Industry 4.0: the importance of Automation in the Digital Transformation of the Pulp and Paper Mills in Brazil

Alessandro Rodrigues Frias[1],Flávio Vasconcelos da Silva[1],
Francisco I. Giocondo César[2,3], Ieda Kanashiro Makiya[2]
[1](FEQ, UNICAMP, BRAZIL)
[2](FCA, UNICAMP, BRAZIL)
[3](IFSP, PIRACICABA, BRAZIL)

ABSTRACT:*Industry 4.0 can be understood as the integration of the digitization to the industrial activity, that is, sensors and equipment connected in network, allowing the fusion between the real and virtual world (Cyber-physical Systems). This concept, called Industrie 4.0, was introduced in Germany, so that German industries were able to maintain leadership in the global equipment manufacturers market (integrating information and communication technologies) and also to become a leading supplier of smart manufacturing technologies. The main focus of Industrie 4.0 is on the shop floor of the manufacturing industry, however, the term Industry 4.0 or Digital Transformation is more embracing, being applied in the value chain and not only in the discrete process industries (manufacturing), but also in the continuous process industries. This Digital Transformation is being responsible for the 4th Industrial Revolution and has three pillars that integrated constitute a foundation within the industries, they are: Automation Systems, Information Systems and Cyber-physical Systems. Therefore, this term paper has as main objective to evaluate the automation level in the pulp and paper mills in Brazil, as well as to analyze the knowledge and actions of these industries for Digital Transformation. The method used in this term paper consists of an exploratory bibliographical research on the Enabling Technologies of Industry 4.0 and a survey research through a questionnaire designed to obtain the level of automation, as well as the positioning of the pulp and paper sector in the use of the Enabling Technologies. Among the expected results, in addition to meeting the main objective proposed, there are answers to the problem that originated this research, that is: What is the Automation level and which are enabling technologies that can be used for Digital Transformation (4th Industrial Revolution) in the Brazilian pulp and paper mills?*

KEYWORDS:*Automation, Industry 4.0, Digital Transformation.*

I. INTRODUCTION

What is the Automation level and which are enabling technologies that can be used for Digital Transformation (4th Industrial Revolution) in the Brazilian pulp and paper mills?

The National Confederation of Industry – Brazil (CNI) conducted a special survey in 2016 with 2,225 companies (910 small, 815 medium and 500 large). That survey disclosed that 42% of Brazilian companies were unaware about the importance of digital technologies (including Digital Automation) for the industry's competitiveness and 46% of the companies that participated in the research did not use or did not know if they used any of the digital technologies. Other results highlighted in the survey were the Ranking of Sectors, where the pulp and paper sector ranked 9th in the use of digital technologies with process focus and ranked 10th in the use of digital technologies focused on development. The digital technologies presented by CNI are preconditions for the advancement of Industry 4.0 in Brazil, since they are the basis for the implementation of enabling technologies in the Digital Transformation of industries [1].

In order to meet the proposed objective, first of all, an exploratory research was carried out on the subject and a questionnaire was developed to put through a sectorial research in several pulp and paper mills in Brazil. Therefore, this term paper has as main objective to evaluate the Automation level in the pulp and paper mills in Brazil, as well as to analyze the knowledge and actions of these industries for Digital Transformation.

II. THEORETICAL REFERENTIAL

2.1 Automation

In the middle of 1960, during the 3rd Industrial Revolution, the Automation appeared in the industries through Programmable Logic Controllers

(PLC). Since then, a transformation occurred on the shop floor where the main responsibility was Electronic Automation (PLC, Robots and Industrial Networks). The evolution continued with the use of Supervisory Systems, Industrial PC and New Industrial Communication Protocols. With the emergence of Automation, communication protocols based on pneumatic systems (3-15 PSI) began to be replaced by analog communication protocols (4-20 mA). The industrial networks have as main objective the communication between the equipment and the controllers (PLC) and even with the existence of the Ethernet standard for computer networks since of 1970s, this standard only began to be used in the communication networks of industrial automation in the 1980s and 1990s, being called digital communication. After the 1990s, several industrial communication protocols appeared, for example: IEC 61.158 (Standard Industrial Protocols), Industrial Ethernet and Wireless Industrial. In parallel with the evolution of Automation Technology (AT), Information Technology (IT) has also evolved and there is currently a convergence between these technologies for Industry 4.0 [2].

According to Pereira et al., [3], Automation Technology can contribute to increase economic activity and mitigate environmental impacts, when used in Industry 4.0.

2.2 Industry4.0orDigital Transformation

Industry 4.0 can be understood as the integration of the digitalization to the industrial activity, that is, sensors and equipment connected in network, allowing the fusion between the real and virtual world [4].

This concept, also called Industrie 4.0, came about in Germany so that German industries were able to maintain leadership in the global equipment manufacturers market (integrating information and communication technologies) and also become a leading supplier of intelligent manufacturing technologies [5].

The main focus of Industrie 4.0 is on the shop floor of the manufacturing industry, however, the term Industry 4.0 or Digital Transformation is more embracing, being applied in the value chain and not only in the discrete process industries (manufacturing), but also in the continuous process industries. This Digital Transformation is being responsible for the 4th Industrial Revolution and has three pillars that integrated constitute a foundation within the industries, they are: Automation Systems, Information Systems and Cyber-physical Systems.

According to Schwab [6], the word "revolution" means abrupt and radical change. It occurs mainly with the emergence of new technologies, being perceived through changes in social structures and economic systems. Now a days we are living the fourth industrial revolution, which arises after the consolidation of the automation, that is, based on the digital revolution (internet, sensors, artificial intelligence and automatic learning).

2.3 Enabling Technologies

The enabling technologies are presented by Schwab [6] as technological drivers of the 4th Industrial Revolution and are divided into three categories: Physics (Autonomous Vehicles, 3D Printing, Advanced Robotics and New Materials), Digital (Internet of Things - IoT) and Biological (Synthetic Biology). Other technologies are also highlighted by Schwab (2016), such as: Big Data, Cyber Security, Artificial Intelligence and Augmented Reality.

Kagermann, et al. [5] shows in his work some enabling technologies, such as: Big Data, IoT, IoS, Cyber Security, Cloud Computing and Virtual Simulation.

CNI presents the main enabling technologies of Industry 4.0, such as: IoT, Big Data, 3D Printing, Cloud Computing, Sensors and Actuators, New Materials, Simulation Systems, Machine-to-Machine Connection Systems, Communication Infrastructure, Hybrid Manufacturing , Advanced Robotics and Artificial Intelligence [7].

According to Cheron and Ahmed [8], among the main enabling technologies, Big Data and Artificial Intelligence (AI) can be highlighted in practical applications, but AI has a huge potential for growth and currently there are several applications in the areas of business and manufacturing, highlighting the following advantages: the ability to automate work functions to improve manufacturing efficiency, improve business processes in transportation and supply chains logistics, predict performance and behavior, increase revenue, recognize standards and Big Data interpretation.

Another enabling technology that has been widely used is Cloud Computing. For Villemuer and Ahmed [9], a lot of industries have embraced and are adopting cloud computing, and this is revolutionizing IT and business operations, as cloud platforms and services offer several benefits such as cost savings and faster deployment of applications, but a greater scope for identity management and security controls is needed. With this, another enabling technology called Cyber

Security becomes indispensable to meet security requirements.

In the previous subchapter, Industry 4.0 is initially defined as the integration of the digitization to the industrial activity and such integration is demonstrated above with the enabling technologies, that is, the AI depends on Big Data, which in turn depends on Cloud Computing and which must use Cyber Security. Thus, Digital Transformation will become a reality once the integration of enabling technologies exists.

III. METHODOLOGY

The method used in this paper consists of an exploratory bibliographical research, where some bibliographical references were applied on the subject in question, being consulted the following databases for scientific research: Web of Science, Scopus and Science Direct. Two other research bases were also used: Scholar Google and Google. The search for publications in the databases was restricted in English and Portuguese. The article entitled "Industry 4.0: Bibliometric analysis and guidelines for future research perspectives" [10] served as a basis for the relevance analysis of the enabling technologies of Industry 4.0 selected for the survey research.

To obtain the expected results, the survey research was conducted through a partnership between the State University of Campinas (UNICAMP) and the Pulp and Paper Brazilian Technical Association (ABTCP) in several Brazilian pulp and paper mills. A questionnaire was prepared with 43 questions divided into 5 sectors, one of them being the Automation sector.

The questionnaire was made available through Google Forms for a group of 689 professionals (ABTCP Database), where 221 of these professionals answered the questionnaire, that is, 32% of respondents.

IV. RESEARCH RESULTS

The systematic review of the literature allowed a background on the main concepts of Industry 4.0 or Digital Transformation, as well as the enabling technologies and the importance of automation within this context. As a result of the literature review, 17 enabling technologies were obtained and of these 17 were selected 9 technologies with greater application in industries of continuous processes. In order to evaluate the relevance of these 9 enabling technologies selected to compose the survey research questionnaire, a bibliometric analysis of the Industry 4.0 by César et al. [10] was used, which through a data analysis and treatment obtained 97 articles for the theoretical reference of the bibliometric research and among all the performed analyzes were identified the main economic activities in Industry 4.0, where the industry is the main focus and application. Thus, the 72 articles classified as industrial economic activity were analyzed (Table 1), where at least one citation of each of the 9 enabling technologies was verified in these articles and as a result one has the enabling technologies and the quantity of articles that they were cited (Figure 1).

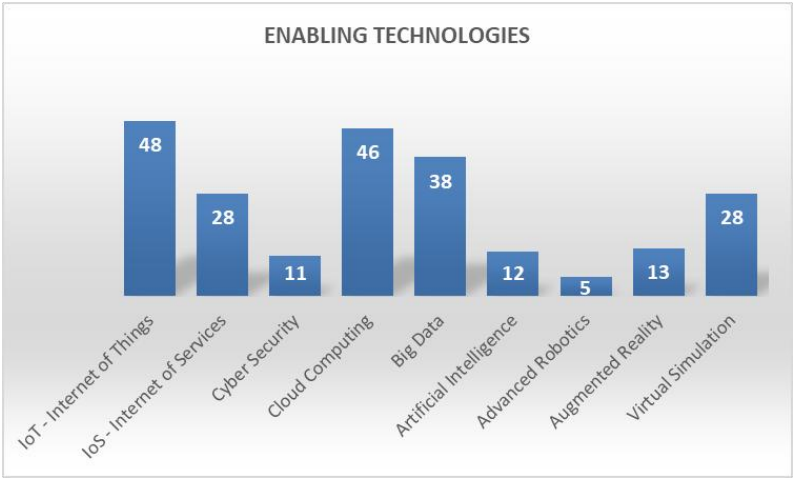

Figure 1: Result of the citation analysis of the enabling technologies in the 72 articles classified as industrial economic activity by César et al., (2018).

Table 1: Citation analysis of the enabling technologies in the 72 articles classified as industrial economic activity by César et al., (2018).

	ENABLING TECHNOLOGIES								
AUTHOR / YEAR	IoT	IoS	Cyber Security	Cloud Computing	Big Data	Artificial Intelligence	Advanced Robotics	Augmented Reality	Virtual Simulation
1 - WEIDMULLER GLOBAL INDUSTRY MANAGEMENT (2012).	✓								
2 - KAGERMANN, H.; WAHLSTER, W.; HELBIG, J. (2013).	✓	✓	✓	✓	✓				✓
3 - ANDERL, R. (2014).	✓	✓		✓	✓				
4 - BLEICHER, F. (2014).	✓	✓							
5 - BRETTEL, M. et al. (2014).	✓	✓		✓					✓
6 - DELOITTE (2014).	✓	✓	✓	✓	✓	✓	✓		
7 - DRATH, R.; HORCH, A. (2014).				✓					
8 - GORECKY, D. et al. (2014).								✓	
9 - HENG, S. (2014).	✓	✓		✓	✓				
10 - PAELKE, V. (2014).								✓	
11 - PLEWA, N. (2014).	✓								
12 - BLANCHET, J. et al. (2014).	✓		✓	✓	✓				
13 - SCHUH, G. et al. (2014).	✓			✓					✓
14 - SCHUH, G. et al. (2014a).									✓
15 - SHROUF, F.; ORDIERES, J.; MIRAGLIOTTA, G. (2014).	✓	✓		✓	✓				
16 - VARGHESE, A.; TANDUR, D. (2014).	✓			✓					
17 - YEN, C. T. et al. (2014).				✓					
18 - ADEYERI, M. D.; MAPOFU, K.; ADNUGA, O. (2015).						✓			✓
19 - ADOLPHS, P. (2015).	✓								✓
20 - AICHHOLZER, G. et al. (2015).	✓	✓	✓	✓	✓	✓		✓	✓
21 - ALBRECHT, J. et al. (2015).									✓
22 - AGHERI, G. et al. (2015).				✓	✓				
23 - BAUER, W. et al. (2015).	✓	✓							
24 - BUHR, D. (2015).	✓	✓		✓	✓		✓		
25 - CAO, B. et al. (2015).					✓				
26 - EST, R.; KOOL, L. (2015).	✓			✓	✓	✓	✓	✓	✓
27 - FALLER, C.; FELDMULLER, D. (2015).				✓					✓
28 - GAUB, H. (2015).				✓					
29 - GERLITZ. L. (2015).	✓								
30 - HERMANN, M.; PENTEK, T. (2015).	✓	✓		✓	✓				
31 - ICA – International Controller Association (2015).	✓	✓		✓	✓				✓
32 - KOCK, F. (2015).	✓	✓		✓	✓				
33 - KOLBERG, D.; ZUBHLKE, D. (2015).						✓		✓	
34 - LEE, J.; BAGHERI, B.; KAO, H. A. (2015).					✓				
35 - LESSEL, P.; MULLER, M.; KRUGER, A. (2015).									
36 - LI, X. et al. (2015).	✓				✓	✓			
37 - LUKAC, D. (2015).	✓			✓					
38 - MAZAK, A.; HUEMER, C. (2015).									
39 - McKinsey & Company (2015).	✓			✓	✓	✓	✓	✓	✓
40 - PAVLOV, V.; KNOCH, S.; DERU, M. (2015).					✓				
41 - PEREZ, F. et al. (2015).	✓	✓		✓	✓				
42 - POSADA, J. et al., (2015).	✓	✓	✓	✓	✓			✓	✓
43 - ROSENDAHL, R. et al. (2015).									
44 - RUBMANN, M. et al. (2015).	✓		✓	✓	✓		✓	✓	✓
45 - ALDIVAR, A. A. F. et al. (2015).	✓	✓		✓	✓				✓
46 - SCHEUERMANN, C.; VERCLAS, S.; BRUEGGE, B. (2015).									
47 - SCHLECHTENDAHL, J. et al. (2015).				✓					
48 - SCHLEIPEN, M. et al. (2015).	✓	✓							
49 - SHAFIQ, S. I. et al. (2015).	✓	✓		✓				✓	✓
50 - SILVA, R. M.; SANTOS FILHO, D. J.;MIYAGE, P. E. (2015).				✓					
51 - SOMMER, L. (2015).	✓			✓	✓				✓
52 - STORK, A. (2015).	✓			✓	✓			✓	✓
53 - TORO, C.; BARANDIARAN, I.; POSADA, J. (2015).				✓	✓				
54 - VDMA (2015).	✓	✓		✓	✓				✓
55 - WAHL, M. (2015).	✓	✓							
56 - WAN, J.; CAI, H.; ZHOU, K. (2015).	✓	✓		✓	✓				✓
57 - WOLTER, M. I. et al (2015).	✓	✓		✓	✓				✓
58 - ZHOU, K. LIY, T.; ZHOU, L. (2015).	✓			✓	✓				✓
59 - BRETTEL, M.; KLEIN, M.; FRIEDERICHSEN, N. (2016).									
60 - CHENG, F. T. et al. (2016).	✓			✓	✓				
61 - DIN / DKE / VDE (2016).	✓	✓	✓	✓	✓	✓		✓	✓
62 - DORST, W. et al. (2016).	✓	✓	✓	✓	✓			✓	✓
63 - EROL, S.; SCHUMACHER, A.; SHINH, W. (2016).	✓								
64 - GRANGEL-GONZALEZ, I. et al. (2016).	✓	✓		✓	✓				
65 - IVANOV, D. et al. (2016).									
66 - LANGMANN, R.; ROJAS-PENA, L. R. (2016).	✓		✓	✓	✓				
67 - MOSTERMAN, P. J.; ZANDER, J. (2016).	✓					✓			✓
68 - PFEIFFER, T. et al. (2016).				✓				✓	✓
69 - SMIT, J. et al. (2016).	✓	✓	✓	✓	✓	✓			✓
70 - STOCK, T.; SELIGER, G. (2016).	✓	✓		✓	✓	✓			
71 - WANG, S. et al. (2016).	✓			✓	✓				✓
72 - WANG, S. et al. (2016a).	✓	✓	✓	✓	✓	✓			

After analyzing the citations of the 9 enabling technologies selected for the survey research in the 72 articles about Industry 4.0, we have the Internet of Things (IoT), Cloud Computing and Big Data technologies cited in more than 50% of the articles analyzed. In the survey research carried out in the Brazilian pulp and paper mills, the 3 main enabling technologies chosen by more than 50% of the respondents were also mentioned above, but in the following order: Cloud Computing, Big Data and Internet of Things (IoT). Table 2 shows a comparison by means of the classification obtained with the analysis of citations of the enabling technologies and also of the survey research carried out in the Brazilian P&P mills.

Regarding the automation level of the P&P mills, the traditional automation pyramid for evaluation was used. To better understand and determine the level of automation of each industrial plant, a pyramid with 6 layers was used, starting with the base (Field Devices, Measuring Instruments and Actuators) to the top of the pyramid (Business Management) and obtained the following result in the view of the 90 automation professionals who answered the survey research questionnaire (Figure 2).

Table 2: Enabling Technologies: Analysis of citations and research survey in the P&P mills.

ENABLING TECHNOLOGIES	
Citation Analysis (72 Articles)	**Survey - Pulp & Paper Mills**
67%: IoT - Internet of Things;	74%: Cloud Computing;
64%: Cloud Computing;	65%: Big Data;
53%: Big Data;	58%: IoT - Internet of Things;
39%: Virtual Simulation;	56%: Virtual Simulation;
39%: IoS - Internet of Services;	53%: Artificial Intelligence;
18%: Augmented Reality;	52%: Cyber Security;
17%: Artificial Intelligence;	47%: IoS - Internet of Services;
15%: Cyber Security;	42%: Augmented Reality;
7%: Advanced Robotics.	36%: Advanced Robotics.

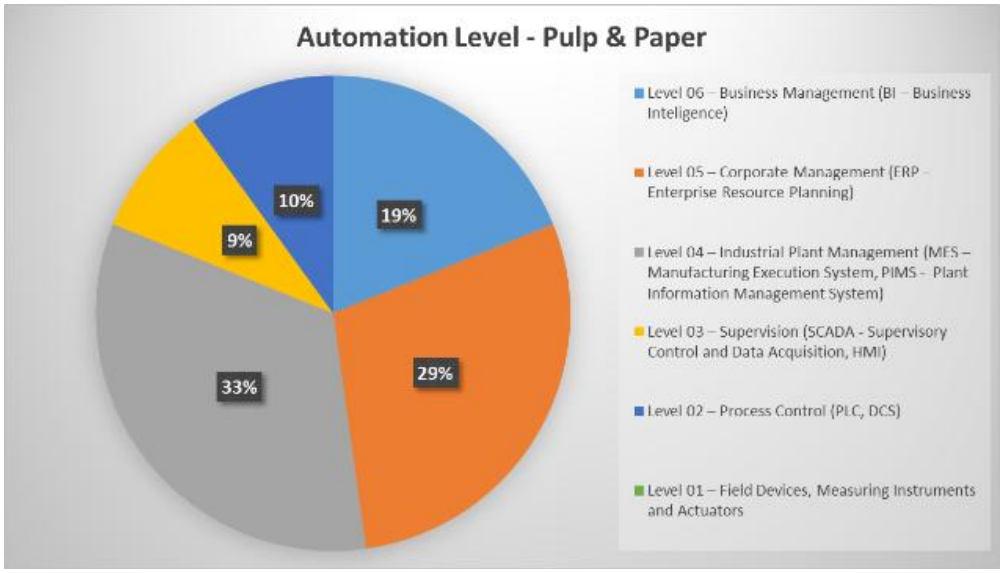

Figure2: Automation Level of the pulp and paper mills in Brazil.

According to the automation professionals that answered the survey research, the automation level of the P&P mills is distributed from level 2 (Process Control) to 6 (Business Management), with 33% of these respondents saying that the P&P sector is classified in level 4 (Industrial Plant Management) and 29% in level 5 (Corporate Management), however, only 19% of the respondents classified the P&P mills as level 6 (Business Management), that is, use BI (Business Inteligence).

Another question addressed in the survey research was to analyze which industrial communication protocol is most used in the P&P mills. The following protocols were presented for the respondents: Communication 4-20mA, Hart, WirelessHart, Foudation Fieldbus, Profibus DP / PA, Profinet, Ethernet-IP, Modbus, OPC, OPC UA, EtherCAT, DeviceNet and ControlNet. Among the communication protocols presented above, the automation professionals were asked to indicate which is the most used in the company that they work and as a result (Figure 3), more than 50% of the respondents said that the most used protocols in the P&P mills are Communication 4-20mA (38%) and Hart (19%), thus justifying the 52% of respondents who classified the automation level between 2 (Process Control) and 4 (Industrial Plant Management).

In order to complement the automation level evaluation in the P&P mills, a survey was requested for automation professionals to classify the integration between Automation and IT. For evaluate this integration, they were used 4 levels of digital generations (G1, G2, G3 and G4) defined by CNI - National Confederation of Industries through IEL - Euvaldo Lodi Institute in the reports on Risks and Opportunities for Brazil in the face of Disruptive Innovations [11] and [12]. Figure 4 shows that 57% of the respondents classified the integration between Automation and IT in the P&P mills between G1 (Isolated Automation, with the use of IT in a punctual way) and G2 (Automation, with the use of IT without integration or of partial form between areas) and only 16% of respondents said that the integration between Automation and IT is G4 (Use of Automation and IT in an integrated, connected and "intelligent" way. Use of information to support decisions).

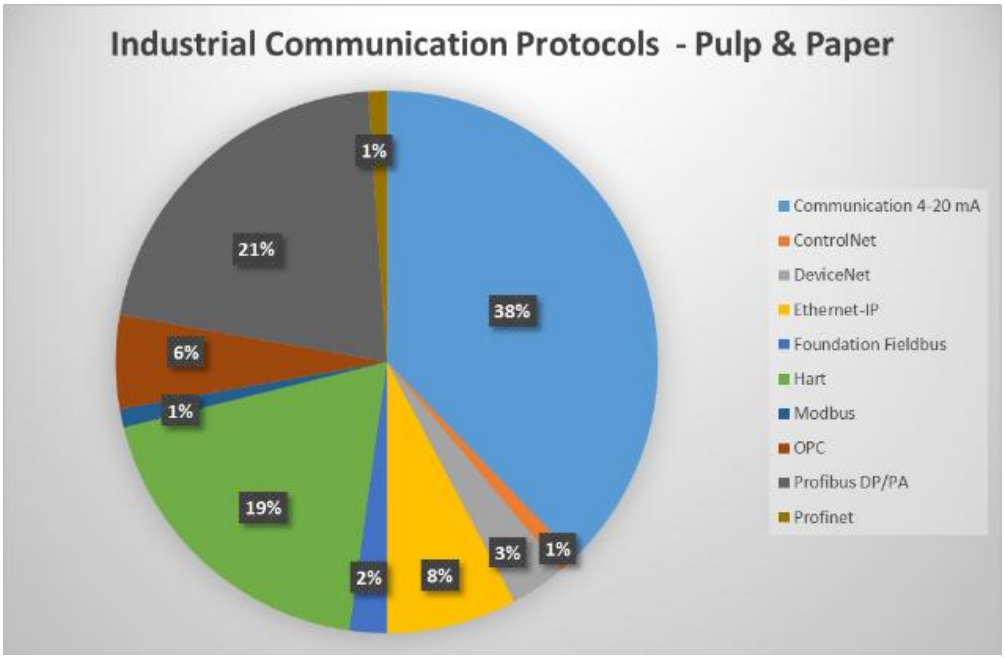

Figure 3: Industrial Communication Protocols used in the pulp and paper mills in Brazil.

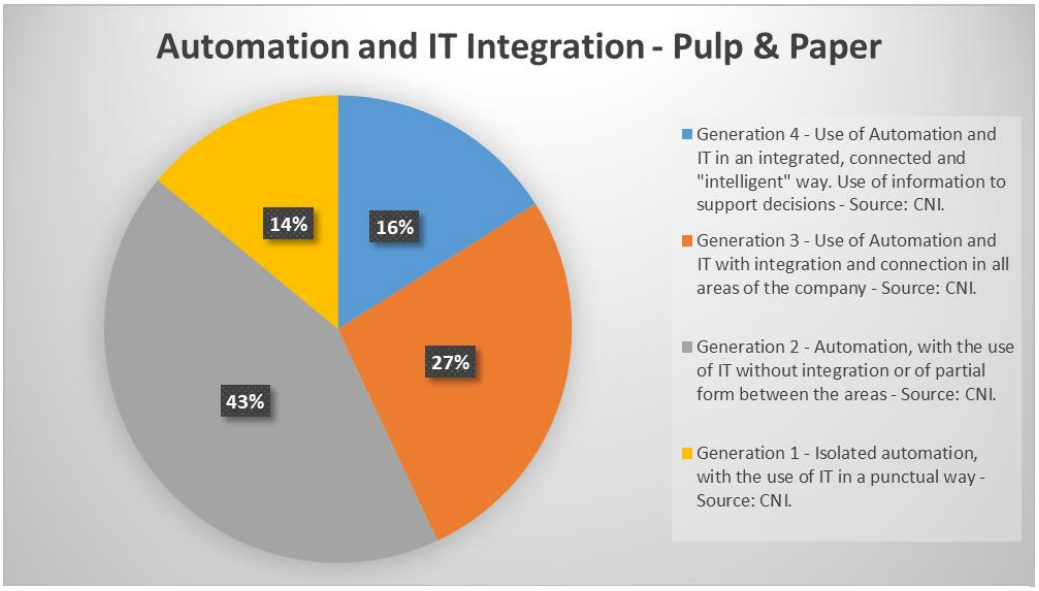

Figure 4:Automation and IT Integration in the pulp and paper mills in Brazil.

V. FINAL CONSIDERATIONS

Among the expected results, in addition to meet the main objective proposed, there are answers to the problem that originated this research, that is: What is the Automation level and which are enabling technologies that can be used for Digital Transformation (4th Industrial Revolution) in the Brazilian pulp and paper mills?

Automation has a crucial role in this transformation, because depending on the automation level in an industry it becomes possible (or not) to implement enabling technologies. This term paper presented, through the results of the survey research put through in the Brazilian pulp and paper mills, that there are gaps which need to be treated to improve the level of automation of the plants and consequently increase the integration with the Information Systems.

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