Telefónica's electromechanical switchboards

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1. The needs of the new automatic power plants

The history of Telecommunications in general, and of Telefónica in particular, has been a permanent history of research and innovation, but, although each step taken has been important, there is no doubt that there have been particularly important milestones due to the change they implied, both in the quality of the service and/or the functionalities it provided to its end customers and in the efficiency it generated in the operators themselves. thus allowing the optimization of new investments for a faster development of the infrastructures necessary for its territorial deployment and the modernization and implementation of new technologies that would allow it to be at the forefront of the world at all times.

One of those moments was, in my opinion, the automation of the first manual power plants. These were initially very important because, together with the continuous deployment of local, national and international networks, they made it possible to connect people for the first time through voice regardless of distance. They have therefore gained an important weight in the history of telephony.

However, in the early years of the 20th century, the need was seen to go a step further, which would improve the time it takes to establish a call, which was very long at that time as it was based on the manual operation of telephone operators who did the necessary interconnection work to complete the call between two customers. This also created significant efficiency issues and affected the privacy of communications.

To solve these problems, the first automatic exchanges were born around 1915 in the field of local calls of the exchange itself. Therefore, it was a shift from manual switching by humans to switching by electromechanical elements that were capable of making these interconnections autonomously without human intervention.

To better understand what was done, we need to have a good understanding of how a call was made in a manual exchange. When customer A wanted to call customer B, a crank was turned on his telephone set which, by means of a magnet, generated an alternating current which, when it reached the exchange, lowered a small plate or turned on a light in the panel of the manual exchange. In this way, the operator identified the calling customer and could connect with him by clicking a plug on that customer's socket. After talking to the customer, he already knew where to direct the call, which could be to a customer from his own exchange, to an intercity manual box, for provincial or national calls, to an international manual box, for international calls, or to a special services table, where other telephone operators would establish the corresponding routes. To make it simpler, let's imagine that customer B belonged to the same exchange as customer A. In that case, the first operator could carry out the connection operation if the size of the manual switchboard allowed it or directed it to other telephone operators in its own manual switchboard who had access to that customer's socket. In both cases, the destination operator again used a plug that connected to the socket of client B, producing a call signal to his telephone set. Once informed that she had a call, the telephone operator used a switchboard that she had on the table in the box and communication was established, releasing the items used and withdrawing from the conversation.

The operators, therefore, located and identified clients A and B and made the appropriate routings so that the call was established end-to-end. The automatic exchanges had to do exactly the same thing, but without human intervention, as long as the call was from that local exchange. If the call was directed to a manual, long-distance, international or special service switchboard, the automatic exchange was limited to directing the call to those exchanges manned by telephone operators who had to establish the following routes to advance the call to its final destination.

It took many years for this interurban and international interconnection to be automated thanks to a new generation of automatic power stations. We'll cover that new development later.

At this point, I would also like to comment on a couple of very important aspects of telephone exchanges. The first point has to do with the phone traffic generated by customers. If customers of a given exchange make many more calls than those of another and the duration of those calls is longer on average, it is clear that the size of that exchange will have to be larger to avoid saturation and congestion of the service.

It is the same thing that happens with car traffic, which forces you to size streets, highways and highways based on the number of vehicles and the use that drivers make of them. The same is true of telephone exchanges. In manual exchanges, with more traffic, larger switchboards, more telephone operators, and more outbound links to other manual exchanges were needed. If, as was already foreseen, the growth of telephony was going to be quite rapid, this growth seemed unfeasible with these solutions and could only be solved in an efficient way with the new automatic exchanges.

The second aspect has to do with how we can identify the customer and know where they want to call without the intervention of telephone operators. When many customers dependent on a central office want to call, it is therefore necessary to identify them. In the manual control panels, this was indicated by the light on the panel, but in the automatic control panels, it was necessary for the customer to provide more information. This meant that very different telephone sets had to be available at the customer's home, which had to meet two basic characteristics, the first was that they had a central battery, that is, that the power supply to the terminal was provided by the exchange through the access network of copper wire pairs so that it could detect that a customer wanted to make a call, and the second was that they provided information to know where they wanted to call. This stage, which involved many possible inputs and few outputs, is known as the concentration stage.

That's why telephone sets had to evolve to disk-dialing ones. The control unit identified the customer by closing the power circuit when the receiver was raised, sent it a tone as an indication that it could dial and the customer turned a dial that allowed it to dial from 0 to 9. The disc rotated and if we had dialed a 9, 9 pulses were sent to the control panel and so on with other numbers, so we told our control panel where we were calling. This, in turn, led Telefónica, like other operators, to develop a national numbering plan that evolved in the number of digits needed until it reached the current 9. In short, each customer of an automatic control unit was identified by the numbering assigned to it.

Once the concentration stage was overcome, the next step was that, with the numbering blocks that arrived at the exchange, a distribution stage began to decide the route that the call should follow. Once this route had been established, let's imagine that it was the same exchange as that of the calling customer, we had to identify among all the end customers we were interested in order to, by means of a call signal that activated the ringing of the telephone set, communicate that we had a call. This stage with few inputs and many outputs is known as the expansion stage.

I wanted to make this introduction, before going into the specific technologies that Telefónica implemented from 1926 onwards, so that the rest of this document can be better understood. He also wanted to make it clear that the implementation of automatic control panels required parallel developments and high-level strategic decisions, both for the innovation of a new generation of terminals at the customer's home and for the development of a numbering plan that had to be able to contemplate the growth that would come in the future.

2. Rotary switchboards

The first generation of telephone exchanges was called Rotary Exchanges, so called because their connection network was based on the use of rotary switching machines that were driven by vertical axes that were in continuous rotation driven by a motor. They also had a horizontal axis in their lower part that in turn transmitted the rotation of the engine to the vertical axes that were the ones that drove the machines when they had to be used.

These systems, with different versions, covered the service of large cities for much of the 20th century with an acceptable level of quality, ceasing to provide service with the appearance of digital exchanges in the 80s and 90s.

The first Telefónica automatic exchange in Spain was inaugurated by King Alfonso XIII in August 1926 in Santander, and he did the same in December of that year with the inauguration of the first exchange in Madrid.

It is important to remember a fact that was key to the development of telephony in Spain for much of the twentieth century and that was a consequence of the signing, in 1924, of the contract between the Spanish state and the newly created National Telephone Company of Spain (CTNE) promoted by ITT. Given that the contract established that the equipment had to be manufactured in our territory, ITT decided in 1926 to create Standard Eléctrica S.A. based on an initial asset that it already had in our country, the Bell Telephone Company, which had been founded in 1922.

This led to the Standard/ITT Rotary plants being the main protagonists of the subsequent deployment of these technologies in large Spanish cities.

For that CTNE it was important to show its commitment and for this it made the decision to locate these first plants in unique buildings that would be a symbol of the strength of the new company. To make it a reality, he sought out first-rate architects to construct his new buildings, the best known being the Gran Vía Building in Madrid, which also became the headquarters of the new company.

We must not forget that the concept of automatic telephony in these times was only fully valid in the local calls of these exchanges, since calls to other destinations passed through manual exchanges attended by telephone operators, something that I have already talked about before, but that I want to remember in order to better establish the context conditions of that time.

From here I will try to give an overview of the operation of these plants and the main elements that made it possible. However, it should be borne in mind that these plants evolved over time, with the emergence of new models of plants with this technology, such as 7A1, 7A2 and 7D. There was also a 7B model that was never marketed. This process of improvement of each of the versions was constant over time, seeking to improve the concepts that we already mentioned at the beginning of this article, the call establishment time, trying to optimize the number of elements necessary to achieve it, the space to be occupied in the central and the resources necessary for preventive and corrective maintenance work. It was seen, for example, that the 7A systems were too expensive for plants with less than 5000 lines and that gave rise to the 7D system that simplified the elements and created new ones to complete that simplification.

These plants are based on the use of a series of electromechanical elements, with a very high percentage of mechanics. The connections of its network advance thanks to switching machines, of which there are two types, search engines and selectors, which work with very important rotational movements driven by the vertical axes that we mentioned earlier.

Additionally, there is a control unit called a recorder, which governs the different stages of the interconnection. It must be taken into account that these exchanges are of the so-called progressive advance since each stage is independent of the previous one, being the registrar the one who establishes how progress is made since he has the necessary information to be able to do so, as we will see later.

Another basic element of these control panels are the relays, which are fundamental switching elements throughout the connection process, since they have a coil that, when it receives the appropriate intensity, is capable of moving, due to the electromagnetic force that has been generated, a metal armature that they have, being able to act on one or more contacts. closing the corresponding circuits and, ultimately, establishing the planned connections.

To understand it better, let's make a call through one of these exchanges. As we already know, at the home of client A we have a telephone set with dial dialing.

It all starts when we pick up the receiver of the phone. At that moment, the power supply circuit, which the exchange gave to the device, is closed, and that information circulates through a pair of copper wires that reach the building where the telephone exchange is located. There is an element, called a distributor, whose mission is to connect the different pairs of cables that access the building with the points of each number of the automatic control unit, making this connection through copper wires, called bridges, which connect each pair with the number assigned to each number of that control unit. This information causes the search engine or search engines, since the number will depend on the expected telephone traffic, to start moving until they position themselves in that group of customers and turn until they locate the specific customer, thus establishing the corresponding contact. Once the client is located, a finder locates a free recorder and connects the circuit from that logger to the telephone set through those finders. Once this happens, the recorder sends a ringtone back to the phone that has been picked up. Each browser has many inputs to which it has access and only one output. Therefore, depending on the traffic, the same group of customers will be able to access several search engines, although only one free one will be in charge of accessing the client.

Upon receiving the ringtone, the customer starts dialing on the dial of the device, dials the first number that will generate a number of pulses similar to that number, once the dial returns to its sleep state, the next one is dialed and so on. These impulses are captured and stored by the recorder who has all the information to route the call. With all these steps, we have completed the stage of concentration to which we have already referred.

From this moment on, the registrar sends a first block of numbering to the first group of selectors who, with the help of their computer machines and the movements of the vertical axes, direct the call to the next stage of the call, to the local exchange itself or to some links that communicate that client with the corresponding manual panels. If the latter is the case, the customer can talk to the telephone operators of these manual exchanges and ask them for the address they want. In this way we cover the distribution stage of the plant.

If the call is to another client of the exchange, the registrar will send new numbering blocks to the next groups of selectors. The last group of selectors will receive the last two digits by having access to the customer group in which that particular target customer was located. By rotating these machines, a selector locates that customer and closes the circuit. At that point, we have already closed the circuit between the calling customer and the caller. The exchange sends a call signal to the target telephone set to ring its doorbell. If the customer picks up their phone, communication between the two customers is established. If there is no answer, the switchboard, after a waiting time, generates a busy tone to the calling customer to indicate that the call is not answered. These selectors, unlike search engines, have one input and many outputs. With this, we have covered the so-called expansion stage.

I have tried to make a description as simple as possible, since what I was most interested in was that this simplicity would allow me to understand as well as possible the basic philosophy of operation of this type of automatic control panels. It is evident that over time new models of Rotary power plants were developed and that each of them had, in turn, numerous improvements through new versions.

If we stood in front of these control panels, we could see how the axes and the switching machines they supported turned, as well as how the call progressed through the different stages. None of the later switching systems allowed a visualization of this nature and, therefore, even today when we see their operation, even if it is in a model, it is especially attractive to us.

Due to their many mechanical components, these plants occupied a large space, both in height and surface, on the floors of the buildings that housed them, and it was also very important to keep the electric current that served them very stable because it was key to the proper functioning of the motors and, consequently, of the different rotating axes. since it was necessary to maintain a constant speed of these, which made it necessary to install large diesel generators in the first plants, with a significant occupation of additional space, to guarantee the continuity of service in the event of a power cut, in an electricity network that, in those years, was in many areas quite unstable. Subsequently, these groups evolved to much more efficient technologies. Given the constant movement of these axles, regardless of the traffic they were through, the electricity consumption was very high.

The time it takes to establish a local call in manual switchboards was significantly shortened with this automation, and is now measured in seconds, which undoubtedly represented a very important advance over the previous situation.

From very early on, the company developed manuals that exhaustively defined the function of each element and also how to carry out the maintenance of the plant, whether preventive or corrective. Likewise, the functions of the different groups that worked in these plants were very well defined, something very important and that I will try to explain to you below.

The staffing required to run a Rotary plant was very high. Thus, in a power station that was important due to the number of lines and high traffic, several dozen people carried out the tasks necessary for the smooth running of the plant. This was due to the very nature of the plant, as the mechanical elements required constant adjustment and cleaning. The location of a fault made it necessary to follow the affected circuit or circuits in a fairly artisanal way since the system did not have, at least initially, fault location elements. This meant that complex faults had a very long time to locate and repair.

The staff consisted of three categories of people with different roles:

- Responsible. "There was a head of the plant who was in charge of it. He relied on other managers who were responsible for shifts and, where appropriate, more specific specialized functions. Both the number of these and the distribution of functions depended on the size of the plant. Its functions were to attend to new customer registrations, introduce new versions and improvements, and organize preventive and corrective maintenance.

- Technical operators. – Its main mission was to prepare and execute the various routines established for preventive maintenance, usually at night, when the traffic at the plant dropped significantly. They were also responsible for locating faults, sometimes with the support of a plant manager.
- Mechanical. – They were responsible for cleaning and adjusting all the electromechanical elements of the plant, both as a preventive measure and as a result of a breakdown. They did almost the work of master craftsmen in the adjustments of relays and contacts. Additionally, they had the responsibility of pulling the bridges in the power plant's distributor to connect the copper pairs of the cables with the numbers of the power plant, an activity we talked about earlier.

People with a lot of experience, acquired after some time living with these plants, were able to identify that something anomalous was happening simply because of the noise made by the plant, being able, in many cases, to identify a malfunction and in which organ, which gives an idea of the level of specialization they came to have. All these people were fundamental for these plants to reach the 80s with an acceptable level of quality, since many of the improvements that were implemented over time were the result of the proposals that arose from the operational staff who worked in the plants.

3. Cross-bar switching panels

While Rotary exchanges have long fulfilled the mission for which they were created, they had significant limitations to the full automation of manual service, a key aspiration for the development of telephony worldwide. Let's look at some of the most important ones:

- The call was set in seconds for local calls from the same exchange, but that time increased significantly when it came to other types of calls due to the intervention of manual panels before reaching their final destination.
- The rotating elements of the exchange could generate background noises during the call, making it difficult to talk. In addition, there was a lot of wear on the rotating elements due to the continuous friction.
- The progressive progress of the call in stages, in which one stage knew nothing of the situation of the next, meant that when moving from one stage the call could not always progress because it did not find free elements to do so, causing calls to be lost.
- The electricity consumption was very high because it did not depend on the traffic supported by the plant as there were mechanical elements in continuous movement.
- The spaces needed to accommodate them were very important, making the initial investment very high both for this reason and for the very nature of the system and its minimum necessary. The 7D allowed some progress in this regard, but it was not an adequate solution for much of the territory either.
- It did not allow for the development of solutions for intercity and international connections that had to continue to operate through telephone operators in the corresponding tables.

It was therefore necessary to develop more flexible systems that would allow these problems to be solved for the deployment of automation.

It was not until 1950, possibly conditioned by the outbreak of the Second World War, that a new technology called crossbar switching appeared, so called because the function of access to customers, carried out with search engines and rotating elements in the Rotary, was replaced by tables composed of horizontal and vertical bars in the form of a matrix that, With the necessary activations, it establishes a crossing point that closes a circuit. These elements constituted the so-called multi-selectors, which were the equivalent of a complete group of search engines in rotating systems.

These exchanges had a control unit that, in addition to recorders capable of capturing the number called, could analyse whether there were free elements in the following stages, thus avoiding the loss of calls under normal traffic conditions. This function was performed by a circuit called a marker, which grouped several stages of multi-selectors, signaling the desired input and output of the set, establishing the internal connection of the different stages according to the availability of available links, freeing up the control organs.

Relays evolved on the previous ones, although they performed the same function, that is, to make connections based on the received currents, but they became much more specialized for different functions.

As we have already seen in the Rotary control panels, the evolution of these systems with new versions and improvements was constant over time, with the introduction of electronic circuits, of different generations, in their equipment, especially in the control unit.

The establishment of a call followed the same guidelines as in a Rotary system, but with very different connection circuits that allowed better precision in the occupation of the different elements, thanks to the changes mentioned above.

All this meant that the time to establish a call dropped from half a second, in an environment of 400-450 milliseconds. A great advance, therefore, over previous systems.

Electricity consumption became dependent on telephone traffic at any given time, and was drastically reduced. In the same way, the spaces needed for its installation decreased significantly.

In short, they were much more flexible from all points of view, which allowed us to consider a greater penetration of this type of technology in our territory. In addition, the very nature of these systems, their cost and their simplification, made it possible to start the automation of intercity and international switching by replacing the manual exchanges that performed this function, fulfilling the old dream that a call would be automatic end-to-end regardless of the distance it traveled.

In 1945 the nationalization of Telefónica took place, which implied, among many other things, an agreement with ITT and Standard Eléctrica so that this company would have exclusivity in the delivery of equipment for 20 years. This meant that, during that period of time, coinciding with the appearance of these technologies, this company was the supplier of this equipment, which was developed for the first time by ITT, in 1953.

It was in 1962 when the deployment of this type of exchange began in Spain, both in local exchanges and in the so-called Automatic Interurban Exchanges (CAI) with the new Pentaconta 1000 (P-1000) systems, so called because the line selection elements had 20 fifty with access to 52 customers each and the group 20 secondary sections with 52 levels each for output links.

From the point of view of local centres, they were installed in large cities, without dismantling in most cases the existing Rotarys, to cover the new needs of these populations, but they also allowed smaller towns to be lowered with facilities of around 1000 lines or more, although there were some exceptions of centres with a somewhat smaller number of lines. almost always as a result of the level of traffic they supported.

In the interurban area, numerous exchanges were set up at the regional or provincial level, to perform the function of interurban interconnection, radically reducing the activity of the existing manual interurban exchanges, limiting these to the connections with the manual switchboards of the rural populations that remained unautomated at any given time. The difference with local exchanges is that they did not have a customer access network. They had inbound links that received traffic from local exchanges in their area of influence or from other interurban exchanges and had outbound links for the various destinations.

This development of switching at all levels required further advances in the transmission network and in the signalling systems between exchanges in order to ensure that the network as a whole could significantly improve its performance. This led to a significant effort over many years, both in the cable network and in the necessary transmission networks, whether via cables, including submarines, via radio, or, later, via satellite.

Also noteworthy is the appearance of multi-frequency systems that replaced pulse systems such as those we saw in rotary telephones. These systems, instead of opening a circuit, used a combination of frequencies to identify a number. This allowed the signalling of links between exchanges to be modernised, with multi-frequency transmitters and receivers, as well as information between organs of the exchange, and new families of telephone sets appeared, replacing disk dialing with keypad dialing. These systems based on different frequency tones were very important until the advent of digital control panels.

In the 1970s, a very important simplification of the P-1000 system was introduced, which, based on the same crossbar philosophy, allowed the construction of much smaller power plants. These were the so-called PC-32 power stations that in the 1970s and 1980s made it possible to deploy rural automation plans throughout the territory. It was not, however, until December 1988 that the total automation of the territory was completed with the replacement of the last rural manual switchboard in the town of Polopos in the province of Granada.

At the end of Standard's 20 years of exclusivity, Telefónica decided to allow other providers to enter from 1966 onwards. This led to the creation of Intelsa S.A. in 1971, a company owned by Ericsson and Telefónica, and at the end of the 70s the Swedish company began to install the Swedish company's power plants with this technology. These were the so-called ARF exchanges at the local level and ARM at the interurban level.

The disappearance of mechanical elements and the modernization and simplification of its internal interconnection networks, together with the availability of test and maintenance circuits that helped in the location of faults, had a radical impact on personnel needs. In a P-1000 plant with the same number of lines as a Rotary, the number of managers and operators dropped drastically, with the most abrupt drop in the number of mechanics, as cleaning and adjustment activities were reduced to a minimum.

In addition, the organization of maintenance had to be planned differently in rural areas, since with the massive installation of PC-32 plants it did not make sense to set staff in a specific plant, and it was necessary to create maintenance sectors in the larger provinces to centrally attend to the maintenance of those plants. In some provinces, it was even centralized at the province-wide level. Over time, this process of centralization continued to advance and, as a result, the efficiency of these activities grew very significantly over time.

With the development of computing, in the early 1980s, switching providers decided to change the control unit of some P-1000 and ARF exchanges for computers that performed this function, maintaining the access networks of the exchanges, although doubling the clients accessible by multi-selectors. This gave rise to the P-2000 and ARE exchanges, which are known as semi-electronic exchanges. Its implementation was not easy and its transition process was very short because very soon after the state-of-the-art digital exchanges of that time burst onto the scene.

This was the last attempt to modernise crossbar switchboards, as it was clear that the future belonged to the new digital switchboards, with new functions and very significant improvements in efficiency, in terms of space and staffing needs.

Up to this point I have tried to make a brief summary of a beautiful story, for me, which allowed a vital advance in the telecommunications of our country during the twentieth century, finally reaching the entire territory.

But I don't want, and I don't think I should either, end this article without acknowledging the people at Telefónica and the main suppliers who made this story possible. To the engineers who planned and designed these networks, to the telephone operators who made possible the transition to the end of automation, to the maintenance staff of the exchanges, cable networks and transmission systems, as well as to the various support organizations, because without them this story would not have been possible.

I would like to express in a singular way my recognition and admiration to the managers, technical and mechanical operators, for their daily struggle so that these plants could provide the best possible service for so many years.

Those of us who have been lucky enough to lead these collectives at some point, feel that it has been an honor and a privilege to be able to be part of their history, which they also shared with other collectives that operated our company's transport networks and equipment.

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