COMILLAS
UNIVERSIDAD PONTIFICIA
ICAI

MASTER EN INGENIERÍA INDUSTRIAL

TRABAJO FIN DE MASTER

Bidelek 4.0 – Working on a second "smart" generation

Autor: Juan Diego Monterroso Ruiz
Director: Iñigo Larumbe Cabanas
Co-Director: Gregorio López López

Madrid

Declaro, bajo mi responsabilidad, que el Proyecto presentado con el título

Bidelek 4.0 – Working on a second “smart” generation

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Fdo.: Juan Diego Monterroso Ruiz Fecha: 23/ 08/ 2020

Autorizada la entrega del proyecto

LOS DIRECTORES DEL PROYECTO

Fdo.: Iñigo Larumbe Cabanas Fecha: 22/ 08/ 2020

Fdo.: Gregorio López López Fecha: 22/ 08/ 2020

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BIDELEK 4.0 – WORKING ON A SECOND “SMART” GENERATION

Autor: Monterroso Ruiz, Juan Diego.
Co-Director: Larumbe Cabanas, Iñigo.
Co-Director: López López, Gregorio.
Entidad Colaboradora: Iberdrola España S.A.U.

RESUMEN DEL PROYECTO

Este proyecto analiza las posibles funcionalidades que podrían implementarse en la segunda generación de los contadores digitales para i-DE Redes Eléctricas Inteligentes S.A.U. Para ello, se ha realizado un análisis mediante tres herramientas que proporcionan la suficiente información para determinar las funcionalidades que son viables y deben ser implantadas. Dichas herramientas son: análisis de coste beneficio (del inglés *Cost Benefit Analysis* – CBA), análisis DAFO (del inglés *SWOT – Strengths, Weaknesses, Opportunities and Threats)* y análisis de *Key Performance Indicators* (KPIs).

Palabras clave: Contador inteligente, Funcionalidad, Análisis CBA, Análisis DAFO, KPIs

1. Introducción

La empresa i-DE Redes Eléctricas inteligentes es la empresa del grupo Iberdrola que realiza las actividades de la distribución eléctrica. Esta empresa cuenta con diversos activos entre los que destacan los contadores eléctricos, ya que cada instalación eléctrica tiene uno en el punto frontera entre la instalación propiedad del cliente y la instalación propiedad de la empresa distribuidora.

Los contadores eléctricos han ido evolucionando con la tecnología al igual que todos los equipos de la red eléctrica. Antes se utilizaban contadores electromecánicos que necesitaban una lectura local para realizar la facturación de los consumos. Actualmente, los contadores digitales son los encargados de la medida del consumo eléctrico y pueden enviar la información que registran de forma remota.

Las diversas funcionalidades que debe tener un contador como mínimo se establecen en el RD 1110/2007 [1], aunque existe otra regulación complementaria a este real decreto que establece como se han de realizar las medidas o las tareas impuestas. Junto a las funcionalidades impuestas por la regulación, los contadores tienen otras funcionalidades que son establecidas por la compañía para facilitar la utilización por parte de los clientes o el beneficio de la operación y monitorización de la red eléctrica.

Pero los contadores tienen una vida útil y cuando llega a su fin, estos deben ser sustituidos por una nueva generación. En la nueva generación de contadores se pueden implementar nuevas funcionalidades y tecnologías para hacer viable la utilización de nuevos recursos o la mejora del funcionamiento de estos equipos. El objetivo de este Trabajo Fin de Máster es precisamente analizar y determinar razonadamente qué funcionalidades es conveniente incluir y cuáles no en la nueva generación de contadores inteligentes de i-DE.

2. Definición del proyecto

Esta tesis tiene como proyecto el análisis de las diversas funcionalidades para la próxima generación de contadores que se plantearon en el proyecto BIDELEK 4.0 [2]. Estas funcionalidades fueron planteadas por la distribuidora, los fabricantes, el laboratorio y la regulación. Todas las funcionalidades planteadas tienen unos requisitos distintos que también serán planteados para establecer que se precisa en la nueva generación.

La tesis establecerá las funcionalidades que se deberán implementar y las que serán descartas de la nueva generación. Dando una explicación cualitativa y en los casos necesarios cuantitativa para determinar los casos de negocio y los costes de las diversas funcionalidades.

3. Descripción del modelo/sistema/herramienta

La metodología utilizada para determinar las funcionalidades que conviene incluir en la próxima generación de contadores inteligentes de i-DE y las que no involucra tres análisis diferentes pero relacionados: el análisis SWOT (*Strengths, Weaknesses, Opportunities, and Threats*), el análisis CBA (*Cost Benefit Analysis*) y el análisis sobre KPIs (*Key Performance Indicators*). El proceso que lleva a cabo una funcionalidad se ejemplifica en la Ilustración 1 – Proceso de análisis de una funcionalidad para el contador.

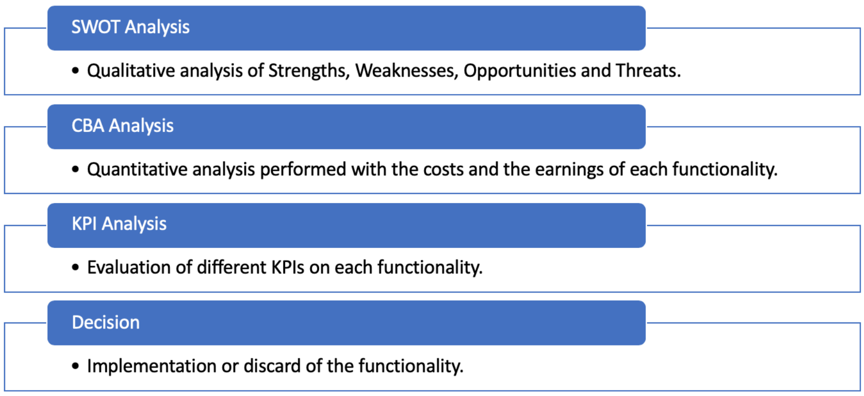

Ilustración 1 – Proceso de análisis de una funcionalidad para el contador

En el caso del análisis SWOT se han identificado las fortalezas, debilidades, amenazas y oportunidades de todas las funcionalidades. Para realizar un análisis homogéneo y comparable se han establecido una serie de preguntas comunes para cada aspecto. Tras contestar estas preguntas se ha realizado un análisis más detallado de cada funcionalidad con el fin de completar el análisis y obtener la máxima información posible.

El análisis CBA se ha realizado haciendo una distinción entre las funcionalidades que precisan una implementación *software* de las funcionalidades que requieren un equipo *hardware* en el contador, ya que las implementaciones *software* tienen un menor coste que el coste asociado a la instalación de un *hardware* en el contador. Tras esta distinción y la computación del coste desglosado según la instalación en campo de los contadores, se procede a estudiar la implicación económica que aportarán cada uno de las funcionalidades realizando unos flujos de caja para el calculo del TIR (Tasa Interna de Retorno) y el VAN (Valor Actual Neto).

Por último, se realiza el análisis de los KPI en el que se clasifican las funcionalidades según la ponderación en los KPI. Las contribuciones de cada funcionalidad en los KPIs se basan en la importancia del factor aportado a cada KPI. Los KPI utilizados son

- Mejora de la seguridad y la calidad de las comunicaciones

- Nuevos y mejores servicios al cliente

- Operación de la red de energía mejorada

- Apoyo efectivo a la evolución de la red de energía

- Beneficios económicos

4. Resultados

De la evaluación de los diferentes análisis se obtienen diferentes conclusiones, ya que las funcionalidades tienen distintas características y cada análisis evalúa de una forma cada aspecto. Del análisis de los KPIs se obtiene el diagrama radial de las funcionalidades que tienen mejores evaluaciones que se muestra en la Ilustración 2 – Resultado de los KPIs para las funcionalidades mejor valoradas.

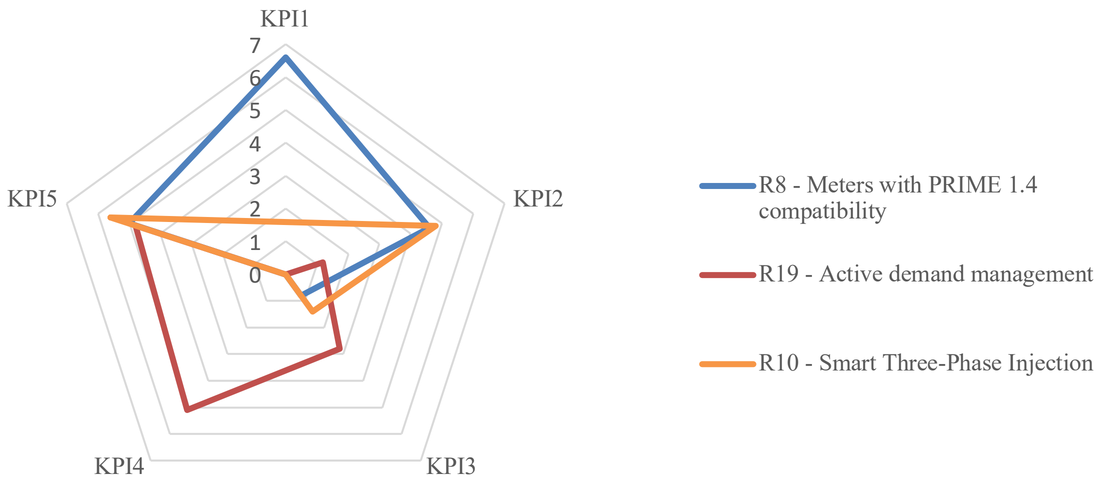

Ilustración 2 – Resultado de los KPIs para las funcionalidades mejor valoradas

Los resultados obtenidos son la decisión final de cada funcionalidad para determinar si deben ser implementadas o descartadas. La toma de decisiones se realiza en base a la información aportada por los análisis, obteniéndose las decisiones mostradas en la Tabla 1. Funcionalidades implementadas o descartadas del proyecto.

Functionality	*Implementation*
R1 - Physical measurement of neutral current	X
R2 - Temporary overvoltage protection	X
R3 - Islanding detection	X
R4 - In Home Display. Information for the user	X
R5 - Point-to-point remote manage of the meter	≈
R7 - Phase detection in PRIME 1.3	X
R8 - Meters with PRIME 1.4 compatibility	✓
R9 - Meter reclosing	✓
R10 - Smart Three-Phase Injection	✓
R11 - Load curve with shorter integration periods	X
R12 - Power load curve of each phase	✓
R15 - IEC 61000 Standard	X
R16 - V-I profile registration	X
R17 - Instant Values and Connectivity	X
R18 - Rotation sequence in three-phase meter	✓
R19 - Active demand management	≈

R20 - Volt-free contact	✓
R21 - Use of supercap for battery replacement	✓
R22 - New report S05 / S05B / S04 /S27	✓
R23 - Led for verification of impulses	✓
R24 - STAR+ Cybersecurity. Narrow band.	✓
R25 - Trigger power information	X
R26 - Reboot Modem PRIME	✓
R27 - Excess Calculation	✓
R28 - Events	✓
R29 - DLMS Efficiency	✓
R30 - Regulatory adaptations	✓
R31 - RMS values	✓
R32 - Instantaneous Values Profile	✓

Tabla 1. Funcionalidades implementadas o descartadas del proyecto

5. Conclusiones

De este trabajo se han sacado una serie de conclusiones entre las que destaca la utilización de una serie de análisis para evaluar de forma eficiente las funcionalidades. No es posible determinar que un sólo análisis es suficiente para tomar una decisión debidamente justificada.

Para tomar esta decisión se ha de tener en cuenta la vida útil del equipo que se está analizando, ya que las decisiones que se han de tomar tienen que ser validas a largo plazo. Además, se debe tener en cuenta la legislación porque es un aspecto clave en los cambios que se puedan imponer. Asimismo, es necesario adelantarse a posibles requisitos *hardware* en los equipos, ya que una vez instalados los contadores sería muy costoso retirarlos para instalar un elemento en el contador o desarrollar un equipo externo para que cumpla con alguna función.

Cabe destacar la importancia de este análisis en tanto en cuanto determinará una inversión de millones de euros por parte de i-DE.

6. Referencias

[1] S. Government, *Real Decreto 1110/2007, de 24 de agosto, por el que se aprueba el Reglamento unificado de puntos de medida del sistema eléctrico,* 2007.

[2] i.-D. R. I. S.A.U., *Proyecto BIDELEK 4.0,* 2020.

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Co-Supervisor: López López, Gregorio.
Collaborating Entity: Iberdrola España S.A.U.

ABSTRACT

This project analyses the possible functionalities that could be implemented in the second generation of smart meters for i-DE Redes Electricas Inteligentes S.A.U. It has been carried out an analysis using three tools that provide sufficient information to determine the functionalities that are viable and should be implemented. These tools are: Cost Benefit Analysis (CBA), analysis of Strengths, Weaknesses, Opportunities and Threats (SWOT) and analysis of Key Performance Indicators (KPIs).

Keywords: Smart Meter, Functionality, CBA Analysis, SWOT, KPIs

1. Introduction

I-DE Redes Electricas Inteligentes is the company of Iberdrola group that carries out the activities of power distribution. This company has several assets among which the electricity meters stand out, since each electrical installation has one at the frontier point between the installation owned by the client and the installation owned by the distribution company.

The electricity meters have evolved with technology as has all the devices on the power network. Previously, electromechanical meters were used, which needed a local reading to make the consumption billing. Nowadays, smart meters are in charge of measuring electricity consumption and can send the information registered remotely.

The minimum functionalities that a meter must have are established in RD 1110/2007 [1], although there is another complementary regulation to this royal decree that establishes how the measures or tasks imposed must be carried out. In addition to the functions imposed by the regulation, the meters have other functions that are established by the company to facilitate their use by clients or the benefit of the operation and monitoring of the power network.

But meters have a useful life and when it comes to the end, they must be replaced by a new generation. In the new generation of meters, new functionalities and technologies can be implemented to make the use of new resources or the improvement of the operation of this equipment feasible. The aim of this Final Master's Degree is precisely to analyze and reasonably determine which functionalities should and should not be included in the new generation of i-DE smart meters.

2. Project definition

This thesis is going to carry out the analysis of the different functionalities for the next generation of meters that were proposed in the BIDELEK 4.0 project [2]. These functionalities were proposed by the distributor, the manufacturers, the laboratory and the regulation. All the proposed functionalities have different requirements that will also be proposed to establish what is needed in the new generation.

The thesis will establish the functionalities that should be implemented and those that will be discarded from the new generation. Giving a qualitative explanation and in the necessary cases it will also be performed a quantitative analysis to determine the business cases and the costs of the different functionalities.

3. Process description

The methodology used to determine which functionalities should be included in the next generation of i-DE smart meters and which do not involve three different but related analyses: SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis, CBA (Cost Benefit Analysis) analysis and KPIs (Key Performance Indicators) analysis. The process that carries out a functionality is exemplified in Figure 1 - Process of analysis of a functionality for the meter.

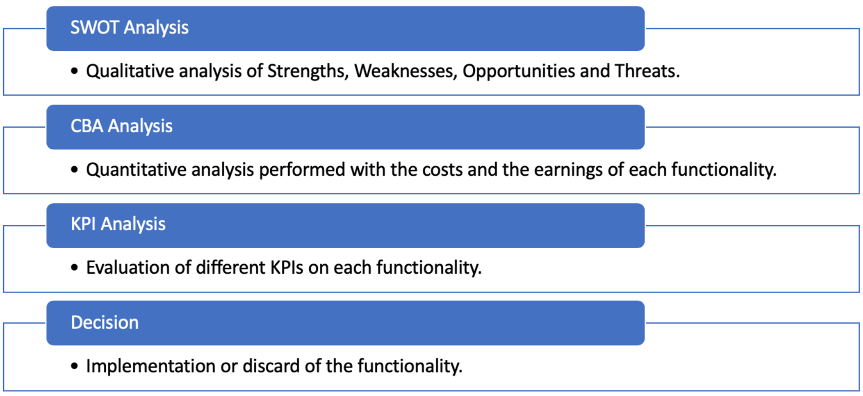

Figure 1 - Process of analysis of a functionality for the meter

In the case of the SWOT analysis, the strengths, weaknesses, threats and opportunities of all the functionalities have been identified. In order to carry out a homogeneous and comparable analysis, a series of common questions have been established for each aspect. After answering these questions, a more detailed analysis of each functionality has been made in order to complete the analysis and obtain the maximum information possible.

The CBA analysis has been carried out by distinguishing between the functionalities that require a software implementation from the functionalities that require a hardware equipment in the meter. Since, software implementations have a lower cost than the cost associated to the installation of a hardware in the meter. After this distinction and the computation of the cost has been performed in accordance with the installation of the meters in the field. Then it will be studied the economic implication that each of the functionalities will contribute by performing cashflows for the calculation of the IRR (Internal Rate of Return) and the NPV (Net Present Value).

Finally, the analysis of the KPIs is carried out in which the functionalities are classified according to the weighting in the KPIs. The contributions of each functionality in the

KPIs are based on the importance of the factor contributed to each KPI. The KPIs used are:

- Improvement of security and quality of the communications
- New and enhanced client services
- Enhanced power network operation
- Effective support for power network evolution
- Economic benefits

4. Results

rom the evaluation of the different analyses, different conclusions are obtained, since the functionalities have different characteristics and each analysis evaluates each aspect in a different way. From the analysis of the KPIs, the following radial diagram of the functionalities that have better evaluations is obtained, which is shown in Figure 2 - KPIs result for the best rated functionalities

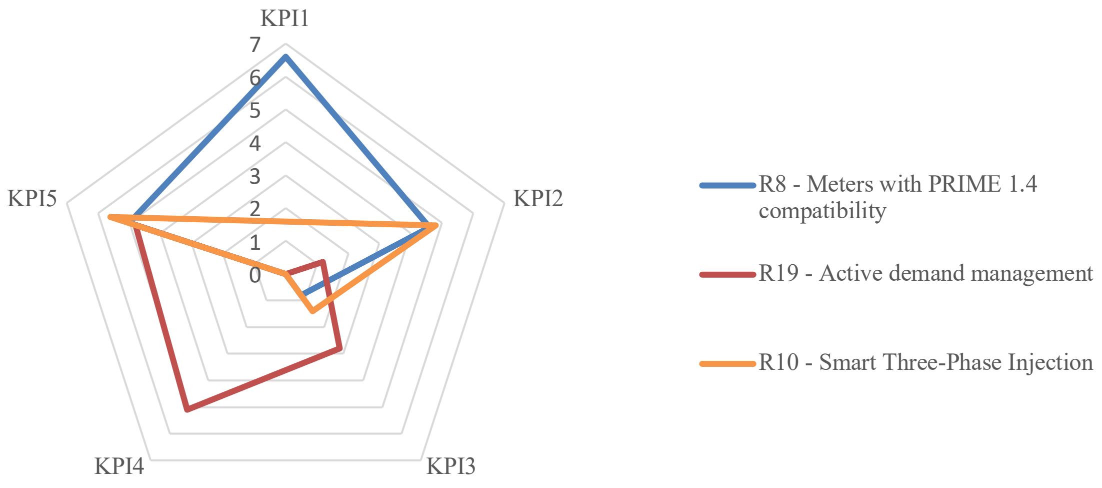

Figure 2 - KPIs result for the best rated functionalities

The results obtained are the final decision of each functionality to determine if they should be implemented or discarded. The decision making is made based on the information provided by the analysis, obtaining the decisions shown in the Table 1. Functionalities implemented or discarded from the project.

Functionality	*Implementation*

R1 - Physical measurement of neutral current	X
R2 - Temporary overvoltage protection	X
R3 - Islanding detection	X
R4 - In Home Display. Information for the user	X
R5 - Point-to-point remote manage of the meter	≈
R7 - Phase detection in PRIME 1.3	X
R8 - Meters with PRIME 1.4 compatibility	✓
R9 - Meter reclosing	✓
R10 - Smart Three-Phase Injection	✓
R11 - Load curve with shorter integration periods	X
R12 - Power load curve of each phase	✓
R15 - IEC 61000 Standard	X
R16 - V-I profile registration	X
R17 - Instant Values and Connectivity	X
R18 - Rotation sequence in three-phase meter	✓
R19 - Active demand management	≈
R20 - Volt-free contact	✓
R21 - Use of supercap for battery replacement	✓

R22 - New report S05 / S05B / S04 /S27	✓
R23 - Led for verification of impulses	✓
R24 - STAR+ Cybersecurity. Narrow band.	✓
R25 - Trigger power information	X
R26 - Reboot Modem PRIME	✓
R27 - Excess Calculation	✓
R28 - Events	✓
R29 - DLMS Efficiency	✓
R30 - Regulatory adaptations	✓
R31 - RMS values	✓
R32 - Instantaneous Values Profile	✓

Table 1. Functionalities implemented or discarded from the project

5. Conclusions

A series of conclusions have been drawn from this thesis, among them the use of a series of analyses to efficiently evaluate the functionalities. It is not possible to determine that a single analysis is efficient to reach a justified decision.

In order to make this decision, the useful life of the equipment being analyzed must be taken into account, since the decisions to be made must be valid in the long term. In addition, legislation must be taken into account because it is a key aspect in the changes that can be imposed. It is necessary to anticipate possible hardware requirements in the meter, since once the meters are installed it would be very expensive to remove them to install an element in the meter or to develop external equipment to fulfill some function.

The importance of this analysis should be highlighted as it will determine an investment of millions of euros by i-DE.

6. References

[1] S. Government, *Real Decreto 1110/2007, de 24 de agosto, por el que se aprueba el Reglamento unificado de puntos de medida del sistema eléctrico,* 2007.

[2] i.-D. R. I. S.A.U., *Proyecto BIDELEK 4.0,* 2020.

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Chapter 1. INTRODUCTION

Iberdrola, S.A.U. is a Spanish company that is dedicated to the energy field. It is one of the most important companies on the Spanish stock exchange and is based in Bilbao Spain. The company operates in many parts of the world, but its presence in Scotland with the subsidiary ScottishPower, in the United States with Avangrid, Mexico or Brazil are more remarkable.

Iberdrola, S.A.U. works in the entire area of the electrical energy business, from energy production to retail activity. Each country and each part of the business has an associated regulation, in this project we will focus on the Spanish case. Although, the Spanish regulation establishes in the law 54/1997 of the electric sector, which was published on November 28, 1997, the legal separation of activities with regulated remuneration from the activities of the non-regulated activities from the economic point of view [1]. It should be noted that in most of the countries in which Iberdrola operates, there is a separation between regulated activities and liberalized activities.

So, Iberdrola was split in Iberdrola Generación, S.A. and Iberdrola Distribución Eléctrica, S.A. Iberdrola Generación, S.A. was in charge of the generation and retail tasks which are the liberalized part and Iberdrola Distribución Eléctrica, S.A. However, in September 2018 the National Commission on Markets and Competition (CNMC) established the re-branding of the activities of the groups in the energy sector to eliminate possible confusion among consumers [2]. Since, the liberalized retailer, the regulated retailer and the distribution companies had similar logos and names. For this reason, "i-DE, Redes Electricas Inteligente" was created and it is in charge of the distribution.

i-DE has more than 11 million connection points and at each point is located a smart meter that provides power, current and voltage values at the point where the meter is placed [3]. These devices allow the reading of the measures in a continuous mode and enable the reading of the data in a remote way. Therefore, it is an important element of the electrical network. Furthermore, the smart meters are distributed within all the operation area from the distribution company which covers 25 provinces from Spain. These provinces are shown in Figure 1.

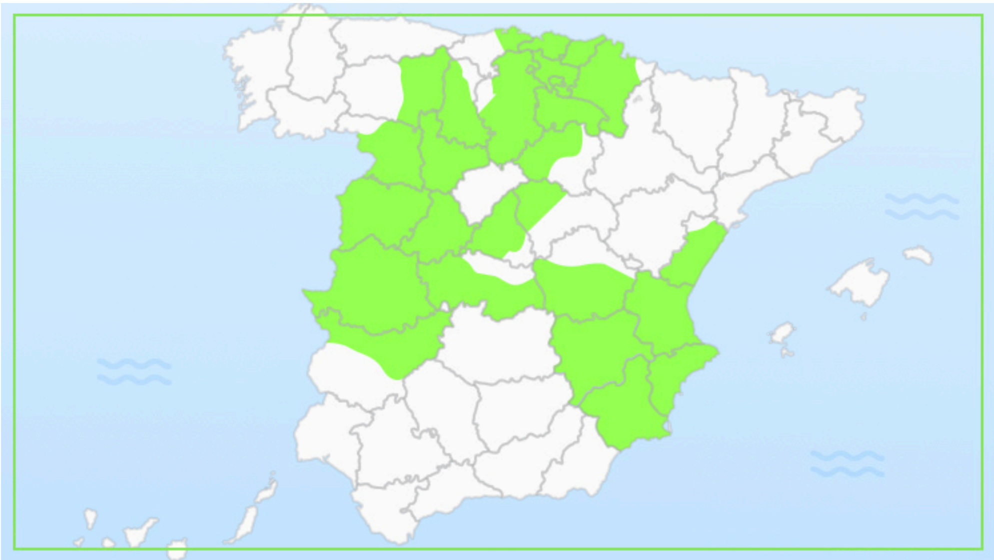

Figure 1. Operation area from i-DE Redes Eléctricas Inteligentes [3]

Smart meters have many functionalities that are installed by the manufacturer according to the requirements of each distributor, but some minimum functionalities are established in the RD 1110/2007, the Royal Decree-Law that states the regulation for the measurement points of the Spanish electrical system. Some of the detailed functionalities in the Royal Decree-Law are the measurement of active and reactive energy, the supply of measurement data remotely and reliably, the possibility of limiting the power demand or the hourly discrimination capacity of the consumption made [4].

On the other hand, the energy transition and technological evolution is manifested in a development of the electrical network. This requires the installation of new element and the adaptation of existing elements in order to implement the necessary capacities to carry out this development. In the case of smart meters, the distributors have identified new functionalities that are necessary in order to know and control the network in a proper condition and let the installation of some technologies. Therefore, these meters need an evolution where the necessary elements are included in order to do the required tasks and the corresponding software must be developed.

It must be taken into account that the smart meters are installed in each user and these devices are property of the distribution company, which afford the investment cost. The method to recover the investment is by charging users for the rental of the measurement equipment. The rental price is regulated and specified in the Royal Decree-Law 1634/2006, which includes the installation and verification costs for the meters. For example, a domestic consumer with a smart meter must pay 0.81 euros per month according to [5]. These regulated prices do not allow the installation of all the functionalities that the distributor can design, but they must analyse which functionalities are economically and technologically feasible.

The main goal of this thesis is to devise a solution to the implementation of the functionalities in the new generation of smart meters of i-DE, performing an analysis of the different functionalities that will allow to know which of them is more necessary based on the benefits provided to the DSO (Distribution System Operator). On the other hand, the analysis will also take into account the economic criteria to establish a relationship between the benefits and the associated cost, since all implemented functionality must be economically feasible.

The analysis must be thorough and critical because all the functionalities implemented will affect all the measuring points, which are eleven million in the case of i-DE. In addition, the useful life of a meter is 15 years. Therefore, leaving a functionality that will be essential in the future could mean a delay of several years until its implementation. On the contrary, investing in a functionality that is not necessary would mean an unnecessary expense.

The thesis of the project will be structured in a specific way and it will be divided in six sections plus the abstract, the references and the annexes. Firstly, Chapter 1 presents the motivation and goals of the thesis. Next, Chapter 2 analyses the actual meter that is going to be updated because it will provide the background to carry out the analysis of the new functionalities. Chapter 3 explains the method employed in the project in order to analyse the functionalities. Chapter 4 presents the analysis of the functionalities, which allows the development of Chapter 5 including all the results and facts that have been discovered.

Finally, Chapter 6 draws conclusions and sketches the possible continuity of the project in an applicative way or performing another analytical method.

Chapter 2. ANALYSIS OF THE STATE OF THE ART

In this project the meter to be analysed is the type 5 meter which is being used in domestic installations or the installation that has a small size. Specifically, the meter must have a contracted power of less than 15 kilowatts for installations of demand or a nominal power lower than 15 kilovolt-ampere for installations of generation. The meter analysed is being used by HC Energía hereinafter EDP Energía, Union Fenosa hereinafter Naturgy, Iberdrola, CIDE (Association of Electrical Energy Distributors) and ASEME (Association of Electrical Companies), which carry out the design together in order to have an equivalent meter [6].

2.1 EVOLUTION OF THE METER

The traditional meter evolved into the smart meter due to the need of new capabilities and improve the previous functionalities. The traditional meter is able to know the energy consumption of the customer measured in kilowatts per hour (kWh). The measurement by the meter is done by induction of magnetic fields in a metal disc that is not magnetic, in which creates a parasitic current due to the induction. The magnetic fields are created by a voltage coil and a current coil which interact with the eddy currents. The interaction of each eddy current with the magnetic field of the coil, that has not created the eddy current, creates a torque into de disc. This torque produces a movement in the disk proportional to the energy that is being consumed by the customer and it will increase the number of the counter.

This type of meter has some disadvantages, such as the need for a company worker or third party to be at the place where the meter is located in order to know the measurement of the energy used or to modify the contracted power. In addition, the lack of real consumption data required the use of estimated values to charge customers. All these disadvantages were the driver for the evolution of the traditional meters into the smart meter, which faces all of them.

The smart meter got the digitalization of the electric consumption, the rotary dial became a led that allows to know if it is consuming or not and the counter became into display where you can consult the information of the meter. The performed changes in the meters are highlighted in Figure 2. Among many other benefits the meter facilitates the knowledge of the data remotely so it can be known the condition of the network more reliably and accurately.

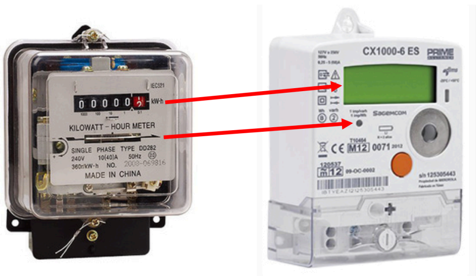

Figure 2. Traditional meter and digital meter changes in its appearance

2.2 SMART METER DEPLOYMENT

The deployment of the smart meters was stablished by the Spanish government in the complementary technical instruction ITC 3860/2007. This order specifies the period of time for the changes of all the meters that the distributors has for the installation, although this period was expanded in the order IET/290/2012.

Currently, there are more than 27.3 millions of electricity meters distributed throughout Spain. These supply points have measurement equipment can be owned by the distributors or the client, although more than 99 percent is owned by the distributors [7]. Each distributor is the owner of the devices in its working area, which is shown in the Figure 3. Although, there are 361 distribution companies in Spain, the analysis will be performed in the bigger ones that own more than 100,000 clients.

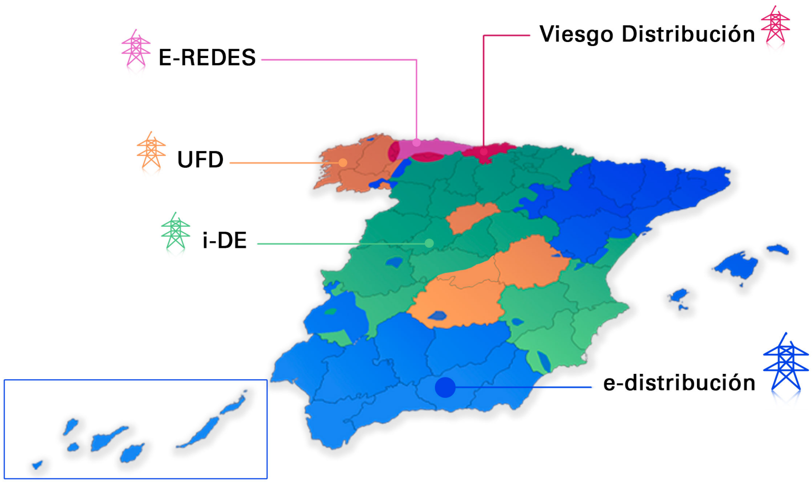

Figure 3. Distributors operation area in the Spanish map [8]

The number of smart meters from the different major distributors are stablished in the Table 1. This data provides the information of the companies that have more clients, so they will have more benefits due to the improvement of the meters. This fact will be analysed further in the following chapters.

Distribution company	*Installed smart meters*	*Integrated percentage (%)*
i-DE Redes Inteligentes	10,675,404	99,82
Grupo Naturgy	3,611,274	99.02
Barras Eléctricas Galaico-Asturianas	164,882	99.7
Viesgo Distribución Eléctrica	507,705	99.66
Hidrocantábrico Distribución Eléctrica	641,604	98.84
Endesa Distribución Eléctrica	11,487,906	98.53

Table 1. Smart meters deployed by major distributors in Spain [7]

As it is stated in the Table 1, the smart meters owned by i-DE are more 10 million. However, i-DE has more than 11 million of smart meters deployed in the low voltage network because this data does not include type 3 and type 4 meters which have more power than 15 kilowatts. Smart meters are connected to the data concentrators that will be the intermediary point between the system and the meters. From the data specified in the Table 1, the meters connected to the concentrator is more than 99 percent of all the installed meters.

2.3 MANUFACTURING FEATURES & MECHANICAL FEATURES

The smart meter has a cuboid shape, i.e. it is a polyhedron closed by rectangles on its faces. In the right side of Figure 2 is shown the actual real smart meter from i-DE. These meters are installed in meter rooms in a concentrated way or individually, they are fixed to the wall using three screws [6]. The dimensions are unified by the distributors and will reduce the costs associated with the installation, since the concentrated meter cabinets will be standard. The reduction of installation cost will be a benefit for the distributor, although the devices and elements are owned by the client, the distributors are in charge of the installation procedures.

The meter is composed by a series of physical elements which are:

- Two buttons.
- One display.
- Three seals.
- One opening meter sensor.
- One service switch.
- One terminal cover.
- One name plate.

One of the buttons can be sealable, it is provided for the association of a specific task. But this task if the distribution company wishes it. The other button will allow the client to perform tasks such as reading through the display or resetting in case the service switch has been opened by exceeding the contracted power.

The seals are used to avoid the attempt of manipulating the meter by third parties and it is an easy method to detect this intention by the personnel of the company. One seal is done by the manufacturer and it provide protection of internal elements because the enclosure is hermetically sealed. Furthermore, a sensor is installed to obtain information about the opening of the meter and the sensor will send an alarm if it occurs. The Reset button has a seal in order to avoid the delete of information that is stored in the memory of the meter. The last seal is allocated in the terminal cover and it provides protection against fraud because it does not let the access to the principal wires of the installation.

The service switch is an important element of the meter. As it is established by regulations, the meter must have an element that controls the power demanded. This element will allow disconnecting the power demand in case of a consumption higher than the contracted power, fraud detection or security reasons. To perform the over-consumption disconnection, the current consumption energy value is compared with the one established in the trigger curve. This curve has been designed taking as a reference the UNE 20317 standard and is programmed in all the meters. The curve is a thermal curve, i.e. even if the contracted power is exceeded, the supply will not be cut off until a certain time has elapsed.

The name plate of the meter provides the information of the meter which is the manufacturer, its precision, its identifier. So, it specifies the information for the identification of the meter, which is an important task because the meter is universal and it is not related to the supply point. It also states the communications technology that is supported in order to give information to the installer.

The degree of IP and IK protection is also detailed in the technical specification made by the distributors. The IP protection is related to the protection provided by the enclosure of the meter detailing the capacity that an external solid or liquid can access the internal elements. Type 5 meter has IP 51 protection, which does not allow the access of dust and supports the drop of water droplets. Meanwhile, the IK protection provides protection against impacts and these meters have an IK 02 protection.

2.4 ELECTRICAL FEATURES & METROLOGICAL FEATURES

The electrical features of the smart meter were designed following the European standard UNE-EN 504070. This standard specifies the general requirements for the measurement units that are connected to AC power. But there are some requirements that are added to this standard as the ability to work at a frequency of 50 Hz plus-minus two percent. The maximum short circuit current that the meter can support is thirty times the maximum stablished current. Finally, the operating voltage range will be higher than the standard from 0,8 to 1,15 times the nominal voltage [6].

These meters will have the ability to meter in both ways, so it will measure the energy imported or consumed and the energy exported or generated. It will also follow the standard UNE-EN 504070 for the precision of the active power as it was done for the electrical features. The metrological capacities for reactive power will be designed as it is specified in EN 62053 [6]. But the established requirements could be enhanced for a better performance. All these features are aligned to the Spanish regulation.

2.5 REGULATION

The functionalities installed of the meter depend on the requirements from the distribution companies and the requirements stablished in the Royal Decree 1110/2007, which regulates the operating status of the measurement devices of the entire power grid. So, this document stablishes the implemented functionalities and the characteristics which are needed in order to carry out these functionalities. Although this document evaluates all the measurement devices as it has been specified, it should be analysed all the functionalities referred to type 5 meter.

All the design of the metrological features has to comply the Royal Decree 244/2016 [9]. This regulation stablishes the currents and voltages that the meter should have and the error that they can produce in the measurement. Furthermore, these features has to comply the ITC 3022/2007 which specifies the metrological control of the meters [10].

2.6 *IMPLEMENTED FUNCTIONALITIES*

As it has been stated before, the functionalities of the meters are installed according to the requirements by regulations and the requirements of the different companies. In order to facilitate the understanding of the causes from the different functionalities, a section will be made for each one of them.

2.6.1 REGULATED FUNCTIONALITIES

The main functionalities of the meters are stated in the RD 1110/2007, which stablish the principal tasks. These tasks are detailed below [4]:

- The smart meter must provide the data required for the proper billing of the power supply or power access and the power to be cleared in the market.
- Record active and reactive power in all directions and quadrants respectively, where power circulation is possible.
- These meters will allow the reading of data through an optical communication port, remotely or through visual reading.
- Control the demanded power by the client using power measurement device or other elements and a dynamic adjustment of the maximum current reference of the contract or demand management requirements can be made.
- Perform disconnections and reconnections from the place where the meter is located or remotely. It is done for additions or deletions of supplies and the management of the demanded power.

- Perform hourly discrimination of the demand with at least 6 programmable periods. So, the energy of each period must be recorded and stored, as well as the maximum power of the quarter hour and the date and time of the maximum.
- Meters must parameterize the integration periods of up to one hour.
- They must record and store hourly profiles of active and reactive energy of a minimum of 3 months.
- Reading the records of the quality parameters remotely.
- Activate the control mode of the power demanded remotely.
- The meters can be synchronized on a regular basis.
- The system has the ability to manage loads in order to reduce demand in order to restore the proper condition of the system.
- The meter will record the amount and the duration of the supply interruptions that have a duration over 3 minutes.
- The data and configuration of the meter will be protected with password in order to avoid the access of unauthorized users.
- The meter will record the number of voltage quality unfulfillment. It will be taken into account overvoltages and undervoltages from the nominal value.

It is imposed some other functionalities that are stablished in complementary technical instruction 3022/2007. The functionalities stated in the instruction are related to the behaviour of the meter for a proper measurement, record of the data in case of loss of power supply and some other tasks from the meter. However, some of them are equal to the previous functionalities, so the following functionalities will be only the different ones [10]:

- The meter has to store the data during two years although it has not a power delivery from the network.
- The clock time can be performed by synchronization with the network frequency or by a quartz oscillator as a normal clock. When there is not power delivery, the time should be working at least during three days.

- The meter will record with time and date the alarm or events related to software or firmware update, changes of parameters, unauthorized accesses and critical events of the meter.
- The led will be used for the verification of power consumption with pulses. In the case of one led, the led should be configurable to indicate active power and reactive power.
- The meter can perform the close of a billing period using three methods, which are:
    - Pressing a sealable button which is a manual close.
    - Instantaneously by remotely or locally communications.
    - Programmed close.

2.6.2 FUNCTIONALITIES FROM THE COMPANIES

In this section from the document will be presented the functionalities that distribution companies add or improve in the meter. For this purpose, it will be presented the functionalities detailed in the technical specification [6]:

- The direction of the power flowing through the meter shall be recorded. This recording will be made at each phase in case the meter is multi-phase.
- The meter will transmit an alarm in case of an internal failure of the device.
- The battery of the meter must be able to maintain the operation for two years as required by law. If this battery is at 10 percent of its reserve it will communicate an alarm.
- An alarm will occur if the voltage drops to 50 percent of the nominal value and the voltage remains below 80 percent for 10 minutes.
- Alarms will be issued in cases of attempted fraud due to meter opening, communication attempts without permission or current flows without voltage.
- An alarm will be given if the voltage at the neutral conductor exceeds 50 percent of the nominal value.

- The led will flash quickly if it is exchanging information with the remote management system. Furthermore, it will remain fixed if the meter is connected to a communications network.
- the meter will have all the parameters to carry out a complete billing process. All of them can be modified and removed if necessary.
- In addition to the power registers already mentioned in Regulated Functionalities. The register of voltages, currents and fi-cosmos per phase, and the average power factor are specified.
- The meters are able to reset the parameters, data and passwords.
- The meters have the capacity to differentiate the client who is accessing to the data or parameters. The access will be authenticated by different passwords and each client will have different read and write permissions. In case of a power failure, all the password will be maintained in the meter.

2.7 COMMUNICATIONS

The Head End System and Meter Data Collector (HES-MDC) is in charge of managing all the information from the meters. The system has bidirectional communication, which lets communication from the system to the meters in the form of orders and from the meters to the system in the form of reports or alarms. The communication network infrastructure depends on the location (rural or urban area) where the equipment is located, the technology that is already installed among other factors.

The Figure 4 stablishes the different configuration of communication network that are implemented in Spain. The more used configurations are number one and two because are used in urban areas. Configuration number one transmit the data through a data concentrator (DC) and configuration number two uses a DC which has no radio communication and a gateway.

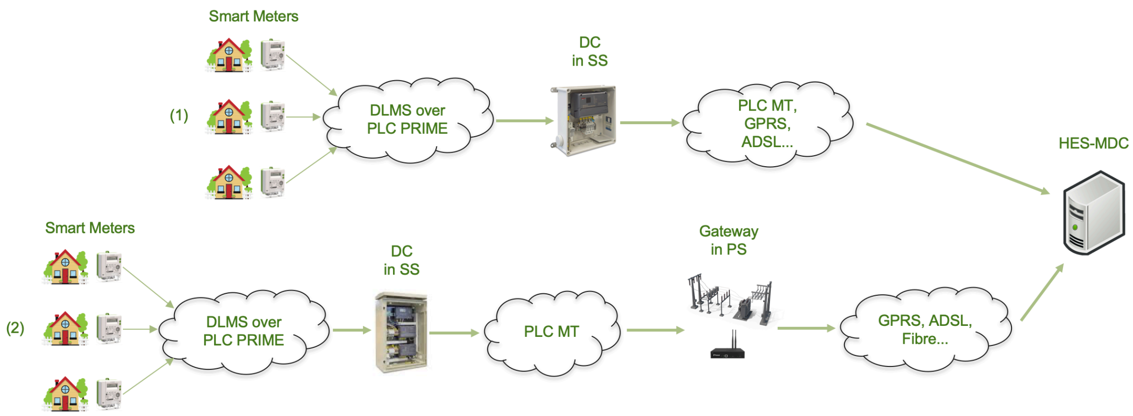

Figure 4. Different configurations of communication network used between HES-MDC and smart meters [11]

The implemented protocols of each communication segment are specified in the Figure 5. The communication configuration is split in the communication process between the smart meters with the data concentrator and the DC with the HES-MDC.

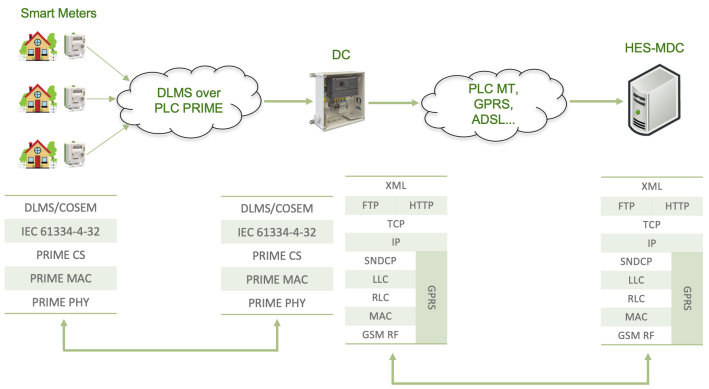

Figure 5. Protocol stack of the different segment from the communication configuration [11]

The communication between smart meters and data concentrators is done using PoweRline Intelligent Metering Evolution (PRIME) protocol. PRIME is a Narrow Band-Power Line Communication (PLC) which transmits data using low voltage cables. These cables that are already deployed for power transmission. It stablishes the services for the Physical (PHY) layer, Media Access Control (MAC) layer and Convergence Sublayer (CS) from TCP/IP architecture. The following services of each layer are used for PRIME 1.3.6:

- PHY layer is stablished the use of PLC Orthogonal Frequency-Division Multiplexing (OFDM) for the modulation and the bandwidth is CENELEC-A, which is composed between the 3 KHz and the 95 KHz. The data rate in the communication is up to 130 kilobits per second.
- In the MAC layer, it has been stablished two types of nodes the base nodes which are the concentrators and the service nodes for the meters and switches. The topology is a tree and the automatic repeat request in order to have a reliable communication is selective end-to-end.
- The convergence layer is divided into a common part sublayer which stablish the division and the assembling of the protocol data unit and the service specific sublayer which specify the use of upper layer. In the case of i-DE, the upper protocol is IEC 61334-4-32.

IEC 61334-4-32 stablishes the services for the logical link control sublayer which enable the data flow between the MAC and the application layer. The application layer is defined by Device Language Message Standard and Companion Specification for Energy Metering (DLMS/COSEM). COSEM is a profile from the DLMS protocol, which is a describe the data model for energy metering data. It also stablishes the rules for data identification. The functionalities of the meter are specified in Object Identification System (OBIS), interface classes and interface objects. The values of the object are stored in attributes that can be read and write depending on the configuration. All these specifications are stated in the Blue Book of the DLMS User Association.

DLMS specifies the communication protocol and it focuses on the application layer. Therefore, it establishes how data is accessed through get and set functions, the ciphering of the information and the access control. It has to be taken into account that the information of the devices can be accessed by the clients or third parties which is the reason for the access control. DLMS specifies the channels where the data can be transmitted. This protocol is stablished in the Green Book of the DLMS User Association. For testing all the communication DLMS User Association creates another book which is the Yellow Book.

When the information pass through this protocols stack, it reaches the concentrator where the data will be transmitted to reach the HES-MDC. In this communication segment the lower levels, one and two, can be done by different communication technologies as GPRS, 3G, PLC over medium voltage, Ethernet, Universal Mobile Telecommunications System (UMTS), Asymmetric Digital Subscriber Line (ADSL). However, all these technologies use STG-DC interface over TCP in the application layer. STG-DC is a communication protocol that enable the transmission of all the data from the meters. Data and information requirements are coded in eXtensible Markup Language (XML), so exchanged information will be in this language. All the request of data from the STG will have a specific parameter to identify the data and also the meter will have an identifier in order to know the meter that has been read.

2.8 SPECIAL DOCUMENTS OF THE TENDER

The process of communication stated in Communications is specified in technical documents that are wrote by the distributor in collaboration with manufacturers of the smart meters and laboratories. The main documents are test book, technical specification of the meter and the concentrator, specification document of the PRIME COSEM profile and specification document of the communication between the DC and the HES-MDC.

The technical specification of the meter stablishes all the features from the meter that will provide the knowledge in order to manufacture the meter. Furthermore, it specifies the meter operation and behaviour in case of events. In the operation of the meter, it is stablished the billing methods due to the associated contracts. Concretely, three types of contract can be configured in different periods. The values recorded in terms of energy are also included in this specification and how they should be recorded in case of reading errors or loss of information.

The specification of the data concentrator stablishes the manufacturing feature as the specification of the meter but it also stablishes the features from the supervisors of low voltage. In the case of the data concentrator, it is also specified the requirement for the delivery of the device. The specification of the DC stablishes all the test that has to be carried out in the DC in terms of manufacturing and data transmission. The test will be carried out in one or more samples of a certain model of concentrator.

The test books for the meters specify the test that will be carried out in the samples of the meter in order to certify a manufactured meter. This document stablished the tests and its process which are the steps that has to be performed in the meter and the expected result of the meter. This document will prevent the errors of manufacturers because they will have the opportunity to check the condition of the meter beforehand. The test will analyse all the events, functionalities, security accesses, parametrization and communications.

The PRIME COSEM profile so called Companion is the document that stablishes all the protocol for the implementation of DLSM/COSEM protocol into the meter devices. The main points covered in the document is the association with the clients that can access to the meter, communications profiles, the complete model of objects that is implemented on the meter. So, this document stablishes the communication and the model of data which is transmitted from the meter to the concentrator.

Finally, STG-CD interface specification stablished how the last segment of communication is performed. It contains the communication profile and the data model in order to access the information from the concentrators. These concentrators will be in charge of communication with the meters but this process will not be seen by the central system.

Chapter 3. EXPLANATION OF THE METHOD

In this chapter of the thesis, the method used in the process of analysis will be presented. This method will evaluate all the functionalities that are proposed. It will be composed of various analysis tools that will be explained below. Furthermore, it will be presented how the analysis will be done to facilitate its comprehension and replicability in future projects.

In this case, the evolution of the meters through the implementation of new features will be analysed. But the functionalities must be developed by the manufacturers and tested by a laboratory. Therefore, the participation of this part should be highlighted and taken into account.

3.1 STAKEHOLDERS INVOLVEMENT

i-DE is the distribution company in charge of designing the functionalities which are required for future technologies and environment. The functionalities will affect different business areas and bring different benefits. Therefore, the company establishes the requirements and the number of functionalities it intends to implement in the meter. Each functionality will provide a different tool in order to enhance the actual operation and planning of the power grid.

As it is stated, the functionalities can be selected by the distributors in order to improve the control of the network. However, they can be imposed from the regulation or implemented for the benefit of the users. The final clients which are the users of the meters will have the benefit of some functionalities. These benefits are specified in the use of certain capabilities that are not installed nowadays. For example, the use of demand management will provide the user an economical benefit because the let the curtailment of its contracted power and the distributor has another tool for the peak curtailment.

The manufacturers are responsible for the technological approach of each functionality. So, they will specify the affected areas of the technical documents associated with the meter and the elements that must be updated both hardware and software. The manufacturers present in the Bidelek 4.0 project are ZIV aplicaciones y tecnología S.L., Sagemcom UK Ltd., Landis Gyr S.A.U. among others. The manufacturers are in charge of the implementation of the functionalities in the meter and provide the samples of the meter to the laboratories in order to carry out the tests. Any cost involved in analysis of the meters are covered by the manufacturer.

Due to this reason, the test has to be delivered to the manufacturer beforehand. The responsible for the design of the test are the laboratories, which in this project are Tecnalia Research & Innovation, DNV GL and Instituto Tecnológico de la Energía (ITE) On the one hand, the laboratory will carry out the test on two samples of the meter which are sent by the manufacturer and it will certify the use of the device on the network. On the other hand, they will update the test books of the meters that collects all the information from the test that will be performed in the samples.

With the knowledge of each functionality plus the elements and costs required by the manufacturer to implement the functionality and the necessary analysis to be performed by the laboratory, the analysis can be carried out. For this purpose, the tools detailed below will be used.

3.2 SWOT MATRIX

The SWOT (Strengths, Weaknesses, Opportunities and Threats) Matrix is a quantitative and qualitive analysis which studies both internal and external aspects. Among the external aspects, there are threats and opportunities. While the internal aspects analysed are the weaknesses and strengths. Therefore, a joint evaluation of all the influential aspects in each functionality is carried out.

The methodology employed for this tool will be asking some questions for all the functionalities that will be the same and some specific questions for each one. The general question will be stated in the following paragraphs, they also present a common point that will be helpful in the comparison process. The questions will be different for each aspect of the SWOT.

The opportunities are positive factors that can give an advantage to each functionality. In addition, they must be exploitable by the company. To identify the opportunities, it can be answered questions such as:

- What are the trends that the market is showing which you can complement?
- What thoughts does society have about it?
- What ecological and technological factors influence and if there is capacity to do so?
- Is it an innovation compared to the existing functionalities?

In the case of threats, it has to be taken into account that they may endanger the implementation of the functionality or to a lesser extent affect the installation due to an increase in size or other reasons. If it is identified a threat sufficiently in advance, it can be avoided or turned into an opportunity. To identify threats, it can be answered questions such as:

- What are the barriers to the development?
- Are there problems to recover the cost?
- Is the functionality affected by regulations or by current technology?

The strengths are all the capacities and resources that the functionality has to benefit from the opportunities and to be able to build advantages. In order to identify them, it can be answered questions such as:

- What new information does the functionality provide?
- What contributions do they make?
- What benefits does the functionality bring to each of the stakeholders?

- What are the benefits in terms of quality?

The weaknesses are the points that the company lacks, those in which it can improve. To identify the weaknesses from the company, it is possible to answer questions such as:

- What do our clients perceive as weaknesses of the functionality?
- How can they be improved?
- Can it be solved through another functionality?
- Does this functionality affect the operation of other functionalities?

3.3 COST BENEFIT ANALYSIS

The Cost Benefit Analysis (CBA) is a tool that provides information of the monetary appraisal but it also includes the society perspective. It analyses the cost produced for the implementation of a technology or the use of an asset and the benefits provided by them in economic terms and quantify the benefit of the society. Therefore, it is a very useful tool to check the viability of the implementation of a strategy, idea, technology among other aspects.

There are two main approaches in order to carry out the analysis, from the policy maker or from the technology adopter. In the case of the policy maker, the analysis is centered in the benefits for the society and the cost allocation is not crucial because it will guide the future regulation. Meanwhile, the technology adopter approach will stablish the basis for future investments. For this analysis, the approach that is going to be used is the technology adopter. The distribution system operator (i-DE) will be the technology adopter.

This process will be helpful in order to find all the factors that are affected by each functionality. It should be highlighted that all the functionalities will be analysed in the same process for the asset and benefit identification, although the computation of financial returns will be performed on each functionality independently.

The CBA will be done in 7 steps, which characterize the project, estimate the benefits and compare these benefits with the cost. Figure 6 states the different steps for the CBA analysis using the guidelines to conduct an CBA. These guidelines were done by the Joint Research Centre of the European Commission based on the EPRI (Electric Power Research Institute) methodology [12].

Figure 6. Steps performed in the Cost Benefit Analysis [12]

These steps will be adapted to the project because it is being analysed the functionalities that may be installed into the meter. So, the characterisation of the Project will be adapted because it will not analyse a technology or a device that can be installed. The project will review the different functionalities then it will present the asset that are necessary to install in the meter for its implementation.

When the functionalities are explained and the assets are stablished, it will be performed the benefit estimation. The estimation of benefit will be based in the benefit associated to each functionality and the monetary benefits for i-DE, although the benefits that will perceive the clients of the distribution company will be presented. The benefits for the manufacturer will be presented because they are proportional to the costs of functionalities implemented.

Among the benefits there are two types, those that are punctual and those that are cyclical. Cyclical benefits will bring profit to the company during the life of the meters, meanwhile the punctual benefit provide the earnings in the year of its installation alone. The analysis will take into account the period from the first installation till the end-of-life from a meter which will be installed in the last deployment.

The installation period that is going to be analysed is ten years and it will begin in 2023. The meter replacement plan is stated in Table 2. The useful life considered for each meter is 15 years, as it is stated in the ITC 155/2020. It should be noted that the useful life of the meters installed in 2016 and 2017 are extended 5 years, although for the analysis is considered that all the meters will have the same useful life. Therefore, the end of the project that is going to be analysed will be 2047 which implies the installation period plus the useful life of the meter.

Furthermore, the new clients that will be connected to the distribution network of i-DE will be considered. New clients are represented in the values of 2023 and 2024, which correspond to an increase of a one percent. This increase is stablished by the business as usual.

Year	*Installed meters*	*Total meters installed*
2023	110,000	110,000
2024	110,000	220,000
2025	122,470	342,470
2026	247,641	590,111
2027	809,159	1,399,270

2028	1,150,255	2,549,525
2029	2,161,249	4,710,774
2030	2,486,926	7,197,700
2031	2,483,457	9,681,157
2032	1,743,483	11,424,640

Table 2. Smart meters installed per year in the meter replacement plan

In the economic analysis of the functionalities there will be two cases. The functionalities that can be economically analysed and the functionalities that have not a direct financial return. The functionalities which does not provide a profit does not mean that are directly discarded because they could be imposed by the regulation or the benefit in some different tasks provides its validation.

In the case of the functionalities that are analysed it will be computed the Internal Rate of Return (IRR) and the Net Present Value (NPV). The NPV is an investment criterion that consists of updating the cashflows of an investment in order to know how much will be earn or lost with that investment. The formula for the calculous of NPV is stated in equation E. 1, on which I_0 stablish the initial investment, C_t are the future cashflows and r is the rate of discount.

$$E.\ 1 \qquad NPV = -I_0 + \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

The IRR is the return that an investment offers. So, it is the percentage of profit or loss that an investment will have for the amounts that have not been withdrawn from the project. It is related to the NPV because it is calculated by equalising to zero the NPV and the IRR is obtained. The formula of the IRR is specified in the equation E. 2. When the value obtained in the IRR is higher than the value of the discount rate, the earnings obtained will be higher. So, the sooner the functionality is installed, the benefits will increase.

E. 2 $$0 = -I_0 + \sum_{t=1}^{n} \frac{C_t}{(1+IRR)^t}$$

For the calculous of these parameters, it should be considered the values of the necessary data. The prices will be constant because they are imposed by the government. Concretely, the prices are stablished on BOE nº 312 from 28th December 2019, which specifies the regulation that will be used for the following years. The cost that are going to be used in the analysis are the cost specified in the tariff 2.0 without time discrimination. The discount rate is the interest rate employed in the project in order to determine the present value of a future cashflow. The value of the discount rate is aligned with EU wide benchmark set by the European Commission. All the data is specified in the

Coefficient	*Value*
Regulated cost of energy consumed (€/kWh)	0.044027
Regulated cost of contracted power (€/kW)	38.043426
Percentage for transmission and distribution (%)	40.33
Percentage for distribution (%)	≈ 76.00
Discount rate (%)	4.00

Table 3. Coefficients employed in the CBA analysis

3.4 KPI ANALYSIS

Finally, a KPIs (Key Performance Indicators) analysis will be carried out to evaluate the different functionalities from an objective point of view. With this analysis, the different characteristics that the functionalities may have will be weighted. Therefore, useful information will be provided to compare the different functionalities in a qualitative way. This analysis will be based on the knowledge obtained in the two previous analyses, since it requires a deep knowledge of the different functionalities.

The evaluation will be performed using five KPIs that will focus on the main features of the functionalities. In order to evaluate the contribution of the functionalities, different contributions will be presented with respect to the KPI. These KPI and the features are the following:

- KPI1: Improvement of security and quality of the communications

The feature that will be evaluated are the Reduction of risk due to non-allowed access into the meter. This feature aims to identify functionalities that improve the security of meters and their information. The second feature will be the Implementation of new communication technologies that allow to improve the communications between the HES-MDC and the meters. The third feature will be the introduction of a change into the communication configurations to have a more reliable communication system. Finally, if it will evaluate if the data transmission with the functionality will be made of a more efficient way.

- KPI2: New and enhanced client services

This KPI seeks the improvement or the creation of new services that the distribution company provides. For its evaluation, the following features are considered New client services that improve the management of energy consumption, new information supply that can be used by the clients or the distributor, reduction of outages or the number of instantaneous disconnections and the reduction of energy losses.

- KPI3: Enhanced power network operation

This KPI aims to verify the contribution that the functionalities have in the operation of the distribution network. Evaluating the following features the implementation of new mechanisms in order to support the balance between the demand and the generation, the supply of new information that can be used for the automation of the system, the reduction of work performed by operators or works on field and the improvement of the security from the supply and the facilities.

- KPI4: Effective support for power network evolution

Effective support for power network evolution KPI aims to obtain an alignment with the energy transition and the achievement of an environmentally friendly business. Therefore, it is tested whether the functionalities promote a system operation that aims to achieve Sustainable Development Goals (SDGs) or reduces emissions both in the form of waste by the distribution company (as the removal of stickers on the meter) or gases produced by the generators. For gas reduction, the introduction of DERs (Distributed Energy Resources) is evaluated.

- KPI5: Economic benefits

This KPI is the simplest and is divided into the provision of benefit to the customer and the distribution company in financial terms.

All the characteristics from the KPI will have a weighting to give more weight to the most important characteristics of the KPI. To carry out the analysis, some points will be established for each characteristic that will be multiplied with the weighting in order to have the final value of each functionality. When all the functionalities are computed, they can be compared.

Chapter 4. ANALYSIS OF FUNCTIONALITIES

In this chapter, it will be carried out all the explanation from the different functionalities and its analysis following the methodology proposed in the Chapter 3. The functionalities, as it has been stated previously, were specified due to the regulation, technical staff requirement, new technology that has to be implemented or certain benefit for a stakeholder.

In the following sections, it will also be stablished the person in charge of its introduction, the benefits related to the functionality. There are some functionalities without a quantified CBA due to its benefits which affect another stakeholder different from the distributor or the functionality is imposed by the regulation, so its implementation is compulsory.

4.1 FUNCTIONALITIES REQUIREMENTS

4.1.1 R1 – PHYSICAL MEASUREMENT OF THE NEUTRAL CURRENT

The implementation of this functionality supposes the measurement of the current that circulates through the neutral wire. This measurement will be carried out in the same way as the measurements of the currents flowing in the wires of each phase. In the case of three-phase meters, the vectorial sum of the currents in the different phases will be done to compare the difference in the currents. The comparison is performed following the equation E. 3.

E. 3 $$\sum_{i=1}^{i=3} \bar{I} + I_N = 0$$

As the measurements are not perfect, it has to be considered a deviation in the computation due to the inaccuracy of the sensors or the digitalisation of the analogue measurement. For this purpose, a partial deviation between the measurements will be allowed which is computed through a percentage that will be configurable. The analysis of the deviation will be carried out following the equation E. 4.

E. 4 $$abs\left(\frac{Module\ (\sum_{i=1}^{i=3}\bar{I}+I_N)}{Module(\sum_{i=1}^{i=3}\bar{I})} * 100(\%)\right) > (Configurable\ parameter)\%$$

This functionality is intended to detect differences between the phase current and the neutral current, detecting possible earth leaks or fraudulent consumption. If a difference is detected the meter will create a starting event and an ending event when the difference no longer occurs. In order to avoid false positives, the difference will have to occur during a minimum configurable time.

4.1.2 R2 – TEMPORARY OVERVOLTAGE PROTECTION

This function consists of measuring the phase voltage for opening the circuit-breaker when an overvoltage occurs. The cut-off will be made in the event of permanent overvoltages, but it will not be made in the event of transient overvoltages as lightning or maneuvers. For the implementation of the functionality, it is necessary the update of the trigger curve in order to change the triggering boundaries and the required time for disconnection.

The voltage will be measured even if the circuit breaker is open for a reclosing when the voltage returns to acceptable values. The reconnection will be made whenever the voltage is within a configurable minimum time. Furthermore, the reconnection will only be performed remotely. It will not be allowed the reconnection on local mode, so there is not another protection to avoid improper reconnections.

This functionality can be simplified by detecting the loss of the neutral wire. Measuring the voltage on each phase, it can be known the loss of the neutral if the voltage is higher over a fifty percent of the nominal value. In this case, the reconnection process is necessary a new event to register the end of neutral wire loss.

4.1.3 R3 – ISLANDING DETECTION

The islanding phenomenon is a new problem produced by the introduction of distributed generation. This phenomenon implies feeding of the loads by the self-consumption generators while these loads are disconnected from the electric network. It compromises the safety of the clients and their facilities, since the electricity supply can be affected by voltage fluctuations, supplies below demand or loss of synchronization among other hazards.

In order to detect the islanding phenomenon, the frequency measurement capability of the meter is introduced. The frequency would be measured by cycles, discarding the detection by voltage levels due to the imprecision in its measurement This functionality would detect if the frequency is within the admissible frequency range. The frequency range is delimited by a maximum and a minimum frequency that will be configurable.

4.1.4 R4 – IN HOME DISPLAY. INFORMATION FOR THE USER

This functionality is directly related to the European Commission recommendation 2012/148/EU. This recommendation establishes in article forty-two a flow of information from the meter to the customer.

Firstly, it stablishes the transmission of consumption data from the meter to the customer and to persons designated by the customer. The data transmission should be in real time to allow for adaptation of customer loads which provides an energy saving due to the adaptation. The data should be delivered securely to the client without compromising his privacy.

After that, the recommendation requires the update of the readings with a sufficient periodicity to serve in the adaptation of consumption. Establishing a minimum update of the information every 15 minutes.

The implementation of this functionality requires the installation of an in-home display in the property of the client. This device will communicate through PRIME 1.4 with the meter from the client. The configuration of the communication is stablished in the Figure 7.

Figure 7. Configuration from the communication between the meter and the In-Home Display [13]

4.1.5 R5 – Point-to-point remote management meter

This functionality proposes the integration of an internal or external communication modem, although an external modem is preferred. The modem will perform all the communications tasks that should be made through PLC. It will receive the communications through PRIME and will send them to the HES-MDC through wireless technology. The communication with the main system can be 2G or 3G, the use of 4G would be optional.

The modem must communicate through PRIME with the meter, so it needs a PRIME interface that must be tested by a competent laboratory. This should have light indicators to know the status of the meter, if it is transmitting, receiving communications or in standby.

4.1.6 R7 – Phase detection in PRIME 1.3

This functionality is intended to inform about the phase in which the single-phase meters are connected. This information can be used for load balancing of the distribution network, which will provide a reduction of technical losses. This functionality will be implemented in all the current meters that are installed and have PRIME 1.3.6.

Phase detection is based on the specification set out in PRIME 1.4. The detection uses the sending of a sub-header from the base node to determine the zero crossing and the time it takes. But it cannot be done from PRIME 1.3.6, as it has no sub-headers. Therefore, it uses the PHY_ZCT.get function, whose mission is to report the exact moment of voltage passing through zero, and the time elapsed between the last communication received or sent and that instant of passing through zero.

4.1.7 R8 – Meters with PRIME 1.4 compatibility

This requirement is intended to update the PRIME version, as there is currently version 1.3.6 and this functionality is intended to install version 1.4. This new version implies changes in the PHY and MAC layers of the protocol, providing an increase in robustness and performance. The transmission band will be extended to 500 kHz, it also improves the flexibility, security of transmission and the data rate is increased from 130 to 128.8 kbps. Therefore, several benefits are obtained from the installation of PRIME 1.4.

This version of PRIME must be interoperable with the previous version and therefore the counters must be plug and play. The operation will be evaluated by LEDs that will determine the status of communications. The reliability of this communication version must be good to reduce maintenance and communication failures.

4.1.8 R9 – Meter reclosing

The meter reclosing functionality attempts to perform an efficient reclosing of the service switch. This switch opens when the power demanded by the house is higher than the contracted power. Once the switch is opened, the circuit must be opened with the differential switch, so the meter will detect an infinite impedance since there are no loads connected.

However, the meter is not always installed next to the differential switch so there may be parasitic impedances affecting the measurement made for reclosing. These impedances are due to the presence of cables, filters or parasitic capacities. As no regulation has been determined for this purpose, each manufacturer perform a different method for reclosing. This functionality aims to establish a value for the impedance that has to be accomplished by all the manufacturers to avoid reclosing faults.

Although, it is being analysed another method which is the automatic reclosing when a certain time has passed since the service switch has opened.

4.1.9 R10 – SMART THREE-PHASE INJECTION

This functionality is intended to make three-phase meters capable of sending spontaneous events through all phases. It will allow sending information if one or two of the phases fails, since currently single-phase meters cannot send this type of event if the failed phase is on which they are connected.

For this purpose, a PRIME transmitter module will be installed that will have the capacity to exchange the injection between the three phases. The choice of the phase to carry out the transmission of events will be made by the meter and the chosen phase for transmitting will be the one with the best communication capabilities. To implement this functionality, a new injection module must be used and a different software must be used.

4.1.10 R11 – LOAD PROFILE WITH SHORTER INTEGRATION PERIODS

The functionality aims to record a new load profile with the information of the demanded energy in the meter. It is also called quarter-hour load profile because the power demand will be recorded each 15 minutes. Therefore, a more detailed profile will be obtained if it is compared to the currently registered profile that measures consumption each hour.

The minimum depth will be 2880 records (24x4x30 equivalent to 1 month of a fourth hour profile).

4.1.11 R12 – POWER LOAD PROFILE OF EACH PHASE

The phase load profile functionality performs the same function as the total load profile but carries out the measurements for each of the phases to which the meter is connected. Therefore, this functionality would only apply to three-phase meters, since single-phase meters are only connected to one phase and the measurement is made with the total measurement.

The measurements that are recorded are the active energy imported and exported and the reactive energy corresponding to the four quadrants. The minimum depth will be 2880 records (24x4x30 equivalent to 1 month of a fourth hour profile).

4.1.12 R15 – IEC 61000 STANDARD

This functionality is intended to apply the IEC 61000 Standard. The standard establishes the requirements that the meter should fulfil in order to reduce unintentional emissions. The reduction of emissions avoids the interference with PLC PRIME communications in the transmission medium. The standard focuses on the CENELEC-A communication bandwidth (3 kHz to 95 kHz) which is the bandwidth used by meters for data transmission.

4.1.13 R16 – V-I PROFILE REGISTRATION

The functionality is intended to record RMS measurements of average, maximum and minimum values. This recording will be carried out for current, voltage and power. The measurement will be performed hourly or daily, it should be configurable depending on the requirements of the operation. Furthermore, they will be made on each phase and the composed value.

The recording will be done in the supervisors and the meters. The minimum depth will be 2880 records (24x4x30 equivalent to 1 month of quarterly hour profile).

4.1.14 R17 – INSTANT VALUES AND CONNECTIVITY

This functionality is intended to record the instantaneous values of voltage, current, power parameters and their respective angles. Currently, these data are not recorded, although it could be accessed when it is required by the operator. This record will provide information about the state of the electrical network for the possible reduction of losses. The measurement will be made hourly, daily, on alternate days or as the operator stablishes, so the cadence of the record must be configurable.

The recording will be done in the supervisors and the counters. The capacity of the register will be 100 records. New OBIS codes will be included for those parameters that have not been previously defined in the Companion to name them when the specific data is required.

4.1.15 R18 – ROTATION SEQUENCE IN THREE-PHASE METER

The functionality R18 – Rotation sequence in three-phase meter is intended to describe the order of the phases to which the meter has been connected. The order of the phases is also known by the sequence of rotation of the meter. This information will be visible through the display and remotely by the system operator.

To carry out this description, a variable will be defined to identify whether the connection of the meter is in direct, inverse or unknown sequence. The unknown sequence identifier determines whether there is a phase failure.

4.1.16 R19 – ACTIVE DEMAND MANAGEMENT

The active demand programme consists on the participation of the clients in the balance of generation and demand of electric power. In order to carry out the participation, consumers reduce the power demanded from the power grid. This activity is beneficial to face demand peaks or the loss of any generator that cannot be faced by other generators.

The functionality intends that the meters are able to reduce the power consumed when it is necessary. The point in time will be determined by the operators and they will reduce the contracted power to a critical residual power that reduces the consumption. The value of the residual power will be between 0 and the contracted power and will be agreed by the user and the distributor whenever there is no regulation about it.

It will also be shown the possibility of making a flexible contract to limit the exported power generated in self-consumption facilities. The residual power must be agreed between the distributor and the customer. In this case, if the residual power is exceeded, a command will be sent to disconnect the generator.

4.1.17 R20 – VOLT-FREE CONTACT

The Volt-free contact functionality allows to send a cut-off command to the inverters, where the generation equipment is connected. This cut-off order will be sent by the network operators if necessary, for the disconnection of the generator. When the meter receives the disconnection command, a volt-free contact will open the contact to transmit the information to the inverter.

The meter must be aligned with the electromagnetic emission restrictions in order to ensure the communications with the HES-MDC.

4.1.18 R21 – USE OF A SUPERCAP FOR BATTERY REPLACEMENT

This requirement stablishes the replacement of the battery which feeds the meter in case of a failure on the power supply by a supercapacitor. The supercapacitor stores energy from the power grid, so it will deliver the energy to the meter in case of a power failure. The supercapacitor has the capacity to recharge itself when the supply is recovered. The energy stored by the supercapacitor allows the meter to be powered for 3 days, although this value can be extended.

The energy reserve in the meter is established in the ITC 3022 which is the current regulation regarding the control and status of the electric energy meters. But this functionality cannot be considered as a research, development and innovation effort because there some prestigious brands in the manufacture of meters that have meters with this technology (Itron, Elster…) and that have been installed in the USA.

4.1.19 R22 – NEW INFORMATION FOR REPORTS S05 / S05B / S04 /S27

This requirement is intended to make data transmission more efficient. For this purpose, it establishes a reduction in the reports that are currently transmitted because some reports, which are stablished in the meters, contain unnecessary information or information that does not provide any value. The reports to be reduced are the closing S04, daily summary S05 and ongoing S07. In the Figure 8 are specified all the fields that are sent when the closing is required. The elements that the requirement would like to reduce are highlighted in red, meanwhile the elements that are highlighted in green will remain.

IdRpt	IdPet	Version	Id	Id2	Ctr	Pt	Fhf	Fhi	Mx	Fx	AEa	AIa	R1a	R2a	R3a	R4a	AEi	AIi	R1i	R2i	R3i	R4i
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	0	20181001000000000S	20180901000000000S	6606	20180925081500FFFS	0	42567	275	0	0	3326						
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	0	20181001000000000S	20180901000000000S	6606	20180925081500FFFS							0	553	0	0	0	123
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	1	20181001000000000S	20180901000000000S	5278	20180907163000FFFS	0	21885	66	0	0	1372						
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	1	20181001000000000S	20180901000000000S	5278	20180907163000FFFS							0	221	0	0	0	53
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	2	20181001000000000S	20180901000000000S	6606	20180925081500FFFS	0	20681	209	0	0	1954						
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	2	20181001000000000S	20180901000000000S	6606	20180925081500FFFS							0	332	0	0	0	70
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	3	20181001000000000S	20180901000000000S	0	FFFFFFFFFFFFFFFFFW	0	0	0	0	0	0						
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	3	20181001000000000S	20180901000000000S	0	FFFFFFFFFFFFFFFFFW							0	0	0	0	0	0
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	4	20181001000000000S	20180901000000000S	0	FFFFFFFFFFFFFFFFFW	0	0	0	0	0	0						
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	4	20181001000000000S	20180901000000000S	0	FFFFFFFFFFFFFFFFFW							0	0	0	0	0	0
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	5	20181001000000000S	20180901000000000S	0	FFFFFFFFFFFFFFFFFW	0	0	0	0	0	0						
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	5	20181001000000000S	20180901000000000S	0	FFFFFFFFFFFFFFFFFW							0	0	0	0	0	0
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	6	20181001000000000S	20180901000000000S	0	FFFFFFFFFFFFFFFFFW	0	0	0	0	0	0						
S04	210559809	3,2	ZIV0004415879	SAG0166003918	1	6	20181001000000000S	20180901000000000S	0	FFFFFFFFFFFFFFFFFW							0	0	0	0	0	0

Figure 8. Closing report S04 with all the transmitted data [13]

4.1.20 R23 – LED FOR VERIFICATION OF IMPULSES

This requirement is intended to allow the disabling of the led status when it is on permanently through remote command. The counter has the led on permanently when the counter is stopped or the circuit is opened.

4.1.21 R24 – STAR+ CYBERSECURITY. NARROW BAND

This functionality aims to improve the security of the meters, so the efficiency of possible undue access to the meter will be improved. In this case, we intend to merge the Management and Firmware clients into a Local Security client. This client will have an independent key that can be modified remotely but never locally.

The keys can be reset to factory values and the established keys will expire after a time defined by the distributor. Incremental retry times for authentication failure, controlled by the counter, will be set to deal with brute force attacks.

4.1.22 R25 – TRIGGER POWER INFORMATION

This requirement is intended to provide information about the tripping of the service switch. For this purpose, an event will be created that can be read through the display and remotely if necessary. The information it will provide is the current at which the service switch has tripped.

4.1.23 R26 – REBOOT MODEM PRIME

The R26 – Reboot modem PRIME functionality will allow the reset of the PRIME communications module. This reset may be required remotely by the operator or locally. It will also have the option to be done in a programmed way from time to time or by means of an imposed algorithm that will detect if there are no communications during a period of time. Each of these ways to require a reset of communication can be disabled.

4.1.24 R27 – EXCESS CALCULATION

This requirement introduces the calculation of excess power over the contracted power. For this purpose, a comparison is made between the measured power and the contracted power as established in the equation E. 5. This calculation is made every 15 minutes and if the resulting value is positive, the total value of the excess is updated. Once the billing period is closed and the total value is stored, the values will be reset.

$$\Delta Ex = (|Pmeasured| - |Pcontracted|) \times 15/60 \qquad \text{E. 5}$$

To carry out this functionality, it is necessary to create new OBIS codes that define the excesses in both export and import.

4.1.25 R28 – EVENTS

Requirement R28 – Events is intended to obtain true and efficient information, thus eliminating possible false positives from meter readings. Therefore, events will be sent spontaneously as long as they meet a series of requirements and the meter is operating. When an event is recorded but the meter is not operational, it will be stored and will not be sent spontaneously.

In the case of undervoltage or overvoltage, when the voltage is recovered within the acceptable values, it will wait 30 seconds with the voltage within the acceptable margins to transmit that it has been recovered. Because it can happen that the voltage is recovered during a very short period of time and it is not acceptable to transmit that the voltage had been recovered.

4.1.26 R29 – DLMS EFFICIENCY

This functionality is intended to introduce a number of possibilities to increase efficiency in DLMS. These possibilities are:

- Selective access to instantaneous value reports, so that the number of values transmitted by the meter is reduced. At the moment, the complete report has to be received.
- Filtering of data in reports by active tariff periods.
- Increase of DC data packet size up to 512kb to reduce the number of transmitted packets.
- A concentrator-counter association will only be made when more than one report will be required in a short period of time. Avoiding the time needed to make a second association.

4.1.27 R30 – REGULATORY ADAPTATIONS

The regulatory adaptation of RD 244/2016 in Annex III establishes that the information provided on the meter's physical label can be replaced by a digital recording of the information. The digital storage should have the same guarantees as the physical label. The functionality intends to stablish this digital record. The information to be registered is:

- Installation date
- Final Uninstall Date (Actual date, not 15 years after installation date)
- Installer name
- Installer's address
- Installer VAT

4.1.28 R31 – RMS VALUES

This functionality aims to obtain the average RMS values of voltage, current and power for the regulation of on-load tap changers in the distribution network transformers. In the case of three-phase meters, the measurement will be performed on all three phases. The value will be an average of the last 5 minutes that have elapsed. This data is more representative of the status than the instantaneous value and therefore more effective for the change of the tap.

For its integration a new report must be created to require this data.

4.1.29 R32 – INSTANTANEOUS VALUES PROFILE

This requirement is a reduced version of requirement R17 – Instant Values and Connectivity. Therefore, it consists of a summarized time profile type with the values of a defined instant. In this case the depth of the record is 50 records and the measurement will only be possible once a day. The measurements recorded will be those of voltage, current and power together with their respective angles. The measurements will be their instantaneous values.

4.2 SWOT ANALYSIS

Once all the functionalities to be analysed with the different tools have been specified. It is going to be discussed the different SWOTs of the functionalities for their qualitative evaluation. The SWOT are going to be made independently for each functionality and it will provide the general point of view because it will explain the pros and cons considered the different point of views.

4.2.1 R1 – PHYSICAL MEASUREMENT OF THE NEUTRAL CURRENT

Strengths	*Weaknesses*
The functionality provides information about the balance of the currents between the phase current and the neutral current.	It will not detect a client which connects directly the phase and neutral wires over the meter.

It avoids the non-payment of energy (non technical losses) due to direct connection of the demand to the power supply avoiding the meter. It benefits all the clients, as they will not pay for these consumptions that are not paid. Reducing the losses of the distributors The distributor has a better knowledge of the consumption from the clients.	The information should be compared with the information of the current above the meter. This functionality/value is retrieved in the functionality R17 – Instant Values and Connectivity.
Opportunities	*Threats*
It is an innovation because nowadays the meters do not measure the neutral wire. The knowledge of the condition in the network related to the power demand is higher, so it can benefit the transactions in the power market. Frauds detected through neutral current versus phase current have a positive trend.	The measurement device for the neutral wire should be suitable inside the meter (single and three-phase). It is an increase in the cost per meter that will only affect to fraud detection and there must be enough detections to be feasible. People will try another method to avoid paying for their consumption.

4.2.2 R2 – TEMPORARY OVERVOLTAGE PROTECTION

Strengths	*Weaknesses*

This functionality will provide the information about the status of the voltage in the network. It can know if the voltage is between the limit or it has occurred an overvoltages (swells) or undervoltage (sags). In case of an actuation of the service switch, the reconnection will be performed when the voltage recovers the proper condition so the operation is reduced. The distributor will not pay the cost of damages in the installation of the clients and claims managements. The client electrical appliances will not suffer any damage. It is an insurance for the electrical installations of the clients.	It can be performed by the protections of the electrical installation. The client could have more power disconnections. The installation of the functionality requires a new service switch in the meter which can disconnect the load when an over-voltage occurs.
Opportunities	*Threats*
It can protect clients from another client that is producing an overvoltage in its installation. It facilitates the integration of distributed generation due to the protection of the clients in the same feeder if the voltage is increased. The amount of distributed generation is increasing.	The neutral wire could not reach the installation of the client. The users without self-consumption may not desire to be affected due to the problem caused by third parties.

The consumption of affected devices in the facilities of the clients will not be reduced.	The implementation of the functionality can affect in the NIEPI and TIEPI. It could appear new claims due to false positive that could affect in the welfare of the clients. An error can be performed in the connection of the meter, so the phase and neutral wires can be changed.

4.2.3 R3 – ISLANDING DETECTION

Strengths	*Weaknesses*
It provides protection to the installation in order to protect the installation that can suffer overvoltage and undervoltage or huge changes in the frequency.	It requires a computational work that is provided by the meter and it could do another task.
Ensure the connection of distributed generation in the installations owned by the clients of the distribution company.	This functionality will disconnect the generation unit in case of an outage and the users can demand the power use by their generator, so it can be seen as a disadvantage of the meter.
In case of an actuation of the service switch, the reconnection will be performed when the voltage recovers the proper condition so the operation is reduced.	It will not provide any economic benefit for the distribution company or the clients.

Opportunities	*Threats*
There is a trend of installation of the clients to install renewable energy sources at home.	This functionality is provided by the inverter which is connected to the generation units.
The goals stablished for 2030 by the European union requires the integration of RES.	The regulation will not impose this requirement to the meters.

4.2.4 R4 – IN HOME DISPLAY. INFORMATION FOR THE USER

Strengths	*Weaknesses*
It provides information to the users of their consumption in real time.	It requires a new communication module.
The users could know the best way to allocate their habits to reduce the electrical bill.	It should be monitored in order to maintain the quality of the system.
It is aligned to the European minimum recommendation.	It needs a display that will be installed in the facilities of the client and it can affect the appearance of them.
	The meter will be transmitting at least each 15 minutes so it can affect the communication with the HES-MDC if the PRIME version is 1.3.6 in the case of PLC is used for

Opportunities	*Threats*

It can be arranged an agreement with the supplier of the displays in order to achieve a secondary benefit.	It can also be achieved using the designed application that can be checked in the mobile phone or the computer, as it is done nowadays by i-DE.
The society is concerned about the electrical bill price and it could be used by older users because it does not need the access through internet.	If the cost is covered by the distributor, they will not be recovered because it is not stablished a financial return for this the new devices. The regulation neither stablish who will pay for the installation or the display nor how to do so

4.2.5 R5 – POINT-TO-POINT REMOTE MANAGEMENT METER

Strengths	*Weaknesses*
This functionality enables a communication between the HES-MDC and a certain meter. So, the communication will be ensured.	It requires a new external module which communicates through PRIME with the meter and wireless with HES-MDC.
The communications channel is available at any time, allowing the communication of events which reduces the time of failure.	It can be solved using a filter (less expensive) although it does not communicate all the time. Few customers will use this solution. Transmission noise can be removed using a filter

Opportunities	*Threats*
The improvement in telecommunication infrastructure facilitates this kind of communication.	The increase in the cost per meter is high.
The electromagnetic emissions are increasing and they affect the communication through PLC.	The society could not accept the increase of radiation that each meter would produce.
Now there is a GTP (Gateway Prime) solution that fulfil the requirements but it is quite expensive.	The 2G or 3G coverage should be enough to transmit the information.
	The modem could not suite in the location where the meter is placed.

4.2.6 R7 – PHASE DETECTION IN PRIME 1.3

Strengths	*Weaknesses*
The functionality provides the information on where each meter is connected.	It can be improved using PRIME 1.4 because the functionality is already implemented in the protocol.
The distributors will reduce its expenditures in tasks as maintenance or failures management due to the reduction of overvoltages when there is no balance.	The functionality has an end-of-life in the following years.

ARIADNA will not provide the algorithm to perform this task. The clients may be reduced the payments through the regulated costs a cause of technical losses.	It requires the implementation of the requirement R12. It requires a new firmware version also in the data concentrator side.
Opportunities	*Threats*
The balance of power over the cables can reduce the cross-sectional area of the cables. So, the use of cupper is reduced. There is a tool for the balance of loads on the secondary substation which is called GTS. The implementation is only through a firmware upgrade.	The meter should be perfectly synchronized for the phase detection.

4.2.7 R8 – METERS WITH PRIME 1.4 COMPATIBILITY

Strengths	*Weaknesses*
It will reduce the meters that cannot be reading because it avoids the noises in the channel and it provide robust modes of communication. So, it ensures the data transmission from the meters. It provides information of the meter on the phase where it is connected.	It requires a new communication module for the data transmission with PRIME 1.4 not only in the meter but also in the secondary substation. It needs the installation of a new microprocessor.

It improves the data transmission, acquiring an efficient communication channel. The transmission band with is higher compared to PRIME 1.3.6 and the data rate is also higher.	It requires the implementation of the requirement R12.
Opportunities	*Threats*
The integration of new generation units, quarterly load profile and demand response activities has to be monitored in LV network, so it will be necessary exchange more data and PLC bandwidth. The new functionalities required by the distributor needs an efficient and fast communication There is a tool for the balance of loads on the secondary substation which is called GTS.	The interoperability between the devices could be affected because all the data concentrators does not support PRIME 1.4. PRIME 1.3.6 is a mature solution with millions of smart meters. The PRIME 1.4 is quite new.

4.2.8 R9 – METER RECLOSING

Strengths	*Weaknesses*
It provides the ability for reconnection in all the installations. The functionality improves the calculation method of the infinite impedance which is a	The number of calls with this issue are not enough to support the functionality. Two methods of reclosing could be confused for the client.

zero impedance, avoiding distortions of long distances or disturbances. The clients will recover their power supply sooner in case of a disconnection. Furthermore, it will not see the problem if the client is not at home. The distributors will receive less claims due to this reason. The functionality will allow the introduction of any type of filter to remove noise from the network.	With the higher times of reclosing there will be safety issues with the client.
Opportunities	*Threats*
The society tries to find a solution before any claim through the mobile phone and it can be transmitted through the internet that they can reconnect the power. The energy measure is higher due to the reduction of time on which the demand is disconnected.	The manufacturers should interchange its knowledge in the determination of the zero impedance. The claims through the phone are not substantial and could show up new type of claims with reclosing method malfunctions.

4.2.9 R10 – SMART THREE-PHASE INJECTION

Strengths	*Weaknesses*

The communication will be performed in the cases when a phase or two is/are lost. The meter will transmit in the cable that has lower interferences or noises. The distributor will have a communication the majority of the time. The client will see this functionality as an increase of the quality of supply.	It requires a new interchangeable plc module. It will not offer a solution for the single-phase meters. There will not be many clients that has the benefit of this functionality, around an 8 % of residential customers and 40% of secondary substation do not have a three-phase meter.
Opportunities	*Threats*
The increase of manoeuvres, the distributed generation and the demand response require a reliable communication in order to transmit all the events that happens in the grid. A device could be installed into the secondary substation if there is not a three-phase meter installed.	The reduction of the failures can affect in the financial return of the functionality for domestic three phase customers with a fix meter rental price. The modules could not feet into the meter.

4.2.10 R11 – LOAD PROFILE WITH SHORTER INTEGRATION PERIODS

Strengths	*Weaknesses*

The information transmitted by the meters is higher.	The memory of the meter has to be increased in order to record the same period of time of data.
The condition of the loads is well known.	The grid operators have to deal with higher amount of data.
The distributors can improve the operation of the grid.	The data transmission will take four times more than the hourly load profile due to the higher amount of data.
The electrical bill can be reduced for the clients because the market offer will have lower periods of time. So, the RES could be better applied.	
I-DE will fulfil REE requirement in advance.	
The implantation cost is minimal.	
Opportunities	*Threats*
The transmission system operator of Spain wants to introduce these periods of integration.	The change in the regulation of actual load profiles registers.
The improvement for RES integration is seen in a proper way by the society.	There is already an hourly load profile that could be modified to quarterly. Maybe a second one for only this purpose is not necessarily

4.2.11 R12 – POWER LOAD PROFILE OF EACH PHASE

Strengths	*Weaknesses*
The knowledge of the demand is deeply. The distributor can take advantage of the data for another tasks as maintenance. The clients may regulate the bill in case they are connected to unbalance voltage. The distributor can improve the balance of the power network, so it will reduce the technical losses.	The installation of new meter will require a higher controllability. The grid operators have to deal with higher amount of data. The data transmitted is higher so the communication will require a longer period of time.
Opportunities	***Threats***
The reduction of losses will be seen good for the society. The balance of the system will improve the operation of the power network.	The memory has to be increase to register all the new data. In Spain, the regulation does not impose to have this information and the billing is with the total consumption.

4.2.12 R15 – IEC 61000 STANDARD

Strengths	*Weaknesses*

This functionality improves the reliability in the data transmitted by the meters in the CENELEC-A. It provides a series of test that can be performed in order to evaluate the data transmission. The distributor will receive all the data from the meters. Clients have a positive opinion about the reduction of emission. The distributor can improve the balance of the power network, so it will reduce the technical losses.	The evaluation of the laboratory is increased. The transmission could be performed wireless as requirement R5 stablishes.
Opportunities	*Threats*
The PLC technology is deployed in all the meters. There is a positive trend about the rate of communication, so the channel should not be interfered.	The meters that does not transmit continue without transmission. The regulation in Spain related to this topic could change because IEC creates a standard.

4.2.13 R16 – V-I PROFILE REGISTRATION

Strengths	*Weaknesses*

The meters will provide the values of the events that are registered, so the information can be analysed.	The data transmission will increase due to the increase of values associated to the reports.
The operation of other devices could use the information for its automation.	The operator has to deal with a higher amount of data.
The distributor will have an effective information of each client.	It can be performed by the functionality R31.
The clients can obtain this information for any claim and also the distributor can use the information to verify these claims.	The use case of this requirement is not clear for i-DE.
Opportunities	*Threats*
The PLC technology is deployed in all the meters.	The memory of the meter will be used by the functionality, so the capacity will be reduced.
The number of renewable generators is increasing that it should be controlled.	

4.2.14 R17 – INSTANT VALUES AND CONNECTIVITY

Strengths	*Weaknesses*
The meters will provide the values of the measured current, voltage and power.	The data transmission will increase due to the increase of values associated to the reports.

The operation of other devices could use the information for its automation. The distributor will have more information of each client, so the operation is enhanced. This information allows to locate possible leaks in the facilities of the client or in the property of the distributor. The clients will have a better quality of supply.	The operator has to deal with a higher amount of data. It can be performed by the functionality R32. The use case of this requirement is not clear for i-DE
Opportunities	*Threats*
The age of the installation is increasing, so it is useful to have more information. The participation of the people in the power grid is increasing. So, more information about them is beneficial.	The information will be stored in the meter, so the capacity of the memory is affected. The cost recovered of this functionality is perceived indirectly.

4.2.15 R18 – ROTATION SEQUENCE IN THREE-PHASE METER

Strengths	*Weaknesses*
It provides information to avoid the wrong installation of the meter. It reduces the error in the billing process due to the reduction of unregistered energy.	The installation requires a new task, so it takes more time. The repair of the error has to be made at the meter locally.

The functionality reduces the numbers of operations on the field that are carried out by subcontractors. All the clients will have the proper energy bill. This functionality is easy to implement.	
Opportunities	*Threats*
There are many meters that can be affected with the error than can be solved. It solves a problem that is not registered nowadays in the type 5 meters. The installer can check in the location that is perfectly installed.	The cost of the installation could be increased.

4.2.16 R19 – ACTIVE DEMAND MANAGEMENT

Strengths	*Weaknesses*
The clients can participate in the operation of the grid and support the energy transition. The distributor has another tool in order to have a balance between the demand and the generation and also perform a proper operation.	The client could not have the knowledge of the reduction of power although the distributor had sent a message to the user. The number of clients that has to operate in the system is really high in mesh system.

The demand can be reduced remotely using the meter. It provides the ability to reduce the contracted power. It provides a strong tool to prevent possible blackouts or congestions. The duck curve that is performed by the distributed generation can be managed because it could be flattened using this functionality.	The use case of this requirement is not clear for i-DE
Opportunities	*Threats*
There is an increase of generation and demand that may not be supported by the installed devices and can be used this functionality. Evolution of the peak load due to the increase of electrification, as the electrical vehicles which are going to be the future car fleet. The society can see this functionality as a way of contribution to the community. The objectives of European Union for 2030 is a huge driver for the use of this tool.	The client could not be at home when a reduction is performed, so all the load will be disconnected. There is no consumption in the location that is necessary to reduce or there is not an agreement at this location. Improvement of the efficiency of the loads, so the peak demand could be not affected and the functionality would provide a tool which is not necessary. The regulation continues without a proper definition for the financial return on this activity.

	Nowadays there is no a lack of energy supply.

4.2.17 R20 – VOLT-FREE CONTACT

Strengths	*Weaknesses*
It can provide the input for the disconnection of the generator. It facilitates the operation of the power grid in order to maintain the balance between the demand and the generation. The generator will not have to install a communication module.	The distributor has to deal with several generators that are installed. The client could not desire the disconnection of their modules and could see the functionality as a negative matter.
Opportunities	***Threats***
The Spanish regulation is following the path of this functionality so it may be imposed for T5 meters. The society will support the company due to the alignment for the introduction of RES generation. It is aligned with the European rules 2016/631.	The communication technology provided by the meter should be supported by the inverter. The communication with the meter could not be available/performed when the disconnection is required. There is not a clear regulation for the financial return of the activity.

4.2.18 R21 – USE OF A SUPERCAP FOR BATTERY REPLACEMENT

Strengths	*Weaknesses*
The use of a supercapacitor will reduce the waste produced by the batteries that energize the meter in case of an outage. The supercapacitor can be recharged from the network. This functionality can avoid the reduction of life performed on the battery due to the storage period that occurs between the date of the manufacture and the date of installation and the installation. The supercap fulfil RD1110/2007 storage requirement.	It is difficult to choose a duration of energy that the supercapacitor will provide. The clients may not agree in the payment for the recharge of the supercapacitor.
Opportunities	*Threats*
It will reduce the ecological impact of the waste produced by the meter. The technology of supercapacitors has been studied and developed over a long period. There are some brands that use the same technology in different countries.	The dimensions of the supercapacitor could be higher than the internal space of the meter. The increase of energy storage in the supercapacitor incurs in higher prices.

4.2.19 R22 – NEW INFORMATION FOR REPORTS S05 / S05B / S04 /S27

Strengths	*Weaknesses*
The new report creates an efficient report without unnecessary information. The data storage of the HES-DC is reduced because some data is not transmitted. The functionality affects to the reports that are usually required, so the use communication channel is reduced. S05/S5B reports are sending everyday	The computation of the data in data concentrators is affected. An algorithm can discard the data that is neither required nor valuable.
Opportunities	*Threats*
The increase of data required by the experts require storage and a channel for communication. The number of meters used in the system is increasing, so the duration of communication in the DC will increase. T5 customers could take advantage of it (10.7 million customers)	The communication with meters that are not delivering information will not be solved. The capacity of the memories is increasing.

4.2.20 R23 – LED FOR VERIFICATION OF IMPULSES

Strengths	*Weaknesses*

The client will be more secure against possible thefts because the led will be off when there is no consumption. The distributor will not receive phone calls asking about the Led. The consumption of the Led is avoided when there is not consumption.	In a verification of the meter, the supervisor cannot check with a quickly visual inspection if the meter is alive.
Opportunities	*Threats*
The relation between client and distribution company could be improved.	Once this new solution will be known the thief could check whether the display blinks or not.

4.2.21 R24 – STAR+ CYBERSECURITY. NARROW BAND

Strengths	*Weaknesses*
The functionality implies an improvement on the security of the meter.	The functionality implies in more workload for the staff of the distribution company.
The clients that can access to the meter are reduced in order to be more efficient.	The subcontractors have to deal with a new system for the access to the meter.
The possibility of fraudulent access is reduced.	The HES have to exchange the optical passwords with the MDM in almost real time.

The optical port password is more secured and the distributor will only know the passwords all the time.	
Opportunities	*Threats*
The advances in security are appreciated by the customers It is more aligned with RD1110/2007 using higher security. The HES will manage optical port passwords.	The new system has to be interoperable with all the devices of the subcontractors.

4.2.22 R25 – TRIGGER POWER INFORMATION

Strengths	*Weaknesses*
The meter will register the power whenever the service switch operates. The client could access to this information in order to adapt the contracted power. This functionality will reduce claims by the clients because the information is accessible.	The system has to register a new information. It can be done with the information of the maximeter.
Opportunities	*Threats*
The clients will have a closer relation with the distribution company.	The number of claims due to this matter is almost zero.

	The regulation does not impose this register.

4.2.23 R26 – REBOOT MODEM PRIME

Strengths	*Weaknesses*
This functionality will reduce the change of meters and avoid the change of meters that are not damaged around a 15-20%. The distributor can recover the communications with meters that are not transmitting. The functionality will not affect to the clients.	The meter has to receive the reboot signal and it could be affected if the meter does not have communication. Maybe sometimes the modem reboot is not needed and a total reboot should be performed
Opportunities	*Threats*
The number of meters without communications is high. The clients will have a positive view of the distributor if they reduce the meter that are removed.	The reset of the supply of one meter does not affect on the quality of the supply. It has to be very well specified (consumption must not be affected) and implemented by all manufacturers

4.2.24 R27 – EXCESS CALCULATION

Strengths	*Weaknesses*

This functionality provides the calculous of the excess above the contracted power. The time of excesses will be registered. The distributor will have the data that should be provided to the retailer about excesses	The excesses are calculated each 15 minutes but it can be required a shorter integration period by the clients. The clients may not agree in the payment of this new factor. Now the excesses will be calculated by the MDM with the hourly load profile.
Opportunities	*Threats*
The regulation is aligned with the functionality Circular 3 of 2020.	There is an increase of the calculous performed by the meter.

4.2.25 R28 – EVENTS

Strengths	*Weaknesses*
The transmission of events will be performed transmitting the beginning and the end of the event. The end of event will be sent after it has fulfilled a series of requirements, avoiding false positives. The distributor will have an enhanced information of the events.	The end of the events has to be checked all the times before it has delivered.
Opportunities	*Threats*

The increase of the network and the introduction of new systems will require more information for its operation. The meter will calculate this value.	The computational workload could be reduced in another tasks. A new report S4E must be integrate in the HES and data concentrators only for T3 customers.

4.2.26 R29 – DLMS EFFICIENCY

Strengths	*Weaknesses*
The increase of efficiency of DLMS will benefit the data rate received. The data from the report can be accessed independently. The association between the DC and the meter will be one for several reports. The packet size will be increased The distributor will have an efficient data transmission	The data can be accessed in the traditional way although it takes more time.
Opportunities	*Threats*
The increase of meters installed require more time in order to perform an analysis but the functionality can be a huge benefit for it.	The DC has to deal with the increase of packet.

There are many unnecessarily data exchange every day.	There is not a direct financial return with the functionality. A new object has to be included in all meters. New STG-DC implementations.

4.2.27 R30 – REGULATORY ADAPTATIONS

Strengths	*Weaknesses*
The physical sticker will be removed from the meter. The system will have a register of each meter. The clients could access to the same data if they want to do it. The distributor can access to the data without reaching the location where the meter is located.	The register could not be checked through the display. The customers don't usually check the meter display. This information could also be included in the app.
Opportunities	*Threats*
The regulation allows the implementation of this functionality. The client will have a positive view of reducing material used by the meter.	The time required to introduce the data could be increased. Legislation is not clear whether HES information is enough or it must be in the meter.

4.2.28 R31 – RMS VALUES

Strengths	*Weaknesses*
The functionality will provide information about the RMS values of the current, voltage and power. It facilitates the automation of different devices. The distributor will have a better knowledge of the power network. There is actually a use case in I-DE for this requirement	The distributor has to deal with more information.
Opportunities	*Threats*
The increase of distributed generation and demand response require more information for the operation of the network. It can be performed the task of the functionality R16.	The measures will be increased so the sensors will increase its workload. The data will require a space in the memory of the meter.

4.2.29 R32 – INSTANTANEOUS VALUES PROFILE

Strengths	*Weaknesses*

The meter will register the instant values of a specific time. So, it can be analysed the condition of the consumptions. It can be used for the automation of the devices. The functionality is easy to implement There is a possibility to locate leaks in the facilities.	The operator has to perform an evaluation process to take advantages of the information.
Opportunities	*Threats*
The introduction of distributed generation and demand response will need more information of the status of the power network. The relation between the distributor and the client is improved because they will now more details about their consumption. It can be performed the task of the functionality R17.	The memory will have to increase the data storage.

4.3 CBA ANALYSIS

In this section is going to be presented all the Cost Benefit Analysis performed in the different functionalities. As it was stated in the Explanation of the Method, there are some conditions that will be common to all analyses such as the discount rate.

Firstly, it will be made a distinction between the functionalities that require a hardware and software implementation from those that only require a software implementation. The functionalities which requires a hardware are specified on Table 4. The cost of the hardware implementation is based on the installation of meters. For this, we have computed the total cost of the hardware and applied a percentage each year of meter installation according to the number of meters installed.

Functionality	*PLC communication module*	*Measurement module*	*Service Switch*	*GPRS-PLC modem*	*Battery module*	*Volt-free Contact*
R1 – Physical measurement of neutral current		X				
R2 – Temporary overvoltage protection			X			
R5 – Point-to-point remote manage of the meter				X		
R8 – Meters with PRIME 1.4 compatibility	X					

R10 – Smart Three-Phase Injection	X					
R20 – Volt-free contact						X
R21 – Use of supercap for battery replacement					X	

Table 4. Hardware required by the analysed functionalities

The cost of the functionalities which do not require the implementation of hardware will incur in the cost of development and installation of the software. This cost will be paid in the first year of deployment because it should be developed for the first meters installed. However, there are functionalities which do not provide an economical benefit so they will not be analysed with this method such as the islanding detection (R3).

It must be established that the costs considered in the whole analysis are costs of implementation considered by a certain manufacturer. Therefore, the consideration of other manufacturers may vary. In addition, the income considered are estimates that may suffer changes due to external elements that have not been considered in this analysis.

After this consideration, it is going to be stated the analysis of the functionalities and how it is performed.

4.3.1 R1 – PHYSICAL MEASUREMENT OF THE NEUTRAL CURRENT

This functionality requires the new hardware for the measurement of the current flowing in the neutral wire. The total cost of all the hardware is approximately 28.5 millions of euros and the cost of implementation is 15 thousands of euros. The benefits earned with this functionality are the fraudulent consumptions detected due to the unbalance between the phase and neutral current. This type of consumptions is detected over the irregularity F229 (i-DE code) and they present a positive trend.

The evolution of fraudulent consumption has been made using a logarithmic curve to compute an increase without a disproportionate increase. But the detection is evaluated following the percentage of the installation, so the benefit will increase in the years. The reason for this assumption is the error detection, all the fraudulent consumption will be detected when all the meters are installed.

Performing a computation of the future cashflows of earnings and expenditures which is represented in Figure 9, the IRR obtained is 5 % and the NPV has a positive value. As the IRR is higher than the discount rate which is a 4 %, the functionality should be installed as soon as possible in order to obtain the major benefits. The NPV becomes positive from 2045 and it is the reason for the reduction on the installation period.

Also, it should be noted that the benefits that have been computed have been realized based on a logarithmic trend of previous yearly data. The data has been obtained from the database of the distribution company. So, the profit is increasing over time.

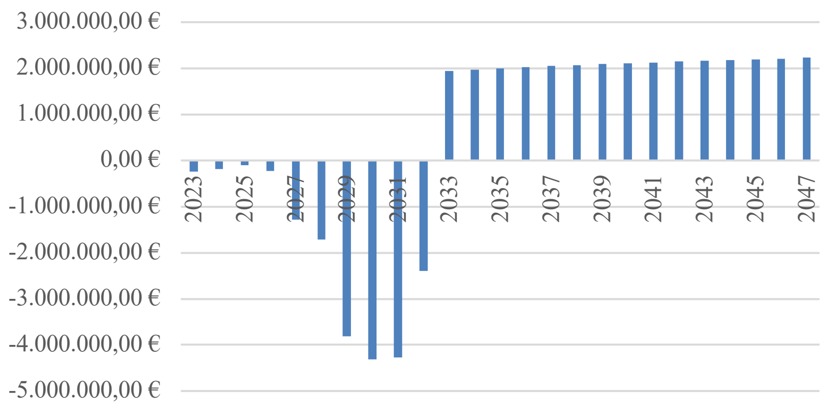

Figure 9. R1 – Physical measurement of the neutral current cashflows

4.3.2 R2 – TEMPORARY OVERVOLTAGE PROTECTION

This functionality has a hardware cost associated with the change of the service switch that will have a total value of approximately 35.6 millions of euros over the installation period. But the benefits that are obtained from its implementation are:

- The reduction of users affected by surges originating in the network. It will avoid the costs that occur when changing users' equipment that has been damaged in the surge. The calculation of this benefit is obtained by multiplying the average cost of an affected contract by the number of affected contracts per year.
- The remuneration for the energy that the equipment would consume if it had not broken down. Because, they stop consuming when they are damaged by the power surge. The consumption is obtained from the average consumption of a household appliance and the number of appliances affected in an overvoltage. The average consumption of a domestic appliance in Spain is 0.48 kWh according to the data of the summary of the consumption of the residential sector in Spain [14]. The value earned by the distribution company of each kWh is computed multiplying the consumption by the cost stablished in Table 3.

Carrying out all the cashflows which are stablished in the Figure 10, the IRR that is obtained is -5 %. The NPV is also negative, so the implementation of the functionality is not feasible for the distribution company in financial terms. From the point of view of the client, it would be a good functionality because it ensures the protection of their facilities.

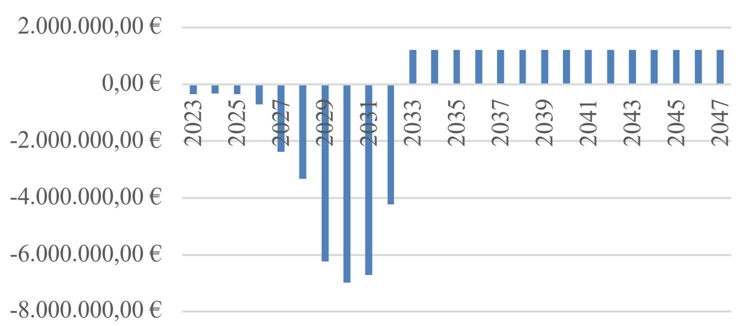

Figure 10. R2 – Temporary overvoltage protection cashflows

4.3.3 R5 – POINT-TO-POINT REMOTE MANAGEMENT METER

R5 – Point-to-point remote management meter functionality allows the communication of HES-MDC with meters that are not read for more than 30 days. Although the trend of unread meters is decreasing, there are currently 55 thousand unread meters. Assuming that the installation of the modem is done on 25 thousand meters, these meters will be read remotely. Therefore, the cost associated with reading on-site would be avoided. The local measurement according to the regulation is required to be at least each two months in the case that there are no remote measurements [15]. Furthermore, the installation of the filter does not incur in any cost due to operation or maintenance because it is a plug and play modem.

The cost of the local measurement is approximately 5 euros for each visit of the subcontractor. Therefore, the multiplication of this cost by the number of meters that are read again and the six times that must be done, will provide the benefit perceived by the functionality. But this benefit will evolve following the installation of the meters.

Once the costs and benefits have been analysed, the cash flows shown in the Figure 11 are obtained. With these cash flows it can be estimated that the IRR which is 16 %. So, as it was stated previously the functionality should be implemented as soon as it is installed, a major benefit will be acquired.

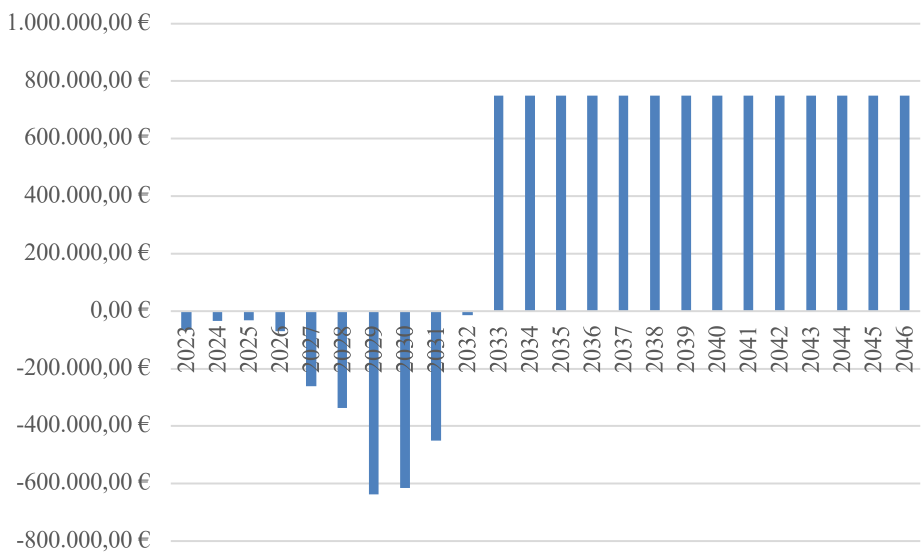

Figure 11. R5 – Point-to-point remote management meter cashflows

4.3.4 R7 – PHASE DETECTION IN PRIME 1.3

This functionality, as it was stated previously, will provide information about the phase to which each meter is connected. The cost is only derived from software development so it can be classified as a lower cost. It should be noted that this functionality requires the information on the load profile of the phases to balance the loads per phase in the most efficient way. Therefore, the costs of the two software developments must be counted.

The benefits are originated from the technical losses, which would be reduced. The losses detected by i-DE in the year 2019 reached 6.50 percent of the total energy distributed. This value is composed of commercial and technical losses, but it can be estimated that the percentage of commercial losses reaches 20 percent. Having the value of technical losses if this functionality is introduced, i-DE estimates that it could reduce the value of technical losses up to 10 percent [16].

It should be taken into account that the benefit provided would be a one-time benefit because once the network is balanced the reduction of losses will not be obtained again. Even if the benefit is obtained only one time, the benefit provided is much greater than the cost and can be seen in the Figure 12. Therefore, it can be said that it is a feasible functionality and should be installed.

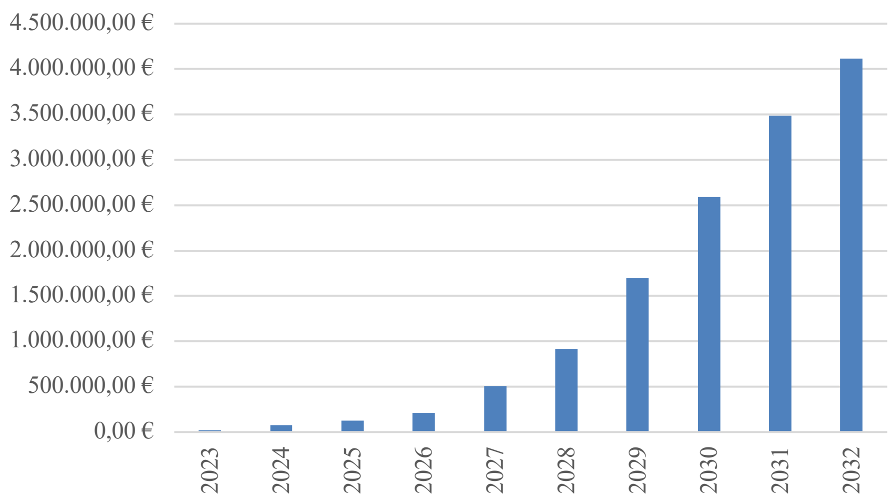

Figure 12. Functionality R7 – Phase detection in PRIME 1.3 cashflows

4.3.5 R8 – METERS WITH PRIME 1.4 COMPATIBILITY

Meters with PRIME 1.4 functionality implements a new communications protocol that allows greater data transmission, use of more channels for transmission among others benefits. However, the most remarkable benefits are the benefits that have a direct financial return. These are the benefit obtained due to the information of the phases in which the meters are connected or the recovery of communications with meters which it was previously impossible to communicate.

The cost required to implement this functionality is broken down into a software development cost and a cost for all the new communication modules. The cost of implementation amounts to 100 thousand euros, while the cost of each module will increase the price of each meter. In this analysis we have assumed a cost of 3 euros for the first 100 thousand meters, since they will be prototypes that have not been tested on the network. But once they are tested and functional, the price of the module is estimated to have a reduction and the module will cost 2.50 euros.

For the calculation of the benefits, the analysis previously stated in R7 – Phase detection in PRIME 1.3 has been considered for the benefit associated with the load balance because the phases to which the single-phase meters are connected will be known. On the other hand, the recovery of readings will reduce the cost that had to be paid for doing the reading in a face-to-face way. The resulting saving is 5 euros per on-site measurement, which must be taken six times per meter per year. Finally, it is considered that the meters that recover the reading will be 25000.

With this information we proceed to make the economic analysis that provides the cash flows shown in the Figure 13. These cash flows present an IRR of 9 percent. This certifies the viability of the installation of the PRIME 1.4 protocol.

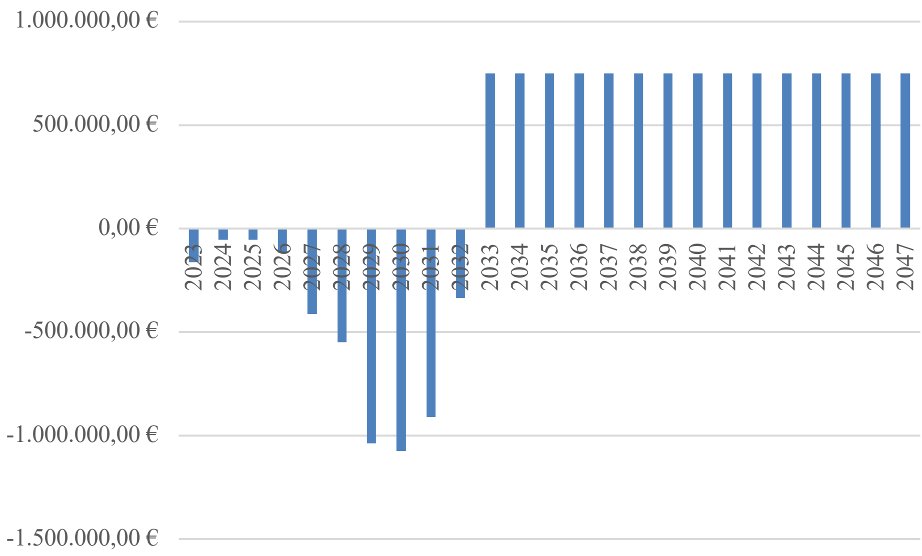

Figure 13. Functionality R8 – Meters with PRIME 1.4 compatibility cashflows

4.3.6 R9 – METER RECLOSING

The functionality of meter reclosing will be evaluated on both aspects if an automatic reclosing is performed after a certain time or if a new method for calculating the infinite impedance is available. The cost of this functionality is a software cost, so it must be implemented in the first year.

To obtain the number of events that will benefit from this functionality, the numbers of the work orders 273 and 275 are obtained, which are the ones that do not require the change of the equipment. From them it is established that 20 percent can be solved with the automatic reclosing and only 10 percent with the new impedance calculation since the normal thing would be to reclose if it is required.

Having the number of events and the cost that requires the subcontractor to perform this operation can be obtained the benefit that would bring the installation of the functionality. This benefit will last over time since the work orders will be reduced whenever the functionality is installed. Carrying out all the cash flow from both aspects, a positive NPV is obtained in both analyses, therefore the functionality should be installed. It does not matter the way that is installed because both are feasible.

4.3.7 R10 – SMART THREE-PHASE INJECTION

The functionality of the intelligent three-phase injection allows to know if any of the phases has been lost, because the single-phase meters connected to this phase will not be able to transmit the event. But with this functionality, the three-phase meter will send the event through the phase which has better communication. Therefore, it is possible to reduce the SAIDI (System Average Interruption Duration Index) which will bring a benefit to the distribution company.

The cost is composed of a software development cost and the cost derived from the new communication module that will be installed in the three-phase meters. It should be taken into account that the three-phase meters connected to the distribution network are eight percent of the total meters. This communication module is new and its cost is not known precisely, so an estimation of two costs has been provided by the manufacturers. In this analysis the most expensive cost will be presented because if it is viable, a lower cost of the module will be more feasible.

A reduction of the SAIDI can bring different benefits according to the area where the secondary substation is located, distinguishing between urban, semi-urban, concentrated rural and dispersed rural areas. Their values will be harmonised using an average to obtain the common value for all areas. This value is established in euros per reduced kVAh and the reduction will be carried out in one phase of a secondary substation that has three-phase meters. Only 60 percent of the secondary substations have meters of this type.

The average contracted power of a secondary substation is 606 kW in i-DE. The active power has been changed to apparent power using of a power factor of 0.85 because if it is higher it will be more beneficial. Furthermore, it is estimated that failures will be detected in 10 percent of all secondary substations.

Finally, it has to be considered the time that this functionality would reduce. In this case the time reduction is considered to be one hour, as this would be the time required by the clients to contact the customer service and verify this fault.

Performing all the calculous for the cashflows, the Figure 14 is obtained and the IRR is 22 percent. So, the implementation of the functionality is justified.

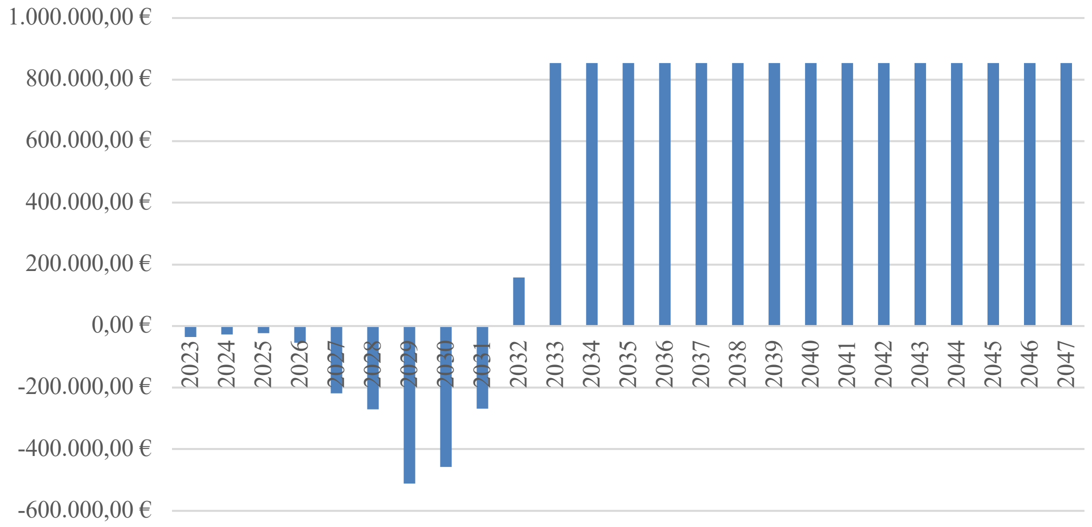

Figure 14. Functionality R10 – Smart three-phase injection cashflows

4.3.8 R18 – ROTATION SEQUENCE IN THREE-PHASE METER

This functionality is intended to obtain information on how the meter is connected to the phases. This information can reduce the wrong readings made by the meters due to an inversion in the intensity.

Currently, the meter type 5 is a direct measurement meter because it does not use transformers to make voltage or current measurements. Therefore, only an irregularity can be given in the inversion of currents, but in other types of meters the possibility of voltage permutation should also be taken into account.

In order to evaluate the number of meters that could be affected by the inversion of currents, an extrapolation of the cases that have been obtained in meters installed at high voltage will be made. In the case of high voltage meters, it can be stated that 0.60 percent were affected by this anomaly.

To obtain the annual consumption that has not been billed, 60 percent will be discounted from the annual consumption of the affected meters. Because this percentage is the error produced when a current inversion is made. The average consumption of a single-phase meter is 10520.63 kWh and the average consumption of a three-phase meter is 17520.63 kWh according to the IDEA (Institute for Energy Diversification and Saving) report [14].

With this information, the energy that will be recovered for billing would be calculated and the cost of the functionality that only affects the software development could be assumed. The cash flows associated with this functionality can be seen in the Figure 15. It must be taken into account that the benefit will only be obtained once, since once obtained they will not be deducted again.

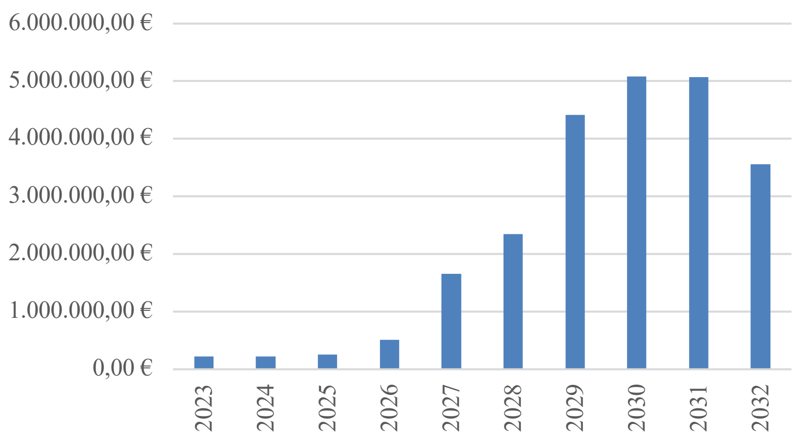

Figure 15. Functionality R18 – Rotation sequence in three-phase meter cashflows

4.3.9 R19 – ACTIVE DEMAND MANAGEMENT

Active demand functionality is a benefit of the operation due to the possible reduction of demand. But currently, due to the reduction of demand by the introduction of more efficient consumption and the integration of renewables, its introduction is more uncertain. Although in the future it may be possible to introduce it to facilitate the flexibility of the operation.

The cost of implementation is due to software development, which is a minimum cost. But the benefits that can be obtained from the operation of this functionality are uncertain for the distributor as well as the benefits that the client would obtain. Since, the regulation does not establish if the client will receive a benefit for its use or for the capacity that it can contribute in the reduction. Nor does it stipulate the remuneration that the distributor would receive for using this capacity.

Therefore, a cost-benefit analysis of this functionality would not be reliable.

4.3.10 R20 – VOLT-FREE CONTACT

This functionality is intended to install a contact in the meter to send a signal to the generators that are used in self-consumption. This contact will be an increase in the cost of the meter but it will not provide any direct benefit to the distribution company. However, the regulation is aligned with the introduction of this contact, so it is necessary to have this contact installed in the meter.

On the other hand, not all customers of the group have these generators for self-consumption. The most efficient way to implement the contact would be the installation of meters with this contact where necessary and install in the rest of customers simple meters.

Carrying out an analysis according to the PNIEC developed by the Ministry for Ecological Transition and Demographic Challenge, in which the gigawatts of renewable energy to be installed in 2025 and 2030 are established, the installations that i-DE will have of this type of meters can be established. Furthermore, knowing their cost, it is also possible to establish the associated annual costs. This information is presented in the Figure 16. Functionality R20 – Volt-free contact cashflows.

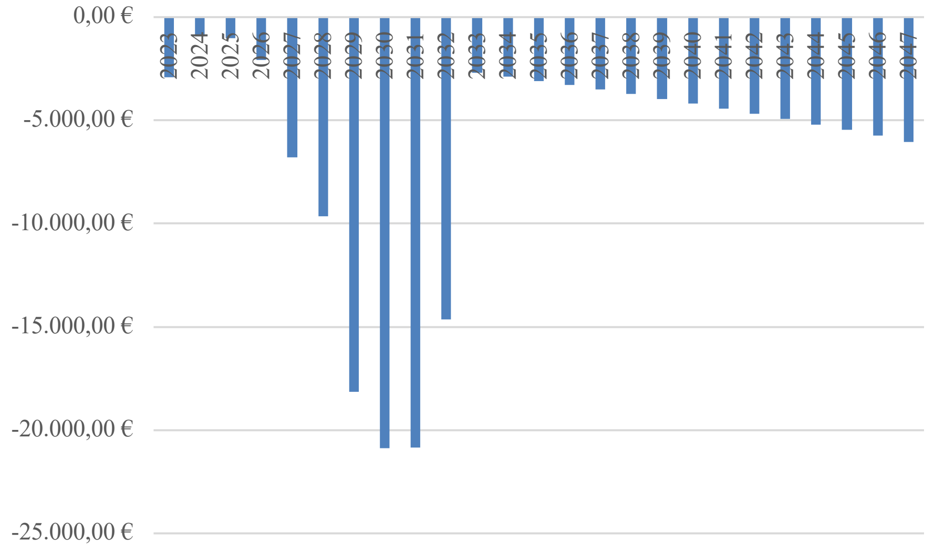

Figure 16. Functionality R20 – Volt-free contact cashflows

4.3.11 R21 – USE OF A SUPERCAP FOR BATTERY REPLACEMENT

In the case of the use of a supercapacitor it is not necessary to make an analysis since the cost of the meter with supercapacitor or with battery is the same. For this reason, it is not necessary to carry out the development of a CBA. The cost of implementation must be taken into account, but it is negligible compared to the earning derived of renting the meters.

But it should be noted that the synchronization in the connection when you have a supercapacitor must be done accurately to ensure that no data is lost from the billing.

4.3.12 R26 – REBOOT MODEM PRIME

The Reboot modem PRIME functionality will allow a reset of the communications without affecting the customer. But this functionality also allows to reduce the repositioning expense in new meters, since currently the meters without communication:

- The meter is changed.
- A filter is added.

- The meter is changed and the filter is added.
- it is restarted by disconnecting the supply.

Therefore, a restart of communications would be related to the disconnection of the supply. The benefit of a successful restart would be the elimination of the cost of meter replacement and the cost of the measurement. If the meter is reset but does not transmit, only the replacement cost is eliminated. These benefits could face the cost of implementing the functionality, since software development has a minimum cost.

4.3.13 OTHER FUNCTIONALITIES

The rest of the functionalities that have been identified in the section Functionalities and that have not been evaluated in the CBA analysis, as it is stated above, will not be analysed because they do not have a direct financial return. In these cases, the installation of the functionality can be supported by the operational benefit which presents or the improvement of the quality of the services that the clients will have.

For instance, the implementation of R23 – Led for verification of impulses functionality will provide a better relation between the clients and the disrtibution company. Because it was a desire proposed by the clients to swtich off the led that appears when the consumption in the installation is zero.

4.4 KPI ANALYSIS

The calculations of all the functionalities were made to obtain the functionalities that contribute more according to the method of KPIs. These calculations obtain different contributions that are stablished on the Table 5. Marks from each functionality on the KPIs.

Functionality	*KPI 1*	*KPI 2*	*KPI 3*	*KPI 4*	*KPI 5*
R1 - Physical measurement of neutral current	0	2,1	0	0	4,8

R2 - Temporary overvoltage protection	0	2,7	3,7	1,7	4,8
R3 - Islanding detection	0	1,2	1,6	1,7	0
R4 - In Home Display. Information for the user	3,4	0	0	0,4	2
R5 - Point-to-point remote manage of the meter	4	1,2	0,8	0	4,2
R7 - Phase detection in PRIME 1.3	0	4,4	0,6	0	5
R8 - Meters with PRIME 1.4 compatibility	6,6	4,6	0,8	0	5
R9 - Meter reclosing	0	4,4	2,5	0	5,2
R10 - Smart Three-Phase Injection	1,6	4,8	1,4	0	5,6
R11 - Load curve with shorter integration periods	0	2,6	0,8	0	5,2
R12 - Power load curve of each phase	0	3,4	0,8	0	3,6
R15 - IEC 61000 Standard	1,4	0	0,8	0	0
R16 - V-I profile registration	0	2	2,5	1	1,8
R17 - Instant Values and Connectivity	0	2,6	2,5	1	3

R18 - Rotation sequence in three-phase meter	0	2,5	1,5	0	3
R19 - Active demand management	0	1,2	2,8	5,1	4,8
R20 - Volt-free contact	1,6	0	2,4	4,5	1,2
R21 - Use of supercap for battery replacement	0	0	0	0	0
R22 - New report S05 / S05B / S04 /S27	3,6	0	0	0	0
R23 - Led for verification of impulses	0	0	1,6	0,4	1,2
R24 - STAR+ Cybersecurity. Narrow band.	1,8	0	1	0	1,8
R25 - Trigger power information	0	1,2	0	0	0
R26 - Reboot Modem PRIME	0,8	0	0,8	0	3,6
R27 - Excess Calculation	0	1,6	0	0	2,4
R28 - Events	2,8	1,6	0	0	3
R29 - DLMS Efficiency	4	0	0,8	0	3
R30 - Regulatory adaptations	0	1,4	0	0	3
R31 - RMS values	0	2	2,3	0	1,8

R32 - Instantaneous Values Profile	0	2,6	2,3	0	3

Table 5. Marks from each functionality on the KPIs

Performing an average on the marks of each KPI, it can be obtained a general value of the KPIs that can order the importance of each functionality. The evaluation is made on 10 in each KPI but it must be stated that it is very difficult to reach the maximum mark due to the different characteristics that are evaluated, which are stablished on KPI analysis. Therefore, very low scores are obtained and it must be established that a score of 7 can be taken as a very good value and 3.5 as acceptable.

It can be said that the functionalities that stand out are the following:

- R8 - Meters with PRIME 1.4 compatibility
- R19 - Active demand management
- R10 - Smart Three-Phase Injection
- R2 - Temporary overvoltage protection
- R9 - Meter reclosing

These functionalities stand out for their different contributions to the operation of the distribution network. Therefore, they are particularly relevant compared to other functionalities. However, this aspect does not mean that the functionalities provide the same benefit for the network. The Figure 17 shows the contributions of the functionalities with the best results in this analysis.

The R8 - Meters with PRIME 1.4 compatibility functionality improves communications and provides new services to customers due to the new communication capacity that the network would have. The R19 - Active demand management functionality facilitates the operation of the system since it allows to reduce loads, so it is also aligned with the SDGs. Finally, the R10 – Smart three-phase injection shows a reduction in time in the failures that occur in the network due to its improvement in communications.

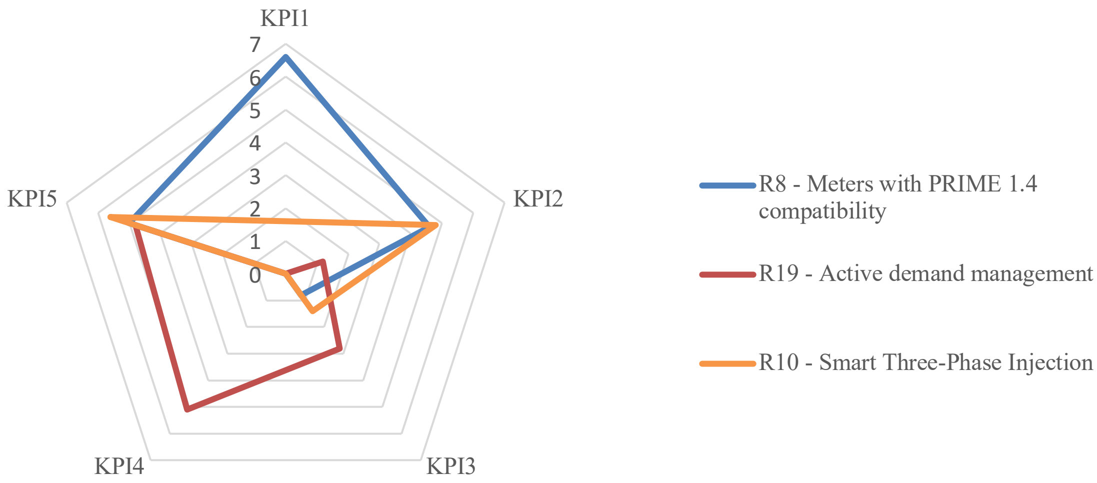

Figure 17. Radial diagram from the best qualified functionalities

Chapter 5. DISCUSSION OF RESULTS

From an objective point, it is not possible to determine which are the best functionalities based on a single analysis as the conclusions obtained from an analysis can be misleading. Not all the functionalities must provide a financial return, which is the information provided by the CBA analysis, nor all the functionalities require a contribution for the client to justify their installation. Instead, an in-depth analysis is required, both quantitative and qualitative, in order to obtain useful information that will provide the basis for making a decision to implement a functionality.

In this chapter is going to be presented the evaluation of the results from the functionalities. The evaluation will be performed considering all the analysis together because it should be used all the information provided by the different analysis to make a decision.

In the case of the analysis of KPIs, the information is clear and concise as stated in KPI analysis because the assessment is specific and does not require final assessments that are influenced by thoughts of the person performing the analysis. These functionalities established by the KPI analysis are the R8 – Meters with PRIME 1.4 compatibility, R19 – Active demand management, R10 – Smart three-phase injection, R2 – Temporary overvoltage protection and R9 – Meter reclosing.

According to the CBA analysis, the functionalities that should be implemented due to the great economic contribution that they would give to the company are R5 – Point-to-point remote management meter, R7 – Phase detection in PRIME 1.3, R8 – Meters with PRIME 1.4 compatibility, R10 – Smart three-phase injection, R18 – Rotation sequence in three-phase meter and R26 – Reboot modem PRIME. It should be noted that these functionalities only include those that bring direct benefit. The rest of functionalities require a cost of implementation that may be small and could be installed.

On the one hand, with the recommendation provided by the two analysis, it could be discarded the implementation of the functionality R7 – Phase detection in PRIME 1.3 because it would have the same benefit as the one provided by the R8 – Meters with PRIME 1.4 compatibility. If it should be taken into account that PRIME v1.3.6 is already installed but it requires a perfect synchronization of the clock. Furthermore, R12 – Power load profile of each phase should be installed in order to perform the balance of the loads.

On the other hand, both method states that the implementation of R8 – Meters with PRIME 1.4 compatibility and R10 – Smart three-phase injection will benefit the data transmission and they will also provide benefit. For this reason, the implementation of R5 – Point-to-point remote management meter should be implemented because the transmission of data is secured. So, a change in the communication configuration will be efficient for the network. But this functionality must have a special casuistry that must be conditioned. The meters should be found in isolation, since the cost of their hardware implementation is higher than if a filter were installed. A filter would mean the improvement of the communication of the meters connected in the same phase while the modem would require one modem per meter. Therefore, the cost of software implementation should be assumed and installed in very specific cases.

The implementation of the R19 – Active demand management functionality, although it is not defined as feasible due to the associated benefits, present a software implementation cost very small and its contribution to the client is high. Therefore, it is a requirement that should be defined by the distribution company if it wants to implement it to face possible changes in the regulation on this matter. In the opposite case, R2 – Temporary overvoltage protection functionality can be observed because it will provide a benefit for the client. However, the implementation cost is not recovered if this functionality is implemented because a change in the service switch is required. Another technology of protection could be implemented to increase the protection of the installations belonging to the customers.

The R1 – Physical measurement of the neutral current functionality allows a fraud detection that is enabled by the CBA analysis, since the retribution provided is higher than the necessary investment. However, this benefit does not have a large profit margin and the financial return depends on the fraud detection. Therefore, a change in the behaviour of clients who practice these activities could affect viability, so their installation is ruled out.

Other functionalities that should be discarded are the R3 – Islanding detection and R4 – In home display. Information for the user due to the lack of remuneration for them. It is not considered in the Spanish regulation, so it will not be paid. The first one is discarded because the functionality is already implemented in the inverters, then a double implementation of the same functionality would be unnecessary. The second functionality is discarded because the information is provided through an application so all the inconvenience related to the installation of an in-home display will be avoided. In addition, the application is already developed and in operation.

The regulation is an important matter as it has been stated. In the case of R11 – Load profile with shorter integration periods functionality, the implementation is neglected due to the regulation. There is no need to store an extra load profile every hour and about every quarter of an hour. The most efficient way would be to change the hourly profile which is currently stored and perform a record of a quarter-hour profile. R20 – Volt-free contact functionality may be required by the regulation in the future, so it should be integrated in the meters that is installed into a self-consumption client. Finally, R27 – Excess calculation is also required by the regulation so its implementation is compulsory.

The requirement for R9 – Meter reclosing brings a great benefit and as the SWOT analysis established strengths can outperform weaknesses and threats. This together with the information from the other analyses establishes that is feasible, so its implementation should be carried out. It must be taken into account that both possibilities are feasible but it is necessary an automatic rescheduling to avoid possible errors in the counters that have filters.

Other type of functionalities is those that provide information that will be used for operation of the power network. But the data requirement should not be implemented in such a way that the communications are being used almost all the time, since the information must be efficient. This means, having a large amount of data does not mean having greater benefits.

Therefore, from a critical point of view R16 – V-I profile registration and R17 – Instant Values and Connectivity functionalities should not be implemented. Because the benefits provided by these functionalities could be obtained from the functionalities R31 – RMS values and R32 – Instantaneous values profile, which are a reduced version. The same reason justifies the implementation of the R22 – functionality.

Other functionalities that provide information are the R18 – Rotation sequence in three-phase meter and the R30 – Regulatory adaptations that provide information about the meter and its connection. The first one is economically viable due to the detection of possible errors in the connection. However, the second one allows the elimination of stickers that can be a source of data loss and could be digitally checked remotely. Therefore, these two functionalities should be implemented.

R28 – Events functionality is from the same type of functionalities that is being analysed which allows to obtain useful information. This functionality should be implemented to avoid failures in the monitoring of the network condition. As other functionalities it only needs a software implementation, so its cost is minimal. There are other functionalities that provides information but it is not necessary such as R25 – Trigger power information because the information can be obtained from another sensors which is already installed. So, this functionality should not be implemented.

The image of the company is an important factor for companies and therefore the distribution company must take into account the concerns of customers. For this reason, the functionality R23 – Led for verification of impulses for this reason should be installed as well as the functionality R26 – Reboot modem PRIME, but the last one also provides a benefit that certifies its implementation. The first will not provide any benefit but its contribution to welfare and its minimum cost allows its implementation.

Continuous improvement is also an important aspect of upgrading equipment on the network. Therefore, the R24 – STAR+ Cybersecurity. Narrow band functionality must be implemented because an improvement in data security is necessary. In addition, the regulation states that the meter information should be stored in the best possible way. Also, the R29 – DLMS efficiency and R15 – IEC 61000 Standard functionalities should be implemented for this reason. But the improvement should be certified and not implement functionality that does not provide. Therefore, R15 – IEC 61000 Standard should not be implemented.

Finally, there is the replacement functionality that due to its benefit in reducing the replacement of spent batteries along with the reduction of waste. It would make it a functionality to be implemented but it has to be defined in a way to ensure the synchronization of the meters with the tablets of the contractors.

Functionality	*Implementation*
R1 - Physical measurement of neutral current	X
R2 - Temporary overvoltage protection	X
R3 - Islanding detection	X
R4 - In Home Display. Information for the user	X
R5 - Point-to-point remote manage of the meter	≈
R7 - Phase detection in PRIME 1.3	X
R8 - Meters with PRIME 1.4 compatibility	✓
R9 - Meter reclosing	✓
R10 - Smart Three-Phase Injection	✓

R11 - Load curve with shorter integration periods	X
R12 - Power load curve of each phase	✓
R15 - IEC 61000 Standard	X
R16 - V-I profile registration	X
R17 - Instant Values and Connectivity	X
R18 - Rotation sequence in three-phase meter	✓
R19 - Active demand management	≈
R20 - Volt-free contact	✓
R21 - Use of supercap for battery replacement	✓
R22 - New report S05 / S05B / S04 /S27	✓
R23 - Led for verification of impulses	✓
R24 - STAR+ Cybersecurity. Narrow band.	✓
R25 - Trigger power information	X
R26 - Reboot Modem PRIME	✓
R27 - Excess Calculation	✓
R28 - Events	✓
R29 - DLMS Efficiency	✓

R30 - Regulatory adaptations	✓
R31 - RMS values	✓
R32 - Instantaneous Values Profile	✓

Table 6. Summary of functionalities implementation for new meters

With this information it is possible to establish the functionalities that will be implemented in the Bidelek 4.0 project for the next generation of electricity meters, which are shown in Table 6. These functionalities will supplement the ones that are already installed in the meter and that were defined in the Implemented Functionalities section.

Chapter 6. CONCLUSIONS

This thesis is the result of an analysis that has been carried out taking into account the points of view of the different stakeholders that are involved in the development of an electric meter. The electric meter is a fundamental equipment in the monitoring, energy billing and diverse tasks that must be carried out in the electric distribution network. Therefore, it must be updated and implemented new functionalities that allow the evolution of the network and at the same time facilitate the tasks of the operators.

In order to make an objective decision on which functionalities should be installed and which should be discarded, deep reflection should be carried out, avoiding the inclusion of personal prejudices. For this reason, the service life of the equipment and its economic and technical implications must be taken into account, as well as the contributions they have in all stakeholders. It can be stated that the benefit for one of the stakeholders of the meter is not enough to justify the installation of a functionality. It is necessary that the functionality contributes to all stakeholders, although it is easier to bring benefits to manufacturers or laboratories because for them the greater number of features, the greater their benefit.

An effective method of comparing features is to use KPIs to identify the key characteristics to be compared. However, in order to evaluate the contribution of KPIs, a thorough knowledge of the functionality is required. This can be done by a previous SWOT analysis or some method of analysis of all the contributions and errors of the functionalities. KPIs provide information and highlight the aspects of each functionality that can be improved.

Legislation is a key aspect in the functionalities that must be installed in the meters, since as it has been established throughout the project the regulation may impose or rule out the installation of a functionality. But the installation of meters is not done every day, so the functionalities also have to be aligned with the regulation and the possible changes they may have or the technology to be promoted. Once the meters are installed it would be much more expensive to implement any hardware device to allow the installation of a new resource.

The data that is transmitted by the meters is increasing due to the new resources or devices requires. For this reason, continuous improvement in meter communications must be made because technology continues to advance and communication capability can be enhanced. In addition, it is necessary not only to transmit more data but also more reliably. For this, modifications can be made in the configuration of those meters that do not transmit by the current configuration. But it must be emphasized that the current configuration, which use PLC technology, is very reliable. Due to this reason, updates should be carried out in the current protocols for its update.

Once the functionalities have been detected and are implemented in the meters, they must be validated in the laboratory. It is not feasible to install a meter with a technology and then this technology does not work as expected or the development made by the manufacturers is correct, because then these meters would have to be removed, updated and reinstalled, which would mean extra costs.

To certify the validity of a meter, a series of tests must be carried out, including the official tests, a test performed by an external laboratory, a test performed by the distribution company and a final test performed by a third party outside the distribution company. This is the system that i-DE performs to avoid possible errors in the meter model. The official tests are composed of three tests that are two metrological and one for checking the standards. The distribution company test is focused on interoperability, since the company cannot be limited by a manufacturer. Therefore, there are several models of meters installed in the network.

To continue with this project, small pilots could be carried out to evaluate if the contributions of the different functionalities that require a hardware device are real because these functionalities are the most expensive in cost terms. In the laboratory, the functionalities can perform an efficient work but the different features of the network with the influence of external factors could influence the performance functionalities. Therefore, a future work would be to carry out the analysis of the evolution of the functionalities in the pilots to certify their implementation. The meters should be installed in small groups but the location of the groups should be different in order to certify the proper operation having different conditions.

Another work that can be continued is the development of algorithms to perform the automation of equipment with the new data provided. Various functions will obtain information that was not previously recorded and this information must be treated. Therefore, it is necessary to develop algorithms that treat the information. In the case of the i-Trafo, it requires an algorithm that checks the information and send an order to the transformer in order to change its condition. i-Trafo is a transformer installed in a secondary substation and has an OLTC that allows optimizing the voltage in the secondary of the transformer. So, the algorithm will send an order an order to optimize the tap on which the transformer is working.

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GLOSARY

Glossary:

Abbreviation	*Meaning*
AMM	Advance Meter Management
CENELEC	European Committee for Electromechanical Standardization
COSEM	Companion Specification for Energy Metering
CD	Data Concentrator
CS	Convergence Sublayer
DER	Distributed Energy Resources
DLMS	Device Language Message Standard
EPRI	Electric Power Research Institute
GPRS	GPRS General Packet Radio Service
HES-MDC	Head End System and Meter Data Collector
IDAE	Institute for Energy Diversification and Saving
IEC	International Electrotechnical Commission
IRR	Internal Rate of Return
ITC	Complementary Technical Instruction
ITE	Instituto Tecnológico de la Energía

NPV	Net Present Value
OBIS	Object Identification System
OFDM	Orthogonal Frequency-Division Multiplexing
PLC	Power Line Communication
PRIME	PoweRline Intelligent Metering Evolution
RD	Royal Decree
RMS	Root Mean Square
SAIDI	System Average Interruption Duration Index
SDGs	Sustainable Development Goals
STG	Sistema de Telegestion which is HES-MDC
TCP	Transmission Control Protocol
XML	eXtensible Markup Language
VPN	Virtual Private Network

ANNEX A: RELATION OF THE THESIS WITH THE SUSTAINABLE DEVELOPMENT GOALS

This final master thesis is directly related to the objectives of sustainable development, since the various functionalities presented throughout the work are related to some of the objectives. Moreover, i-DE as well as the whole Iberdrola group are aware of its development and they have been introduced in the business strategy. The company highlights the objectives that guide its work, such as Affordable and clean energy goal (goal number 7) and Climate action goal (goal number 13). Although, the distribution company contributes directly or indirectly to the rest of the objectives, showing its high degree of involvement in this sense.

Figure 18. Classification of the SDGs of the Iberdrola group [17]

Returning to the participation of this thesis in the development of the objectives, it can be highlighted its participation in some of the objectives, as it is again the goal number 7 and number 13. But also, ensure sustainable consumption and production patterns goal (goal number 12) that is more related to the economy is developed by some functionalities. It is possible to emphasize that the main objective of the work is the goal number 7 on the part of all the functionalities, although each functionality can be analyzed in an isolated way due to its different implications.

In case of goal number 7, the functionalities that we want to implement in the counter are aligned with some of the targets of this goal. Among the targets are the reduction of energy prices and the introduction of renewables in the energy mix, in which the participation of the functionalities is greater. In order to obtain these tasks, the following functionalities are provided:

- Price reduction can be achieved by removing the fraud or the balance of the network which are paid by all users through regulated costs and for them the R1 – Physical measurement of the neutral current, R8 – Meters with PRIME 1.4 compatibility and R12 – Power load profile of each phase functionalities offer a solution.
- The introduction of renewable energies requires increased monitoring and control of the power grid, which is achieved with the R19 – Active demand management, R31 – RMS values and R32 – Instantaneous values profile functionalities. In addition, regulation may require management of renewable sources and for this purpose R20 – Volt-free contact functionality is introduced.

If the contribution of the functionalities in goal number 13 is analyzed, the contribution is derived from the functionalities that have been previously established for the introduction of renewables. The increase in the percentage of participation of renewable energies in the energy mix is directly proportional to the reduction of greenhouse gases. These gases are produced in non-renewable energy sources by the burning of the energy source such as gas or coal. Therefore, a reduction in their participation contributes to the reduction of the impact that is produced on the ozone layer annually.

Other contributions made by the different functionalities, as previously established, are related to goal number 12. Because increased energy monitoring provides information that can be shared with the customers of the distribution company. This information allows to make a more efficient consumption and it is more economical for them, so it is related again with the goal number 7. In this case the reduction of the load profiles with a shorter integration period will provide more knowledge that can be complemented with the R12 – Power load profile of each phase functionality. In addition, an attempt is made to improve communications and digitalization in order to obtain updated and accurate information. To this end, functionalities such as R5 – Point-to-point remote management meter or R8 – Meters with PRIME 1.4 compatibility are actively involved.