Figure 7. Robots working in the PSA Vigo plant.

Many power quality problems occurring in a node of the network (harmonic, flicker, sags, etc.) and their effects are inversely proportional to the short circuit capacity of the network at that node; therefore, if the factory is connected to the network of 220 kV, with a higher short circuit capacity than the network of 132 kV, then it will not suffer such severe consequences of poor power quality.

On the other hand, the connection to the 220 kV network would mean annual savings of one million Euros in the PSA-Vigo's electricity bill, which is something the company has also put before the Secretary of State for Energy to argue its request to a 220 kV connection; its effect on the reliability of the electricity supply is important so as not to see the production process altered, as in other plants in the group, such as Figueruelas (Zaragoza) and almost all the car factories in Spain [10].

The Spanish Transmission network operator, REE, itself considers this action necessary, which is already reflected in its 2015-2020 planning (New Vigo 2020 Project), but so far it has not materialized, pending that the Ministry of Ecological Transition approves the "exceptionality" of the project to authorize the investment, which amounts to 70 million Euros, since part of this link would have to be underground, which makes the works more expensive.

This project is crucial both for the Balaídos (Vigo) plant and for the future needs of the city of Vigo, the only large Spanish city connected to a 132 kV network.

On Figure 3 of reference [6] the authors illustrate four alternative solutions. As this chart indicates, it is generally less costly to tackle the problem at its lowest level, close to the load, because solutions such as enhanced equipment specifications cost a small number of Euros since sensitive parts have very low current ratings. As solutions at higher levels of available power are entertained, the solutions often become more expensive.

## 6. Conclusions

The best solution to address a problem involving voltage sags or short interruptions depends on the customer's particular circumstances and the distribution network characteristics.

Equipment included in industrial processes, such as in PSA-Vigo, may be particularly susceptible to voltage sags. The reason for this is that such equipment is interconnected, and a failure of any component can cause the shutdown of the manufacturing line or the entire industrial plant.

It should also be borne in mind that different categories of equipment and even different brands of equipment within the same category (for example, two different models of motor speed control circuits) may have completely different sensitivities to voltage sags. This makes it difficult to develop a single standard that defines the sensitivity of equipment included in industrial processes.

Robots need constant voltage to operate properly and within certain safety conditions. Any sudden variation in voltage, especially that caused by the sags, can lead to the execution of unsafe robot or machine operations. Therefore, these types of machines are often adjusted to stop working from levels around 90% of the rated voltage.

The wide range of sensitivities presented by industrial equipment underlines the importance of collaborating with the manufacturers to ensure that the equipment can function within the electromagnetic environment in which it will be used, and it is possible to develop specifications based on realistic power system conditions. It is also important to understand that the entire process in an industrial plant can depend on the sensitivity of a single piece of equipment. Together, the process involves control circuits, contactors, robots, logical devices, etc, which are, in turn, integrated, each and every one of them, in the operation of the plant. This can also make it difficult to identify the sensitive part in a process, after the whole process has been stopped.

The fact that voltage sags are not usually destructive for electrical equipment does not detract from the severity of their effects, as they can cause serious damage to the production generated by these pieces of equipment. Stoppages in production processes generate economic losses and defects in manufactured products.

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