# The transcendence of Smart Grids in Industry 4.0

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***Abstract*** **— This document understands and explains Industry 4.0 and the implementation of the smart grids since electrical distribution systems are currently rigid and without intelligence. The implementation of intelligent automatic systems will allow power companies to have real-time knowledge of the entire network, rapid reaction, problem detection and minimization of the impact of a failure, technologies, tools and techniques will also be applied. All this adapts to a cape with the adaptation between consumption and production of electricity that requires a high availability of all energy sources. The amount of energy that can be received is used when consumption exceeds production and production is maintained at a constant level, or with less abrupt variations. This allows an increase in efficiency, a reduction in costs, a greater ease of network management and an increase in its average life.**

***Keywords — smart grid, electrical storage, industry 4.0, interdisciplinary, disciplinary synergy, energy, Energy engineering.***

## I. INTRODUCTION

Industry 4.0 will fundamentally change the way we live, live, work and live together. In its scale, scope and complexity, the transformation will be unlike anything mankind has ever experienced before, as manifested [2], cited by [1]. And it is not for less, that revolution is expected to profoundly change the means of production, people's livelihoods, and the future of jobs, among many other important aspects of daily life.
According to the director of the World Economic Forum, “the fourth industrial revolution is not defined by a set of emerging technologies in themselves, but by the transition to new systems that are built on the infrastructure of the previous industrial revolution, [2].
According to [3]. The term industry 4.0 refers to a new model of organization and control of the value chain throughout the product life cycle and throughout the manufacturing systems supported and made possible by information technologies.
The term industry 4.0 is widely used in Europe, although it was coined in Germany. It is also common to refer to this concept with terms like "Smart Factory". In short, it is the application to the industry of the "Internet of Things" (IoT) model. All these terms have in common the recognition that the manufacturing processes are in a process of digital transformation, an "industrial revolution" produced by the advancement of information technologies and, particularly, of information technology and software, [ 3].
However, when making a historical recapitulation, it will be seen that at the beginning of this technological evolution, of all these ages, (1st industrial revolution, 2nd, 3rd, etc.). The greatest achievement was thanks to technological innovations of an energy nature as detailed in the following section.

## II. THEORETICAL FRAMEWORK

The first industrial revolution (1784) was distinguished by the integration of mechanical power systems powered by hydraulic turbines and thermal machines with manufacturing systems, whose principal artifact and workhorse were the steam engine for increased industrial production, and with this, from the academic and human capital perspective of that time, it caused the creation and development of Mechanical Engineering programs both for the design of new mechanisms and new steam engines more efficient, as well as for the operation and installation of the same, so it was necessary to specialize mechanical engineering in its two largest aspects, mechanical design and thermodynamics and heat transfer. But in the same way and to avoid the usual human error, various control engineering devices were devised and adapted, several control engineering devices, such as the steam engine speed regulator, creating the first technological synergy of Industry 1.0, see figure 1.

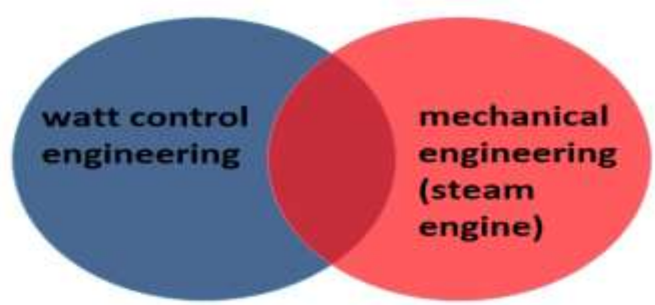


*Figure 1. Synergy of the 1st Industrial Revolution.*

The second industrial revolution (1870), see figure 2, established the production lines in the plant with reduction in production times and mass production of products with identical characteristics was organized for batch production. And with the generation of electricity, electric motors were designed as power units in manufacturing systems and stimulated the creation and development of Electrical Engineering programs, [4].

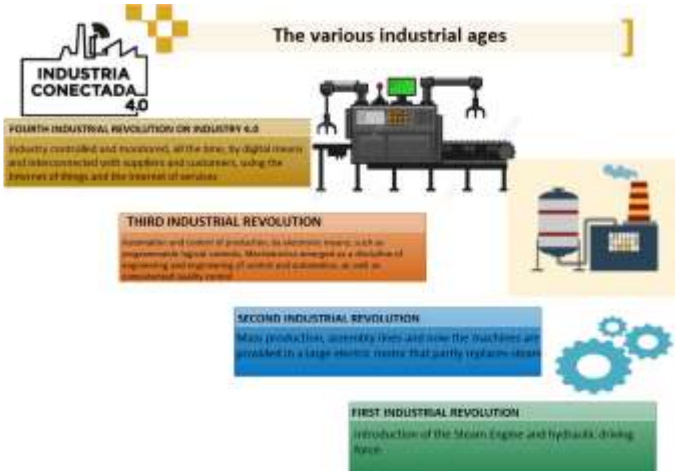


*Figure 2 The various industrial Ages through which humanity has passed, [4].*

In this context, it can be stated that the now known as Industry 2.0, produced the need for a technological education 2. 0, which required much more participation of science in the training of new electrical engineers, since to understand the electrical phenomena it was necessary to be able to model them mathematically. From here we can emphasize that a series of interdisciplinary relations are being woven between the diverse productive needs of these technological Ages. Starting with mechanical engineering, intertwining with control engineering, and continuing with electrical power engineering. In an almost contemporary way, the link between Mechanical and Electrical Engineering is created in the drive of both hydraulic and pneumatic turbines to produce electrical energy in large hydroelectric and thermoelectric power plants, giving way to Electromechanical Engineering, see figure 3.

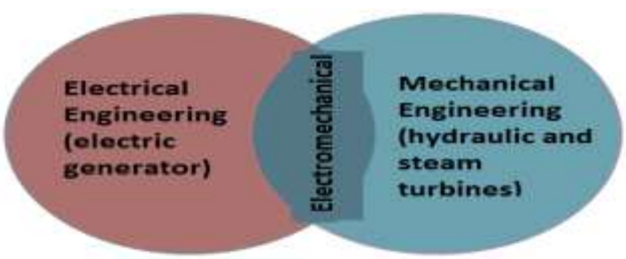


*Figure 3. Synergy of the 2nd industrial revolution.*

The third industrial revolution (1980), Ibid, is characterized by the intensive and extensive use of automation and robotization based on electronics integrated into devices such as microcontrollers, programmable logic controllers (PLCs) and digital computers to exercise the function of process control.

Therefore, the transition from Industry 2. 0 to 3. 0 implied a great development of electronic engineering in a great number of aspects, among which we can mention in order of appearance the vacuum valve electronics. Later, thanks to a great contribution to the physics of semiconductors, the solid-state electronics arises, with which the electronic valves can be replaced by solid-state semiconductor devices and thus gain a lot of efficiency and reliability in the operation of electronic devices and at the same time microminiaturize the increasingly complex signal processors. This leads to the creation of complex computers and with the creation of these comes computer engineering. Computer languages and later computer science. At the same time, electronics are becoming very useful for communications, which is why the emergence of communications and instrumentation electronics can also be seen.

With the handling of all the electronic signals with which the human being interacts, the analogical electronics, the acoustic electronics arise and it is then also that with the analogical electronics, the engineering of control and automation can be nourished of her creating a great field of application as it is it the electronics of control that takes so much of the analogical electronics, in its beginnings, with the operational amplifiers and later with the digital electronics, with its joint the means to automate in this Age in which we are still living and that we can consider like Industry 3. 0, [4].
In this great electronic age as it was the second part of the 20th century. A great synergy is achieved with the branches that arose in the past along with the flourishing computer engineering and it is when Mechatronics in Japan emerges as the branch that integrates all the others that arose previously with the enormous advantages that electronics and computing brought with them, thus achieving enormous competitive advantages that were not available in the past, [4].

From the perspective of energy technologies, which is the essence of this research, the electronic age brought with it a series of contributions that have achieved a modern and advanced monitoring and supervisory control system that is quite efficient and effective, for the dispatch and control of energy in every modern nation. Similarly, advances in power electronics have greatly enabled the interconnection and synchronization of renewable technology power generation plants from non-fixed energy sources (wind and solar), [5].
On the other hand, and on the eve of the 4. 0 industry, it can be seen with historical evidence that mechatronics is a discipline of transition from the latter part of the 3. 0 industry to the 4. 0 [4,6]. And if we observe in detail, we can notice that this discipline has a multidisciplinary origin and a transdisciplinary goal. And it is shown in the face of Industry 4. 0. As the discipline of the Tangible of this Age, which is about to begin, see figure 4.

In this regard, in Industry 4.0, at least nine well-identified technologies converge, which are integrated into this concept, but which belong to different disciplinary fields, which previously did not coincide with figure 5.

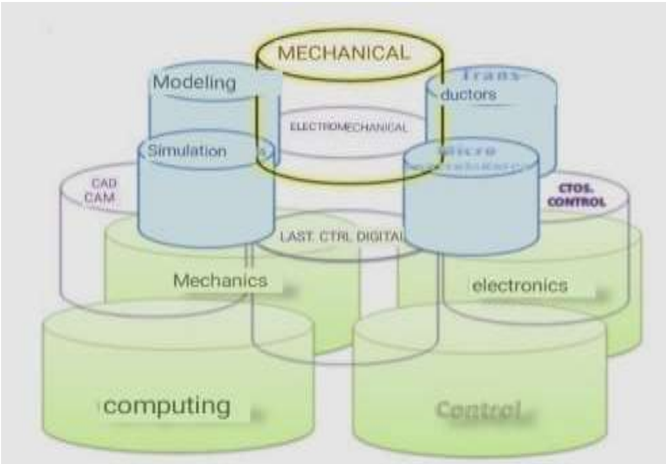


*Figure 4. Multidisciplinary synergy of the 3rd industrial. revolution, [3].*

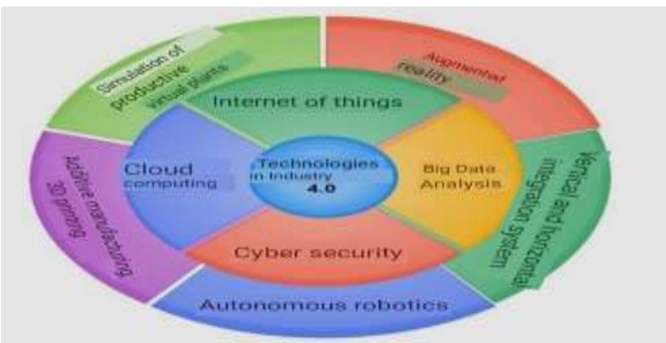


*Figure 5. Leading technologies of Industry 4.0, [4].*

From the previous image, and unlike the first two industrial revolutions, detailed in this article, there is no longer a first-line technological evolution that is of the energy or electrical energy type.

Summing up, even with all that has been added to it in terms of modernity and advanced technology, it can be pointed out that with the 140 years of existence of the electrical sector in the world. Its operation and the initial technologies in terms of conventional electricity generation, transport and distribution have changed relatively little in reality and according to the roadmap that Industry 4.0 has, in theory, all the technologies that will converge in this new era, they consider as resolved the great question that implies having a highly secure electrical supply in terms of continuity and very high performance in terms of the quality of the technical product. Question that is still a significant distance to be achieved in a very broad sense, [7].

While it is true that Industry 4.0 promises to be a more efficient productive sector from an energy perspective than Industry 3.0, due to all the intelligence that both the machines and the logistics and the personnel that operate it will have. That promise of being more efficient will necessarily require a supply of the before mentioned quality, [1].

## III. Smart Grid

On the other hand and in parallel to the planning of the 4.0 industry, they have walked or advanced in their own way and also at their own speed, the roadmap that seeks to modernize the electricity sector at an international level, with the emblem of getting to have in the near future the Smart grid. The same that is driven by the advance of renewable generation technologies and the technologies that have emerged and some others that are about to emerge from energy storage, [7].

Likewise, the electrical systems have become a source of wealth and in some way an indicator of the development of nations. The consumption of electrical energy, with a few exceptions, has not stopped growing and is currently undergoing a new revolution with the digital automation of processes, both in production and services. Although it is true that when the electrical system fails, there are many detriments, the general population, except for isolated circumstances, perceive that the current electrical system works well in most developed nations [7].

According to industry 4.0 experts, it will be more efficient in terms of energy consumption because its objectives include optimizing both the production and use of energy for manufacturing. But while it will be more efficient and perhaps therefore lower consumption, it will require a higher quality of electricity supply, in both its aspects, both high continuity and a level of voltage and frequency that fluctuates in a much lower range than the current standard allowed.

Therefore, Industry 4.0 will require for the nine essential technologies to work, a high availability of electricity, which will be possible with the modernizing trend of the electricity sector in each nation that tends towards the smart grid. According to [6] it will have the following characteristics:

- It must allow for the bi-directional flow of energy
- Uses two-way communication
- It should be as far as possible; self-repairing: anticipating, detecting and responding to disturbances to avoid or reduce disruption.
- Incorporates the consumer as an active agent, modifying consumption in response to real-time energy prices
- Resists natural phenomena, physical and cybernetic attacks
- Accommodates all types of energy generation and storage sources
- It operates efficiently and optimizes the use of electricity generation, transmission and distribution assets.

To a large extent, the characteristics of the electricity system of the future will be achieved with the incorporation of "intelligence", based on information and communication technologies (ICTS):

- Sensors and advanced measurement systems
- Communication and data processing networks
- Actuation and control systems

Electrical distribution systems are currently rigid and virtually "unintelligent". These systems respond to faults by counting currents produced by short circuits and opening circuit breakers to isolate the faults according to a pre-established coordination of protections, for obvious rigid reasons. Some slightly more advanced systems (through hardware and software) can determine the location of the fault and perform circuit breaker operations in order to provide an alternative power network after the fault in order to minimize the number of affected customers. However, these operations remain very limited in scope. A similar situation occurs in voltage control, even today the networks have very little capacity to have local responses in real time to adapt to some changes or face severe contingencies, [7].

The implementation of intelligent automatic systems can give the electric companies a real-time knowledge of the whole network allowing a quick reaction, the previous detection of potential problems and the minimization of the impact of a failure. In addition, if a direct connection is available to all end customers, the status of their lines, consumption and supplies can be checked and action taken before the fault is reported, of course if the fault does not occur spontaneously [7]. Technologies, tools and techniques, many of which are already available in other industrial applications, will be applied to the smart grid, incorporating more information and knowledge to make the grid more efficient, both in terms of energy and operational safety [7].

Traditionally, the supply of electricity within large electrical power systems has been composed of a supervisory control and acquisition data system (SCADA), which has made it possible to monitor and control this process from generation to power substations. This is done to detect needs for increasing or reducing generation or to respond to system instabilities.

In this context, computing, and telecommunication technologies, besides control technologies, will now have to permeate into the electricity distribution, both in the monitoring of the network, and in the control of the distributed generation connected at this voltage level. In relation to the above and in the same way as most industrialized nations currently make intensive use of specific renewable energy sources; large wind farms connected to the transmission grid and these are managed centrally. Also distributed generation, both renewable and conventional, will have to be "observable" and "controllable" in the distribution network. In this way the intelligent distribution networks will act as a means that:

- Allow the active participation of consumers
- Accommodate all generation and storage options (if any)
- Allow the development of new products, services and markets in the electricity sector.
- Optimize the operation of network elements.
- Anticipate and respond to system disturbances.
- Resist attacks and natural disasters

## IV. ELECTRICAL STORAGE.

In this context, one of the key issues will be the adaptation between consumption and production of electricity itself, which requires high availability of all energy sources (especially fossil fuels that are currently more manageable) to compensate for the fluctuations and intermittency in energy production, especially of non-fixed energy sources, such as some renewable energy technologies, solar and wind, [5].

Only an appropriate management capacity of the network can avoid cuts, fluctuations, and instabilities, ensuring the adequate quality in the supply of electricity, always.

The introduction of energy storage elements will make it possible to accumulate energy during the time that production exceeds consumption, a fact that is carried out in renewable systems whose production has been cataloged as a no firm energy source, mainly due to the fact that primary energy (wind or solar radiation, are not manageable or dispatchable at will as it is the case of photovoltaic.

- In this context, it is visualized that the availability of storage systems will allow soon:
- Ensure a correct balance between demand and consumption
- Better management of transmission and distribution networks
- Promote demand management
- Improve the competitiveness and safety of the electricity network
- Improving established energy markets
- Enhance "smart grids".
- Avoiding long user interruption times TIU
- Work in isolation during widespread and long-term power outages.

The stored quantity is used when consumption exceeds production and allows the production plant to be kept at a constant level, or with more leisurely variations. This allows an increase in efficiency, a reduction in costs, greater ease of plant management, and an increase in the average life of the plant.

In this line of action, the people who have operated the electrical power system for years, are currently facing a challenge that involves the operation of the same, under the slogan of allowing the continuous and constant penetration of more and more renewable technologies with no firm primary energy sources, such as wind and photovoltaic technology mainly. This challenge has already been overcome to some extent by the main European and some Asian nations which, to depend less and less on hydrocarbons to generate electricity, have increasingly promoted the use of renewable energy technologies [7]. Therefore, and as the second era in this wave of modernization of the electricity sector worldwide, and given that unstable energy sources are being used more and more, more money and time has been invested in applied research, in energy storage technologies that can ultimately increase the plant factor of renewable generation systems. Among the energy storage mechanisms are.

1. Mechanical energy, whether in the form of potential energy from waterfalls, kinetic energy from flywheels, or elastic energy from pressurized gases.
2. The chemical energy released in the formation of high binding energy molecules ($CO_2$, $H_2O$), through the combustion of low binding energy molecules, such as gasoline (octane), alcohols, Hydrogen, or methane.
3. Electrochemical energy associated with oxidation/reduction processes of chemical species and that can be transformed into electrical energy by means of electrochemical cells.
4. Electromagnetic energy obtained in a region attributed to the presence of an electromagnetic field, and which is expressed as a function of the intensities of the magnetic field and the electric field.
5. Thermal energy based on the good concentration capacity of certain materials due to their specific characteristics and / or their phase change characteristics, [7].

Various functionalities are expected from all storage systems, depending on their location on the network and according to their typology, such as those detailed below:

- **Load leveling.** It involves the load of the storage system when the cost of energy is low to be used when the cost is high, to ensure a uniform load for generation, transmission, and distribution.
- **Peak/valley compensation.** It allows the use of the energy accumulated in periods of consumption during peak periods of maximum consumption, trying to avoid the use of the most expensive power plants at times of maximum consumption and seeking to optimize the efficiency in the use of base plants in energy supply during off-peak periods by increasing the load at these times.
- **Cargo tracking.** It allows the storage system to be used as a filter, buffer, or buffer that absorbs or injects energy to balance the variations between generation and consumption in short time intervals.
- **Control of active reserves (injection into the network).** This functionality is very close to the previous one, although the difference is that the network operator activates the storage to compensate for the differences between scheduled generation and actual consumption to ensure network quality.
- **Technical product quality.** Reduction of disturbances in the network (fluctuations and intermittencies) softening the effects of oscillations (flicker) and/or voltage drops (voltage sags). This provides robustness, as it reinforces stability against transients, ensuring consistency of tension, and damping any power oscillation. The storage element can be used to give the waveform.
- **Investment delay.** The use of storage systems makes it possible to temporarily defer actions to improve the transport and distribution system in the network by allowing the network to be dimensioned in a more balanced way concerning the average consumption, avoiding extra loads.
- **Demand management.** Using storage systems in the user area that allows minimizing the cost of energy or even obtain profits by purchasing energy outside of consumption peaks and managing them.
- **Intermittent mitigation.** Using storage systems to facilitate the use of renewable sources, such as photovoltaic and wind energy. The energy storage allows reducing the impact of its variability on the electrical network.
- **Contingency plan.** Using storage systems to deal with various problems in the end-user area, such as voltage fluctuations, frequency regulation, loss reduction by reducing network use in periods of increased load, facilitating the reduction of transport costs, and in general, the offer of a reservation in case of disconnection, facilitating reconnection after a general blackout.
- **The balancing or leveling of loads.** Prevents voltage fluctuations and ensures frequency regulation for end-user equipment. Another use would be the security of supply for emergencies, to maintain a very high level of reliability concerning the consumer. With this, improving the quality of supply in terms of having an uninterruptible supply, reducing the TIU, [7].

## V. ENERGY ENGINEERING TECHNOLOGIES NECESSARY FOR INDUSTRY 4.0

At this point we can note that the technologies that will take on the greatest importance in the smart grids will be the following.

- Electronic control of static power converters
- Modular renewable generation systems, both at macro levels, but even more, at mini and micro levels.
- Converters based on power electronics.
- Electrical storage systems, both macro and micro levels.
- Intelligent energy management systems, for the control of micro electrical networks.
- Transformers with intelligent control, for bidirectional control of energy in distribution networks
- Technologies for the management of auxiliary services in electricity distribution networks.
- Uninterruptible high and low power electrical energy systems.

## VI. CONCLUSIONS

This work details the main technologies in Industry 4.0 and describes the importance of having a smart grid for the famous smart factory, as Industry 4.0 has also been called. It is described in detail, which implies the smart grid, which also brings with it the increasingly frequent interconnection of renewable energy technologies and therefore also leads to the increasingly necessary use of energy storage systems of various technology, which once developed massively, will allow its increasingly frequent use with systems known as micro-electrical networks or micro Smart Grids.

Finally, it is described that it will be necessary for the near future systems that provide electrical energy with quality of supply of higher quality than the current one.

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