Plan to incorporate SDN (Software Defined Network) technology in the evolution of Smart Grids

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Abstract — *SDN (Software Defined Network) is a telecommunications system that is becoming increasingly popular in telecommunications networks. The great advantage of this system is the automation of the network, achieving a separation of the overlay and underlay. This achieves a much greater optimisation of the current systems as well as a drastic increase in the quality of service, reducing telecommunications interruptions to a minimum. The development of this system in the telecommunications network of an electricity distribution company is vital for its evolution. Electricity distribution companies need a powerful telecommunications network to operate their new intelligent distribution networks, the Smart Grids, which have a high level of computerisation and automation. Therefore, the evolution of Smart Grids cannot be conceived without an improvement of current telecommunications and SDN has to be implemented in these telecommunication networks.*

The TFM develops the advantages of implementing SDN and carries out a technical and economic feasibility study for its implementation in Iberdrola's telecommunications network. Subsequently, a proposal is made for the installation of the system over the next few years.

Index Terms — Smart Grids, Telecommunications, SDN, DSO.

I. Software Defined Network

SDN (Software Defined Networks) is a new model of telecommunication networks that provides flexibility, agility and allows centralized management.

Traditional networks depend on physical devices, hardware, such as traditional switches and routers. They have control on each of the devices. SDN allows separation of the control plane from the data plane. This allows you to have a centralized and programmable management of the network.

In SDN the control plane is centralized. Control is performed by the network controller who is responsible for monitoring and directing traffic within the network. The controller, which is software, uses communication protocols such as Open Flow to set and control network rules and policies.

The great revolution that SDN has is the separation of the control plane and the data plane. This allows for more flexibility and adaptability in the network. The network administrator can program and manage network policies centrally which gives efficiency when making configuration changes, saving having to configure each device individually.

SDN also enables network virtualization. This means that there is the possibility of creating logical networks as well as virtual segments in a shared physical infrastructure. This would facilitate the creation of isolated and customized network environments for different services or users. The SD-WAN are software-defined networks that extend over a wide area. This technology brings the advantages of SDN to WANs.

WAN (Wide Area Network) networks are extended scope networks that connect different facilities and different local networks. The objective of these networks is that the information generated in any LAN network reaches a device that is in another LAN network. These WAN networks have traditionally been based on complex and expensive connections such as MPLS (Multiprotocol Label Switching), but as time has advanced and technology has evolved towards virtual applications, with cloud storage so greater agility and speed in network control is necessary. These needs have found in SDN technology a possible solution. SD-WAN takes from SDN the use of centralized controllers to manage and orchestrate the WAN. This facilitates the aggregation of more network connections, allows connections with different technologies that are managed with centralized configurations, which facilitates the implementation of new network policies and configuration changes in the event of problems.

In conclusion, SDN is a new approach to telecommunications networks that allows the separation of control plane and data plane, which achieves advantages in network operation, versatility and scalability, security and resilience.

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II. Smart Grids

Smart Grids are intelligent electrical energy distribution networks. These networks are a natural evolution of traditional distribution networks, which have had to evolve towards digitalization and automatization. This implies a new way of conceiving these distribution networks and a new way of operating with them.

The intention of Smart Grids is to improve efficiency, sustainability and reliability in the process of electricity distribution. To achieve this, Smart Grids must incorporate automation devices and of course a stable telecommunications network that allows the sending and receiving of information. Smart Grids encompass new elements that are distributed throughout the distribution network that were not there before. Examples of this type of elements are batteries, electric vehicles, distributed generation, smart meters, etc.

All these elements have created the need to have an intelligent distribution network that allows all these new elements to be managed simultaneously, as well as to automate traditional elements that already existed in it such as primary and secondary substations.

Smart Grids therefore seek to have a complete monitoring of the network, as well as a remote operation from a control center.

One of the biggest changes in the distribution network is the incorporation of renewable generation into it. This renewable generation cannot be managed, being at the mercy of environmental conditions. That is why networks need to automate and autonomously manage all these variations in electricity production.

The risk of power interruption is something that many factories and businesses cannot afford, so it is essential that in the event of a problem the system is replaced as soon as possible. This is also one of the characteristics of Smart Grids that have the ability to be managed remotely to replenish the service in much shorter time than to date. Distribution networks become Smart Grids once they are automated and given the necessary resources so that you can manage everything mentioned above. One of the most important elements is a telecommunications network that supports all the sending of information that is generated in it and that allows the reception of action orders in affordable times.

III. TELECOMMUNICATION IN SMART GRIDS

Telecommunications are fundamental for the operation and evolution of Smart Grids. Telecommunications systems combine various technologies to transmit information from its sender to its receiver. These technologies use different physical channels, such as fiber optic cables, coaxial cables, electric power transmission cables with the use of PLC technology, and can also use wireless channels such as those used by 4G technology and satellites. All these alternatives are combined to offer a most versatile network, making possible the remote control and remote management of the entire Smart Grid, as well as greater control in distributed generation and information on generation and consumption in real time.

The use of telecommunications allows the remote control and remote management of the equipment that is in the network. Thanks to this remote management, real-time measurements can be taken of all the Smart Meters that exist in the network and the data can be processed in the control center.

Also thanks to telecommunications, it will be possible to operate the generation of distributed generation from a control center, allowing orders to be sent to generation groups to produce energy according to the needs of the demand at that time (known demand thanks to the Smart meter).

The needs of remote operation of the network in the event of problems are solved through the use of telecommunications. These allow each of the cells of the primary and secondary substations to be operated so that circuits are opened and closed in an automated and centralized manner in the control center to isolate faults and minimize the impacts of problems. This is essential as the distribution network is operated radially, which implies that circuits have to be opening and closing at the moment in which any problem occurs and thanks to telecommunications this can be done remotely.

The networks used in telecommunications are mainly of two types: local area networks (LAN) or wide area networks (WAN). Local area networks are local area networks as the name suggests. It is responsible for interconnecting the equipment and services of a very small area such as an office or a substation. These local area networks are interconnected with each other through wide area networks which are responsible for making a network of networks, interconnecting the different offices and substations with each other.

Cybersecurity is essential in telecommunications and even more so in telecommunications of an essential service such as the distribution of electricity. An attack on this telecommunications network can cause the incorrect operation of a substation leaving thousands of people without electricity. That is why a strong cybersecurity policy and various protocols are followed to minimize the impact of a possible attack.

In telecommunications, the sending of information can be divided into three layers: Transmission Medium, Transmission Network and Switching Network.

• **Transmission medium:** It is the physical medium by which data is transmitted. This medium can be an optical fiber, an electrical cable, a coaxial cable, etc. In the case of fiber optics, dark fiber is the transmission medium, which is the unlit cable.

• **Transmission network:** The transmission network is responsible for making point- to-point connections, that is, transmitting information through the physical channel between a sender and a receiver. Within a physical medium such as fiber optics, an element is needed to transmit information within the medium. An example of this transmission network is DWDM or SDH. The DWDM sends the information through different wavelengths within the fiber optic cable.

• **Switching network:** The switching network is responsible for transporting information from the sender to the final receiver. This receiver may not be contiguous to the sender, having the information pass through several receivers (nodes), to the final receiver. The switching network is responsible for making the most optimal path through the different nodes to the final receiver. A widely used technology for the switching network is MPLS, which can also be used directly in the transmission network.

Layering shows how they are classified according to the different layers, but the same layer can be divided into two: Backbone and Access Network

• **Backbone:** It is the network that is responsible for sending the information collected by the access network and sends it through the different nodes. In an electric simile, the backbone would be the transport network. The backbone must be stable and robust, so technologies with high capacity and speed of data transmission are required. An MPLS system in this type of network is one of the best solutions.

• **Access Network:** The access network is the network that serves the end nodes, and is connected to the backbone. In an electrical simile, the access network is the distribution network. This access network does not have to be as powerful as the backbone, but it must nevertheless access geographically remote locations. That is why solutions such as radio links and 4G technology can sometimes be better solutions than MPLS.

Tecnology	Network	Layer	Aplication
MPLS	Backbone / Access	Switching Network	Primary Substations / Data centers
Optical Fiber	Access	Transmission medium	Offices / Secondary substations / Primary Substations / Data centers
Point to point radiolink	Backbone / Access	Transmission Network	Primary Substations
PLC	Access	Switching Network / Transmission Network	Smart Meter / Secondary Substations
Point to multipoint radiolink	Access	Transmission Network	OCR, Primary Substations
4G	Access	Switching Network / Transmission Network	OCR / Secondary Subestations

IV. ADVANTAGES OF SDN IN SMART GRIDS

The application of SDN in the telecommunications networks of Smart Grids seeks to improve and optimize the operation of telecommunications and therefore provide greater reliability to the remote management of Smart Grids. SDN technology provides advantages that are on par with very few telecommunications systems.

The main advantages can be divided into three: Centralization of the control plane, separation of the underlay and overlay and the separation of Hardware and Software.

1) Centralization of Control Plane

One of the biggest advantages that SDN brings to the telecommunications network is the centralization of the control plane. This means that all control of the SDN system can be done from a single point, avoiding having to access each device individually to make configuration changes.

This centralization allows for software routing (rather than IP as traditionally done). This allows that, in the event of any type of problem in the telecommunications system, the system autoconfigures and forwards the data packets by the new most optimal route, improving the speed of data transmission which is essential for the correct teleoperation of some Smart Grid systems.

Having the control plane centralized and separate from the data plane provides a great benefit when sending new protocols and configuration policies. In traditional systems each device has its own control, then when modifying a configuration, it has to be modified device by device. With SDN, a new, single configuration order can be sent that applies to all computers, significantly streamlining the equipment reconfiguration process as well as policy changes. This has a great impact on security, since in the event of some type of cyberattack or breach in the system, a new security policy is sent that is applied instantly throughout the system, drastically reducing the reconfiguration time and the possible errors that may occur when repeating an action so many times (it is easier to err repeating an action 1000 times than to do it in a single action).

From all the above it can be deduced that with the centralization of the control plane there is an improvement in the efficiency of the operation of the system since time is saved in the reconfigurations, time is saved in sending information thanks to software routing and the possibility of error when making new configurations is reduced.

2) Underlay & Overlay Separation

The separation of the underlay and overlay consists of separating the data transmission channel (underlay) with the emitted data or services (overlay). The underlay channels are described in point 4.1 and the overlay services can be any service needed by the distribution network (remote control, remote management, security system, voice calls, etc.).

This separation is a great revolution in telecommunications since it allows to treat all redundant technologies as a single one.

Distribution networks are an essential service and you cannot afford to lose service. That is why the telecommunications systems that support them have redundancy, that is, they are connected by at least two technologies to avoid losing service in case of failure of a system.

By treating all underlay channels as one, SDN has the ability to unite the data transmission capacity of all channels and have full bandwidth availability. Sometimes having two telecommunications systems, the established communication policies make one channel is 100% and does not allow the sending of more information and yet the other channel is 15%. The SDN has the ability to automatically separate each service from the overlay for each channel of the underlay, leaving part of other channels free so as not to saturate any of them. In the previous case, SDN for example would balance and go from 100% channel 1 and 15% channel 2 to 60% channel 1 and 65% channel 2. In case of decay of any of the channels of the underlay all the traffic would be redirected automatically by others getting not to lose connection at any time and without loss of data packets. This translates into a greater bandwidth available at all times and a greater optimization of the entire system, allowing to reduce the investment costs in new telecommunication networks for the same level of service.

The separation of underlay and overlay makes it possible to offer Layer 2 (data link layer) telecommunications services over Layer 3 (network layer) services. This is an advantage for companies such as Iberdrola that designed their telecommunications system on level 2 services but the evolution of telecommunications has required the use of level 3 that are more effective in some applications. The use of level 2 over level 3 offered by the SDN means that Iberdrola does not have to change the architecture of its telecommunications system to obtain the advantages of level 3, with the consequent economic savings that this entails by not having to assemble a new telecommunications system from scratch.

Using Level 2 over Level 3 also solves looping issues that occur in Level Two connections when a redundant path is added. This could be solved by the Spanning tree, but the SDN solution is more stable.

The connections that are currently made in secondary substations that are located in remote areas and without the possibility of accessing through a telecommunications cable are connected by 4G from teleoperators outside the electricity distribution company. This implies that to perform the configuration of each 4G router the company has to make a configuration of an APN for the installation of each sim card in the router and have access to it from the network management center. With SDN the APN is generic which implies that a new configuration will not be made for each project of a new 4G router but all will carry the same configuration using a generic one.

3) Software & Hardware Separation

The separation of hardware and software implies an advantage in terms of dependence on suppliers. With the current system, installing hardware with defined software means that in order to have compatibility between all computers in the system, the hardware and software service provider has to be the same. This separation of hardware and software allows the installation of the software of a supplier (the one that best suits the needs of Smart Grids) and has dependence when it comes to depending on who is the hardware supplier. This is beneficial for companies that impose this system since they are not "tied" to the conditions of a single supplier.

This separation also implies the possibility of installing a universal hardware, that is, that the hardware is compatible with the software of any company so, in case of changing the SDN software, it would not be necessary to change the hardware.

By treating software and hardware independently, the system controls software as a single unit rather than individual hardware. This allows the monitoring of the system to be more effective allowing, as mentioned above, the centralization of the control plane.

V. Viability of SDN implentation

A) Technical Viability

Installing SDN involves installing SDN equipment to replace those currently mounted. The equipment of the telecommunications network is distributed throughout all the sites connected to the telecommunications network. These locations can be: Offices, Primary Substations or secondary substations.

1) Offices

Companies whose activity is the distribution of electricity usually have offices distributed throughout the area in which they distribute. In them, a quantity of data is generated and processed, and even more so in the offices where the control and operation centers of the network are located. Therefore, in the offices there are equipment that requires great power to process all the information, but they are environments that have enough space and have conditions that are suitable for the installation of computer devices. The Hardware

The current SDN equipment has ports that allow connection to current systems so these devices would be installed in the same way as current equipment, not being necessary major modifications and therefore not assuming any technical problem its implementation in offices.

2) Primary Substations

The operation of the substations as explained in section 3.1 of this document, have the mission of transforming the voltage levels between different circuits, therefore, in these facilities there are different voltage levels.

Substations usually occupy a fairly large area, especially those that are isolated by air (AIS) and have a building in it where some of the switchgear is located, such as computer equipment. This is why space is not a limiting issue in order to install new devices as it can be the different levels of voltage.

The way of connecting the equipment is similar to the current ones and as mentioned in point 5.1.1, it is not a restrictive technical issue so you can change one equipment for another for telecommunications connections. The technical problem that can be encountered in the implementation of SDN equipment in substations are the ground connections of the computer equipment, as well as the supply voltage levels of the equipment and other non- functional technical requirements.

Computer equipment must be grounded on the low-voltage side of the substation. In the case of SDN that should not change. The problem that SDN equipment incurs is supply voltage levels. This equipment is powered continuously, like many of the auxiliary services, so that they continue to operate thanks to the batteries in case of power failure in the substation. Current equipment has supply voltage levels of 48 volts, however, the SDN is powered at 12 volts, therefore, the voltage must be adapted to 12 volts. This is a drawback that can be easily solved with a 48V to 12V DC-DC converter.

Therefore, it is possible to install SDN equipment in substations without making substantial modifications to the substation.

3) *Secondary Substations*

Secondary substations have the same operating objective as substations except that, for lower voltage levels and for smaller circuits. The secondary substations are usually located in very limited spaces, being able to be prefabricated and be inside buildings or in the vicinity and can also be on top of poles that support power lines. These conditions of location of the secondary substations make space a restrictive element to consider.

Currently, most of Iberdrola's secondary substation have a 4G mobile telephony connection. SDN routers should replace 4G routers, so so that space is not an issue, SDN routers should not be larger than current 4G routers. Major SDN vendors offer products that have similar sizes, so this shouldn't be a problem. Yes, it is the power supply and the need to add as in the primary substations a converter from 48V to 12V, which implies having a device in a space where before there was only one. These converters are not large enough to imply a space problem then would not be a restrictive element.

Another problem that arises in the secondary substations as they arose in the substations are the ground connections. These connections must be made correctly so as not to have problems with the different earths of the two existing voltage levels.

Secondary substations are exposed to extreme temperatures. This means that the equipment that is in the must work correctly in this range of temperatures that can range from -10oC to 60oC. Suppliers comply with this requirement in their products currently.

Other characteristics that the SDN equipment to be installed in the secondary substations must have to be technically viable is a degree of IP protection that protects them against water and dust, as well as having a sufficient number of connections to service all the necessary systems in the secondary substations and redundancy so that in case one of the systems fails, the SDN has another underlay channel available. In SDN routers that replace 4G routers, two antennas must be available for two operators and thus offer redundancy.

SDN providers must also comply with hardware and software independence and a universal CPE, this being essential so that the SDN deployment can be carried out correctly without depending on a single provider in the future.

B) *Economical Viability*

SDN helps to reduce some of the operating costs of the telecommunications system. The reduction of these costs and the increase in benefits implied by the installation of the SDN, must be less than the investment cost since in another case the implementation of the SDN system would imply economic losses. Therefore:

$$\Delta CO + \Delta CM + \Delta RC + \Delta CS - \frac{INV}{PA} \geq 0$$

ΔCO ≡ Operating cost savings
ΔCM ≡ Maintenance cost savings
ΔRC ≡ Savings associated to security risk
ΔCS ≡ Increase in operating income of quality of service
INV ≡ Investment required for SDN deployment
PA ≡ Equipment amortization (12 years)

1) *Operating Cost Saving*

The operation of Iberdrola's telecommunications network has a cost that aims to be reduced thanks to the implementation of SDN in the network.
The reduction of these costs will come from reducing the volume of programming hours, by reducing the number of new protocols and policies when performing thanks to the centralization of the control plane. Currently, providers that offer this type of service offer it at an average price of 400€ per day. Throughout a day the number of teams that are able to change on average are 500, making 5 changes of this type throughout the year.
It is planned to change 45,768 computers to SDN which means that in a future schedule a single order will be made instead of the 45,768 (one for each team) that must be made now.

$$\Delta CO = \frac{CJ}{NEJ} * NC * (NE - 1)$$

$$\Delta CO = \frac{400\,\frac{€}{day}}{450\,\frac{equipment}{day}} * 5\,\frac{changes}{year} * (45.768 - 1)Equipment$$

$$\Delta CO = 203.408{,}89€$$

ΔCO ≡ Operating cost saving
CJ ≡ Cost per day
NC ≡ Number of changes
NE ≡ Total equipment
NEJ ≡ Equipment changed per day

2) *Maintenance Cost Saving*

The maintenance of Iberdrola's telecommunications network has a cost that is also intended to be reduced with the implementation of SDN.
At present, whenever a problem of some consideration occurs in any telecommunications equipment of a secondary substations, a patrol must be sent to go on site to solve it.
The cost of sending this patrol is 200€ per patrol and the SDN aims to reduce by 50% the number of times a year that a patrol is sent to a secondary substation. The coefficient of action of

each patrol in a secondary substation is 0.3. Therefore, the SDN has an economic saving in this aspect that is detailed below:

$$\Delta CM = CR * CAT * RASDN * NCT$$
$$\Delta CM = 200\frac{€}{reparation} * 0{,}3 * 0{,}5 * 45768$$
$$\Delta CM = 1.373.040€$$

ΔCM ≡ Operating cost saving
CR ≡ Operation total cost
CAT ≡ Coefficient of action in each secondary subestation
RASDN≡ Reduction of actions thanks to SDN
NCT ≡ Total secondary subsations

3) Cibersecurity Insurance Saving

Cybersecurity is an issue that concerns any company that has computer services and essential information in computer systems. Even more so companies that have essential services such as the distribution of electricity. This is why most companies have insurance that assumes part of these cybersecurity risks in exchange for an annual fee. The fee is calculated based on the risks of cyberattack, and the SDN decreases these risks. Therefore, the share of a possible cybersecurity insurance would be reduced with the implementation of SDN.
The fee of a cybersecurity insurance for a risk of 50,000€ is 1000€ per year, assuming that this price is linear, the fee of this type of insurance is 2% of the insured capital. Electricity distribution companies move billions of euros and therefore their insured capital will be hundreds of millions of euros. Assuming that 10% of the total assets are insured, a total of 1,418,616,200€ would be insured. This implies that the fee of a cybersecurity insurance would be:

$$Fee = 141{,}861{,}620 * 2\% = 2{,}820{,}000€$$

Taking into account that the quota reduction associated with the risk reduction implied by the SDN is 5%, the fee reduction would be:

$$\Delta RC = RC * R$$
$$\Delta RC = 2{,}820{,}000€ * 5\%$$
$$\Delta RC = 141.000€$$

ΔRC ≡ Saving associated to security risk
RC ≡ Insurance cost
R ≡ Reduction estimation

4) Quality of Service Revenue Increases

The application of SDN can considerably improve the SAIDI and SAIFI, and it is expected that the SAIDI will be improved in 2 minutes and 0.1 the SAIFI.
In 2018 (the last year available), the remuneration that Iberdrola distribución (I-DE) had was 1,768,619,211€ of which 3,498,503€ was associated with the quality of supply.
The total remuneration associated with the quality of supply of all distribution companies was 6,789,216€.

With this quality improvement, and assuming that its competitors do not have this improvement, the increase in government remuneration associated with service quality can be increased by 15%.
Therefore, the income that the SDN will contribute in terms of service improvement is:

$$\Delta CS = CS * R$$
$$\Delta CS = 3{,}498{,}503€ * 15\%$$
$$\Delta CS = 524{,}775.45€$$

ΔCS ≡ Saving associates to quality of services
CS ≡ Quality of service Remuneration
R ≡ Percentage increase estimate

5) Initial Investmet

The initial investment required would be reduced if the end of life of the current equipment were taken advantage of, having to consider only the difference in cost of the equipment.
The calculation of how much is the maximum investment to be made will be made so that the introduction of the SDN is economically viable, and therefore not accept proposals from suppliers with a higher figure.
The useful life of the SDN equipment is approximately 20 years, but to calculate the investment the amortization period of computer equipment will be taken into account, which is 12 years.
Therefore, the maximum added value that SDN equipment can have is:

$$PA * (\Delta CO + \Delta CM + \Delta RC + \Delta CS) \geq INV$$

ΔCO ≡ Operating cost savings
ΔCM ≡ Maintenance cost savings
ΔRC ≡ Savings associated to security risk
ΔCS ≡ Increase in operating income of quality of service
INV ≡ Invesment required for SDN deployment
PA ≡ Equipment amortization (12 years)

$$12 * (203.408 + 1.373.040 + 141.000 + 542.858) \geq INV$$

$$27.123.672€ \geq INV$$

The maximum cost increase that can be allowed for the installation of the SDN to be economically viable is: € 27,123,672.
Therefore, when 45,768 SDN equipment is installed in the secondary substations, the unit extra cost of each equipment cannot be greater than:

$$\frac{27{,}123{,}672\ €}{45{,}768\ equipment} = 592€/equipment$$

Each equipment must have a maximum extra cost of € 592 with respect to 4G equipment.

VI. Iberdrola Deployment Plan

Once it has been demonstrated that SDN is beneficial for Smart Grids, and provides a long list of advantages as demonstrated in the previous chapters, and once the feasibility study has been carried out indicating that it is technically and economically viable, Iberdrola wants to carry out a plan to deploy this system in its telecommunications network.
This deployment plan will consist of several phases until the system is fully integrated.

A) Phase 0 & 1

Phase 0 and 1 were the first phases of the deployment plan. These began in 2021 and targeted a scope of 50 offices, Phase 0 and 50 operational facilities (substations and repeaters), Phase 1. These initial phases served as a pilot to verify that indeed all the theoretical potential that the SDN had in practice was fulfilled.
The difficulty of performing this deployment was to do so without losing the communications of the previous system. This was done successfully and all the problems that arose in its implementation were solved, preventing those errors from occurring in phase one, which will be the first non-pilot phase to be carried out.

B) Phase 2

Phase 2 aims to deploy SDN in secondary substations that have 4G connectivity. Therefore, it is intended to replace the currently implemented 4G router with a new SDN router.

This is intended to take advantage of the end of life of 4G routers to, as discussed in point 5.2.5 of this document reduce the investment costs of SDN.
Iberdrola has 98,209 secondary substation, of which 75,884, or 42%, are connected to the telecommunications network using 4G mobile technology.

	Quantity	% of Total
Iberdrola's Secondary Substations	98,209	---
Secondary Substations connected by 4G (TGB, GTP, Router)	75,884	77.27%
SS connected by 4G (Router)	27,839	28.35%
SS connected by PLC with 4G output (Router)	1,429	1.46%
SS connected by 4G that Will change to PLC	-7,500	-7.64%
SS to connect with SDN	21.768	22,16%

As can be seen in the table, the SDN will be taught in 21,768 secondary substations since it is necessary to consider the 27,839 secondary substations currently connected by 4G with remote management and / or automation (which are the most critical in the operation, hence these are selected for a first phase) to which we must add the secondary substations that are currently connected by PLC, but according to studies carried out by Iberdrola it is convenient to change your connection to 4G. In the same way, those secondary substations that are connected by 4G but will be modified to PLC must be eliminated from the change.
Iberdrola also has 100,000 OCR (Network Cutting Bodies), which are not as dependent on 4G as secondary substations, but there are some that use this technology. Of the 100,000 OCRs owned by Iberdrola, 3,000 are connected via 4G and are therefore contemplated in this second phase for replacement by SDN.

	Quantity	% of Total
Total OCR Iberdrola	100,000	---
OCR connected by 4G	3,000	3%

Once contemplated the secondary substations already installed in which it is intended to make the change to SDN, it is necessary to take into account the new secondary substations to be built, which will be already connected through SDN technology and the migrations of technologies to 4G, which will be migrated to SDN directly. In the table below you can see these new secondary substations.

	CT/year
New CT (Client)	1,000
New SS (Iberdrola own)	300
New OCRs	300
Total New SS	1,600
Migration TGB to 4G	300
GTP to 4G Migration	100
Total SS Migrated	400
TOTAL	2,000

Once the table has been analyzed, it is observed that 2,000 secondary substations per year must be added to the deployment plan.

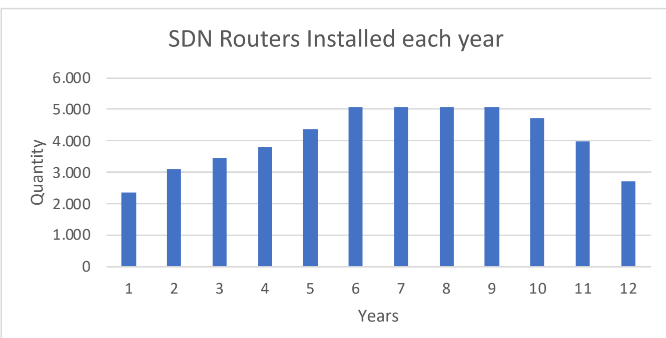
This phase 1 aims to begin coinciding with the beginning of the year 2025 and is intended to end in the month of December of the year 2036, that is, the duration of this phase will be 12 years. Therefore, the total number of SDN routers to be installed over 12 years will be:

$$12 years * 2.000 \frac{SS}{year} + 21.768 + 3.000 = 48.768\ Routers$$

The installation of these routers will be done in the manner determined in Table 4 over the 12 years of this phase of the project. At the beginning, the installation will be smaller since problems that appear will be solved, which will be solved in the intermediate and subsequent years and therefore more progress can be made in the implementation.

	Year 1 2025	Year 2 2026	Year 3 2027	Year 4 2028	Year 5 2029	Year 6 2030
New SS	2,000	2,000	2,000	2,000	2,000	2,000
Switching 4G to SDN	362	1,085	1,446	1,808	2,350	3,073
Total Installed Year	2,362	3,085	3,446	3,808	4,350	5,073
Total Installed accumulated	2,362	5,446	8,893	12,700	17,051	22,124

	Year 7 2031	Year 8 2032	Year 9 2033	Year 10 2034	Year 11 2035	Year 12 2036
New SS	2,000	2,000	2,000	2,000	2,000	2,000
Switching 4G to SDN	3,073	3,073	3,073	2,712	1,989	723
Total Installed Year	5,073	5,073	5,073	4,712	3,989	2,723
Total Installed Cumulative	27,198	32,271	37,344	42,056	46,045	48,768



Tables before show how many SDN routers will be installed in each year. The installation of the routers takes into account that at the beginning of the deployment problems may arise as mentioned above, but also as said in point 5.2.5 a deployment plan has been followed that encourages changing 4G equipment for SDN equipment when the former are reaching the end of their useful life in order to reduce investment costs.
The deployment of SDN routers must remove the currently installed router, perform the installation of the new SDN router. Once it is installed, the configuration must be made so that it connects with all the rest of the SDN system and the connections must be made to the two mobile operators, so that they emit correctly through a private teleoperator.

C) Future Phases

Phase 2 seeks to implement SDN in automated and/or remotely managed secondary substations, but there are still some secondary substations, which do not enter this first phase. The goal is that when phase 2 is fully developed, the scope of SDN will be expanded with new phases that include more secondary substations and other points in the network.

VII. Conclusions

This document has described SDN technology, analyzing its advantages and the operation of Smart Grids, which everything indicates will evolve from a DNO model to the DSO model.
Smart Grids need a powerful, stable and resilient telecommunications system that is capable of transporting all the information necessary for their proper operation. It is therefore that seeing the advantages that SDN brings to a telecommunications network, it is the most effective system today to manage a telecommunications network. The advantages in the operation are clear, but a reduction in the operating cost of the telecommunications network is also expected, so the economic advantages are also present.
Most telecommunications companies are implementing the SDN system in their telecommunications network and more and more technology companies are developing their own SDN system, which means that there is more variety of suppliers and therefore more facilities for a future massive implementation.
Iberdrola has been a pioneer in the implementation of this system and most likely due to the needs, electricity distribution companies copy this strategy and end up implementing it also due to its enormous potential.
The SDN is still in the process of development and the advances that are expected to arrive will make the SDN a more powerful and versatile system even if possible, thus increasing the number of projects focused on this development.

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