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Electric utility 4.0: Trends and challenges towards process safety and environmental protection

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ABSTRACT

The traditional manufacturing business model is changing for new emerging models. Many changes are related to the industry 4.0 challenge and among them there is a concern regarding how industries will meet the objectives of sustainable operations, especially on that of environmental protection and process safety. Some industries are making great efforts to get aligned with the industry 4.0 paradigm, and for the Electric System Industry, it is no different. Because of its strategic and environmental importance, the electric system industry must be investigated. In this article we used qualitative research based on a systemic approach, using the Soft System Methodology (SSM) to address the challenges brought by the industry 4.0 paradigm in the electric system industry in Brazil, focusing on the topic of environmental protection and process safety. Moreover, we point out important capabilities needed by these companies to keep up with the new industrial revolution. Results from the SSM have exposed important management gaps and hence have shown new possible management models that can contribute to the modernization of the electric utilities in Brazil, making these industries more sustainable. In fact, it is imperative for companies to detail the organizational capabilities they will need to thrive in the business process. Therefore, we conclude the paper by indicating the three main dynamic capabilities that have emerged: new policies to enable innovation, bureaucracy reduction, and investments in education.

1. Introduction

A digital transformation is now underway in the industrial ecosystem. Industries are enhancing their digital functionality in manufacturing processes and operations as well as in their portfolios, enabling innovative digital and data-based services (Zhong et al., 2017).

The industry 4.0 term stands for the fourth industrial revolution and generates impact on all industries around the world (Stock and Seliger, 2016; Prause and Atari, 2017). It is a shorthand name to describe the fast changes in the value chain of industries, which are encouraged by the concepts of the industrial internet and digital factory. The Industry 4.0 paradigm encompasses multi-dimensional aspects of business operations and brings improvements in industrial processes, as material usage, circular economy, and supply and value chain (Strandhagen et al., 2017a,b). The application of Industry 4.0 and related concepts and technologies is part of an ongoing discussion, which has effects throughout the entire industry.

Past revolutions in manufacturing were focused on the automation of single machines or processes. Now, the new revolution promises to generate analyses and communicate data to improve value on products and services in an optimized and intelligent way (Schwab, 2017). Therefore, information from lower levels of automation, single machines, process variables, and production logs must be condensed, communicated and learned flawlessly and rapidly. These characteristics set the new global picture of value creation and the role of the new industry (Geissbauer et al., 2016).

We can set the scene of the industry 4.0 framework. This framework is composed primarily of the core capability of *Data & Analytics*, where digitization of data from production processes and services lead to the integration of vertical and horizontal value chains (Marques et al., 2017). Moreover, this capability enables the design of new digital business models and the greater access of customers to services. One can observe that to achieve such paradigms, the use of contributing technologies is paramount. We can pinpoint different cutting-edge technologies such as cloud computing, Internet of Things (IoT) platform, advanced human-machine interfaces,

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augmented reality, mobile devices, smart sensors, 3D printing, authentication & fraud detection, customer interaction, advanced algorithms for data and big data analysis, artificial intelligence and machine learning. (Baccarelli et al., 2017; Wan et al., 2016, Monostori et al., 2016; Li et al., 2017). It is no accident that the estimates of investments made by industries in such technologies are around US$ 907 bn (Geissbauer et al., 2016).

For Shim et al. (2017) the new automation can help increase the capacity for product customization, mass production, flexibility, and quality of products (Mourtzis et al., 2016; Lee et al., 2014), attending different needs and desires from customers.

Besides all these changes, this industrial revolution also represents a desire to respond to present issues related to the principles of sustainable development (Bakkari and Khatory, 2017). It is clear that environmental concerns from the industry impact production innovations, strategies, and processes (Sarkis and Zhu, 2018).

As pointed out in Geissbauer et al. (2016), some challenges such as data security, human control, energy efficiency, and pollution are concerns that are very prominent in diverse industrial sectors. With the advent of smart production systems, these concerns will have to be revisited and debated in order to fit the new market dynamics into sustainable goals.

Sustainability is a crucial value for all industries to develop processes, products, or services (Gregori et al., 2017). Industry 4.0 can provide opportunities for the implementation of sustainable manufacturing (Stock and Seliger, 2016). Standard mass customization can be excellent for old industrial purposes (Shim et al., 2017) but when it comes to sustainable operations (Kleindorfer et al., 2005) and sustainable supply chain management (Seuring and Müller, 2008) there are other activities that poses several implications on economic, environmental, and social aspects regarded to the Triple Bottom Line (TBL) of sustainable value creation (Kiel et al., 2017).

In this case, managers need to think about how the industry 4.0 can meet the objectives of sustainable operations, especially about environmental protection and process safety. Industries of the electric system are composed of a complex network of power plants, transmission, and distribution wires and have a high environmental impact. As an example, according to REN21 Report (2016) hydropower is produced in 150 countries. China is the largest hydroelectricity producer, with 920 TWh of production in 2013, representing 16.9% of the domestic electricity use. The construction of a hydropower plant can be a planned environmental intervention, but it always has a high impact on the ecosystem. Once working, the project produces no direct waste and has a considerably lower output level of greenhouse gases than fossil fuel powered energy plants (REN21 Report, 2016). Changes focused on process safety will reduce the risk of water shortage and maintain efficient population access. Furthermore, changes in environmental protection can protect surrounding areas of electrical stations and the nearby populations.

Not only power generation has an important role in the environment but also power transmission and distribution. We can pinpoint the effects on ecosystems, animals, and plants that result from the air, water, waste, and landscape impacts these networks cause. Moreover, faults or transient events can directly affect the safety of employees and communities (EPA United States Environmental Protection Agency, 2017).

Previous works have mentioned relevant shifts related to manufacture industries (Zheng et al., 2018; Wang et al., 2016; Kang et al., 2016). However, in the case of utility companies, few papers focus on its systemic impacts (Kleineidam et al., 2017; Shrouf et al., 2014) and none provided management solutions for striking such changes. In this paper, we shall discuss the inevitable trend regarding management practices that electric utility companies will face within the paradigms of industry 4.0. Specifically, an electric utility is a company in the electric system that owns and operates equipment and facilities for the generation, transmission, and distribution of electric energy. Therefore, electric utilities are industries that have a great impact on the environment and is, at the same time, a strategic industry for a country (Ralff-Douglas and Zafar, 2015). The term industry designates the set of activities that manipulate raw materials for the production of consumer goods. In the case of the electricity industry, electricity is a product used indirectly to produce light, movement, heat or any other energy transformation.

It is crucial to associate environmental protection and process safety to outcomes of a properly designed management system for utility industries. Meanwhile, we ask what are the challenges, within the ongoing industry 4.0 changes, that electric system utilities have to address to guarantee a more sustainable environment and safer processes? For that, the Soft System Methodology (Checkland, 1981) was chosen as an adequate methodology, since it is useful to solve complex and ambiguous problems. An interview with a specialist in the electric system industry dynamics will provide qualitative data.

2. Sustainable operations: environmental protection and process safety

One of the main scopes of data digitization is achieving more efficient operations (Gregori et al., 2017). Digitization represents a real opportunity towards value-oriented sustainable activities through several conditions, especially regarding environmental protection (EP) and process safety (PS). Associating both themes, Industry 4.0 can improve risk assessment and minimize oscillations throughout industrial processes with benefits to the material, products, waste and energy management.

From process safety dynamics, one can state that uncertainty is inherent and unavoidable in operations since it belongs to the physical variability of a system response (Markowski et al., 2009). Process safety is the common global language used to communicate the strategies of hazard identification and analysis, risk assessment and evaluation, safety measures, and safer critical decision-making. The common objective of any safety assessment and risk analysis technique is to assure that a process or a system is designed and operated to meet "accepted risk" or a "threshold" criterion (Ferdous et al., 2013).

Industry 4.0 requires standardization (Müller et al., 2018) and stability of processes within and among companies. Process safety encloses data management to predict the reliability of technological systems over a given period. It is an integral part of process development and manufacturing rather than an "add-on" to the process (De Rademaeker et al., 2014). Process digitalization also means more control on management operations, reducing errors, gargles, lack of components, or unestablished production rhythm.

For example, Gabriel and Pessel (2016) points out that smarter logistics are responsible for reducing transport processes as well as unnecessary material flows. Delivery mistakes, needless awaiting times, and turned-back goods can also be minimized by data transparency throughout the entire supply chain. Additive manufacturing, which is one of the core technologies in the Industry 4.0 era, and physical transportation procedures are decreased, especially for spare parts (Oettmeier and Hofmann, 2017). In the same vein, transparency in the intra/inter-firm logistics (Oesterreich and Teuteberg, 2016) can be help increase process stability and reduce risks of ruptures.

Besides the enhanced process safety management, in general, Industry 4.0 enables the reduction of greenhouse gas emissions by data-centered and traceable carbon footprint analyses (Peukert et al., 2015) of the value chain or networks (Herrmann et al., 2014). In specific terms, strategic opportunities in environmental pro-