + T_m}{K_o + T_a}\right)}$$

Where:

- I: RMS current [kA]
- A_{mm^2}: Conductor cros section [mm²]
- T_m: Maximum allowable temperature [ºC]
- T_a: Ambient Temperature [ºC]

- T_r: Reference Temperature for the material constants [ºC]
- α_r: thermal coefficient of the resistibity at the reference temperature [1/ºC]
- α_o: thermal coefficient of the resistibity at 0 ºC [1/ºC]
- ρ_r: resistivity of the ground conductor at the reference temperature
- K_o: 1/ αo [ºC]
- t_c: duration of the curent [s]
- TCAP: thermal capacity per unit volum [J/cm^{3}ºC]

Supposing the material of the earthing system is copper commercial hard-drawn, according to the Table 1 from the IEEE Std 80-2000:

α_r	K_o	T_m	ρ_r	TCAP
0,00381	242	1084	1,78	3,42

$$A = \frac{25}{\sqrt{\left(\frac{3{,}42 \cdot 10^{-4}}{1 \cdot 0{,}00381 \cdot 1{,}78}\right) \ln\left(\frac{242 + 1084}{242 + 30}\right)}} = 88{,}45\text{mm}^2$$

The section chosen for the copper wire is 95 mm^2

4.3 DESIGN REGARDING THE SAFETY OF THE PEOPLE

4.3.1 Admissible values of step and touch voltage

When an earth fault occurs, elements of the installation may turn to a non-zero voltage elements. If a person or an animal is in contact with it at that very moment, current could flow throw them.

The safety of a person depends on preventing the critical amount of shock energy from being absorbed before the fault is cleared and the system de-energized. The maximum driving voltage of any accidental circuit should not exceed the limits defined as follows.

In order to determine the maximum admissible step value (ESTEP) it is used the following expression (supposing the human who stands the fault weights 70kg or more)

$$E_{STEP} = (R_B + 6 \cdot C_s \cdot \rho_S)\frac{0{,}157}{\sqrt{t_s}}$$

Being:

- ρ_S: resistivity of the concrete [10^6 Ωm]
- R_B: human body resistance, which is usually considered 1000 Ω
- C_S: Correction factor of the resistivity due to the concrete

$$C_S = 1 - \frac{0{,}09 \cdot \left(1 - \frac{\rho}{\rho_S}\right)}{2 \cdot h_S + 0{,}09} = 1 - \frac{0{,}09 \cdot \left(1 - \frac{150}{10^6}\right)}{2 \cdot 2{,}1 + 0{,}09} = 0{,}979$$

- ρ: resistivity of the ground [150 Ωm]
- t_S: fault duration [s] [0,5s]

U_T= 1.304,467kV

In order to determine the maximum admissible touch value (ETOUCH) it is used the following expression (supposing the human who stands the fault weights 70kg or more)

$$E_{TOUCH} = (R_B + 1{,}5 \cdot C_s \cdot \rho_S)\frac{0{,}157}{\sqrt{t_s}}$$

Being:

- ρ_S: resistivity of the concrete [10^6 Ωm]
- R_B: human body resistance, which is usually considered 1000 Ω.
- C_S: Correction factor of the resistivity due to the concrete

$$C_S = 1 - \frac{0{,}09 \cdot \left(1 - \frac{\rho}{\rho_S}\right)}{2 \cdot h_S + 0{,}09} = 1 - \frac{0{,}09 \cdot \left(1 - \frac{150}{10^6}\right)}{2 \cdot 2{,}1 + 0{,}09} = 0{,}979$$

- ρ: resistivity of the ground [150 Ωm]
- t_S: fault duration [s] [0,5s]

U_T= 326.283 kV

4.3.2 Earth Resistance calculation

Resistance of the lance:

$$R_L = \frac{\rho_S}{L} = \frac{150}{1,5} = 100\Omega$$

Resistance of the wire

$$R_w = \frac{2 \cdot \rho}{L} = \frac{300}{2 \cdot \pi \cdot 1,5} = 31,83\Omega$$

Total Resistance: R_W in parallel with R_L

R_{WL}=24,145 Ω

4.3.3 Concrete Resistance

Resistance of the concrete:

$$R_c = 0,2 \cdot \frac{\rho_H}{V} = \frac{10^6}{2,1 \cdot \pi \cdot 0,5^2} = 121.260,91\Omega$$

Being V: concrete volume

The human body will be in series with the concrete resistance, therefore, the equivalent resistance will be:

R_{BC}=122.260,9 Ω

4.3.4 Ground Resistance

The resistance of the ground depends on the area to be occupied by the grounding system. It can by estimated with the following equation [Equation 10 of the IEE 80-2000]:

$$R_G = \frac{\rho_S}{4} \cdot \sqrt{\frac{\pi}{A}}$$

Where:

- R_G: Ground resistance [Ω]

- ρ_S: Soil resistivity [Ω·m]
- A: Area occupied by the earthing system [m²]

Taking into account that the diameter of the block foundation is 1m and the distance between the concrete and the copper wire is 1 m (as it is shown on the sketch); the radius of the earthing area is 1,5m.

$$R_G = \frac{150}{4} \cdot \sqrt{\frac{\pi}{\pi \cdot 1{,}5^2}} = 25\ \Omega$$

4.3.5 Real Touching Voltage

If any fault may occur while a person is touching the pole, the equivalent electrical resistance for the fault current is the human body and the concrete resistance in parallel with the earthing system in series with the ground resistance.

Thus, the equivalent resistance is:

$$\frac{1}{R_{EQ}} = \frac{1}{R_{WL}} + \frac{1}{R_{BC}} \rightarrow R_{EQ} = 24{,}14\ \Omega$$

$$R_{TOT} = R_{EQ} + R_G = 24{,}14 + 25 = 49{,}14\Omega$$

The current flowing throw the person shall be:

$$I_B = I_F \cdot \frac{\frac{1}{R_{BC}}}{\frac{1}{R_{BC}} + \frac{1}{R_{WL}}} = 2{,}54 \cdot \frac{\frac{1}{122.260{,}9}}{\frac{1}{122.260{,}9} + \frac{1}{24{,}14}} = 0{,}5\ A$$

The touching voltage suffered by the person shall be

$$V_B = I_B \cdot R_B = 500{,}991V$$

As the voltage suffered by the person is lower than the maximum step value, the safety conditions are fulfilled.

5. CONCLUSION

The earthing system at each pole will consist of:

- A buried copper plain wire of 95 mm^2 section disposed as perimeter loop which its earth resistance is 31,83 Ω.
- One vertical coppered steel lance earthing of 14 mm diameter and 1,5 m length which its earth resistance is 100Ω.

TRANSITION

1. SUBJECT

The main objective of this section is to describe the engineering of the connections between electrical overhead lines and transformers feeding the pumps of every well of the project.

2. DESCRIPTION OF THE IMPLEMENTATION OF THE CONNECTION

The report describes the following elements:

- Pole opposite every well
- Fuse cut out situated in each phase of the feeding circuit
- Metal oxide surge arrester in each phase offering protection against power surges for the transformer.
- Terminal (outside)
- Medium voltage power cable with copper conductors.

2.1 GENERAL CHARACTERISTICS

2.1.1 OHL Conductor

The conductor will be the one described at the part "Overhead line" on the "Chapter I: Conductor Calculus". The conductor will be Aluminium-Steel (ACSR/AW) type MERLIN.

2.1.2 Insulation

The insulation will be the one described at the part "Overhead line" on the "Chapter IV: Insulation Justification".

2.1.3 Well Pole

The poles selected for the transition is the 0C14D. The description and the calculation of these poles have been explained with detail on the Overhead Line section, at the Chapter II: Pole Calculation.

The overhead line accessories needed for this proposal are the following:

- Mounting of insulators: crossarm, L100x100x12x2400
- Crossarm installation: brace, L50x50x4x828
- Fuse cut-out installation: fuse cut-out mounting channel
- Surge arrester installation: surge arrester mounting channel
- Connection to cutout: terminal plug

It is important to note that for the transition three crossarms will be needed. The first one is the conventional one, in which the insulators are located. The second one, perpendicular to the first one, withstands the fuse cut-outs. Finally, the third one, parallel to the third one, will withstand the surge arresters.

The OHL conductor will connect with the transition by the use of a terminal plug. The terminal plug for ACSR or aluminium conductors shall be compression type and made of aluminium with tin plated copper plug. The connector bores shall be prefilled with filler (oxide inhibiting or sealing) compound and capped. The plug shall be bendable to desired angle for easier insertion to equipment terminals.

Foundations

The foundations which apply to the transformers feeding are the ones described at the "Chapter IV: Foundations" for the type of pole OC14D.

Numbering, Signage And Electrical Risk

Each pole should be individually identified and numbered. Also marked with a danger sing plate.

2.1.4 Fuse Cut Out

The fuse cut-out and its fittings must withstand the service conditions and the effect of direct solar radiation at their installed locations. The temperature of exposed surface shall be 75 °C excluding internal heating.

The fuse cut outs shall be suitable to operate under typical system parameters:

SYSTEM PARAMETERS	
Nominal System Voltage	33 kV
Highest Operating Voltage (rms)	36 kV
Frequency	60Hz

Table 32 System Parameters

The design criteria and construction requirements of the fuse cut out are:

- Current Rating (given by the manufacturer): 100A.
- Interrupting Capacity: minimum 8 kA RMS Symmetrical
- Minimum Dielectric withstand values:
    - Power frequency withstand 1min Dry and wet.
        - To earth and between poles: 70 kV
        - Across the isolating distances: 80 kV.
    - Impulse (1.2x 50 μ sec)
        - To earth and between poles: 170 kV.
        - Across the isolating Distances: 200 kV.
- Radio interference voltage: The maximum value shall be: 650 μV at 1 MHZ.

Fuse link: The drop out fuse cut outs is suitable in all respects for fuse links. It should be K- type with removable button head and with the length of 787.4 mm (31 inches).

Insulation level: The basic insulation level for 33 kV is 170Kv.

Interchangeability: The fuse holder and tube of a dropout fuse cut-out shall be dimensionally compatible with a universal type IEC and NEMA fuse links of corresponding rating.

Creepage distances: 1320 mm creepage distance with stand-off insulator.

Fuse tube: shall be bone fiber lined epoxy fiber glass with exterior ultra violet (U.V) protected, solid cap and single vented with arc shortening rod. Solid link shall also be used in place of as and when required.

Mounting arrangement: The dropout fuse cut-outs is suitable for vertical mounting. NEMA brackets are provided for both type of dropout fuse cutouts. The brackets including bolts, nuts, lock washers etc. shall be in accordance with ANSI C 37.42 to prevent swiveling. The upper, lower fuse unit and fitting shall be reusable. The fuse holder shall be easy to operate with hot stick.

Fuse tube assembly: The assembly shall be designed in such a way that the fuse tube can be pushed-in into the slot even without taking due care even when the closing force is applied from angle. The toggle mechanism shall provide locking action to protect the fuse link from shock. A spring assisted flipper shall assist arc interruption by the withdrawal of the fuse tail.

The fuse cut out chosen is designed to be used on overhead distribution systems in a totally exposed environment. The V Series Drop-out disconnector fuse unit can primarily be used for the protection of distribution transformers and the protection of spur sections of overhead lines from the main backbone line.

The technical data schedule of the fuse cut out chosen is the following:

TECHNICAL DATA		
DESCRIPTION.	SEC SPECIFIED VALUES	VENDOR PROPOSED VALUES
System voltage	33 kV	33 kV
Max design voltage	36 KV	36 KV
Continuous current capacity	100 A	100 A
Interrupting current (symmetrical)	8 KA	8 KA
BIL at altitude ≤ 1000 m	170 KV	170 KV
Power frequency with stand 1 min dry and wet:		
To earth and between poles	70kV	70kV
Across the isolating distances	80 kV	80 kV

Impulse (1.2 μ sec)		
To earth and between poles	170 kV	170 kV
Across the isolating distances	200 kV	200 kV
Max radio interference voltage	650 μV	650 μV
Ambient temperature during rise test	-	28ºC
Temperature rise of contacts	-	68ºC
Temperature rise of terminals	-	62ºC
Material of support insulators	Porcelain	Porcelain
Colour of the insulator	Glazed brown/ grey	Grey
Manufacturer stand-off insulator	-	Mexico
Type of main contacts material	Copper	Copper
Fuse cut-out with single or stand-off insulator NEMA brackets	Required	Yes
Cutout suitable for removable button head fuse link	Yes/ no	Yes
All assemblies potted into the porcelain	Required	Yes
Angle of the fuse insulator to the vertical	15°- 20°	15°- 20°
Shed to be incorporated into upper contact assembly	Required	Yes
All current carrying parts of copper or copper alloy	Required	Yes
Conductors terminals tin plated	Required	Yes
Contacts silver clad	Required	Yes
All ferrous components galvanized	Required	Yes
Load break hooks fitting	Required	Yes
Arc interruption assisted by a spring operated flipper	Required	Yes
The protection of fuse link from mechanical shock by latching of toggle mechanism	Required	Yes
Non expendable type fuse cap	Required	Yes
The fuse tube marked with manufacturer, model continuous and interrupting current rating, rated	Required	Yes

voltage and date of manufacture.		
Routine tests carried out on 100% of the offered items	Required	No
Type test certificates included in the tender along with complete descriptive literature	Required	Yes

Table 33 Fuse Cut Out Technical Data

Fuse cut out must be installed in the next accessory for pole OC14D:

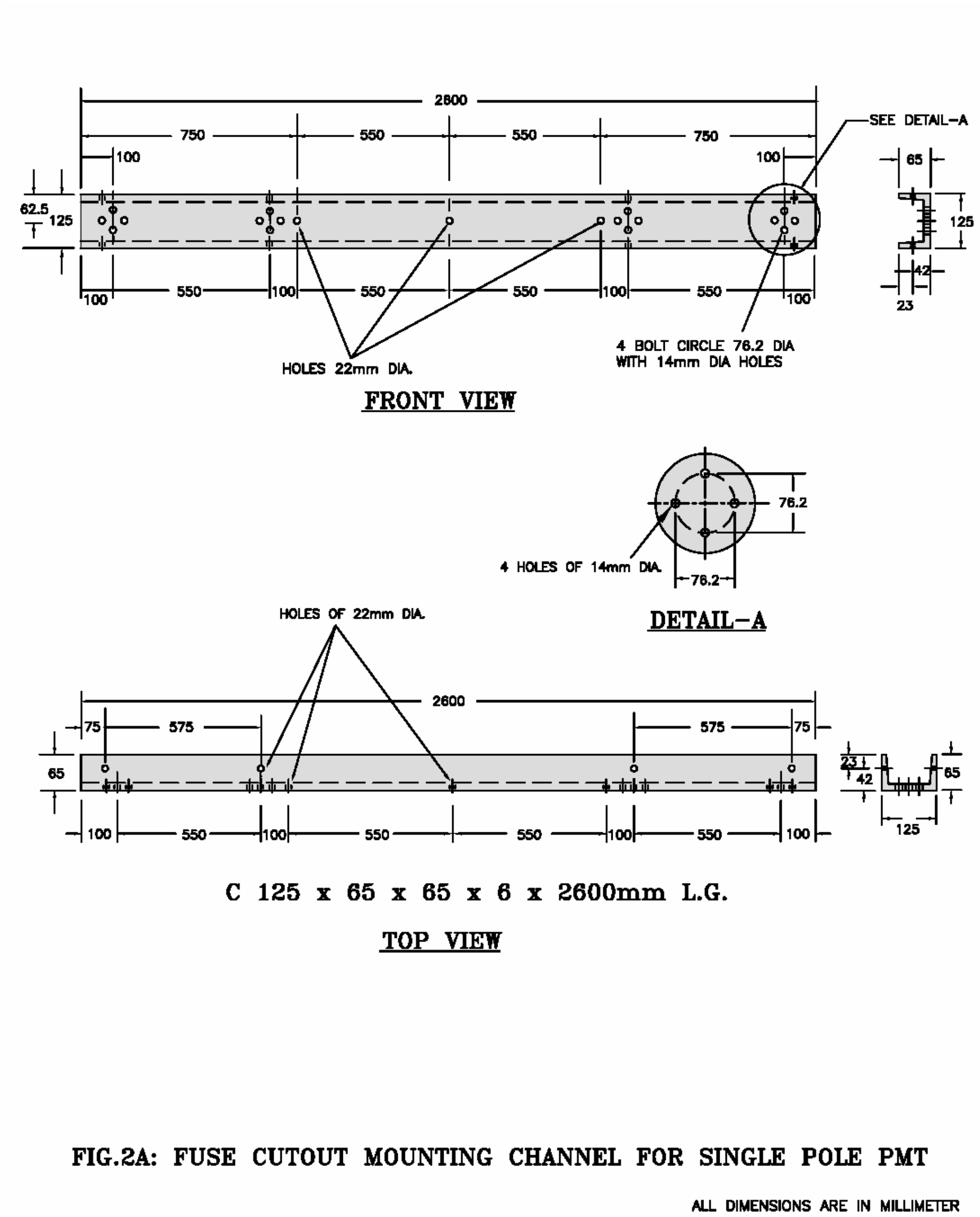


Image 38 Fuse Cut Out Mounting Channel Sketch

2.1.5 Metal Oxide Surge Arrester

The surge arresters shall be suitable for installation in a system of the given parameters:

SYSTEM PARAMETERS	
Nominal System Voltage	33 kV
Highest Operating Voltage (rms)	36 kV
Frequency	60 Hz
Configuration	3 W
Neutral Arrangement	Effectively earthed and/or low resistance
Short Circuit Levels	25 KA
Power Frequency withstand voltage (Dry)	80
Power Frequency withstand voltage (Wet)	75
Creepage Distance	25/40mm/KV
Nominal discharge current based on 8/20 microsecond wave form	10 KA
Maximum residual voltage (KV peak for 8/20 micro second discharge current wave form having peak of 10KA)	130 KV

Table 34 Surge Arrester Characteristics

The selection criteria are:

1.

$$U_C \geq \frac{U_S}{\sqrt{3}} = \frac{33}{\sqrt{3}} = 19{,}05\text{kV}$$

Being:

- U_S: Nominal operation voltage; for our case 33kV

2.

$$TOV_C(10s) \geq k \cdot \frac{U_s}{\sqrt{3}} \cdot \left(\frac{T_t}{10}\right)^{0{,}02} = 1{,}4 \cdot \frac{33}{\sqrt{3}} \cdot \left(\frac{0{,}5}{10}\right)^{0{,}02} = 25{,}12\text{ kV}$$

Being:

- U_S: Nominal operation voltage; for our case 33kV
- k: Earth Fault Factor; as it is solidly connected to earth; for our case 1,4
- Tt: Clearance earth fault time: 0,5s

3.

$$U_{BIL} \geq 1{,}2U_P = 1{,}2 \cdot 130kV = 156kV$$

Being:

- U_{BIL}: Basic insulation level of the protected equipment

It is important to note, that, due to the mobile wave, the voltage of the protected equipment is bigger than the residual voltage. The nearer the surge arrester is from the equipment, the bigger is the protection.

The maximum distance between the surge arrester and the protected equipment is:

$$L = \frac{U_{BIL} - U_P}{2S} \cdot V = \frac{156 - 130}{2 \cdot 1000} \cdot 300 = 3{,}9m$$

Being:

- L: Maximum Distance (m)
- U_{BIL}: Basic insulation level of the protected equipment (The minimum value is 156kV)
- Up: Residual Voltage (130 kV)
- S: Slope of the overvoltage wave (1 000 kV/µs)
- V: wave's propagation speed (300 m/µs approx)

4. As the nominal discharge current based on 8/20 microsecond wave form is 10kA the surge arrester shall be Class 1 or upper.

	5kA	10 kA			20kA	
Nominal Voltage		Class 1	Class 2	Class 3	Class 4	Class 5
$U_S \leq 66$ kV						
66kV $\leq U_S \leq$220 kV						
220 kV $\leq U_S \leq$380 kV						
$U_S \geq$ 380 kV						

Table 35 Usual Values of the Nominal Discharge Current

The surge arresters and its fittings withstand the effect of direct solar radiation at their installed locations. The temperature of exposed surfaces is regarded as 75ºC plus the effect of internal heating.

Therefore, arresters shall be designed to prevent ingress/deposit of sand over the outer and inner surface of surge arresters due to the possible presence of sand storms.

The surge-arrester chosen is a metal oxide nonlinear resistor type gapless, designed for outdoor service and shall be housed in sealed casing to prevent ingress of moisture and dust.

The duty class of the surge arrester distribution d depends on the nominal discharge current, as the one used at the execution project is 10kA nominal discharge current, it can be classified as an arrester-heavy duty class.

Over Pressure Relief Device: Arrester shall be provided with a pressure relief device, a mean for relieving internal pressure in an arrester and preventing explosive shattering of the housing following prolonged passage of flow current or internal flashover of the arrester.

Disconnection Feature: Disconnector shall be incorporated. It is a device for disconnecting an arrester from the system in the event of arrester failure to prevent a persistent fault on the system and to give visible indication of the failed arrester. The method of operation of disconnector shall be described by supplier.

Insulator Detail: As it will be described at the technical data schedule, all the insulators shall have to withstand 36 kV. The creepage distance is based on nominal line-to-line voltage and shall be 25/40mm/KV minimum for dry and wet areas respectively. Insulator sheds shall be designed to minimize trapping of contamination. Moreover, the insulator chosen shall be made of polymer "Silicon rubber housing made by direct molding method" and shall be grey coloured.

Corrosion Protection: All metal parts shall be hot dip galvanized.

Terminals: Terminals shall be clamp type and shall be constructed for conductor either copper or ACSR and continuous work shall be guaranteed without any deterioration.

The surge arrester chosen is based on a cage of pre-stressed fiber reinforced plastic rods for high mechanical strength, reducing the risk of internal components being ejected.

In the extremely rare event of the resistors being overloaded, arcing cannot result in a build-up of critical internal pressure, since the resistors are not enclosed in a sealed mechanical shell. Thus, the arc can escape through the silicone sheath, leaving the mechanical support structure of the enclosure unharmed.

The cage is lightweight design and yet it offers excellent torsional, tensile and cantilever strength: Maximum working cantilever strength of 350 Nm.

Silicone rubber is resistant to UV and ozone exposure as well as to all common organic and non-organic solvents and cleaning agents.

Fuse cut out are suitable for a temperature range from –55° C to +60° C. As the service conditions are: Minimum: -5ºC and Maximum: 55ºC; the ambient temperature will not have a negative impact on the surge arrester.

The application altitude up to 3600 m a.s.l, as Riyadh is 250m a.s.l. the altitude will not have a negative impact.

The technical data of the surge arrester that shall be used at the project execution coming from the manufacturer Hubble Power Systems:

D E S C R I P T I O N	VENDOR PROPOSED VALUES
Standard to which the arrester is made	IEC 60099-4

System voltage	33 kV
Rated voltage	36 kV
Nominal discharge current	10 kA
Pressure relief class	Yes
Power frequency withstand voltage	100 kV
Creepage distance	1320.8 mm
Short circuit levels	20 kA
BIL	250
Max. continuous operating voltage (MCOV)	29 kV
Maximum residual voltage, KV	106.0 @ 10 kA
Net weight, Kg	6.0 kg
Safe cantilever strength at line terminal, KN	225.97
Insulator type	ESP Polymer
Colour of glazed porcelain/polymer	Grey
No. per standard packing	35/pallet & 1/carton
Dimensional drawings and data submitted with proposal	Yes
Method of operation of disconnector	LA Detonation
Moisture sealing system	Silicone Grease
Mounting arrangement	Vertical or Horizontal
Marking	Yes
Nameplate with complete information	Except serial number

Table 36 Surge Arrester Technical Data

2.1.6 Terminal

Image 39 Terminal

The terminal chosen is a termination kit, three phases – three cables without metal terminals.

- Section: 50 - 185 mm^2
- Isolated thickness: 23,1 mm
- Body length: 600 m

2.1.7 Underground Conductor

The only underground conductor cables for rated voltage of 36 kV (Um) which are standardized by the SEC regulation for 33kV are the extruded XLPE insulated cables with the following characteristics:

CABLE SIZE (mm^2)	DESCRIPTION
1x500/35	Single core, unarmored, copper
3x240/35	Three core, armored, copper
3x185/35	Three core, armored, copper
1x50/16	Single core, unarmored, copper

Table 37 Permitted Insulated Conductors

Image 40 Insulated Transition Conductor

From them, the cable chosen conductor is Cu/XLPE/STA/PVC 3x185/35 mm^2 30 kV CWS.

The **conductor** is uncoated annealed copper Class 2 as per IEC 60228, and is round, compacted and stranded. The conductor size, shape and material are as specified above.

Conductor Semi-Conducting Screening: Conductors of the cables are screened. The conductor screen consists of an extruded black semi-conducting material compatible with the insulation of the conductor and has an allowable operating temperature equal to or higher than the insulation. The outer surface of the conductor shield is cylindrical and is firmly bonded to the insulation. The extruded shield is easily removable from the conductor.

Insulation: The insulation is extruded solid dielectric cross-linked polyethylene (XLPE).
The cross linking process does not expose the material to water or steam.
The average insulation thickness does not be less than the specified nominal value.

Insulation Semi conducting Screening: Core insulation of the cables is screened. The insulation semi-conducting screen consists of an extruded black semi-conducting material applied directly over the insulation.

The extruded insulation semi conducting screen is easily strippable without damaging the insulation, leaving no conducting material that cannot readily be removed.

Metallic Screening: All cores with semi-conducting insulation screening have a supplementary copper wire screen helically applied in intimate contact with the non-metallic semi-conducting screening. A copper tape counter-helix is applied over the copper wires.
The minimum size of copper tape binder shall be 0.1 x 15 mm.

Outer Sheath: The outer sheath material is red PVC type ST2, as per IEC 60502-2. Minimum thickness at any point does not be less than 80% of nominal value.

The values given by manufacturer about the cable are:

TECHNICAL DATA	
Reference manufacturing standard	IEC 60502-2
Max. permissible continuous conductor temp.	90 °C
Maximum short circuit temperature for 1 s	250 °C
Max. permissible cont. temp. of inner covering	90 °C
Max. permissible cont. temp. of outer sheath	90 °C
Rated voltage 'Uo/Um' (kV)	18/ 30 (36kV)
Number of cores	3
Conductor material	Cu
Shape of conductor	Compacted Round (Class 2)
Conductor cross-section	185 mm^2
Approximate diameter of conductor	15.9 mm
Number of strands of conductor /Wire Diameter before compaction	37/2.62
Minimum thickness of conductor shield (mm)	0.7
Insulation material	XLPE
Nominal thickness of insulation (mm)	8.0
Approximate Diameter Under Insulation Semicon	33.3 mm
Approximate thickness of extruded strippable semi-conducting insulation shield material (mm)	1.1 mm
Approximate Cross Section Area of Copper Wire Screen (mm2)	35 mm^2
Approximate No. & Thickness & Width of Helically Copper Tape Screen (mm)	1x0.1x15
Core identification (Red, Yellow, Blue)	Yes

Filler material	Non-Hygroscopic Filler
Blinder Tape	Polymeric Tape
Inner Covering Material	PE Compound
Minimum/Nominal thickness of Inner Covering (mm)	1.48/2.10
Diameter under Inner Covering (mm)	80.6
No. &With& Nominal Thickness of Galvanized Steel Tape Armour	2x60x0.8
Outer sheath material	PVC Type ST2
Approximate Diameter unde Outer Sheath	96 mm
Colour of Outer Sheath	BLACK
Marking Embossed as Specified	Yes
Approximate Wight of Conductor (kg/km)	4765
Conductor DC Resistance at 20ºC	0.0991
Conductor AC Resistance at 90ºC	0.1274
Inductance	0.3610
Inductive Reactance	0.136
Conductor Impedance at 90ºC	0.186
Capacitance (picoF)	0.2122
Charging Current (A/km)	1.386
Earth Fault Capacitive Current (A/km)	2.401
Short Circuit Rating of Cable based on Maximum Conductor Operating Temperature (1s)	
Conductor(kA)	26.46
Screen(kA)	4.50
Conductor Temperature before Short Circuit (ºC)	90
Conductor Temperature at the end of Short Circuit (ºC)	250
Screen Temperature before Short circuit (ºC)	85
Screen Temperature at the end of Short circuit (ºC)	200
System Short Circuit for one Second (kA)	26.46
Permissible load in Amps under Maximum Service Conditions given in this Specification	
In Air with Ambient Temperature (40ºC)	415 A

Direct in Ground with the following conditions: · Ambient Ground Temperature: 35ºC · Depth of laying in ground: 0.8m · Soil Thermal Resistivity: 1.2K.m/W	395 A
Maximum pulling Tension (KN)	27.8
Maximum side wall press (kN/m)	24.1
Minimum Bending Radius (m)	1.150
Maximum partial discharge at 1.73 times of Uo rated voltage (5PC for Type Test, 10PC for Routine Test)	Yes
Meets Spark Test Requirements for jacket	Yes
Meets all Test requirements of IEC-60502-2	Yes

Table 38 Transition Insulated Conductor's Technical Data

The values are based on the following conditions:

- Ambient air temperature: 40ºC
- Ambient ground temperature: 35ºC
- Depth of laying in ground: 0,5 m
- Soil thermal resistivity: 1,2 ºK·m/W

Installation of the Conductor

The cable will be installed between the terminals and the transformer. At the beginning, while goes on the pole, it will lay in free air, joint to the pole with the stainless steel strap. And 2 m high the floor, it will be covered with a steel plate of 3 mm thickness.

The cable will be installed direct buried in ground from the bottom of the pole until the transformer. The duct is an enclosure of insulation material (plastic is recommended) intended for the protection of cables which are drawn in after erection of the ducting. The three cored cables compounding the simple circuit will lay flat touching, in horizontal formation.

The installing conditions will be:

- Surrounding environment (air/ground/wall): Ground
- Burial Depth: 1 m
- Number of cables per trench: 1

2.1.8 Earthing System

Earthing During the Underground Section

The screens will be connected at both sides of the cable to earth, connection called "SOLID BONDED".

Earthing During the Overhead Section

Each pole has its own earthing and it is connected buy an earthing nut. The earthing nut of the pole should be made of steel Grade 4.6 and shall comply with the applicable requirements of ASTM A307 and ASTM A563 or equivalent and hot-dipped galvanized in accordance with the requirement of 01-SDMS-01 with minimum average coating thickness of 0.053 mm, equivalent to 381 g/m^2.

The grounding rods provided under this specification shall be sectional type. The rods are rolled threaded at each end and can be joined together with couplings.

The grounding rod shall be made of solid steel core covered with a uniform copper coating. The copper is applied electrolytically forming a metallurgical bond between the steel core and the copper. The steel core shall be cold drawn to ASTM A1080 AISI C1017 or equivalent. The copper coating shall be type DHP alloy No. 122CDA to ASTM B-572 or equivalent with 99.5 % pure copper and minimum coating thickness of 0.25 mm.

The grounding rod coupling shall be made of silicon bronze, counter bored to enclose fully the threads on the rods. The design shall ensure that when assembled, there will be direct rod-to-rod contact when the rod driving force is applied.

The grounding rod driving head shall be of high strength steel, threaded to fit the grounding rod coupling. The design shall ensure that there is direct driving head to rod contact when the rod driving force is applied. The driving head shall be suitable for re-use.

3. ELECTRICAL CALCULATIONS. CURRENT CAPACITY

3.1 OHL CONDUCTOR

The electrical calculation of the OHL conductor have been detailed explained at the section Overhead Lines, on the Chapter I: Conductor Calculation on the point 2, Electrical Calculation.

The maximum ampacity due to the given characteristics of the MERLIN conductor is 396A.

Therefore, the power per three-phase circuit at 33kV:

$$S = \sqrt{3} \cdot U \cdot I \cdot n = \sqrt{3} \cdot 33 \cdot 396 \cdot 1 \cdot 10^{-3} = 22{,}63 MVA$$

3.2 UNDERGROUND CONDUCTOR

The needed value of current for the installation comes from the expression:

$$S = \sqrt{3} \cdot U \cdot I \cdot n$$

Where,

- S: Nominal power of pump (kVA)
- U: Nominal voltage of the grid: 33kV

Being:

$$P = S \cdot \cos \varphi$$

Where,

- P: Nominal power of pump (390 kW)

- cos(φ): power factor (0,9)

Thus, the current that shall be transported throw the underground conductor is:

$$I = \frac{390kW}{\sqrt{3} \cdot 33kV \cdot 0,9} = 7,58A$$

For the cable chosen at the project, CU/XLPE/PVC 3x185mm^2 – copper conductor, unarmoured, 36kV, the value of I_{MAX}, given by the manufacturer, is 395, which is bigger than the current that shall be transported on the facility. Hence, the cable suits perfectly.

3.2.1 Rating assumptions

The calculation of the current ratings, current rating equations (100% load factor) and calculation of losses are based on IEC 60287 series, and the values of current ratings are verified with the tabulated value in IEC 60502-2.

The calculation is based on the standard dimensions of cables based on IEC 60502-2, which may have a slight difference from the applied cable dimension, which are following the best common manufacturing practices.

The values given in the tables before are for one circuit installed thermally isolated from other circuits or any other heat source.

The basis of the standard conditions is the climate conditions of the Kingdom of Saudi Arabia, which are:

- Ambient Air Temperature: 40 °C
- Ambient Ground Temperature: 35°C
- Depth of laying in ground: 0.8 m
- Soil Thermal Resistivity: 1.2 °K.m/W

As the conditions of the project are not the same, derating factors shall be applied. The derating factors considered for the installation conditions of the project are:

	AMBIENT CONDITION	DERATING FACTOR	REFERENCE
Ambient Air Temperature	55 °C	1	IEC-60364-52 Table A.52-14 (52-D1)
Ambient Ground Temperature	40°C	0.96	Table 3 Bahra Cables Catalog
Depth of laying in ground	1 m	0.98	Table 4 Bahra Cables Catalog
Soil Thermal Resistivity	2 °K.m/W	0.82	Table 5 Bahra Cables Catalog

Table 39 Derating Transition Conductor's Factors

The table including the different derating factors suggested by the manufacturer are:

2 INSTALLATION CONDITIONS FOR DIRECT BURIAL CABLES

For a cable installed direct buried, the following tables will be used to calculate the current rates based on the actual soil thermal resistivity, Ground ambient temperature and the Depth of Laying.

Table 3 : Rating factors for ground temperature variation

Ground Temparature	15°C	20°C	25°C	30°C	35°C	40°C	45°C	50°C	55°C
Rating Factors	1.17	1.12	1.08	1.04	1.00	0.96	0.90	0.85	0.80

Table 4 : Rating factors for depth of laying

Depth of Laying	Single Core Cables		Three Core Cables
	Nominal conductor size mm2		
	≤ 185 mm2	> 185 mm2	
0.50	1.04	1.06	1.04
0.60	1.02	1.04	1.03
0.80	1.00	1.00	1.00
1.00	0.98	0.97	0.98
1.25	0.96	0.95	0.96
1.50	0.95	0.93	0.95
2.0	0.93	0.90	0.93
2.5	0.91	0.88	0.91
3.0	0.90	0.86	0.90

Table 5 : Rating factors for variation in thermal resistivity of soil (average values)

Rating Factors	Soil Thermal Resistivity (°C m / W)							
	0.8	0.9	1.0	1.2	1.5	2.0	2.5	3.0
Single Core Cables								
≤ 50 mm²	1.19	1.16	1.11	1	0.91	0.83	0.77	0.69
> 50 mm² & ≤ 185 mm²	1.21	1.16	1.13	1	0.92	0.82	0.76	0.69
240 mm² and above	1.23	1.17	1.17	1	0.92	0.82	0.76	0.68
Three Core Cables								
≤ 50 mm²	1.15	1.12	1.09	1	0.89	0.85	0.80	0.72
> 50 mm² & ≤ 185 mm²	1.16	1.13	1.09	1	0.89	0.85	0.80	0.72
240 mm² and above	1.17	1.14	1.10	1	0.90	0.85	0.79	0.72

Image 41 Capture of the Derating Factors from the Catalogue

Conclusion

The current rating capacity under less favourable conditions is:

$$I = 395 \cdot 1 \cdot 0{,}96 \cdot 0{,}98 \cdot 0{,}82 = 304{,}725A \geq 7{,}58A$$

As the calculated value (304,7A) is greater than the requested current for the installation (7,58A) the cable is valid.

3.2.2 Voltage drop and short circuit capacity

When the current flows in conductor, there is a voltage drop between the ends of the conductor.

To calculate voltage drop for a three-phase circuit it is used the following formula:

$$V_d = \sqrt{3} \cdot I \cdot L \cdot (R \cdot \cos(\varphi) + X \cdot \sin(\varphi))$$

Where:

- Vd: Voltage drop V
- I: Load current (7,58 A)
- R: AC resistance (0,1274 Ω/km)
- X: Reactance (0,3610 Ω/km)
- L: Length: between 35 and 45km(40 km)
- cosφ: Power factor (0,9)

As for the short-circuit current, the cables must have a short circuit current greater than the interrupting current from the fuse cut-out to be valid (8kA).

Using the software *"Bahra Cable Voltage Drop & Short Circuit Current Calculator Tool"* for making the calculations of voltage drop and short circuit capacity taken into account the following:

- Conductor type: Cooper
- Insulation type: XLPE
- Three core
- Three phase

Thus, the voltage drop and the short circuit current shall be:

- Voltage drop: 0,2393 mV/A/m
- Short current capacity: 26,46 kA

Image 42 Bahra Calculation Software's Capture

3.2.3 Maximum permissible length

There are two kind of losses in the wire:

Dielectric Losses

$$P_{DIELECTRIC} = 2 \cdot \pi \cdot C \cdot U_0^2 \cdot \tan(\delta) \cdot 10^{-6} \left[\frac{W}{km \cdot phase}\right]$$

- C: Capacitance to neutral (μF/km)
- Uo: Voltage between phase and earth (V)
- tan δ: Dielectric power factor

As there is no current circulation in the shield due to the fact the grounding system chosen is SOLID BONDED (earthing at both sides of the cable) this value is 0 W/km.

Ohmic losses

$$P_O = R \cdot I^2 \cdot (1 + \lambda_1) = 0{,}1274 \cdot 7{,}58^2 = 7{,}32 \frac{W}{km}$$

- R: Resistance of the conductor (0,1274 Ω/km)

- I: current at the normal service conditions (7,58A)
- λ_1 = Relation of the losses at the shield in proportion with the total losses in all the conductors of the wire. (0 (given by the manufacturer))

Total losses

The total losses are:

$$P'_T = 3 \cdot (P_O + P_D) = 3 \cdot (7{,}32 + 0) = 21{,}96\ \frac{W}{km}$$

The length of the cable in this installation is between 35m and 45m. As the 45m is the most unfavorable condition, the total losses are calculated for this length:

$$P_T = L \cdot P'_T = 45 \cdot 10^{-3} \cdot 21{,}96 = 0{,}99W$$

In relation with the total power that is being transported (390kW), the total losses represent the following percentage:

$$\Delta P_T = \frac{P_{\text{TOTAL LOSSES}}}{P_{\text{TOTAL TRANSPORTED}}} \cdot 100 = \frac{0{,}99}{390000} \cdot 100 = 2{,}53 \cdot 10^{-4}$$

Hence, the losses can be considered negligible.

UNDERGROUND LINE

1. SUBJECT

This section contains the calculation of the undergrounded electrical line from "MV-building" to LOT4 transformers for its execution.

The aim of this Project is the analysis, description and evaluation of the underground electric line at 33kV which connects the medium voltage cells from the already existing substation to the future substation in order to feed the Water Treatment Plant . Thus, the whole line will be completely buried, without any need of aerial transitions.

2. DESCRIPTION OF THE INSTALLATION

The specific needs that the line shall meet are the following:

Requirements	LOT 4
Power	25 MW
Number of circuits	1
Nominal Voltage	33kV
Highest voltage	36kV
Length	297 m
Nominal Current	437A

Table 40 Underground Line Requirements

As it has been mentioned above, the aim of this underground electric line at 33kV is to connect the medium voltage cells from the already existing substation to the future substation. The final length of the line shall be 297m.

At the definitive disposition, the underground line will flow directly buried with a trefoil distribution. Every phase-conductor will be fitted into a plastic PVC tube of 160mm diameter.

3. DESCRIPTION OF THE UNDERGROUND SECTION

3.1 MATERIALS

3.1.1 Dry Insulation Wire

The only underground conductor cables for rated voltage of 36 kV (Um) which are standardized by the SEC regulation for 33kV are the extruded XLPE insulated cables with the following characteristics:

S. No.	Cable Size, mm^2	Description
1	1x500/35	Single core, unarmored, copper
2	3x240/35	Three core, armored, copper
3	3x185/35	Three core, armored, copper
4	1x50/16	Single core, unarmored, copper

Table 41 Permitted Insulated Conductors

Consulting the manufacturer conductor catalogue, the different characteristics of every conductor of the four mentioned above are given. The characteristic which differentiates the choosing conductor is the total capacity of transporting current of the cable. This current is the maximum current which is allowed to transport multiplied by the different rating factors which depend on the service conditions of the line.

The four conductors with its different admissible currents are the following:

S. No.	Material	Cores	I_{MAX}	Tª Rating	Depth Rating	Resistivity Rating	I_{TOT} (A)
1x500/35	Cu	Single core	680A	0,95	0,95	0,85	521,645
3x240/35	Cu	Three core	445A	0,95	0,95	0,85	341,371
3x185/35	Cu	Three core	395A	0,95	0,96	0,87	313,409
1x50/16	Cu	Single core	211A	0,95	0,96	0,87	167,416

Table 42 Admissible Currents for the Permitted Conductors

As we can see, the only wire that suits the electrical conditions given by the facility is the 1x500/35 single core copper conductor.

Image 43 Underground Conductor

The **conductor** is uncoated annealed copper Class 2 as per IEC 60228, and is round, compacted and stranded. The conductor size, shape and material is as specified above.

Conductor Semi-Conducting Screening: Conductors of the cables are screened. The conductor screen consists of an extruded black semi-conducting material compatible with the insulation of the conductor and has an allowable operating temperature equal to or higher than the insulation. The outer surface of the conductor shield is cylindrical and is firmly bonded to the insulation. The extruded shield is easily removable from the conductor.

Insulation: The insulation is extruded solid dielectric cross-linked polyethylene (XLPE) The cross linking process does not expose the material to water or steam.
The average insulation thickness does not be less than the specified nominal value.

Insulation Semi-Conducting Screening: Core insulation of the cables is screened. The insulation semi-conducting screen consists of an extruded black semi-conducting material applied directly over the insulation.

The extruded insulation semi conducting screen is easily strippable without damaging the insulation, leaving no conducting material that cannot readily be removed.

Metallic Screening: All cores with semi-conducting insulation screening have a supplementary copper wire screen helically applied in intimate contact with the non-metallic semi-conducting screening. A copper tape counter-helix is applied over the copper wires.
The minimum size of copper tape binder shall be 0.1 x 15 mm.

Outer Sheath: The outer sheath material is red PVC type ST2, as per IEC 60502-2. Minimum thickness at any point does not be less than 80% of nominal value.

The data sheet given by the manufacturer of the cable which fulfils the requirements specified on the SEC 11-SDMS-03 are:

DESING AND CONSTRUCTION REQUIREMENTS	
Reference manufacturing standard	IEC 60502-2
Max. permissible continuous conductor temp.	90 °C
Maximum short circuit temperature for 1 s	250 °C
Max. permissible cont. temp. of inner covering	90 °C
Max. permissible cont. temp. of outer sheath	90 °C
Rated voltage 'Uo/Um' (kV)	18/ 30 (36kV)
Number of cores	1
Conductor material	Cu
Shape of conductor	Compacted Round (Class 2)
Conductor cross-section	500 mm^2
Approximate diameter of conductor	26,4 mm
Number of strands of conductor /Wire Diameter before compaction	61/3,34
Approximate No. & Width& Nominal Thickness of Semi Conductive Tape	2 x 40 x 0,18
Approximate thickness of extruded semiconducting conductor shield	0,7 mm
Insulation material	XLPE
Nominal thickness of insulation	8.0 mm
Approximate Diameter Under Insulation Semicon	44,5 mm
Approximate thickness of extruded strippable semi-conducting	1,5 mm

insulation shield material	
Approximate Cross Section Area of Copper Wire Screen (mm^2)	35 mm^2
Approximate No. & Thickness & Width of Helically Copper Tape Screen (mm)	1x0,1x15
Core identification (Red, Yellow, Blue)	Not Applicable for single core
Filler material	-
Blinder Tape	Polymeric Tape
Inner Covering Material	-
Diameter under Inner Covering	-
Outer sheath material	PVC
Approximate Diameter under Outer Sheath	50 mm
Colour of Outer Sheath	BLACK
Marking Embossed as Specified	Yes
Approximate Wight of Conductor	4351 kg/km
Conductor DC Resistance at 20ºC	0,0366 Ω/km
Conductor AC Resistance at 90ºC	0,0512 Ω/km
Inductance	0,3380 mH/km
Inductive Reactance	0,127 Ω/km
Conductor Impedance at 90ºC	0,137 Ω/km
Capacitance	0,3114 μF/km
Charging Current	2,033 A/km
Earth Fault Capacitive Current	2,033 A/km
Short Circuit Rating of Cable based on Maximum Conductor Operating Temperature (1s)	
Conductor	71,50 kA
Screen	4,50 kA
Conductor Temperature before Short Circuit	90 ºC
Conductor Temperature at the end of Short Circuit	250 ºC
Screen Temperature before Short circuit	85 ºC
Screen Temperature at the end of Short circuit	200 ºC
System Short Circuit for one Second	71,50 kA
Permissible load in Amps under Maximum Service Conditions given in this Specification	
In Air with Ambient Temperature (40ºC)	860 A

Direct in Ground with the following conditions:	680 A
– Ambient Ground Temperature 35ºC – Soil Thermal Resistivity: 1.2K.m/W	
Maximum pulling Tension	25,0 kN
Maximum side wall press	30,2 kN/m
Minimum Bending Radius	0,828 m
Maximum partial discharge at 1,73 times of Uo rated voltage (5PC for Type Test, 10PC for Routine Test)	Yes
Meets Spark Test Requirements for jacket	Yes
Meets all Test requirements of IEC-60502-2	Yes

Table 43 Underground Conductor Technical Data

3.1.2 Terminals

The outdoor/indoor heat-shrink unipolar terminal will be installed. Three of them in the cells and the other three at the transformer.

The unipolar terminal which are outdoor/indoor type have the following main characteristics:

- Cover: Polymer
- Nominal voltage: 33 kV
- Withstand voltage at industrial frequency: 70 kV
- Minimum creepage (pollution level III): 25 mm/ kV

3.2 CIVIL WORK

The 33 kV circuit goes through a duct of 0,6m wide and 1,2m depth, besides the crossings with other services which force a deeper dimension.

The ducts will host (per circuit), 3 tubes of 160 mm. flat arranged for the 33 kV conductors, 1 tube of 110 mm (as an extra one, just in case the earthing system needs to be changed) and a tube for the communications cable formed by 4 tubes of 40 mm.

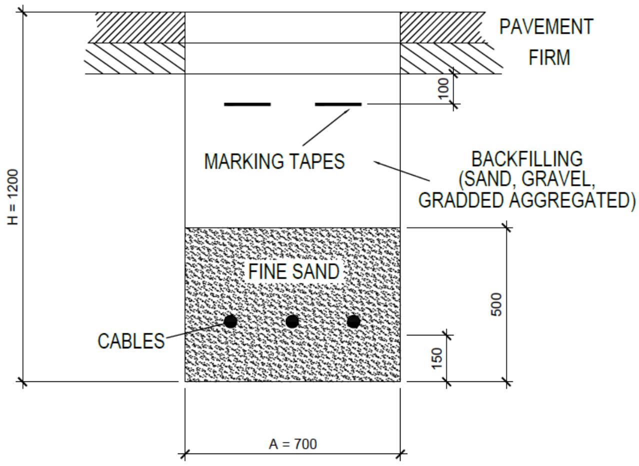


Image 44 Underground Conductor's Disposition's Sketch

3.2.1 Earthing

The earthing system of the shields shall be SOLID BONDED; that is to say, the shield will be rigidly joint to the earth at both edges of the installation. This means that the line will be connected to the mesh earthing system of both of the substations in which it is connected. The substations, as the tension level is characterized as medium voltage, the neutral arrangement shall be solidly grounded or put to earth through a low resistance.

4. ELECTRICAL CALCULATIONS

4.1 MAXIMUM ADMISSIBLE CURRENT

The needed value of current for the installation comes from the expression:

$$S = \sqrt{3} \cdot U \cdot I \cdot n$$

Where,

- S: Nominal power of transformer: 25MVA
- U: Nominal voltage of the grid: 33kV

$$I = \frac{25\ \text{MVA}}{\sqrt{3} \cdot 33\text{kV}} = 437{,}38\ \text{A}$$

Due to this requirements, the conductor chosen for this facility is the XLPE insulated PVC sheathed cable copper unarmored conductor:

Image 45 Underground Conductor

The electrical current value given by the manufacturer for this cable is 680A and is based on the following conditions of the Kingdom of Saudi Arabia, which are:

- Ambient Air Temperature: 40 °C
- Ambient Ground Temperature: 35°C
- Depth of laying in ground: 0.80 m
- Soil Thermal Resistivity: 1,2 °K.m/W

4.1.1 Rating Assumptions

The calculation of the current ratings, current rating equations (100% load factor) and calculation of losses are based on IEC 60287 series, and the values of current ratings are verified with the tabulated value in IEC 60502-2.

The calculation is based on the standard dimensions of cables based on IEC 60502-2, which may have a slight difference from the applied cable dimension which are following the best common manufacturing practices.

The value of current given before (680A) is for one circuit installed thermally isolated from other circuits or any other heat source. For other installation conditions or any value of different air/ ground temperature, depth of laying, different soil thermal resistivity such as ours, it is needed to multiply the tabulated current rating by the de-rating factor values as in tables specified by the manufacturer on its catalogue which will be show just below:

3 INSTALLATION CONDITIONS FOR CABLES IN DUCTS

A duct is an enclosure of metal or insulating material other than conduits or cable trunking, intended for the protection of cables which are drawn in after errection of the ducting.

Table 6 : Rating factors for ground temperature variation

Ground Temparature	15°C	20°C	25°C	30°C	35°C	40°C	45°C	50°C	55°C
All Cable Types	1.16	1.13	1.09	1.03	1	0.95	0.89	0.84	0.79

Table 7 : Rating factors for depth of laying (to center of cable or trefoil group of cables)

Depth of Laying	Single Core Cables – Nominal conductor size mm2 ≤ 185 mm2	Single Core Cables – Nominal conductor size mm2 >185 mm2	Three Core Cables
0.50	1.04	1.06	1.03
0.60	1.02	1.03	1.02
0.80	1.00	1.00	1.00
1.00	0.98	0.97	0.99
1.25	0.96	0.95	0.97
1.50	0.95	0.93	0.96
2.0	0.93	0.91	0.94
2.5	0.91	0.89	0.93
3.0	0.90	0.88	0.92

Table 8: Rating factors for variation in thermal resistivity of soil (average values)

Rating Factors	Soil Thermal Resistivity (°C m / W) 0.8	0.9	1.0	1.2	1.5	2.0	2.5	3.0
Single Core Cables								
≤ 50 mm²	1.13	1.10	1.07	1	0.96	0.87	0.8	0.76
> 50 mm² & ≤ 185 mm²	1.14	1.10	1.07	1	0.95	0.87	0.79	0.74
240 mm² and above	1.15	1.11	1.08	1	0.95	0.85	0.79	0.73
Three Core Cables								
≤ 50 mm²	1.16	1.12	1.08	1	0.97	0.87	0.80	0.76
> 50 mm² & ≤ 185 mm²	1.17	1.13	1.08	1	0.96	0.87	0.79	0.73
240 mm² and above	1.18	1.13	1.09	1	0.96	0.85	0.79	0.72

Image 46 Capture of the Derating Factors from the Catalogue

For the installation conditions of the project, the derating factors are:

	AMBIENT CONDITION	DERATING FACTOR	REFERENCE
Ambient Air Temperature	55 °C	1	IEC-60364-52 Table A.52-14 (52-D1)
Ambient Ground Temperature	40°C	0,95	Table 6 Bahra Cables Catalog
Depth of laying in ground	1,2 m	0,95	Table 7 Bahra Cables Catalog
Soil Thermal Resistivity	2 °K.m/W	0,85	Table 8 Bahra Cables Catalog

The current rating capacity under less favourable conditions is:

$$I = 689 \cdot 1 \cdot 0{,}95 \cdot 0{,}95 \cdot 0{,}85 = 528{,}55\ A$$

As this value is higher than the requested current for the installation (437,38A) the cable is valid.

4.1.2 Nominal Power of the Line

The transport capacity of the line corresponds to a 33 kV voltage and 521,645 A nominal intensity wire; it follows the next formulation:

$$S = \sqrt{3} \cdot 33 \cdot 521{,}645 \cdot 10^{-3} = 29{,}85 \text{ MVA}$$

The nominal power of the line exceeds the power requirements demanded by the client, which is 25MVA.

4.2 NOMINAL ELCTRIC LOSSES

There are two kind of losses in the wire:

4.2.1 Dielectric losses

$$P_{DIELECTRIC} = 2 \cdot \pi \cdot C \cdot U_O^2 \cdot \tan(\delta) \cdot 10^{-6} \left[\frac{W}{km \cdot phase}\right]$$

- C: Capacitance to neutral (μF/km)
- Uo: Voltage between phase and earth (V)
- tan δ: Dielectric power factor (-)

As there is no current circulation in the shield due to the fact the grounding system chosen is SOLID BONDED (earthing at both sides of the cable) this value is 0 W/km.

4.2.2 Ohmic losses

$$P_O = R \cdot I^2 \cdot (1 + \lambda_1) = 9{,}979 \frac{kW}{km}$$

- R: Resistance of the conductor (0,0512 Ω/km)
- I: current at the normal service conditions (437,38A)
- λ_1 = Relation of the losses at the shield in proportion with the total losses in all the conductors of the wire. (0 (given by the manufacturer))

4.2.3 Total losses

The total losses are:

$$P'_T = 3 \cdot (P_O + P_D) = 3 \cdot (9{,}979 + 0) = 29{,}384 \frac{kW}{km}$$

The length of the cable in this installation is 297m.

$$P_T = L \cdot P'_T = 297 \cdot 10^{-3} \cdot 29{,}384 = 8{,}727 \text{ kW}$$

In relation with the total power that is being transported (390kW), the total losses represent the following percentage:

$$\Delta P_T = \frac{P_{TOTAL\ LOSSES}}{P_{TOTAL\ TRANSPORTED}} \cdot 100 = \frac{8{,}727}{25000} \cdot 100 = 3{,}49 \cdot 10^{-4}$$

Hence, the losses can be considered negligible.

4.3 VOLTAGE DROP AND SHORT CIRCUIT'S MAXIMUM CURRENT

When the current flows in conductor, there is a voltage drop between the ends of the conductor.

To calculate voltage drop for a three-phase circuit it is used the following formula:

$$V_d = \sqrt{3} \cdot I \cdot L \cdot (R \cdot \cos(\varphi) + X \cdot \sin(\varphi))$$

Where:

- Vd: Voltage drop V
- I: Load current (437,38 A)
- R: AC resistance (0,0512 Ω/km)
- X: Reactance (0,127 Ω/km)
- L: Length (0,297 km)
- cosφ: Power factor (0,9)

Using the software "*Bahra Cable Voltage Drop & Short Circuit Current Calculator Tool*" for making the calculations of voltage drop and short circuit capacity, the results are:

- Conductor type: Cooper
- Insulation type: XLPE
- Single core
- Three phase

Image 47 Bahra Calculation Software's Capture

- Voltage drop 0,1509mV/Amp/m
- Total voltage drop: 19,6V
- Voltage drop (%): 0,059%
- Short current capacity: 71,5KA

BUDGET

OVERHEAD LINE

MATERIALS

ELEMENT	UNITARY PRICE	QUANTITY	TOTAL PRICE
Conductor	3,00 €/kg	22.875,82 kg	68.627,47 €
Poles	1,35 €/kg	73.191,38 kg	98.808,36 €
Insulators	76,15 €/unit	491 units	37.413,26 €
Anchors and Accesories	6,53 €/set	491 sets	3.208,25 €
Earthing System	7,10 €/kg	176,22 kg	1.251,17 €
Concrete	46,50 €/m3	282,97 m3	13.158,30 €

TOTAL	222.466,81 €

CIVIL WORKS

ELEMENT	UNITARY PRICE	QUANTITY	TOTAL PRICE
Topographic Modeling of the Line Profile	269,47 €/km	13,97 km	3.764,03 €
Stake's Placement	36,75 €/pole	159 poles	5.843,25 €
Access Roads	619,33 €/km	13,97 km	8.650,96 €
Material Withdraw	19,49 €/m3	65,51 m3	1.276,75 €
Excavation	65,59 €/m3	327,54 m3	21.483,35 €
Concreting	80,43 €/m3	360,29 m3	28.978,13 €

TOTAL	69.996,47 €

ELECTROMECHANICAL WORKS

ELEMENT	UNITARY PRICE	QUANTITY	TOTAL PRICE
Mounting and Lifting	180,44 €/pole	159 poles	28.689,96 €
Numbering and Signing	20,61 €/pole	159 poles	3.276,99 €
Stringing, Tightening and Clumping	5.726,92 €/km	13,56 km	77.665,13 €
Earthing System Installation	603,37 €/pole	13 poles	7.843,81 €
Inspection, measurements and tests before the energization	410,95 €/km	14 poles	5.573,04 €

TOTAL	123.048,94 €

SUMMARY

TOTAL	**415.512,22 €**
Materials	222.466,81 €
Civil Works	69.996,47 €

Electromechanical Works	123.048,94 €

Table 44 Overhead Line Budget

TRANSITION

MATERIALS

ELEMENT	UNITARY PRICE	QUANTITY	TOTAL PRICE
Underground Conductor	102,26 €/m	535,60 m	54.772,06 €
Marking Tape	0,13 €/m	374,92 m	48,74 €
PVC Tube	6,67 €/m	26,78 m	178,62 €
Three-Pole Terminal	1.006,08 €/unit	28 units	28.170,24 €
Fuse Cut Out	390,00 €/unit	42 units	16.380,00 €
Surge Arrester	345,00 €/unit	42 units	14.490,00 €
Concrete	44,85 €/m3	257,09 m3	11.530,40 €
Sand	12,10 €/m3	96,41 m3	1.166,54 €

TOTAL	126.736,60 €

CIVIL WORKS

ELEMENT	UNITARY PRICE	QUANTITY	TOTAL PRICE
Trench Excavation	7,64 €/m	535,60 m	4.091,98 €
Concreting	18,15 €/m3	257,09 m3	4.666,20 €
Infilling	6,78 €/m3	16,07 m3	108,94 €

TOTAL	8.867,12 €

ELECTROMECHANICAL WORKS

ELEMENT	UNITARY PRICE	QUANTITY	TOTAL PRICE
Conductor Stringing	103,44 €/m	536 m	55.402,46 €
Clumping and Terminal's Confection	302,71 €/pole	13 poles	4.053,29 €

TOTAL	59.455,75 €

SUMMARY

TOTAL	**195.059,47 €**
Materials	126.736,60 €
Civil Works	8.867,12 €
Electromechanical Works	59.455,75 €

Table 45 Transition Budget

UNDERGROUND LINE

MATERIALS

ELEMENT	UNITARY PRICE	QUANTITY	TOTAL PRICE
Conductor	70,13 €/m	917,73 m	64.360,40 €
Marking Tape	0,13 €/m	611,82 m	79,54 €
PVC Tube	6,67 €/m	917,73 m	6.121,26 €
Terminal	1.579,67 €/unit	6 units	9.762,36 €
Concrete	44,85 €/m3	146,84 m3	6.585,63 €
Sand	12,10 €/m3	55,06 m3	666,27 €

TOTAL	87.575,46 €

CIVIL WORKS

ELEMENT	UNITARY PRICE	QUANTITY	TOTAL PRICE
Trench Excavation	7,64 €/m	305,91 m	2.337,15 €
Concreting	18,15 €/m3	146,84 m3	2.665,12 €
Infilling	6,78 €/m3	18,35 m3	124,44 €

TOTAL	5.126,71 €

ELECTROMECHANICAL WORKS

ELEMENT	UNITARY PRICE	QUANTITY	TOTAL PRICE
Conductor Stringing, Clumping and Terminal's Confection	123,44 €/m	305,91 m	37.761,53 €

TOTAL	37.761,53 €

SUMMARY

TOTAL	**130.463,71 €**
Materials	87.575,46 €
Civil Works	5.126,71 €
Electromechanical Works	37.761,53 €

Table 46 Underground Line Budget

SUMMARY

SUMMARY

TOTAL	**741.035,40 €**
Overhead Line	415.512,22 €
Transition	195.059,47 €
Underground Line	130.463,71 €

Table 47 Budget Summary

PLANS

1. OVERHEAD LINE

1.1 SITE PLAN

1.2 FRONT AND TOP VIEW

1.3 OC14D

1.4 OC14S

1.5 OC13C

1.6 CROSSARM

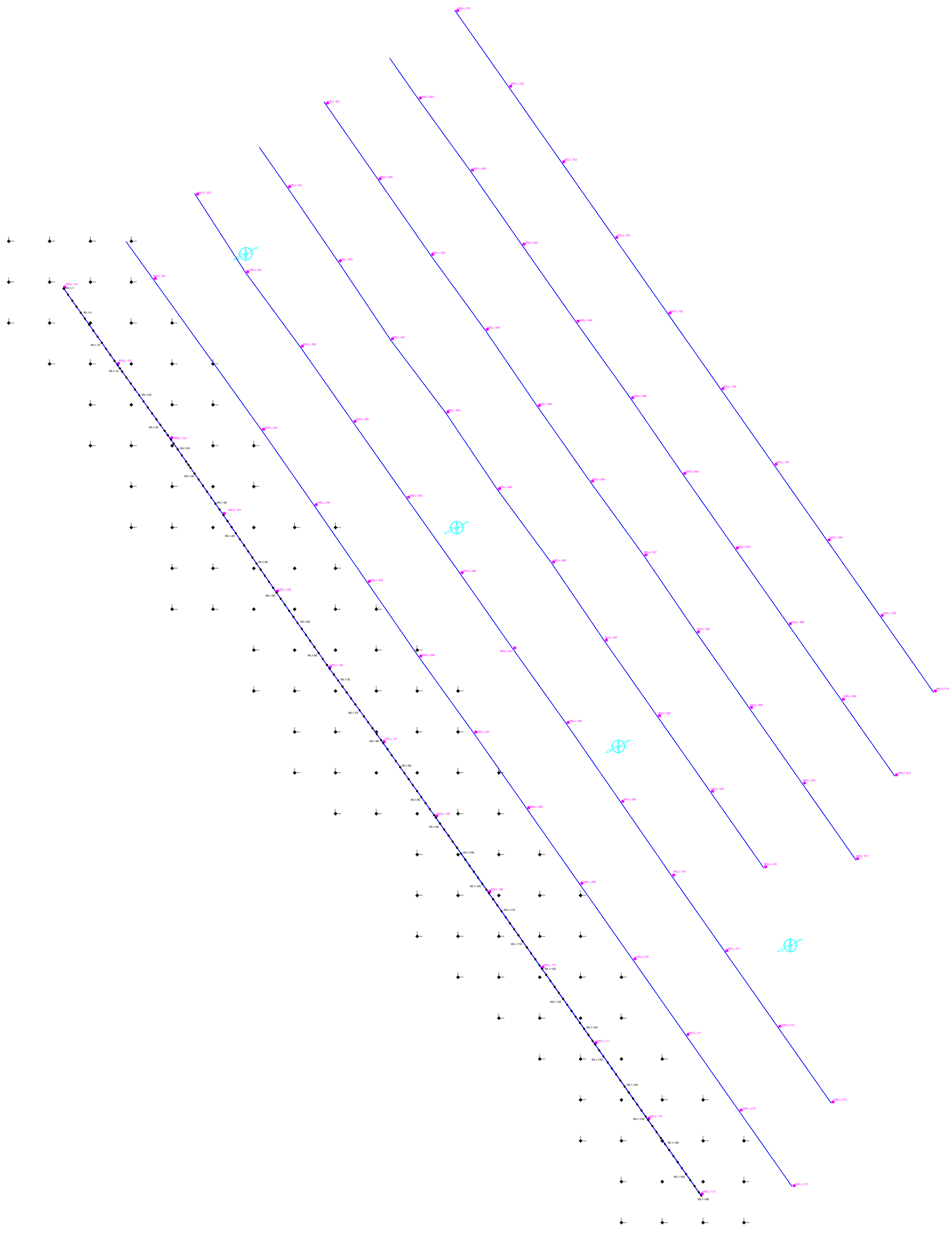
1.7 BRACE SET

1.8 EARTHING SYSTEM

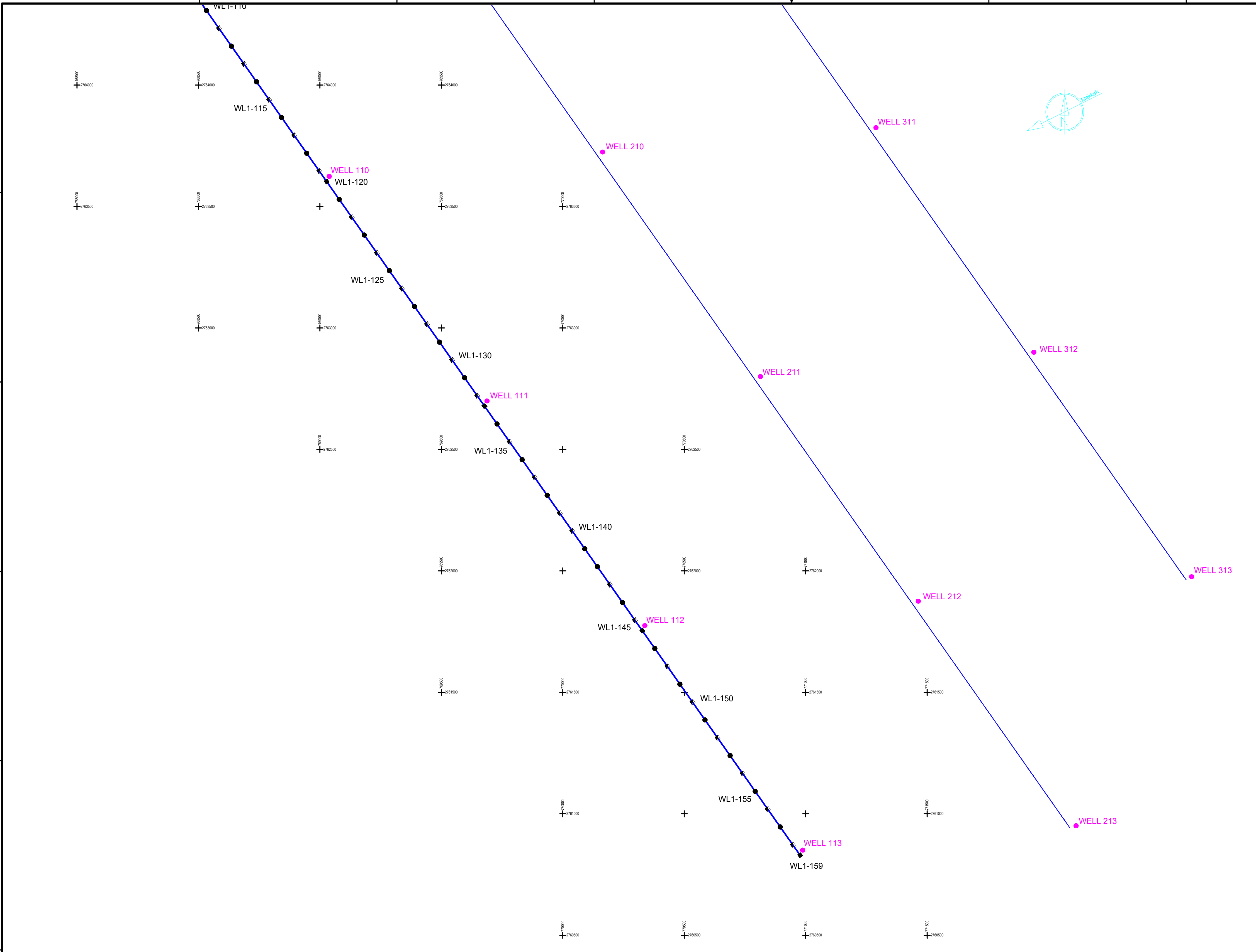
1.9 FOUNDATION

1.10 INSULATOR

1.11 TOP TIE

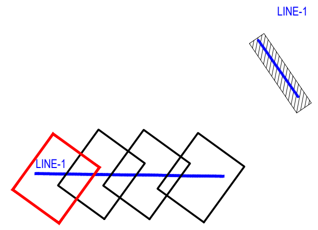


MATERIAL			OVERHEAD LINE
TOLERANCIA			
	NOMBRE	FECHA	SITE PLAN
DIBUJADO	CARMEN AGÚNDEZ LERÍA	10/11/2015	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	13/11/2015	
ESCALA: 1:50000	FIRMA		I.C.A.I.
			Nº DE LAMINA: 1.1



LEGEND

●	POLES OC13S 13m.
■	POLES OC14D 14m.
◩	POLES OC14S 14m.
○	POLES OC18 18m.
●	WELL



POLE	" X "	" Y "	Type	Color Band	Nº Band	Model	Angle (grade)
WL1-110	768532,78	2764307,05	OC13S	Red	1.000	Intermediate	0.00
WL1-111	768584,41	2764233,59	OC14S	Wellow	1.000	Intermediate	0.00
WL1-112	768636,03	2764160,14	OC13S	Red	1.000	Intermediate	0.00
WL1-113	768687,66	2764086,68	OC14S	Wellow	1.000	Intermediate	0.00
WL1-114	768739,28	2764013,23	OC13S	Red	1.000	Intermediate	0.00
WL1-115	768790,91	2763939,78	OC14S	Wellow	1.000	Intermediate	0.00
WL1-116	768842,54	2763866,32	OC13S	Red	1.000	Intermediate	0.00
WL1-117	768894,16	2763792,86	OC14S	Wellow	1.000	Intermediate	0.05
WL1-118	768945,79	2763719,41	OC13S	Red	1.000	Intermediate	0.05
WL1-119	768997,45	2763646,02	OC14S	Wellow	1.000	Intermediate	0.08
WL1-120	769027,72	2763602,94	OC14D	Yellow	2.000	Terminal	0.08
WL1-121	769079,45	2763529,53	OC13S	Red	1.000	Intermediate	0.00
WL1-122	769131,07	2763456,08	OC14S	Wellow	1.000	Intermediate	0.00
WL1-123	769182,70	2763382,62	OC13S	Red	1.000	Intermediate	0.00
WL1-124	769234,32	2763309,17	OC14S	Wellow	1.000	Intermediate	0.00
WL1-125	769285,95	2763235,71	OC13S	Red	1.000	Intermediate	0.00
WL1-126	769337,57	2763162,25	OC14S	Wellow	1.000	Intermediate	0.00
WL1-127	769389,20	2763088,80	OC13S	Red	1.000	Intermediate	0.00
WL1-128	769440,83	2763015,34	OC14S	Wellow	1.000	Intermediate	0.00
WL1-129	769492,45	2762941,89	OC13S	Red	1.000	Intermediate	0.00
WL1-130	769544,08	2762868,43	OC14S	Wellow	1.000	Intermediate	0.00
WL1-131	769595,70	2762794,97	OC13S	Red	1.000	Intermediate	0.00
WL1-132	769647,33	2762721,52	OC14S	Wellow	1.000	Intermediate	0.00
WL1-133	769677,56	2762678,50	OC14D	Yellow	2.000	Terminal	0.00
WL1-134	769729,20	2762605,02	OC13S	Red	1.000	Intermediate	0.00
WL1-135	769780,82	2762531,57	OC14S	Wellow	1.000	Intermediate	0.00
WL1-136	769832,45	2762458,11	OC13S	Red	1.000	Intermediate	0.00
WL1-137	769884,08	2762384,66	OC14S	Wellow	1.000	Intermediate	0.00
WL1-138	769935,70	2762311,20	OC13S	Red	1.000	Intermediate	0.00
WL1-139	769987,33	2762237,75	OC14S	Wellow	1.000	Intermediate	0.00
WL1-140	770038,95	2762164,29	OC14S	Wellow	1.000	Intermediate	0.00
WL1-141	770090,58	2762090,84	OC13S	Red	1.000	Intermediate	0.00
WL1-142	770142,20	2762017,38	OC13S	Red	1.000	Intermediate	0.00
WL1-143	770193,83	2761943,92	OC14S	Wellow	1.000	Intermediate	0.07
WL1-144	770245,46	2761870,47	OC13S	Red	1.000	Intermediate	0.07
WL1-145	770296,99	2761796,95	OC14S	Wellow	1.000	Intermediate	0.00
WL1-146	770327,25	2761753,91	OC14D	Yellow	2.000	Terminal	0.00
WL1-147	770378,87	2761680,45	OC13S	Red	1.000	Intermediate	0.00
WL1-148	770430,50	2761606,99	OC14S	Wellow	1.000	Intermediate	0.00
WL1-149	770482,12	2761533,54	OC13S	Red	1.000	Intermediate	0.00
WL1-150	770533,75	2761460,08	OC14S	Wellow	1.000	Intermediate	0.00
WL1-151	770585,37	2761386,63	OC13S	Red	1.000	Intermediate	0.00
WL1-152	770637,00	2761313,17	OC14S	Wellow	1.000	Intermediate	0.00
WL1-153	770688,62	2761239,71	OC13S	Red	1.000	Intermediate	0.00
WL1-154	770740,25	2761166,26	OC14S	Wellow	1.000	Intermediate	0.00
WL1-155	770791,87	2761092,80	OC13S	Red	1.000	Intermediate	0.00
WL1-156	770843,50	2761019,35	OC14S	Wellow	1.000	Intermediate	0.00
WL1-157	770895,12	2760945,89	OC13S	Red	1.000	Intermediate	0.00
WL1-158	770946,75	2760872,43	OC14S	Wellow	1.000	Intermediate	0.00
WL1-159	770976,98	2760829,41	OC14D	Yellow	2.000	Terminal	0.00

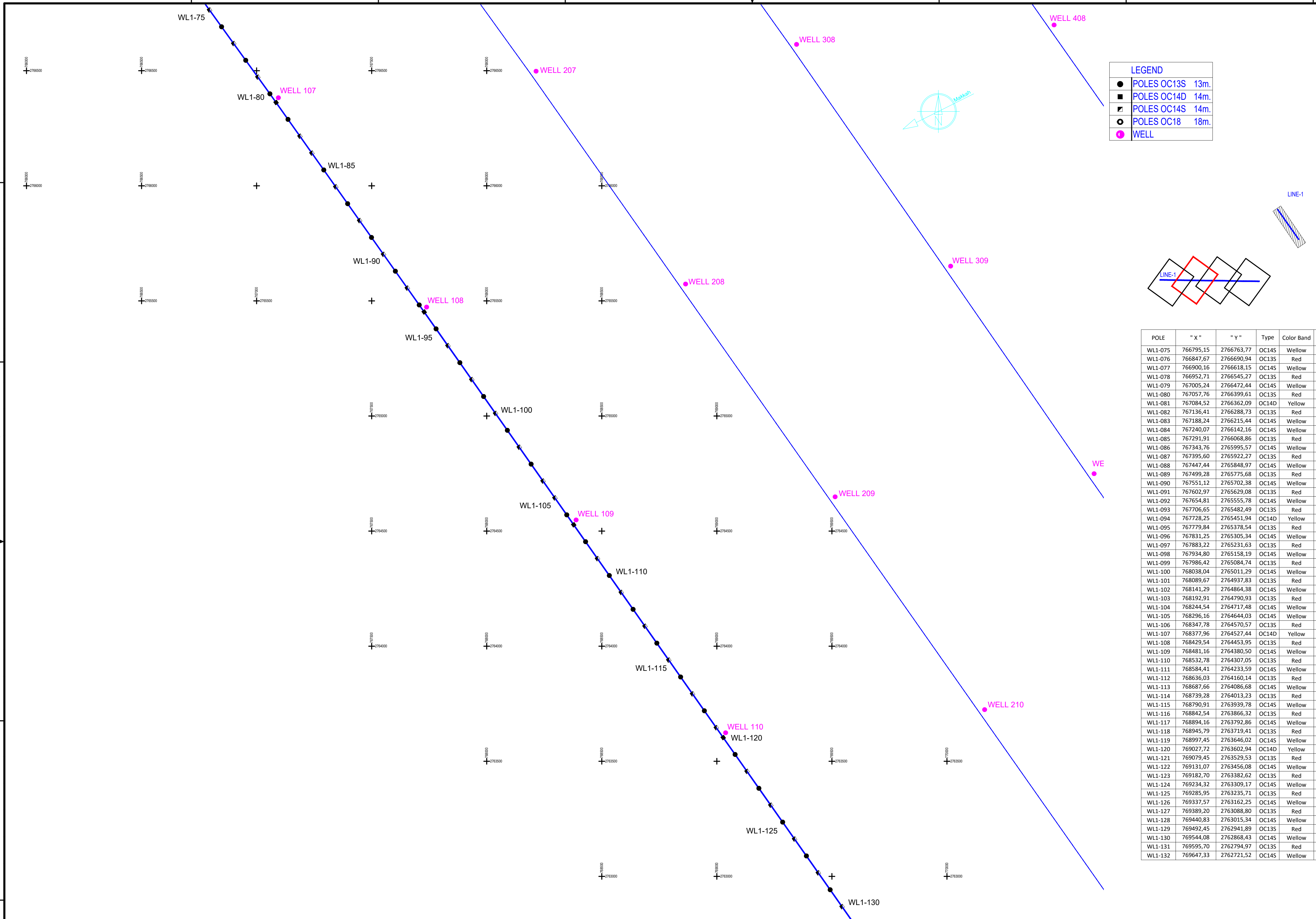
MATERIAL		
TOLERANCIA		
	NOMBRE	FECHA
DIBUJADO	CARMEN AGÚNDEZ LERÍA	18/02/2016
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	23/02/2016
ESCALA: 1:10000	FIRMA	

OVERHEAD LINE

SITE PLAN

I.C.A.I.

Nº DE LAMINA: 1.1.1



POLE	" X "	" Y "	Type	Color Band	Nº Band	Model	Angle (grade)
WL1-075	766795,15	2766763,77	OC14S	Wellow	1.000	Intermediate	0.00
WL1-076	766847,67	2766690,94	OC13S	Red	1.000	Intermediate	0.00
WL1-077	766900,16	2766618,15	OC14S	Wellow	1.000	Intermediate	0.00
WL1-078	766952,71	2766545,27	OC13S	Red	1.000	Intermediate	0.00
WL1-079	767005,24	2766472,44	OC14S	Wellow	1.000	Intermediate	0.33
WL1-080	767057,76	2766399,61	OC13S	Red	1.000	Intermediate	0.25
WL1-081	767084,52	2766362,09	OC14D	Yellow	2.000	Terminal	0.00
WL1-082	767136,41	2766288,73	OC13S	Red	1.000	Intermediate	0.00
WL1-083	767188,24	2766215,44	OC14S	Wellow	1.000	Intermediate	0.00
WL1-084	767240,07	2766142,16	OC14S	Wellow	1.000	Intermediate	0.00
WL1-085	767291,91	2766068,86	OC13S	Red	1.000	Intermediate	0.00
WL1-086	767343,76	2765995,57	OC14S	Wellow	1.000	Intermediate	0.00
WL1-087	767395,60	2765922,27	OC13S	Red	1.000	Intermediate	0.00
WL1-088	767447,44	2765848,97	OC14S	Wellow	1.000	Intermediate	0.00
WL1-089	767499,28	2765775,68	OC13S	Red	1.000	Intermediate	0.00
WL1-090	767551,12	2765702,38	OC14S	Wellow	1.000	Intermediate	0.00
WL1-091	767602,97	2765629,08	OC13S	Red	1.000	Intermediate	0.00
WL1-092	767654,81	2765555,78	OC14S	Wellow	1.000	Intermediate	0.00
WL1-093	767706,65	2765482,49	OC13S	Red	1.000	Intermediate	0.19
WL1-094	767728,25	2765451,94	OC14D	Yellow	2.000	Terminal	0.00
WL1-095	767779,84	2765378,54	OC13S	Red	1.000	Intermediate	0.12
WL1-096	767831,25	2765305,34	OC14S	Wellow	1.000	Intermediate	0.13
WL1-097	767883,22	2765231,63	OC13S	Red	1.000	Intermediate	0.03
WL1-098	767934,80	2765158,19	OC14S	Wellow	1.000	Intermediate	0.00
WL1-099	767986,42	2765084,74	OC13S	Red	1.000	Intermediate	0.00
WL1-100	768038,04	2765011,29	OC14S	Wellow	1.000	Intermediate	0.00
WL1-101	768089,67	2764937,83	OC13S	Red	1.000	Intermediate	0.00
WL1-102	768141,29	2764864,38	OC14S	Wellow	1.000	Intermediate	0.00
WL1-103	768192,91	2764790,93	OC13S	Red	1.000	Intermediate	0.00
WL1-104	768244,54	2764717,48	OC14S	Wellow	1.000	Intermediate	0.00
WL1-105	768296,16	2764644,03	OC14S	Wellow	1.000	Intermediate	0.14
WL1-106	768347,78	2764570,57	OC13S	Red	1.000	Intermediate	0.09
WL1-107	768377,96	2764527,44	OC14D	Yellow	2.000	Terminal	0.00
WL1-108	768429,54	2764453,95	OC13S	Red	1.000	Intermediate	0.00
WL1-109	768481,16	2764380,50	OC14S	Wellow	1.000	Intermediate	0.00
WL1-110	768532,78	2764307,05	OC13S	Red	1.000	Intermediate	0.00
WL1-111	768584,41	2764233,59	OC14S	Wellow	1.000	Intermediate	0.00
WL1-112	768636,03	2764160,14	OC13S	Red	1.000	Intermediate	0.00
WL1-113	768687,66	2764086,68	OC14S	Wellow	1.000	Intermediate	0.00
WL1-114	768739,28	2764013,23	OC13S	Red	1.000	Intermediate	0.00
WL1-115	768790,91	2763939,78	OC14S	Wellow	1.000	Intermediate	0.00
WL1-116	768842,54	2763866,32	OC13S	Red	1.000	Intermediate	0.00
WL1-117	768894,16	2763792,86	OC14S	Wellow	1.000	Intermediate	0.05
WL1-118	768945,79	2763719,41	OC13S	Red	1.000	Intermediate	0.05
WL1-119	768997,45	2763646,02	OC14S	Wellow	1.000	Intermediate	0.08
WL1-120	769027,72	2763602,94	OC14D	Yellow	2.000	Terminal	0.08
WL1-121	769079,45	2763529,53	OC13S	Red	1.000	Intermediate	0.00
WL1-122	769131,07	2763456,08	OC14S	Wellow	1.000	Intermediate	0.00
WL1-123	769182,70	2763382,62	OC13S	Red	1.000	Intermediate	0.00
WL1-124	769234,32	2763309,17	OC14S	Wellow	1.000	Intermediate	0.00
WL1-125	769285,95	2763235,71	OC13S	Red	1.000	Intermediate	0.00
WL1-126	769337,57	2763162,25	OC14S	Wellow	1.000	Intermediate	0.00
WL1-127	769389,20	2763088,80	OC13S	Red	1.000	Intermediate	0.00
WL1-128	769440,83	2763015,34	OC14S	Wellow	1.000	Intermediate	0.00
WL1-129	769492,45	2762941,89	OC13S	Red	1.000	Intermediate	0.00
WL1-130	769544,08	2762868,43	OC14S	Wellow	1.000	Intermediate	0.00
WL1-131	769595,70	2762794,97	OC13S	Red	1.000	Intermediate	0.00
WL1-132	769647,33	2762721,52	OC14S	Wellow	1.000	Intermediate	0.00

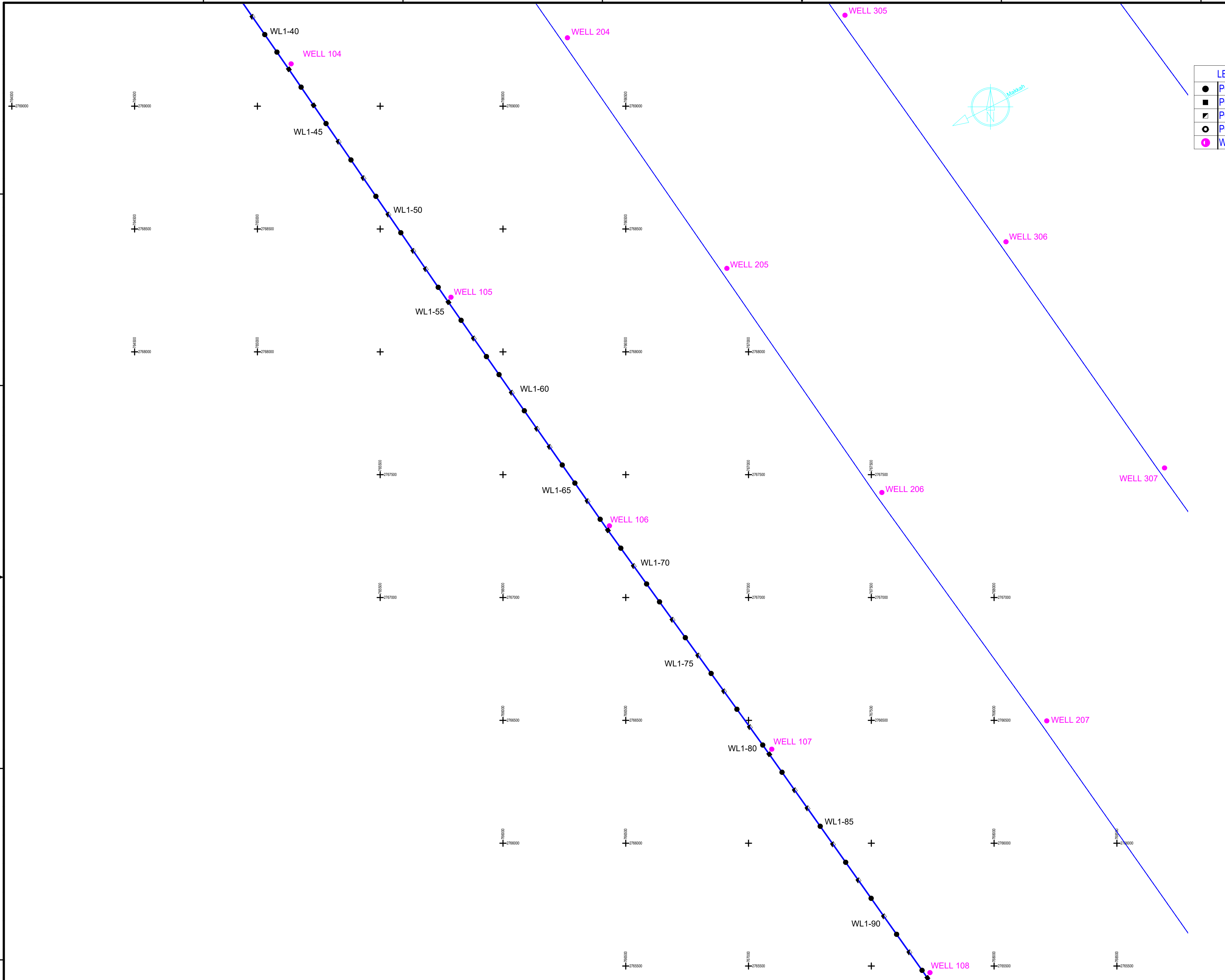
MATERIAL		
TOLERANCIA		
	NOMBRE	FECHA
DIBUJADO	CARMEN AGÚNDEZ LERÍA	18/02/2016
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	23/02/2016
ESCALA: 1:10000	FIRMA	

OVERHEAD LINE

SITE PLAN

I.C.A.I.

Nº DE LAMINA: 1.1.2



POLE	" X "	" Y "	Type	Color Band	Nº Band	Model	Angle (grade)
WL1-039	764979,70	2769363,72	OC14S	Wellow	1.000	Intermediate	0.00
WL1-040	765029,97	2769291,45	OC13S	Red	1.000	Intermediate	0.07
WL1-041	765079,60	2769220,09	OC13S	Red	1.000	Intermediate	0.37
WL1-042	765128,09	2769150,20	OC14D	Yellow	2.000	Terminal	0.00
WL1-043	765177,98	2769077,40	OC13S	Red	1.000	Intermediate	0.00
WL1-044	765228,74	2769003,34	OC14S	Wellow	1.000	Intermediate	0.00
WL1-045	765279,50	2768929,27	OC13S	Red	1.000	Intermediate	0.00
WL1-046	765330,25	2768855,21	OC14S	Wellow	1.000	Intermediate	0.00
WL1-047	765381,01	2768781,14	OC13S	Red	1.000	Intermediate	0.00
WL1-048	765431,77	2768707,08	OC14S	Wellow	1.000	Intermediate	0.00
WL1-049	765482,52	2768633,01	OC13S	Red	1.000	Intermediate	0.00
WL1-050	765533,28	2768558,95	OC14S	Wellow	1.000	Intermediate	0.00
WL1-051	765584,03	2768484,88	OC13S	Red	1.000	Intermediate	0.00
WL1-052	765634,79	2768410,82	OC14S	Wellow	1.000	Intermediate	0.00
WL1-053	765685,55	2768336,76	OC14S	Wellow	1.000	Intermediate	0.09
WL1-054	765736,30	2768262,69	OC13S	Red	1.000	Intermediate	0.51
WL1-055	765777,96	2768202,09	OC14D	Yellow	2.000	Terminal	0.00
WL1-056	765829,54	2768128,34	OC13S	Red	1.000	Intermediate	0.00
WL1-057	765881,12	2768054,58	OC14S	Wellow	1.000	Intermediate	0.00
WL1-058	765932,70	2767980,82	OC13S	Red	1.000	Intermediate	0.00
WL1-059	765984,07	2767907,37	OC13S	Red	1.000	Intermediate	0.00
WL1-060	766035,53	2767833,79	OC14S	Wellow	1.000	Intermediate	0.00
WL1-061	766086,99	2767760,20	OC13S	Red	1.000	Intermediate	0.00
WL1-062	766138,45	2767686,62	OC14S	Wellow	1.000	Intermediate	0.00
WL1-063	766189,91	2767613,03	OC14S	Wellow	1.000	Intermediate	0.00
WL1-064	766241,37	2767539,45	OC13S	Red	1.000	Intermediate	0.00
WL1-065	766292,83	2767465,87	OC13S	Red	1.000	Intermediate	0.00
WL1-066	766344,29	2767392,28	OC14S	Wellow	1.000	Intermediate	0.19
WL1-067	766395,81	2767318,61	OC13S	Red	1.000	Intermediate	0.73
WL1-068	766427,38	2767273,76	OC14D	Yellow	2.000	Terminal	0.00
WL1-069	766479,90	2767200,92	OC13S	Red	1.000	Intermediate	0.00
WL1-070	766532,43	2767128,08	OC14S	Wellow	1.000	Intermediate	0.00
WL1-071	766584,95	2767055,24	OC13S	Red	1.000	Intermediate	0.00
WL1-072	766637,48	2766982,41	OC13S	Red	1.000	Intermediate	0.00
WL1-073	766690,11	2766909,43	OC14S	Wellow	1.000	Intermediate	0.00
WL1-074	766742,63	2766836,60	OC13S	Red	1.000	Intermediate	0.00
WL1-075	766795,15	2766763,77	OC14S	Wellow	1.000	Intermediate	0.00
WL1-076	766847,67	2766690,94	OC13S	Red	1.000	Intermediate	0.00
WL1-077	766900,16	2766618,15	OC14S	Wellow	1.000	Intermediate	0.00
WL1-078	766952,71	2766545,27	OC13S	Red	1.000	Intermediate	0.00
WL1-079	767005,24	2766472,44	OC14S	Wellow	1.000	Intermediate	0.33
WL1-080	767057,76	2766399,61	OC13S	Red	1.000	Intermediate	0.25
WL1-081	767084,52	2766362,09	OC14D	Yellow	2.000	Terminal	0.00
WL1-082	767136,41	2766288,73	OC13S	Red	1.000	Intermediate	0.00
WL1-083	767188,24	2766215,44	OC14S	Wellow	1.000	Intermediate	0.00
WL1-084	767240,07	2766142,16	OC14S	Wellow	1.000	Intermediate	0.00
WL1-085	767291,91	2766068,86	OC13S	Red	1.000	Intermediate	0.00
WL1-086	767343,76	2765995,57	OC14S	Wellow	1.000	Intermediate	0.00
WL1-087	767395,60	2765922,27	OC13S	Red	1.000	Intermediate	0.00
WL1-088	767447,44	2765848,97	OC14S	Wellow	1.000	Intermediate	0.00
WL1-089	767499,28	2765775,68	OC13S	Red	1.000	Intermediate	0.00
WL1-090	767551,12	2765702,38	OC14S	Wellow	1.000	Intermediate	0.00
WL1-091	767602,97	2765629,08	OC13S	Red	1.000	Intermediate	0.00
WL1-092	767654,81	2765555,78	OC14S	Wellow	1.000	Intermediate	0.00
WL1-093	767706,65	2765482,49	OC13S	Red	1.000	Intermediate	0.19
WL1-094	767728,25	2765451,94	OC14D	Yellow	2.000	Terminal	0.00
WL1-095	767779,84	2765378,54	OC13S	Red	1.000	Intermediate	0.12

MATERIAL
TOLERANCIA

	NOMBRE	FECHA
DIBUJADO	CARMEN AGÚNDEZ LERÍA	18/02/2016
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	23/02/2016

ESCALA: 1:10000

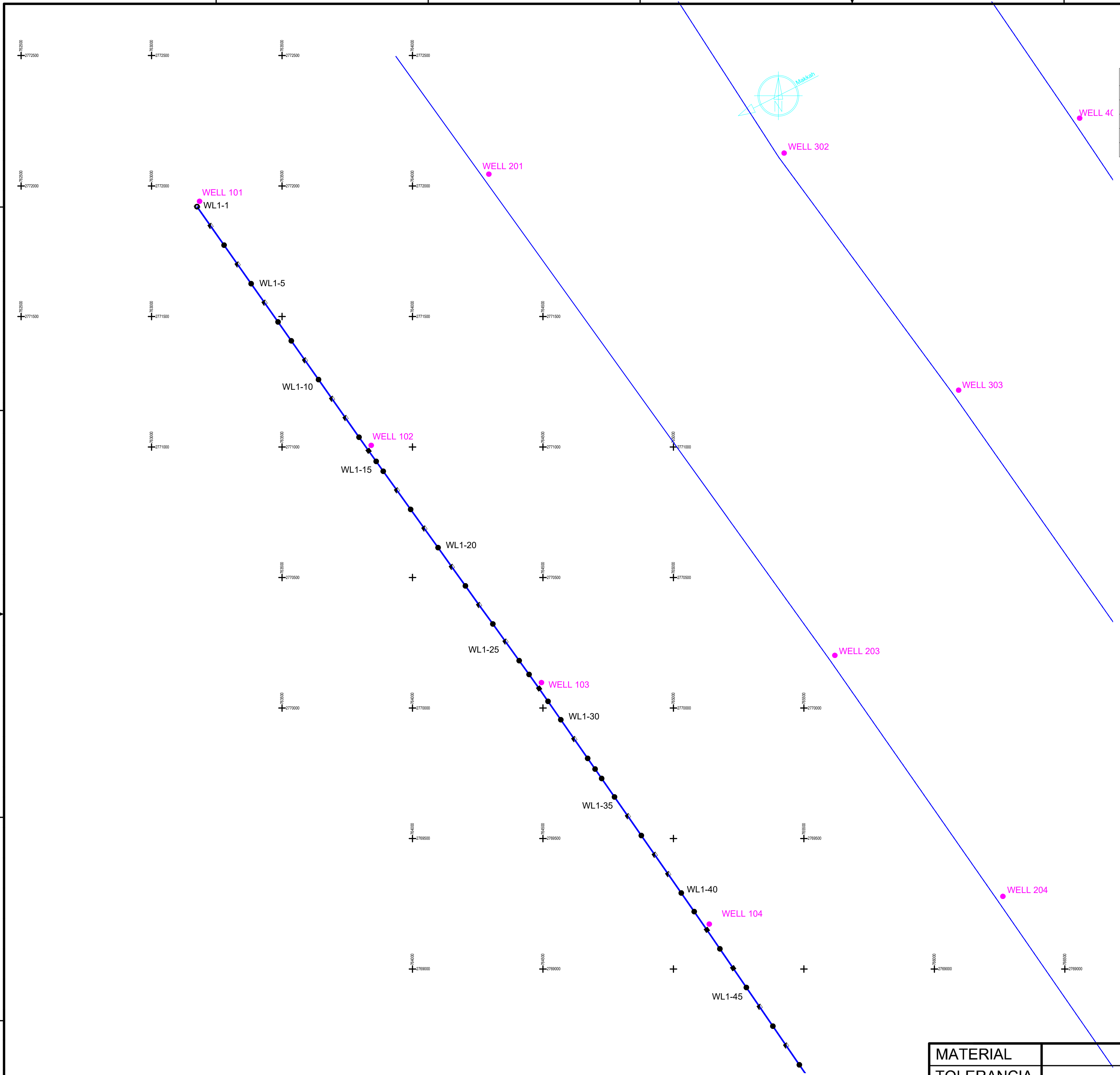
FIRMA

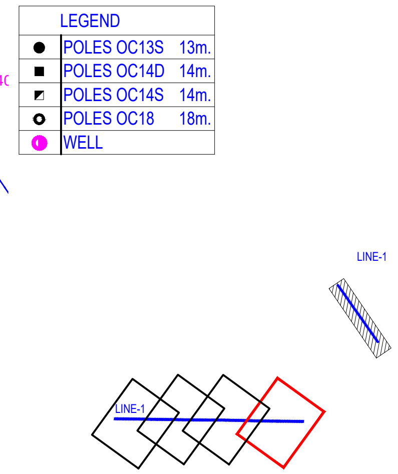
OVERHEAD LINE

SITE PLAN

I.C.A.I.

Nº DE LAMINA: 1.1.3





Pole	" X "	" Y "	Type	Color Band	Nº Band	Model	Angle (grade)
WL1-001	763174,10	2771921,00	OC18D	Green	2.000	Terminal	0.00
WL1-002	763225,98	2771847,19	OC14S	Wellow	1.000	Intermediate	0.00
WL1-003	763277,86	2771773,38	OC13S	Red	1.000	Intermediate	0.00
WL1-004	763329,74	2771699,56	OC14S	Wellow	1.000	Intermediate	0.00
WL1-005	763381,61	2771625,76	OC13S	Red	1.000	Intermediate	0.05
WL1-006	763432,85	2771552,97	OC14S	Wellow	1.000	Intermediate	0.00
WL1-007	763484,55	2771479,30	OC13S	Red	1.000	Intermediate	0.08
WL1-008	763536,31	2771405,66	OC13S	Red	1.000	Intermediate	0.07
WL1-009	763588,11	2771332,07	OC14S	Wellow	1.000	Intermediate	0.07
WL1-010	763639,82	2771258,39	OC13S	Red	1.000	Intermediate	0.05
WL1-011	763691,57	2771184,76	OC14S	Wellow	1.000	Intermediate	0.00
WL1-012	763743,31	2771111,14	OC14S	Wellow	1.000	Intermediate	0.00
WL1-013	763795,06	2771037,51	OC13S	Red	1.000	Intermediate	0.11
WL1-014	763831,65	2770985,65	OC14D	Yellow	2.000	Terminal	0.52
WL1-015	763860,84	2770944,97	OC13S	Red	1.000	Intermediate	0.22
WL1-016	763887,81	2770907,12	OC13S	Red	1.000	Intermediate	0.34
WL1-017	763940,42	2770834,10	OC14S	Wellow	1.000	Intermediate	0.12
WL1-018	763992,89	2770760,99	OC13S	Red	1.000	Intermediate	0.00
WL1-019	764045,38	2770687,86	OC14S	Wellow	1.000	Intermediate	0.00
WL1-020	764097,98	2770614,57	OC13S	Red	1.000	Intermediate	0.23
WL1-021	764150,52	2770541,37	OC14S	Wellow	1.000	Intermediate	0.21
WL1-022	764202,99	2770468,26	OC13S	Red	1.000	Intermediate	0.20
WL1-023	764255,47	2770395,15	OC14S	Wellow	1.000	Intermediate	0.68
WL1-024	764307,92	2770322,07	OC13S	Red	1.000	Intermediate	0.46
WL1-025	764356,31	2770254,64	OC14S	Wellow	1.000	Intermediate	0.00
WL1-026	764408,79	2770181,52	OC13S	Red	1.000	Intermediate	0.17
WL1-027	764446,76	2770128,62	OC13S	Red	1.000	Intermediate	0.81
WL1-028	764485,12	2770074,88	OC14D	Yellow	2.000	Terminal	0.00
WL1-029	764519,37	2770025,58	OC13S	Red	1.000	Intermediate	0.00
WL1-030	764568,37	2769955,19	OC13S	Red	1.000	Intermediate	0.00
WL1-031	764619,86	2769881,10	OC14S	Wellow	1.000	Intermediate	0.00
WL1-032	764671,28	2769807,16	OC13S	Red	1.000	Intermediate	0.00
WL1-033	764699,74	2769766,25	OC13S	Red	1.000	Intermediate	0.00
WL1-034	764724,84	2769730,15	OC13S	Red	1.000	Intermediate	0.00
WL1-035	764774,12	2769659,29	OC13S	Red	1.000	Intermediate	0.00
WL1-036	764825,44	2769585,51	OC14S	Wellow	1.000	Intermediate	0.00
WL1-037	764876,89	2769511,54	OC13S	Red	1.000	Intermediate	0.00
WL1-038	764928,25	2769437,69	OC14S	Wellow	1.000	Intermediate	0.00
WL1-039	764979,70	2769363,72	OC14S	Wellow	1.000	Intermediate	0.00
WL1-040	765029,97	2769291,45	OC13S	Red	1.000	Intermediate	0.07
WL1-041	765079,60	2769220,09	OC13S	Red	1.000	Intermediate	0.37
WL1-042	765128,09	2769150,20	OC14D	Yellow	2.000	Terminal	0.00
WL1-043	765177,98	2769077,40	OC13S	Red	1.000	Intermediate	0.00
WL1-044	765228,74	2769003,34	OC14S	Wellow	1.000	Intermediate	0.00
WL1-045	765279,50	2768929,27	OC13S	Red	1.000	Intermediate	0.00
WL1-046	765330,25	2768855,21	OC14S	Wellow	1.000	Intermediate	0.00
WL1-047	765381,01	2768781,14	OC13S	Red	1.000	Intermediate	0.00
WL1-048	765431,77	2768707,08	OC14S	Wellow	1.000	Intermediate	0.00
WL1-049	765482,52	2768633,01	OC13S	Red	1.000	Intermediate	0.00

MATERIAL		
TOLERANCIA		
	NOMBRE	FECHA
DIBUJADO	CARMEN AGÚNDEZ LERÍA	18/02/2016
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	23/02/2016
ESCALA: 1:10000	FIRMA	

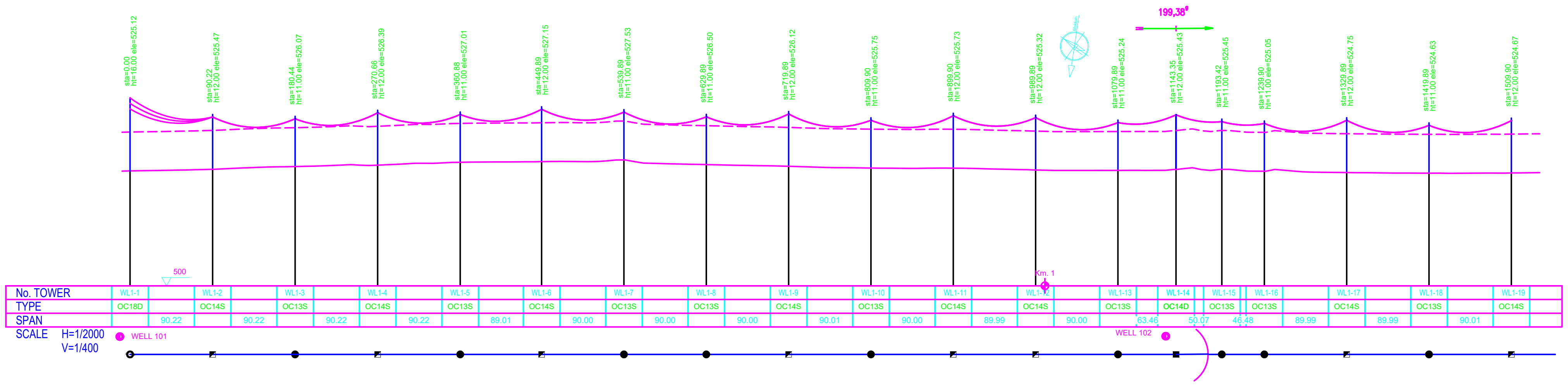
OVERHEAD LINE

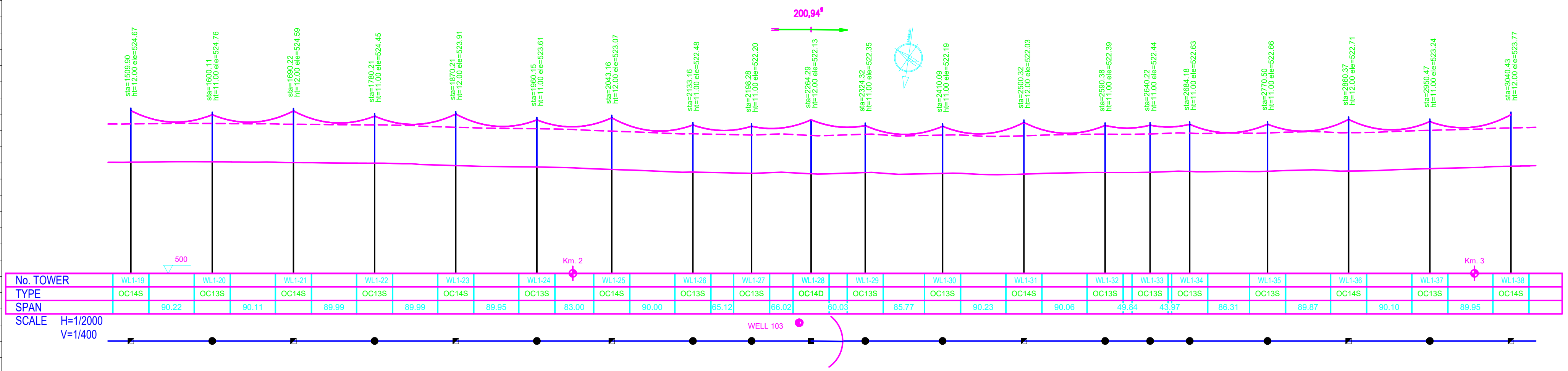
SITE PLAN

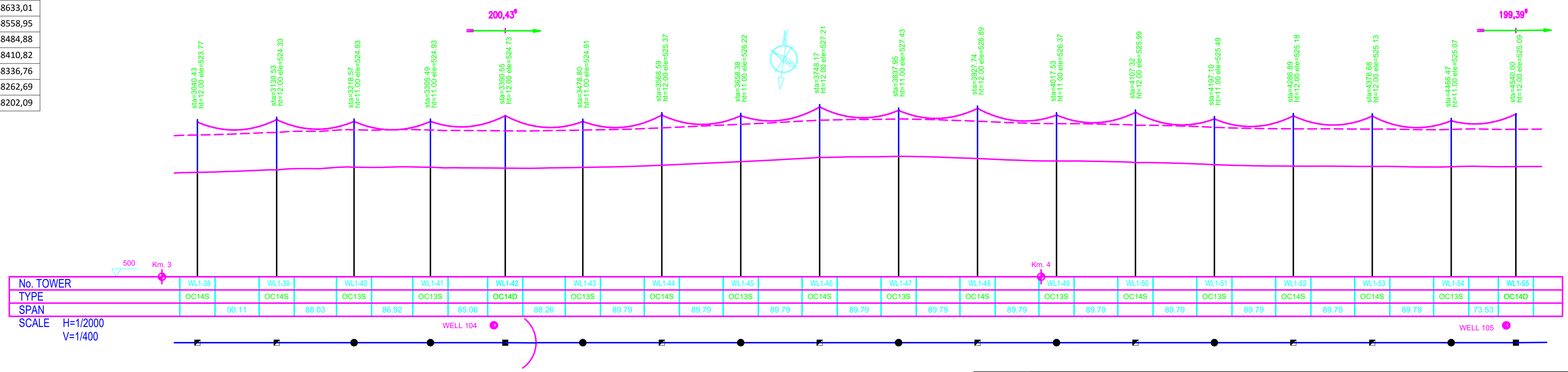
I.C.A.I.

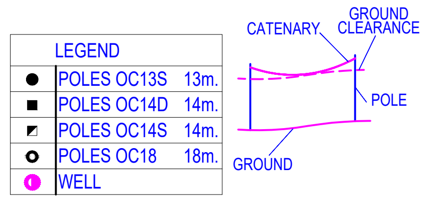
Nº DE LAMINA: 1.1.4

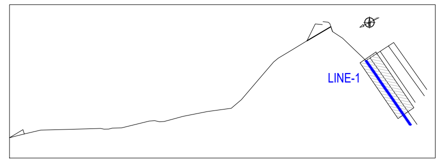
Pole	" X "	" Y "
WL1-001	763174,10	2771921,00
WL1-002	763225,98	2771847,19
WL1-003	763277,86	2771773,38
WL1-004	763329,74	2771699,56
WL1-005	763381,61	2771625,76
WL1-006	763432,85	2771552,97
WL1-007	763484,55	2771479,30
WL1-008	763536,31	2771405,66
WL1-009	763588,11	2771332,07
WL1-010	763639,82	2771258,39
WL1-011	763691,57	2771184,76
WL1-012	763743,31	2771111,14
WL1-013	763795,06	2771037,51
WL1-014	763831,65	2770985,65
WL1-015	763860,84	2770944,97
WL1-016	763887,81	2770907,12
WL1-017	763940,42	2770834,10
WL1-018	763992,89	2770760,99
WL1-019	764045,38	2770687,86
WL1-020	764097,98	2770614,57
WL1-021	764150,52	2770541,37
WL1-022	764202,99	2770468,26
WL1-023	764255,47	2770395,15
WL1-024	764307,92	2770322,07
WL1-025	764356,31	2770254,64
WL1-026	764408,79	2770181,52
WL1-027	764446,76	2770128,62
WL1-028	764485,12	2770074,88
WL1-029	764519,37	2770025,58
WL1-030	764568,37	2769955,19
WL1-031	764619,86	2769881,10
WL1-032	764671,28	2769807,16
WL1-033	764699,74	2769766,25
WL1-034	764724,84	2769730,15
WL1-035	764774,12	2769659,29
WL1-036	764825,44	2769585,51
WL1-037	764876,89	2769511,54
WL1-038	764928,25	2769437,69
WL1-039	764979,70	2769363,72
WL1-040	765029,97	2769291,45
WL1-041	765079,60	2769220,09
WL1-042	765128,09	2769150,20
WL1-043	765177,98	2769077,40
WL1-044	765228,74	2769003,34
WL1-045	765279,50	2768929,27
WL1-046	765330,25	2768855,21
WL1-047	765381,01	2768781,14
WL1-048	765431,77	2768707,08
WL1-049	765482,52	2768633,01
WL1-050	765533,28	2768558,95
WL1-051	765584,03	2768484,88
WL1-052	765634,79	2768410,82
WL1-053	765685,55	2768336,76
WL1-054	765736,30	2768262,69
WL1-055	765777,96	2768202,09





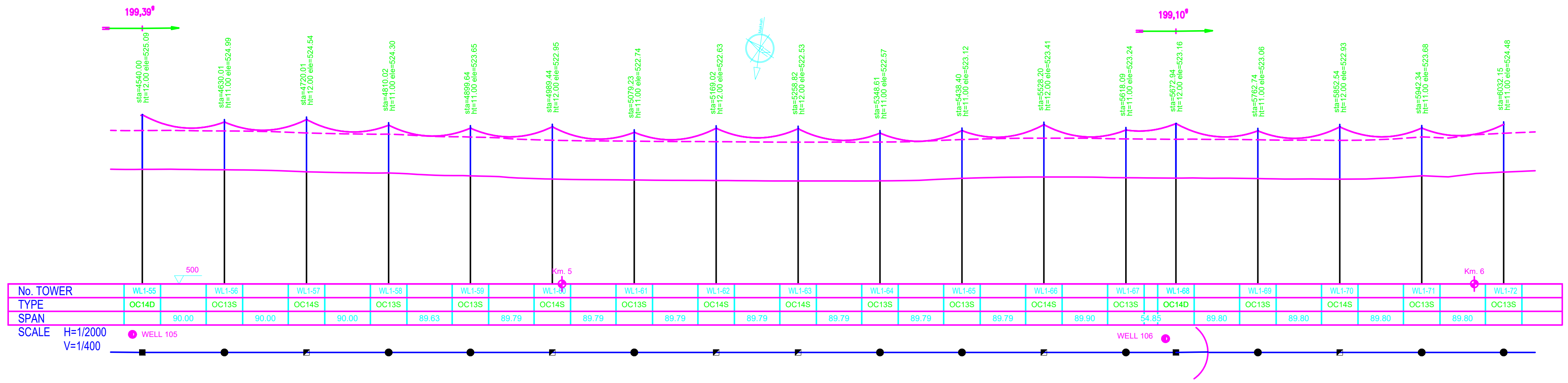


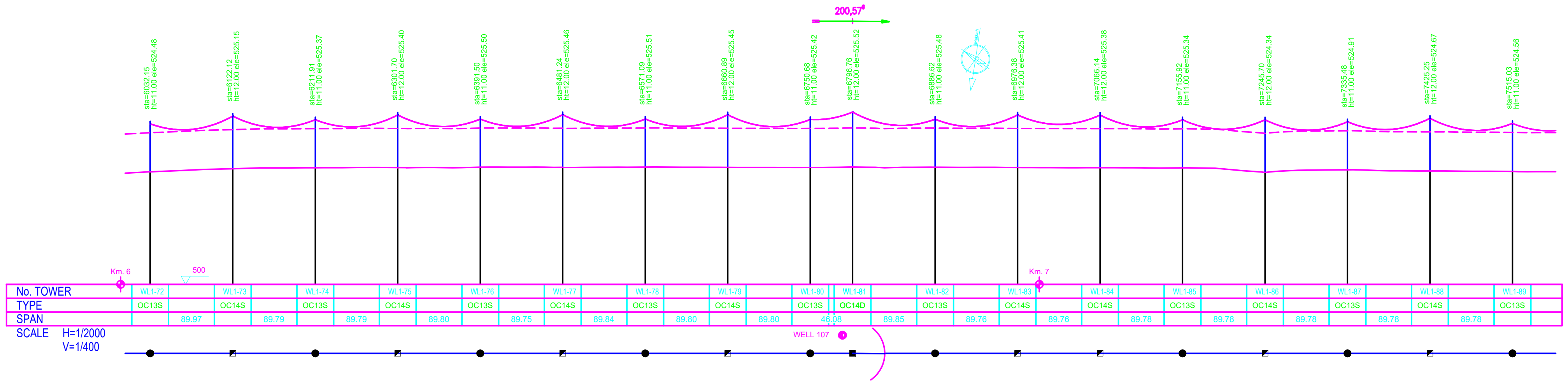


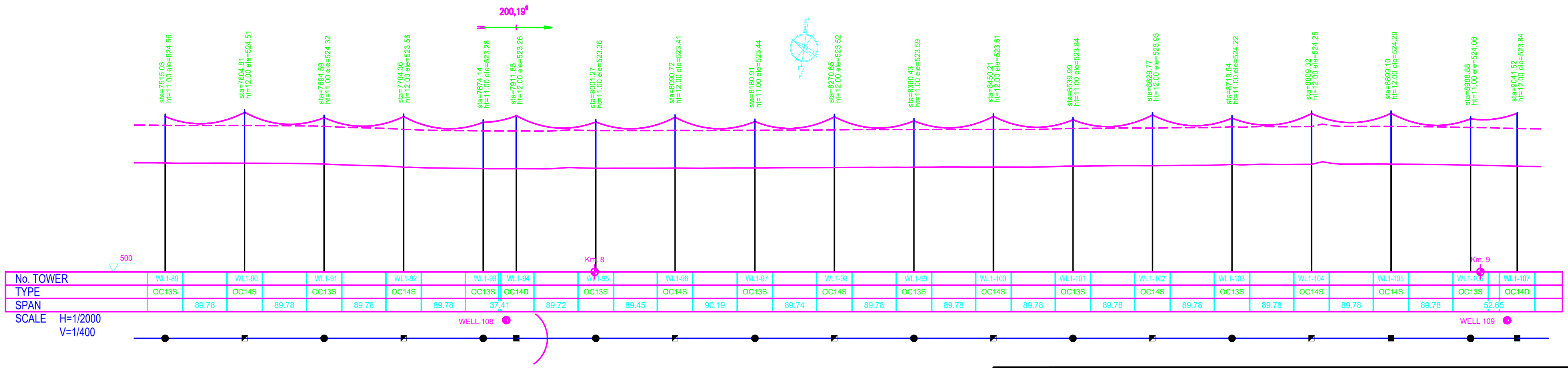


MATERIAL			OVERHEAD LINE FRONT AND TOP VIEW OF THE LINE
TOLERANCIA			
	NOMBRE	FECHA	
DIBUJADO	CARMEN AGÚNDEZ LERÍA	18/02/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	23/02/2016	
ESCALA: HORIZONTAL 1:2000 VERTICAL 1:400	FIRMA		I.C.A.I. — Nº DE LAMINA: 1.2.1

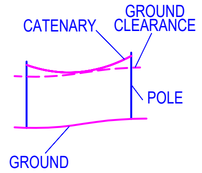
Pole	" X "	" Y "
WL1-055	765777,96	2768202,09
WL1-056	765829,54	2768128,34
WL1-057	765881,12	2768054,58
WL1-058	765932,70	2767980,82
WL1-059	765984,07	2767907,37
WL1-060	766035,53	2767833,79
WL1-061	766086,99	2767760,20
WL1-062	766138,45	2767686,62
WL1-063	766189,91	2767613,03
WL1-064	766241,37	2767539,45
WL1-065	766292,83	2767465,87
WL1-066	766344,29	2767392,28
WL1-067	766395,81	2767318,61
WL1-068	766427,38	2767273,76
WL1-069	766479,90	2767200,92
WL1-070	766532,43	2767128,08
WL1-071	766584,95	2767055,24
WL1-072	766637,48	2766982,41
WL1-073	766690,11	2766909,43
WL1-074	766742,63	2766836,60
WL1-075	766795,15	2766763,77
WL1-076	766847,67	2766690,94
WL1-077	766900,16	2766618,15
WL1-078	766952,71	2766545,27
WL1-079	767005,24	2766472,44
WL1-080	767057,76	2766399,61
WL1-081	767084,52	2766362,09
WL1-082	767136,41	2766288,73
WL1-083	767188,24	2766215,44
WL1-084	767240,07	2766142,16
WL1-085	767291,91	2766068,86
WL1-086	767343,76	2765995,57
WL1-087	767395,60	2765922,27
WL1-088	767447,44	2765848,97
WL1-089	767499,28	2765775,68
WL1-090	767551,12	2765702,38
WL1-091	767602,97	2765629,08
WL1-092	767654,81	2765555,78
WL1-093	767706,65	2765482,49
WL1-094	767728,25	2765451,94
WL1-095	767779,84	2765378,54
WL1-096	767831,25	2765305,34
WL1-097	767883,22	2765231,63
WL1-098	767934,80	2765158,19
WL1-099	767986,42	2765084,74
WL1-100	768038,04	2765011,29
WL1-101	768089,67	2764937,83
WL1-102	768141,29	2764864,38
WL1-103	768192,91	2764790,93
WL1-104	768244,54	2764717,48
WL1-105	768296,16	2764644,03
WL1-106	768347,78	2764570,57
WL1-107	768377,96	2764527,44

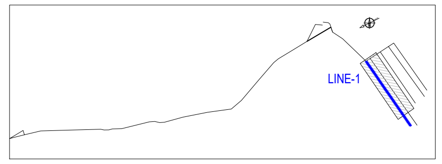






LEGEND	
●	POLES OC13S 13m.
■	POLES OC14D 14m.
◩	POLES OC14S 14m.
○	POLES OC18 18m.
●	WELL





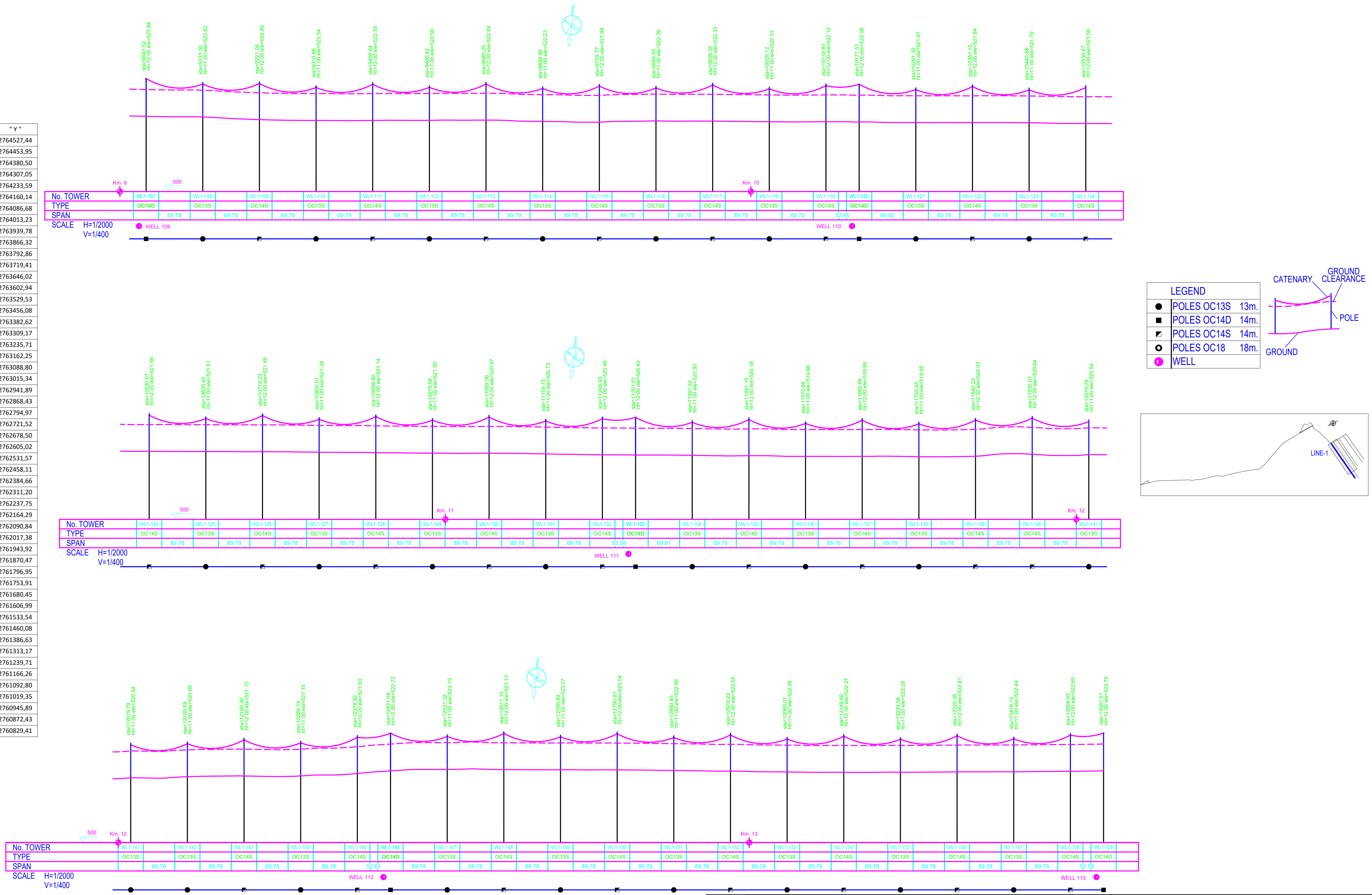
MATERIAL		
TOLERANCIA		
	NOMBRE	FECHA
DIBUJADO	CARMEN AGÚNDEZ LERÍA	18/02/2016
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	23/02/2016
ESCALA: HORIZONTAL 1:2000 VERTICAL 1:400	FIRMA	

OVERHEAD LINE FRONT AND TOP VIEW OF THE LINE

I.C.A.I.

Nº DE LAMINA: 1.2.2

Pole	" X "	" Y "
WL1-107	768377,96	2764527,44
WL1-108	768429,54	2764453,95
WL1-109	768481,16	2764380,50
WL1-110	768532,78	2764307,05
WL1-111	768584,41	2764233,59
WL1-112	768636,03	2764160,14
WL1-113	768687,66	2764086,68
WL1-114	768739,28	2764013,23
WL1-115	768790,91	2763939,78
WL1-116	768842,54	2763866,32
WL1-117	768894,16	2763792,86
WL1-118	768945,79	2763719,41
WL1-119	768997,45	2763646,02
WL1-120	769027,72	2763602,94
WL1-121	769079,45	2763529,53
WL1-122	769131,07	2763456,08
WL1-123	769182,70	2763382,62
WL1-124	769234,32	2763309,17
WL1-125	769285,95	2763235,71
WL1-126	769337,57	2763162,25
WL1-127	769389,20	2763088,80
WL1-128	769440,83	2763015,34
WL1-129	769492,45	2762941,89
WL1-130	769544,08	2762868,43
WL1-131	769595,70	2762794,97
WL1-132	769647,33	2762721,52
WL1-133	769677,56	2762678,50
WL1-134	769729,20	2762605,02
WL1-135	769780,82	2762531,57
WL1-136	769832,45	2762458,11
WL1-137	769884,08	2762384,66
WL1-138	769935,70	2762311,20
WL1-139	769987,33	2762237,75
WL1-140	770038,95	2762164,29
WL1-141	770090,58	2762090,84
WL1-142	770142,20	2762017,38
WL1-143	770193,83	2761943,92
WL1-144	770245,46	2761870,47
WL1-145	770296,99	2761796,95
WL1-146	770327,25	2761753,91
WL1-147	770378,87	2761680,45
WL1-148	770430,50	2761606,99
WL1-149	770482,12	2761533,54
WL1-150	770533,75	2761460,08
WL1-151	770585,37	2761386,63
WL1-152	770637,00	2761313,17
WL1-153	770688,62	2761239,71
WL1-154	770740,25	2761166,26
WL1-155	770791,87	2761092,80
WL1-156	770843,50	2761019,35
WL1-157	770895,12	2760945,89
WL1-158	770946,75	2760872,43
WL1-159	770976,98	2760829,41



MATERIAL	
TOLERANCIA	

	NOMBRE	FECHA
DIBUJADO	CARMEN AGÚNDEZ LERÍA	18/02/2016
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	23/02/2016

ESCALA:
HORIZONTAL 1:2000
VERTICAL 1:400

FIRMA

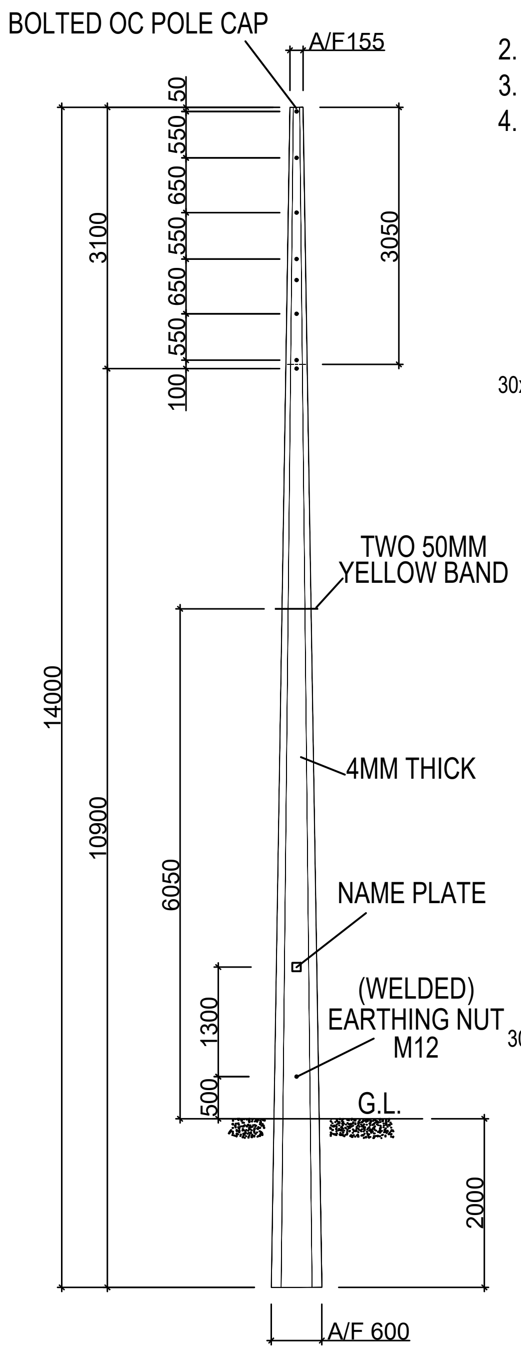
OVERHEAD LINE FRONT AND TOP VIEW OF THE LINE

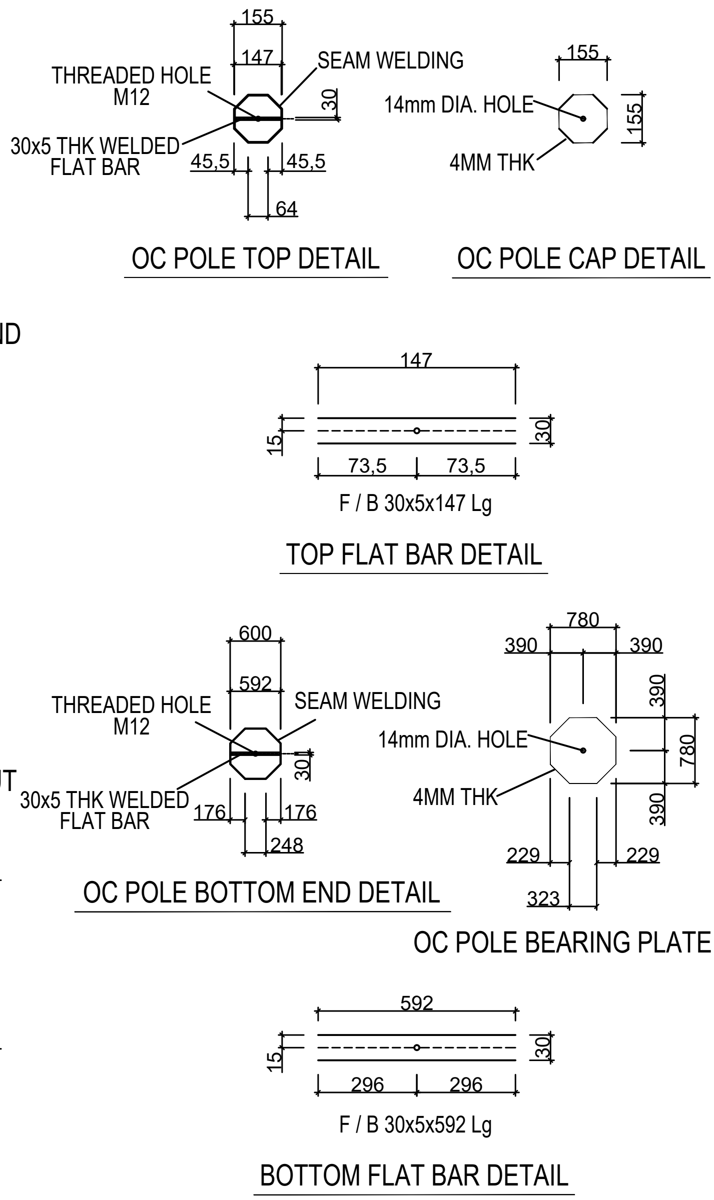
I.C.A.I.

Nº DE LAMINA: 1.2.3

NOTES:

1. ALL HOLES OF OCTAGONAL STEEL POLE, OC14D 14 METERS SHALL BE OF 22mmØ TO SUIT M20 BOLT
2. ALL HOLE SHALL BE PROVIDED WITH PLASTIC PLUGS
3. THE STEEL POLE SHALL BE IN A SINGLE PIECE
4. ALL HOLES SHALL BE DRILLED PRIOR TO GALVANIZING



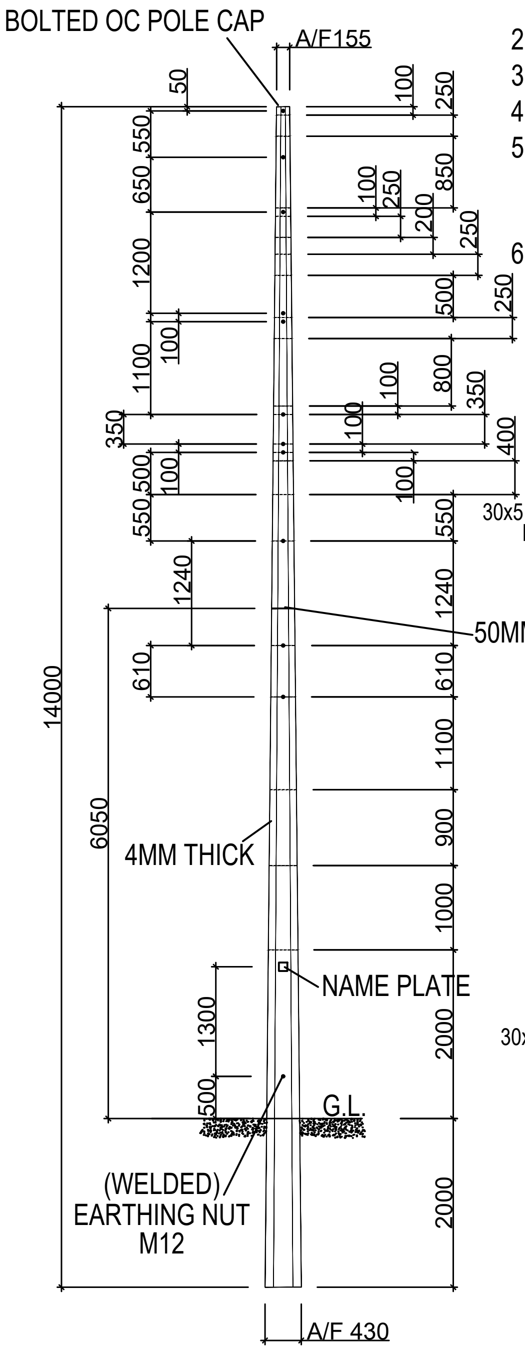


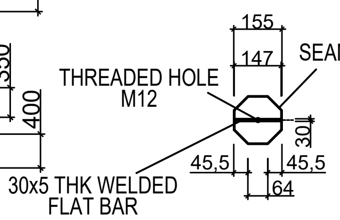
ALL DIMENSIONS ARE IN MILLIMETER

MATERIAL			OVERHEAD LINE
TOLERANCIA			
	NOMBRE	FECHA	OC14D POLE
DIBUJADO	CARMEN AGÚNDEZ LERÍA	25/04/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	28/04/2016	
ESCALA: 1:100	FIRMA		I.C.A.I.
			Nº DE LAMINA: 1.3

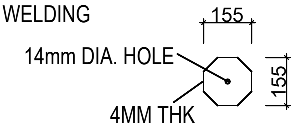
NOTES:

1. ALL HOLES OF OCTAGONAL STEEL POLE, OC14S 14 METERS SHALL BE OF 22mmØ TO SUIT M20 BOLT EXCEPT INDICATED BY "A"
2. HOLES INDICATED BY (A) ARE 18mmØ (2 NOS ONLY)
3. ALL HOLE SHALL BE PROVIDED WITH PLASTIC PLUGS
4. THE STEEL POLE SHALL BE IN A SINGLE PIECES
5. THE HOLE AT 3100mm (- - - -) FROM POLE TOP IS DESIGNED POR BRACING OF FUSE CUTOUT CHANNEL OF SINGLE POLE MOUNTED TRANSFORMER
6. ALL HOLES SHALL BE DRILLED PRIOR TO GALVANIZING

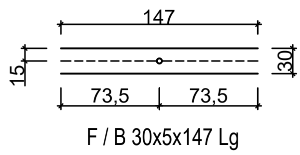




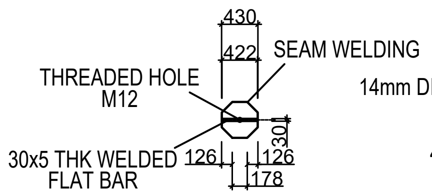
OC POLE TOP DETAIL



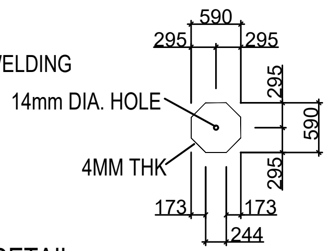
OC POLE CAP DETAIL



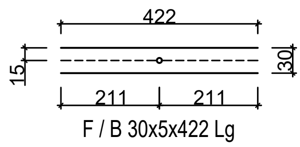
TOP FLAT BAR DETAIL



OC POLE BOTTOM END DETAIL



OC POLE BEARING PLATE



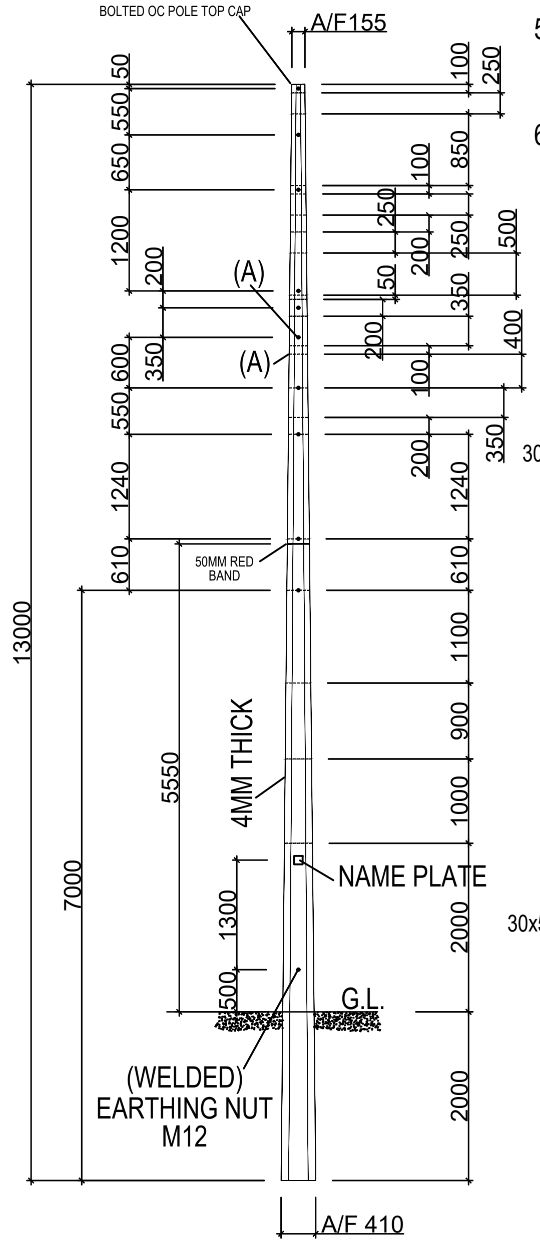
BOTTOM FLAT BAR DETAILS

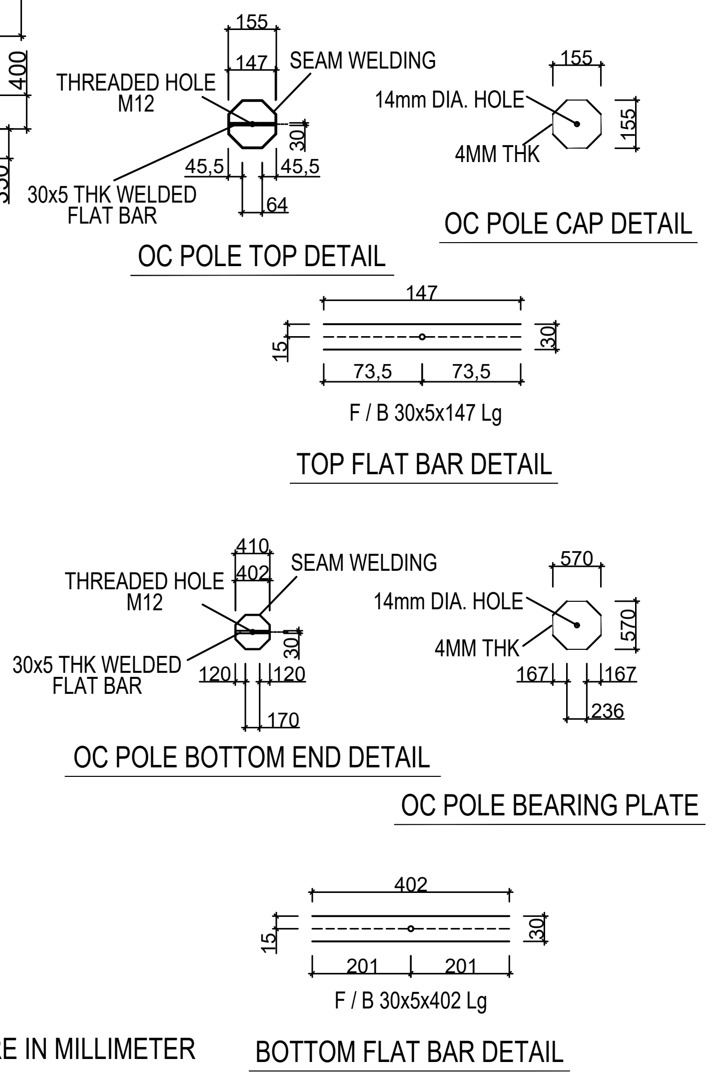
ALL DIMENSIONS ARE IN MILLIMETER

MATERIAL			OVERHEAD LINE
TOLERANCIA			
	NOMBRE	FECHA	OC14D POLE
DIBUJADO	CARMEN AGÚNDEZ LERÍA	26/04/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	28/04/2016	
ESCALA: 1:100	FIRMA		I.C.A.I. / Nº DE LAMINA: 1.4

NOTES:

1. ALL HOLES OF OCTAGONAL STEEL POLE, OC13S 13 METERS SHALL BE OF 22mmØ TO SUIT M20 BOLT EXCEPT INDICATED BY "A"
2. HOLES INDICATED BY (A) ARE 18mmØ (2 NOS ONLY)
3. ALL HOLE SHALL BE PROVIDED WITH PLASTIC PLUGS
4. THE STEEL POLE SHALL BE IN A SINGLE PIECES
5. THE HOLE AT 3100mm (- - - -) FROM POLE TOP IS DESIGNED POR BRACING OF FUSE CUTOUT CHANNEL OF SINGLE POLE MOUNTED TRANSFORMER
6. ALL HOLES SHALL BE DRILLED PRIOR TO GALVANIZING



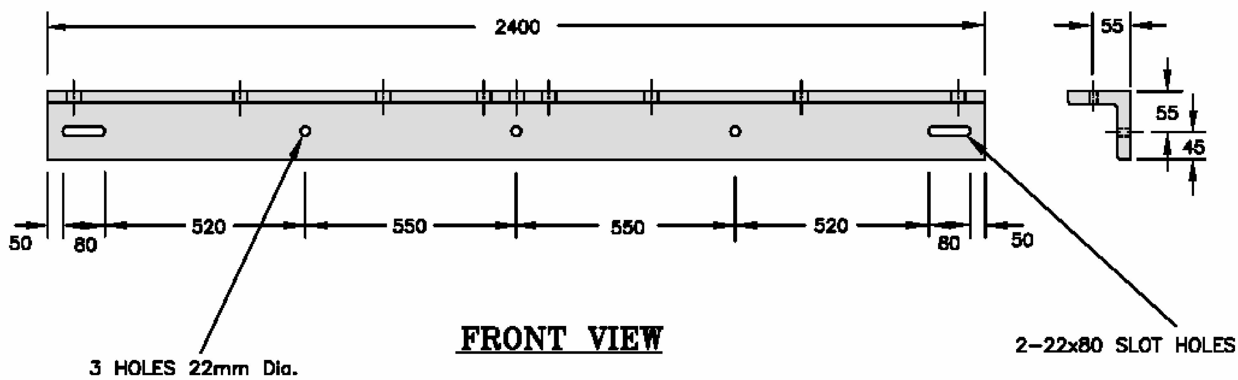


ALL DIMENSIONS ARE IN MILLIMETER

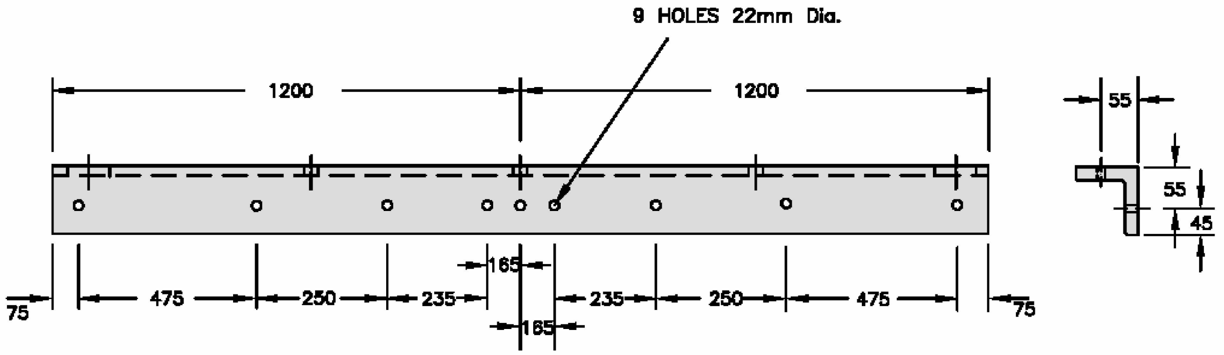
MATERIAL		OVERHEAD LINE
TOLERANCIA		OC14D POLE

	NOMBRE	FECHA
DIBUJADO	CARMEN AGÚNDEZ LERÍA	27/04/2016
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	28/04/2016

ESCALA:	FIRMA		Nº DE LAMINA:
1:100		I.C.A.I.	1.5



FRONT VIEW

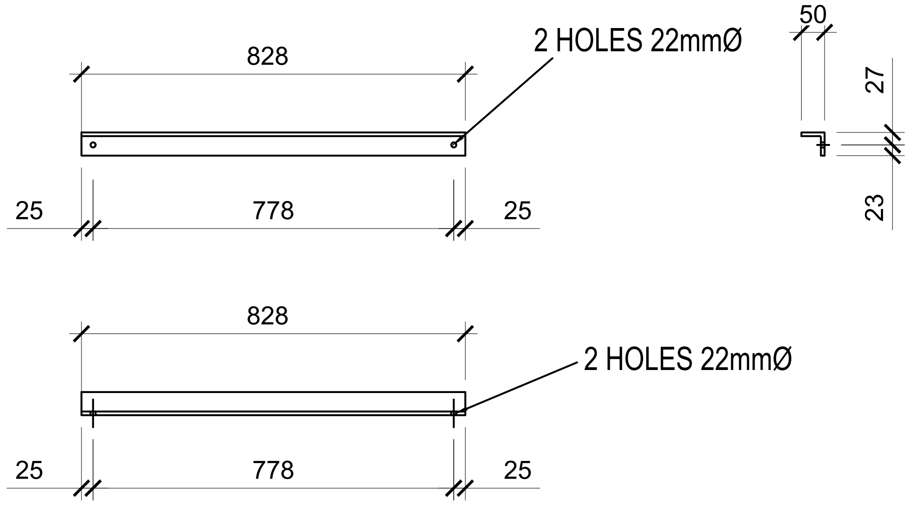


TOP VIEW

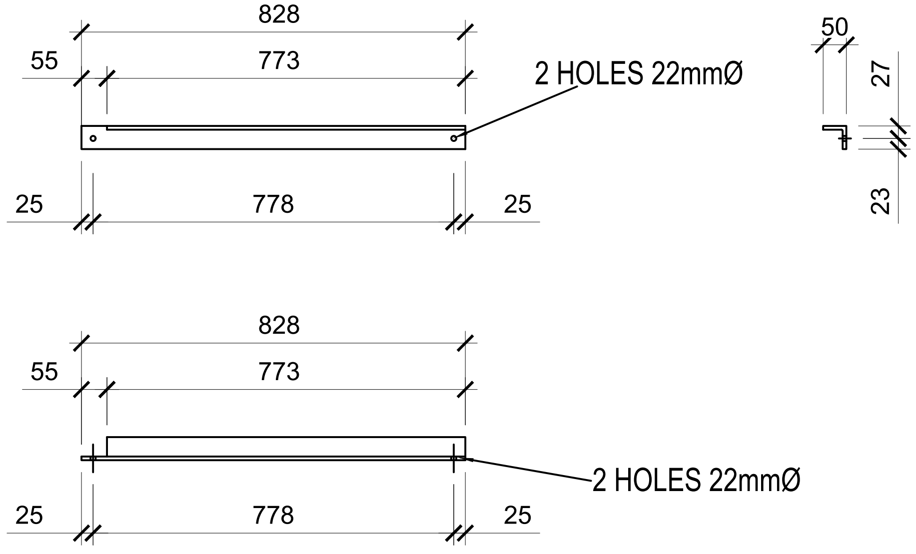
FIG.1: CROSSARM – L 100x100x12x2400mm L.G.

ALL DIMENSIONS ARE IN MILLIMETER

MATERIAL		OVERHEAD LINE
TOLERANCIA		
	NOMBRE	FECHA
DIBUJADO	CARMEN AGÚNDEZ LERÍA	CROSSARM
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	
ESCALA: 1:10	FIRMA	I.C.A.I. — Nº DE LAMINA: 1.6



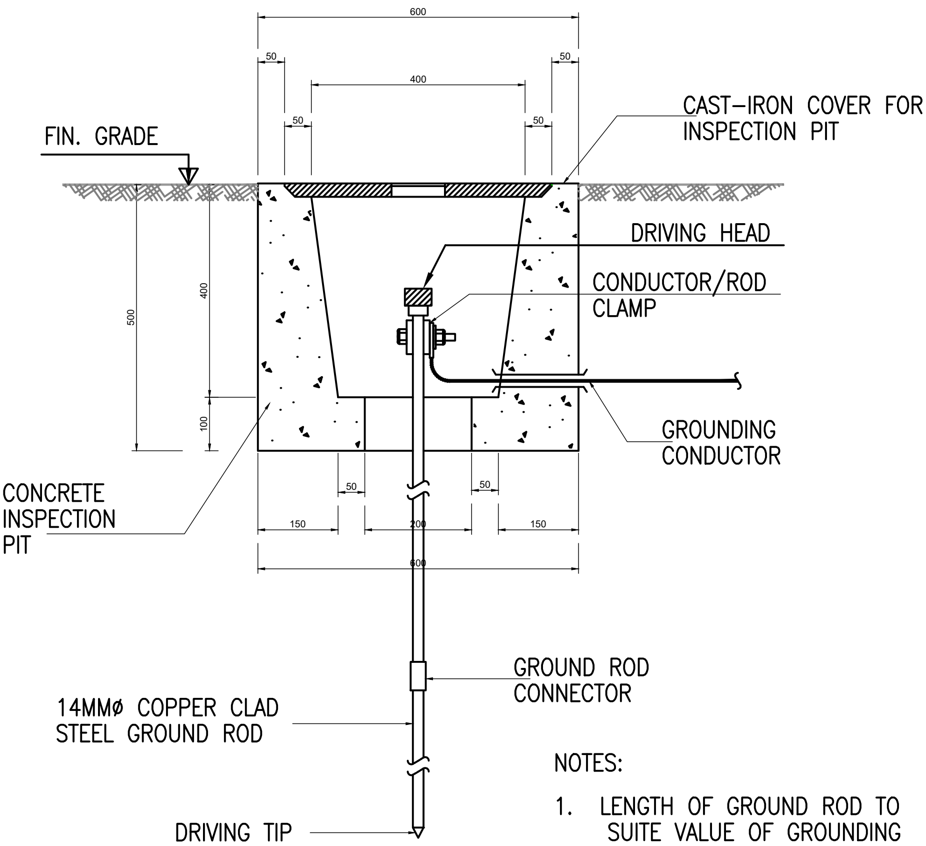
BRACE - L 50x50x4x828mm L.G.



BRACE - L 50x50x4x828mm L.G. ONE END CLIPPED

ALL DIMENSIONS ARE IN MILLIMETER

MATERIAL			OVERHEAD LINE
TOLERANCIA			
	NOMBRE	FECHA	BRACE SET
DIBUJADO	CARMEN AGÚNDEZ LERÍA	02/05/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	05/05/2016	
ESCALA: 1:10	FIRMA		I.C.A.I.
			Nº DE LAMINA: 1.7



NOTES:

1. LENGTH OF GROUND ROD TO SUITE VALUE OF GROUNDING RESISTANCE REQUIRED.

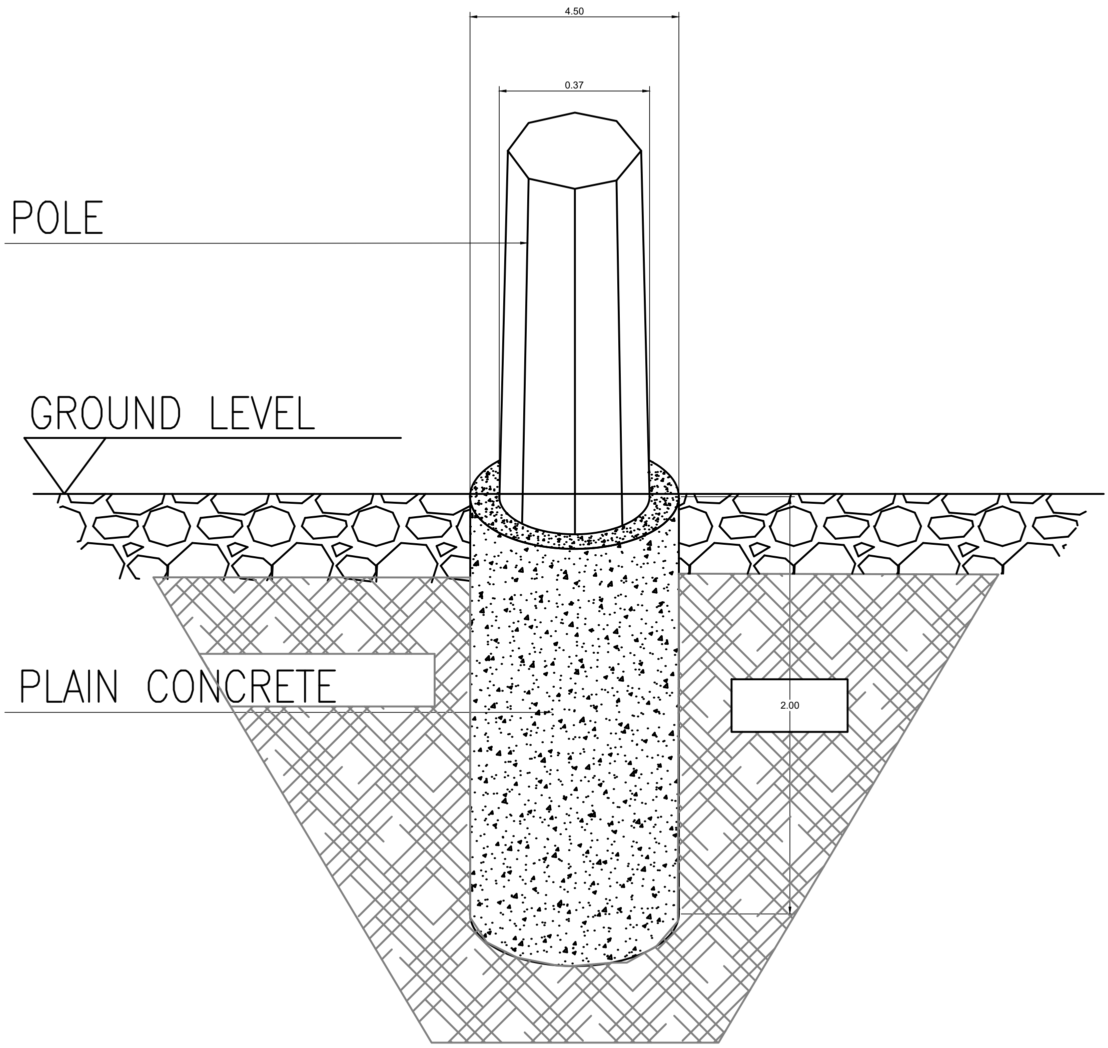
MATERIAL		
TOLERANCIA		
	NOMBRE	FECHA
DIBUJADO	CARMEN AGÚNDEZ LERÍA	02/05/2016
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	05/05/2016
ESCALA: 1:50	FIRMA	

OVERHEAD LINE

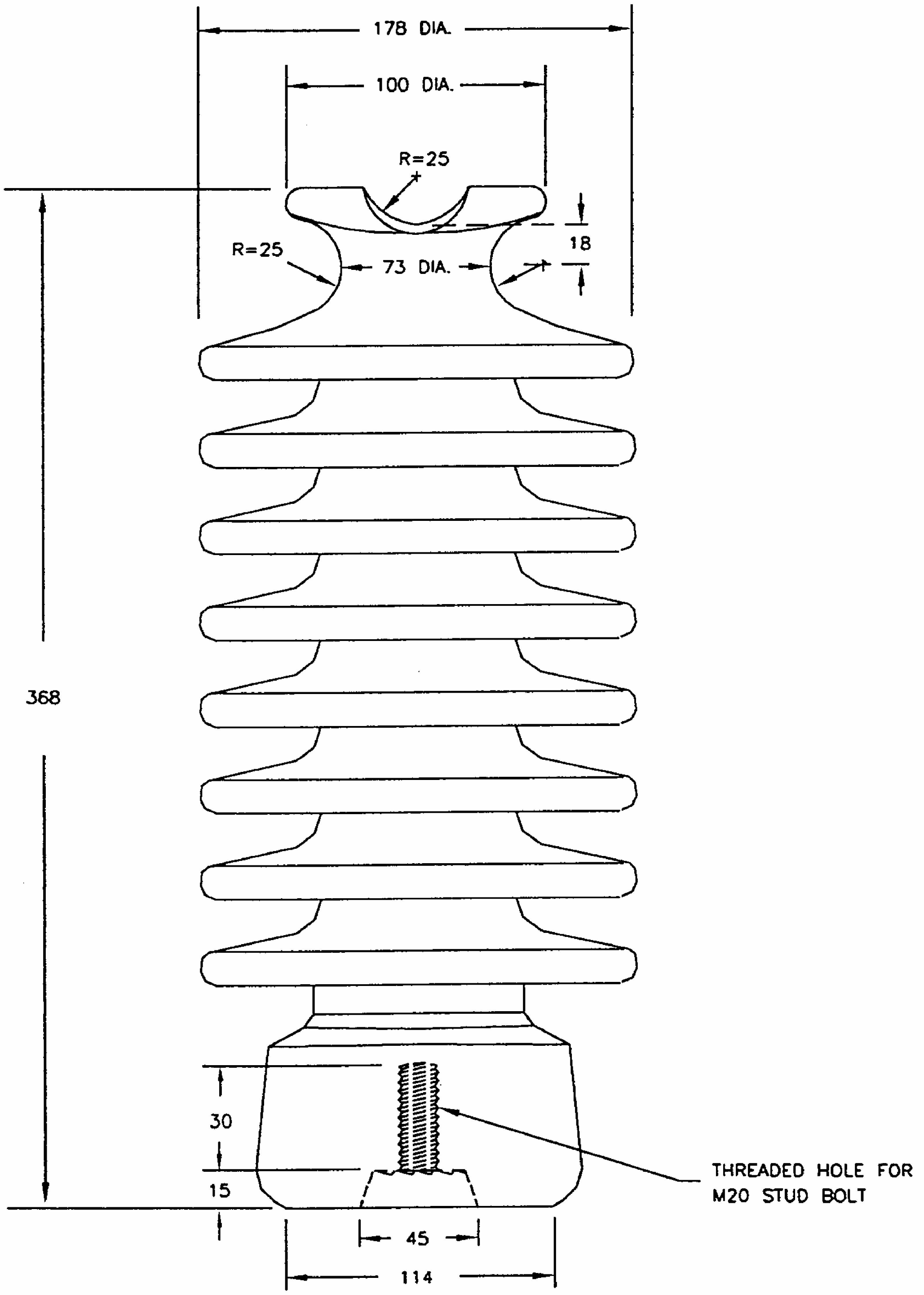
EARTHING SYSTEM

I.C.A.I.

Nº DE LAMINA: 1.8



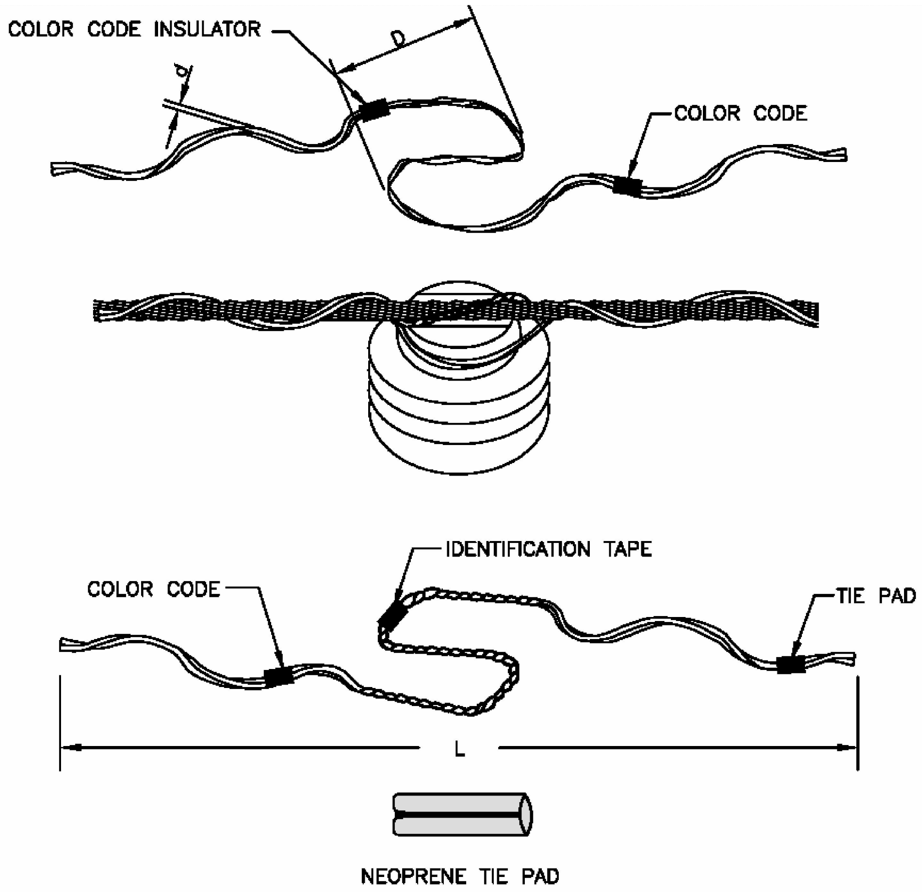
MATERIAL			OVERHEAD LINE
TOLERANCIA			
	NOMBRE	FECHA	FOUNDATION
DIBUJADO	CARMEN AGÚNDEZ LERÍA	02/05/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	05/05/2016	
ESCALA: 1:10	FIRMA		I.C.A.I.
			Nº DE LAMINA: 1.9



33KV LINE POST INSULATOR
WITH TOTAL CREEPAGE DISTANCE 825mm
(25mm/KV)

TOLERANCES: AS PER IEC/ANSI
ALL DIMENSIONS ARE IN MILLIMETER

MATERIAL			OVERHEAD LINE
TOLERANCIA			
	NOMBRE	FECHA	INSULATOR LINE POST
DIBUJADO	CARMEN AGÚNDEZ LERÍA	02/05/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	05/05/2016	
ESCALA: 1:1.5	FIRMA		I.C.A.I. — Nº DE LAMINA: 1.10



SR. NO.	CONDUCTOR		ROD DIA.	LENGTH (L)	NO. OF STRANDS	COLOR CODE	REMARKS
	NAME	O.D					
1	MERLIN	17.35	3.0	730	2	WHITE	W/O ARMOUR ROD
2	MERLIN	17.35	3.0	915	4	GREEN	WITH ARMOUR ROD
3	QUAIL	11.34	2.59	635	2	BLUE	W/O ARMOUR ROD
4	QUAIL	11.34	3.0	815	2	RED	WITH ARMOUR ROD

NOTE:–

– MATERIAL: ALLUMINIUM COATED STEEL WIRE

FIG.35: PREFORMED LINE POST INSULATOR TOP TIE

ALL DIMENSIONS ARE IN MILLIMETE

MATERIAL			OVERHEAD LINE
TOLERANCIA			
	NOMBRE	FECHA	TOP TIE
DIBUJADO	CARMEN AGÚNDEZ LERÍA	07/05/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	13/05/2016	
ESCALA: NA	FIRMA		I.C.A.I. — Nº DE LAMINA: 1.11

2. TRANSITION

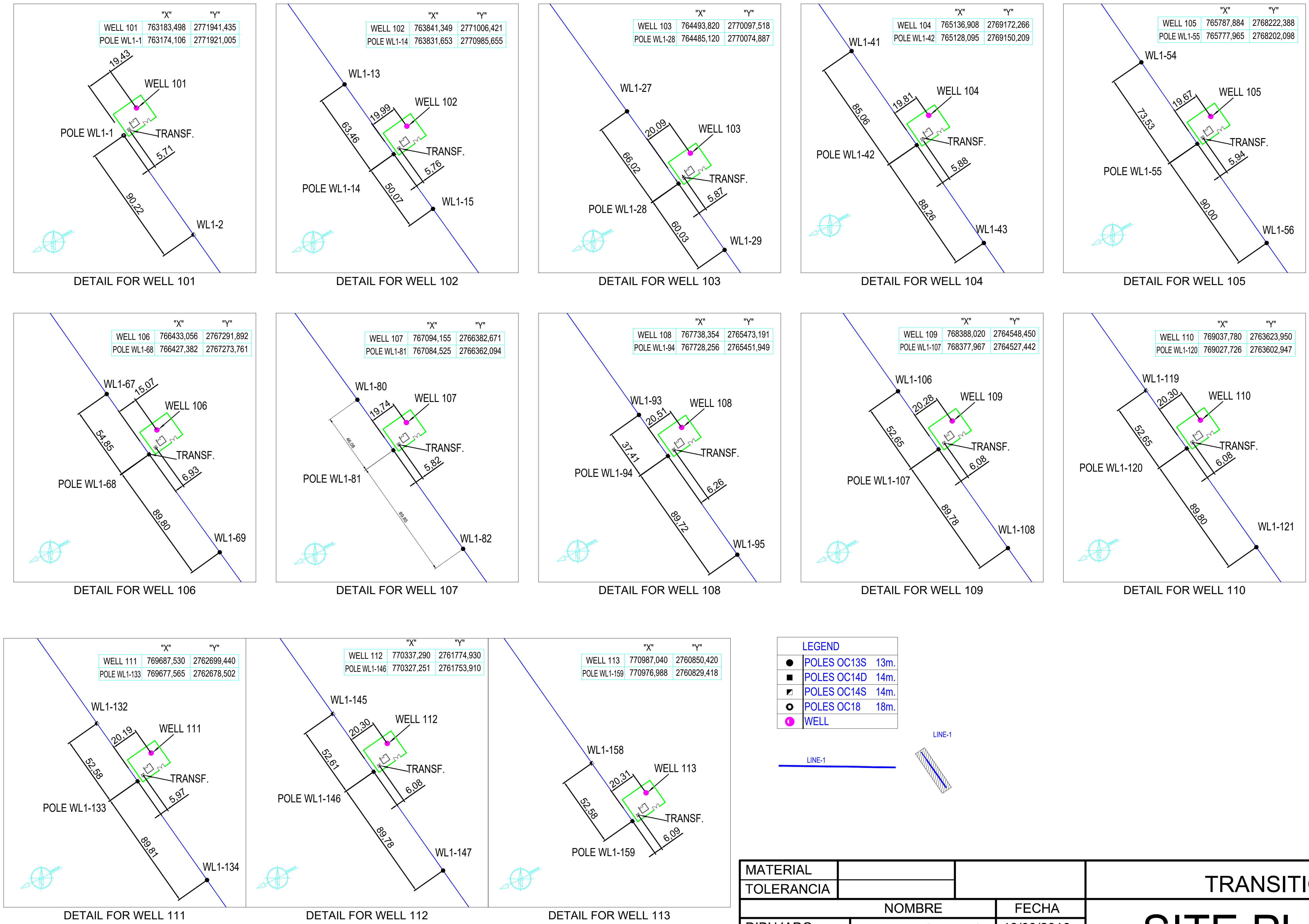
2.1 SITE PLAN

2.2 FACILITY PLAN

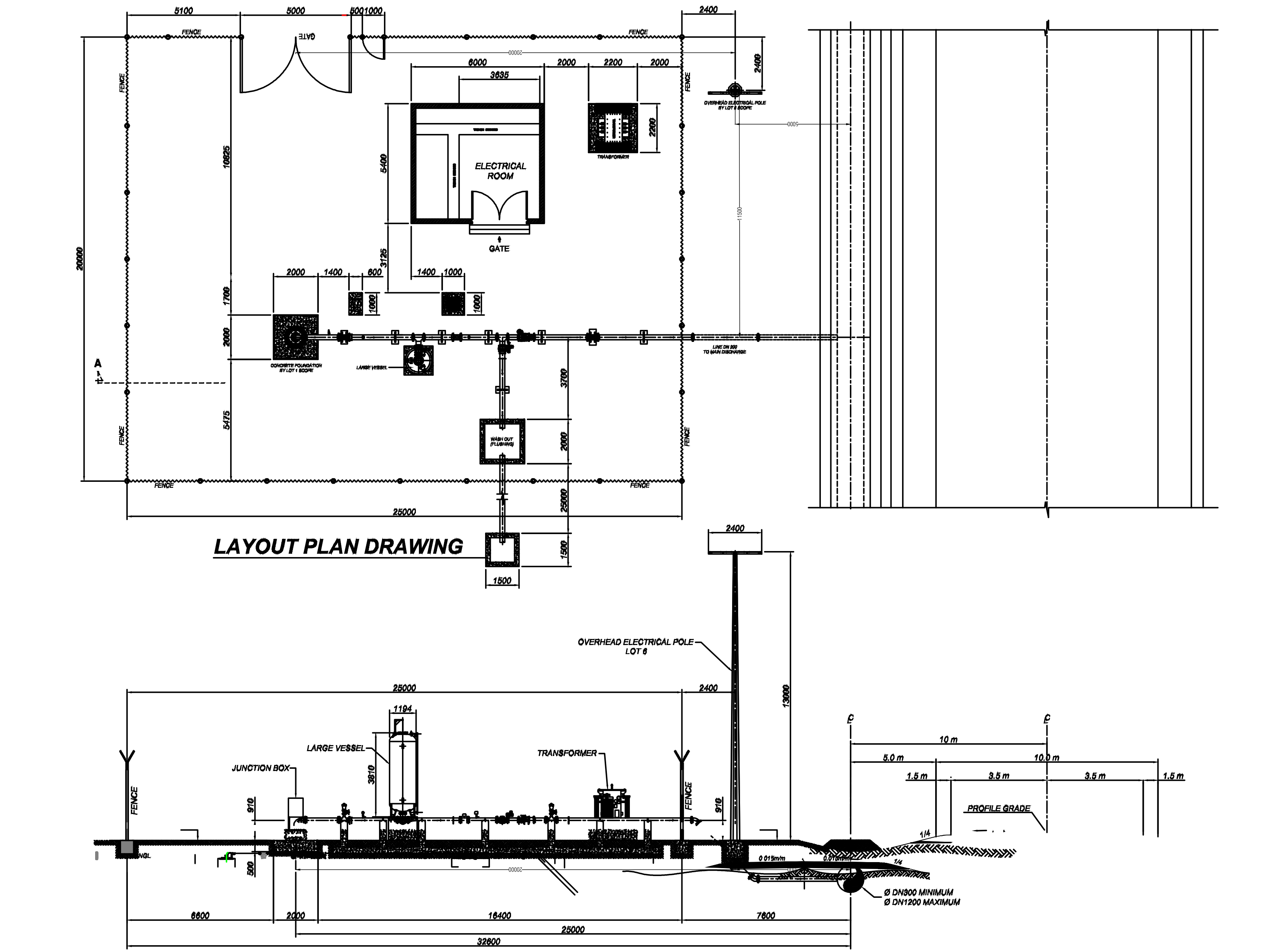
2.3 TRANSITION POLE

2.4 FUSE CUT OUT CROSSARM

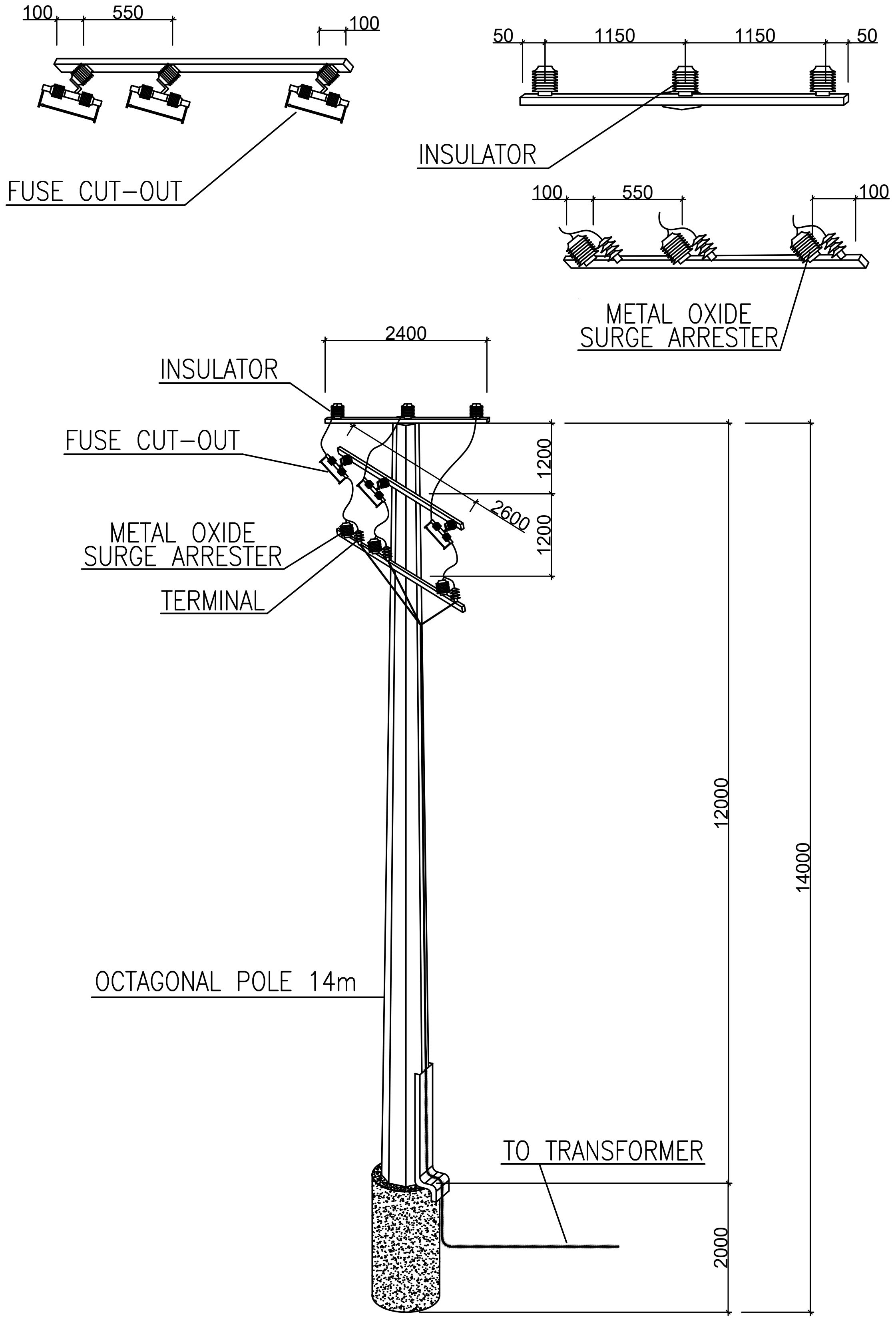
2.5 INSTALLATION



MATERIAL			TRANSITION
TOLERANCIA			
	NOMBRE	FECHA	SITE PLAN
DIBUJADO	CARMEN AGÚNDEZ LERÍA	18/03/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	24/03/2016	
ESCALA: 1:1000	FIRMA		I.C.A.I. — Nº DE LAMINA: 2.1

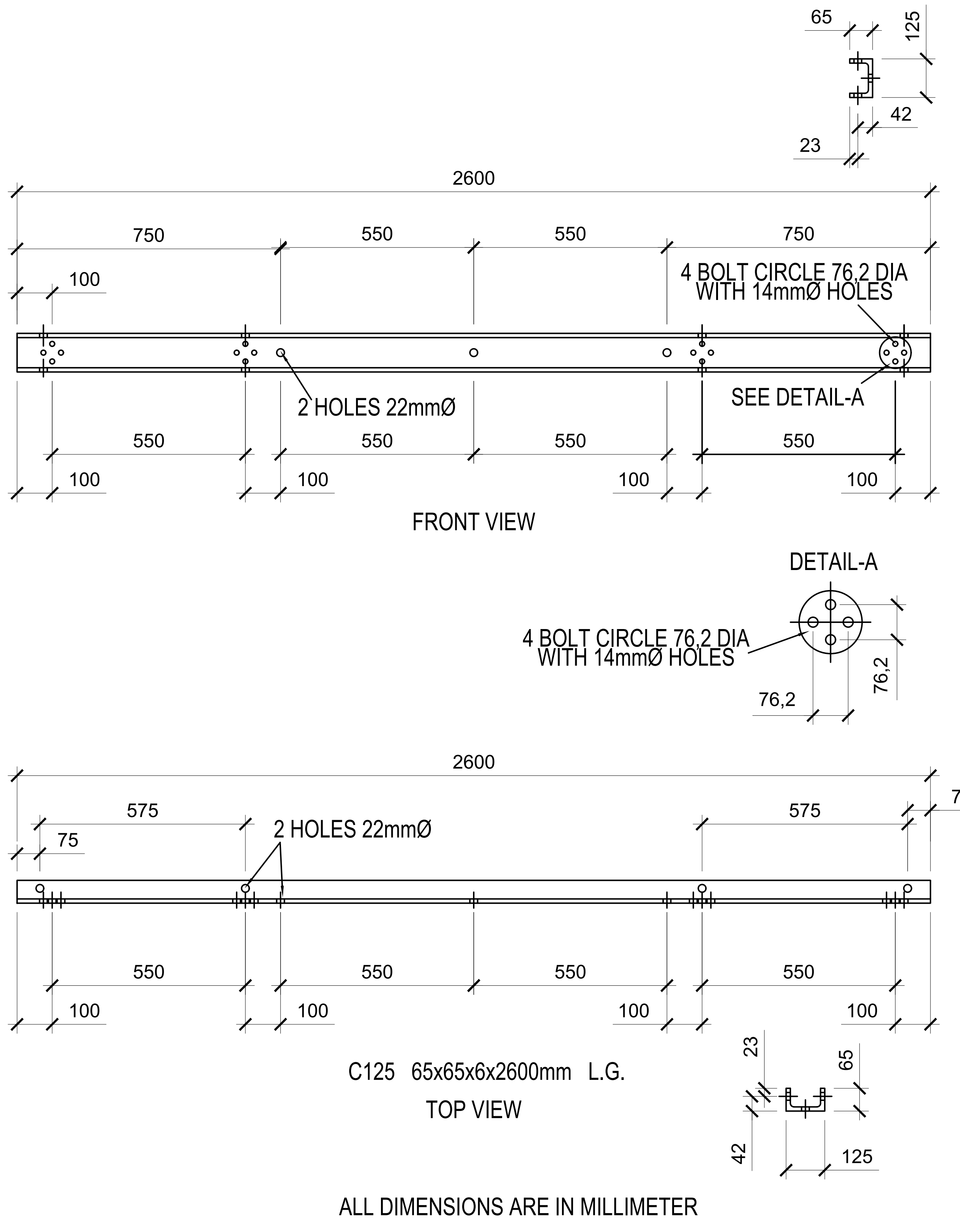


TRANSITION		
FACILITY PLAN		
I.C.A.I.	Nº DE LAMINA:	2.2
	NOMBRE	FECHA
DIBUJADO	CARMEN AGÚNDEZ LERÍA	02/05/2016
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	05/05/2016
ESCALA: 1:50	FIRMA	
MATERIAL		
TOLERANCIA		



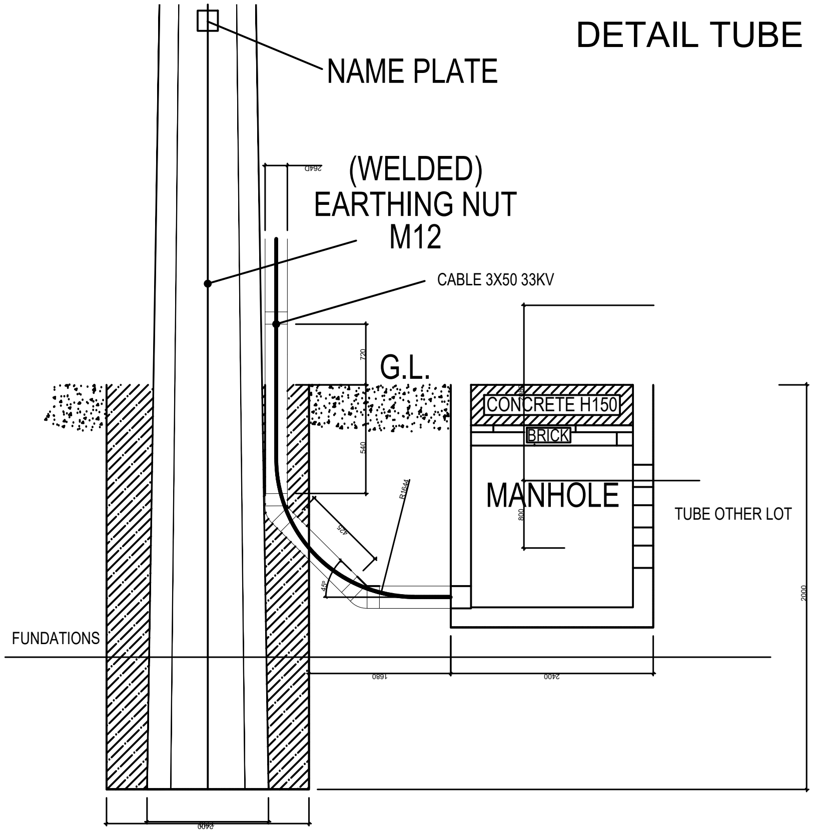
OCTAGONAL STEEL POLE 14m MEDIUM VOLTAGE D.C. (OC14D)

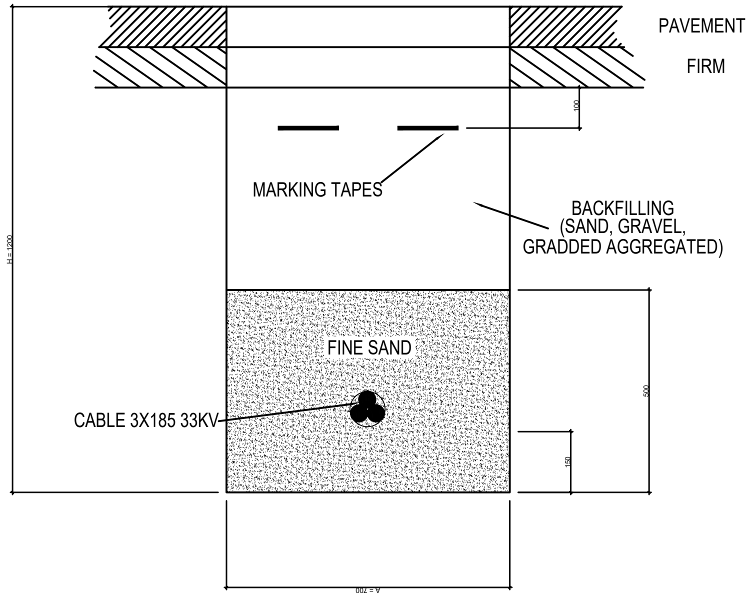
MATERIAL			TRANSITION
TOLERANCIA			
	NOMBRE	FECHA	TRANSITION POLE
DIBUJADO	CARMEN AGÚNDEZ LERÍA	25/04/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	28/04/2016	
ESCALA: 1:100	FIRMA	I.C.A.I.	Nº DE LAMINA: 2.3



MATERIAL			TRANSITION
TOLERANCIA			
	NOMBRE	FECHA	FUSE CUT OUT CROSSARM
DIBUJADO	CARMEN AGÚNDEZ LERÍA	04/05/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	13/05/2016	
ESCALA: 1:10	FIRMA	I.C.A.I.	Nº DE LAMINA: 2.4

DETAIL TUBE 110





ALL DIMENSIONS ARE IN MILLIMETER

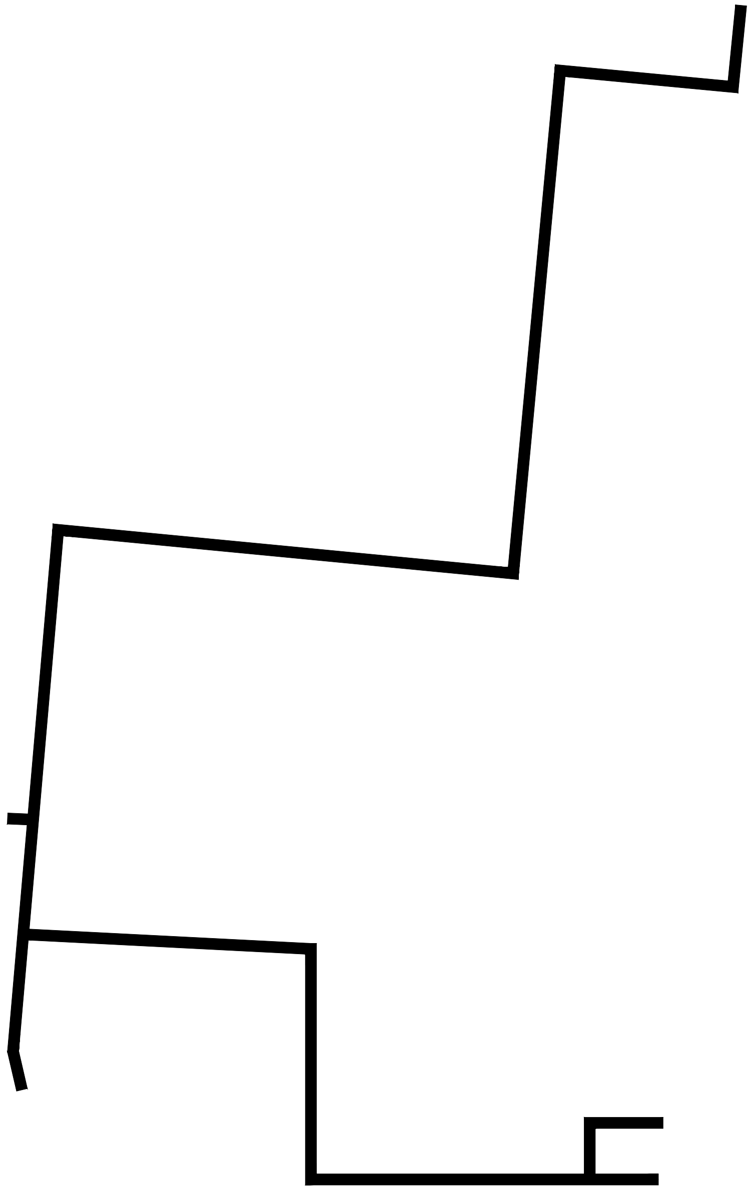
SKETCH CABLES DIRECT IN GROUND

TRANSITION INSTALLATION	I.C.A.I.	Nº DE LAMINA: 2.5
	NOMBRE	FECHA
DIBUJADO	CARMEN AGÚNDEZ LERÍA	25/05/2016
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	27/05/2016
MATERIAL		
TOLERANCIA		
ESCALA: 1:50	FIRMA	

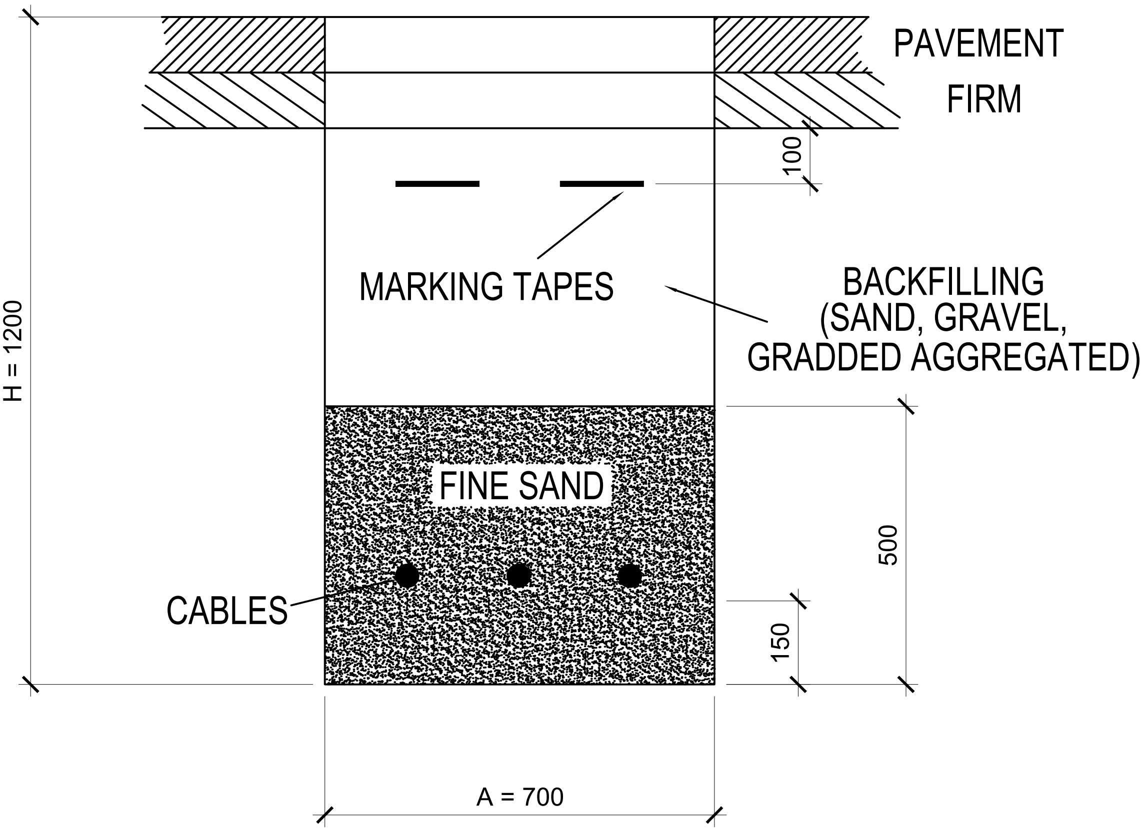
3. UNDERGROUND LINE

3.1 SITE PLAN

3.2 SECTION



MATERIAL			UNDERGROUND LINE
TOLERANCIA			
	NOMBRE	FECHA	SITE PLAN
DIBUJADO	CARMEN AGÚNDEZ LERÍA	20/05/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	25/05/2016	
ESCALA: 1:100	FIRMA		I.C.A.I.
			Nº DE LAMINA: 3.1



ALL DIMENSIONS ARE IN MILLIMETER

MATERIAL			UNDERGROUND LINE
TOLERANCIA			
	NOMBRE	FECHA	SECTION CABLES DIRECT IN GROUND
DIBUJADO	CARMEN AGÚNDEZ LERÍA	02/05/2016	
COMPROBADO	INMACULADA BLÁZQUEZ GARCÍA	05/05/2016	
ESCALA: 1:10	FIRMA	I.C.A.I.	Nº DE LAMINA: 3.2

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