Industry 4.0:A Review On Future Manufacturing

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Abstract-*Industry 4.0 may be the next big thing, with extensive research being undertaken across industries and institutions, but a consensus on a formal definition is yet to be reached. As a result, there are challenges to academic discussions and proper implementation. Based on a literature review, the paper provides a definition of Industry 4.0 and gives a brief explanation of industrial revolutions, Components of Industry 4.0, which are Cyber-physical system (CPS) and Internet of Things (IoT) discreet technology involved, and lastly its impact on the future of the manufacturing sector.*

Keywords-Industry 4.0; Industrial revolutions; Cyber-physical system; Internet of Things

I. INTRODUCTION

Industrial development plays a vital role in the economic development of a country. Many historical facts show that the countries with strong industrial sector have showed more economic growth, and in order for the industrial development, key innovations are required. The solution for the development lies in the fourth industrial revolution. We face many diverse and fascinating challenges today in the field of manufacturing one of them is the understanding of the new revolution in manufacturing. We are in the beginning of a revolution that is fundamentally changing the way we live, work and relate one another [1]. Henning kagermann the head of the German national academy of science and engineering used the term Industrie 4.0 in 2011 to describe a proposed government sponsored industrial initiative [2]. Since then many companies and organizations have realized the potential behind the fourth revolution and has taken initiatives for successful digital transformation. Industrial leaders are integrating their business to whole new world and here lies the next productivity wave which not only offers unexpected efficiency improvements but also a major competitive advantage. This transformation is known as the Fourth industrial revolution, also called Industry 4.0 representing the link between Industrial production (IP) and Information Technology (IT).

INDUSTRY 4.0.

Industry 4.0 refers to the technological evolution from the embedded system to Cyber-Physical system (CPS). Physical systems which are connected through intelligent network to form Cyber Physical System. This means that the production system no longer simply processes the product but the product communicates with the machinery to tell it exactly what to do. The interaction of the real and virtual worlds represents a crucial new aspect of the manufacturing and production process [3]. The engineering challenges keep getting bigger and bigger most manufactures key assets are the physical world that is the workers, machine and tools. But the new revolution helps manufacturers to use the data produce by these physical assets to drive insights. The collection of these data in real time helps manufacturers to solve some of the oldest and toughest challenges they face. In the future manufacturers need to focus how quickly they produce, flexibility and cost effective they are. Product life cycles are increasingly getting shorter and demand for the customized product is increasing. The manufacturers need to mass manufacture the custom products and adapt to the agile manufacturing and the solution lies in the fourth revolution i.e. Industry 4.0. with this the business, science and politics worldwide are joining hands to make Industry 4.0 a reality. from the government plans perspective,

- In 2011, the German government passed the ‘High-Tech Strategy 2020’ action plan, which annually sets billions of euros aside for the development of cutting-edge technologies. As one of the ten future projects in this plan, the ‘Industrie 4.0’ represents the German ambitions in the manufacturing sector (Kagermann, Wahlster, and Helbig 2013).
- Since 2012 the United States (US) government began a series of national-level discussions, actions and recommendations, titled ‘Advanced Manufacturing Partnership (AMP)’, to ensure the US to be prepared to lead the next generation of manufacturing (Rafael, Jackson Shirley, and Liveris 2014).
- The French government initiated a strategic review in 2013, named the ‘La Nouvelle France Industrielle’, in which 34 sector-based initiatives are defined as France’s industrial policy priorities (Conseil national de l’industrie 2013).

- In 2013, the United Kingdom (UK) government presented a long-term picture for its manufacturing sector until the year of 2050, called the ‘Future of Manufacturing’. It aims to provide a refocused and rebalanced policy for supporting the growth and resilience of UK manufacturing over the coming decades (Foresight 2013).

- The European Commission lunched the new contractual Public-Private Partnership (PPP) on ‘Factories of the Future (FoF)’ in 2014. It is under the Horizon 2020 programme that plans to provide nearly 80 billion euros of available funding over 7 years (from 2014 to 2020) (European Commission 2016).

- In 2014, the South Korea government announced the ‘Innovation in Manufacturing 3.0’ that emphasised four propulsion strategies and assignments for a new leap of Korean manufacturing (Kang et al. 2016).

- The Chinese government issued the ‘Made in China 2025’ strategy alongside the ‘Internet Plus’s plan in 2015. It prioritises ten fields in the manufacturing sector to accelerate the informatization and industrialisation in China (Li 2015).

- In 2015, the Japanese government adopted the 5th Science and Technology Basic Plan, where attentions have been paid to the manufacturing sector for realising its world-leading ‘Super Smart Society’. (Cabinet Office 2015)

- The Singapore government has committed $19 billion to its RIE 2020 Plan (Research, Innovation and Enterprise) in 2016. Eight key industry verticals have been identified within the advanced manufacturing and engineering domain (National Research Foundation 2016).

II. HISTRORY OF INDUSTRIAL REVOLUTIONS

To understand the current revolution, we need to look at its predecessor. Which gives us an insight of how different it is from the other three. The following diagram shows a timeline of evolution in manufacturing and industrial sector in general.

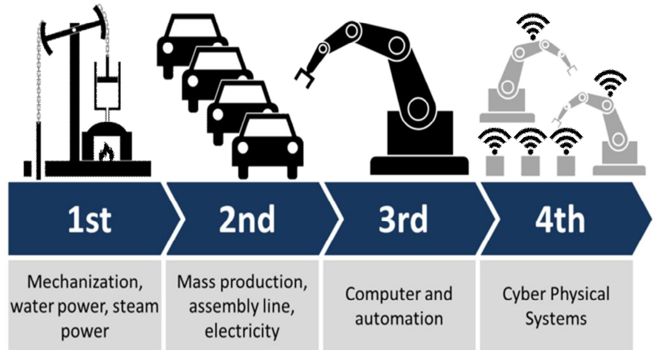

Figure 1: Time line of Industrial Revolutions

Industry kept advancing for every 50-60 years, by now it has experienced three revolutionary stages that is three industrial revolutions. The first mechanical loom was from the year 1784 and later towards the end of 18th Century the first industrial revolution was triggered which was the result of influence of mechanical loom and stem power. The second industrial revolution happened at the beginning of the 20th century, mass production by Henry ford, electrification of machinery like the conveyor belts and division of labor by Frederick Taylor these started the second revolution. During the 1970’s the advent of computer technology, Programmable Logic Controller (PLC) and telecommunications triggered the third revolution, which paved the way for automation and robotics. Today the industry is being transformed to the fourth stage with the influence of autonomous robots, Internet of Things (IoT), Internet of Service (IoS) and Cyber-Physical System (CPS) which is known as Industry 4.0. The fourth industrial revolution is the next stage of the automation of manufacturing process. This is a whole new level of automation by introducing customized and flexible mass production technologies. Here the human defines the requirements and the process takes place autonomously because of these technological influence the manufacturers can communicate with computers rather than operate them. It means machines using self-optimization, self-configuration and even artificial intelligence to complete complex tasks to deliver vastly superior cost efficiencies and better-quality goods or services.

III. INDUSTRY 4.0 COMPONENTS

Cyber-Physical Systems, Internet of Things, and Internet of Services are the most common three terms cited in academic research publications related to the industry. Consequently, and given its initial stage, these are the three main components of the industry.

A. Cyber-Physical Systems

As mentioned above, a cyber-physical system aims at the integration of computation and physical processes. This means that computers and networks can monitor the physical process of manufacturing at a certain process. The development of such a system consists of three phases:

- **Identification**: Unique identification is essential in manufacturing. This is the very basic language by which a machine can communicate. RFID (Radio-frequency identification) is a notable example of that. RFID uses an electromagnetic field to identify a certain tag that is often attached to an object. Although such technology has been around since 1999, it still serves as a notable example of how Industry 4.0 operated initially.
- **The Integration of Sensors and Actuator:** This is essential for a machine to operate. The integration of sensors and actuators simply means that a certain machine's movement can be controlled and that it can sense changes in the environment. However, even with the integration of sensors and actuators, their use was limited and does not allow them to communicate with each other.
- **The Development of Sensors and Actuators**: Such development allowed machines to store and analyze data. A CPS now is equipped with multiple sensors and actuators that can be networked for the exchange of information.

B. Internet of Things

A cyber-physical system still sounds familiar to us today. Machines can exchange data and, in a lot of applications, can sense the changes in the environment around them. Fire alarms are a good example of that. The Internet of Things, however, is thought to be what truly has initiated Industry 4.0.

The Internet of Things is what enables objects and machines such as mobile phones and sensors to "communicate" with each other as well as human beings to work out solutions. The integration of such technology allows objects to work and solve problems independently. Of course, this is not entirely true as human beings are also allowed to intervene.

C. The Internet of Services

It is easy to see that in today's world each and every electronic device is more likely to be connected to either another device, or to the internet. With the huge development and diversity in electronic and smart devices, obtaining more and more of them creates complexities and undermines the utility of each added device. Smart phones, tablets, laptops, TVs or even watches are becoming more and more interconnected, but the more you buy, the added value of the last device becomes unrecognizable. The Internet of Services aims at creating a wrapper that simplifies all connected devices to make the most out of them by simplifying the process. It is the customer's gateway to the manufacturer.

IV. TECHNOLOGY OF INDUSTRY 4.0

Industry 4.0 is a new area where the Internet of things alongside cyber-physical systems interconnect in a way where the combination of software, sensor, processor and communication technology plays a huge role for making "things" to have the potential to feed information into it and eventually adds value to manufacturing processes. Industry 4.0 ultimately aims to construct an open, smart manufacturing platform for industrial-networked information applications. The hope is that it will eventually enable manufacturing firms of all sizes to gain easy and affordable access to modelling and analytical technologies that can be customized to meet their needs. The concept Industry 4.0 is best defined by the project's "smart factory" through the merging of the virtual and physical worlds through cyber-physical systems and the resulting fusion of technical and business processes [6]. The industrial manufacturing life cycle becomes orientated towards the increasing individualism of customer requirements and encompasses: the idea and the order for development and production, the distribution of products plus recycling, and furthermore including all related Services. The interconnection of human beings, objects and systems leads to dynamic, real time optimized and self-organized inter-company value creation systems which are evaluated and optimized using criteria such as costs, availability and resource efficiency. Industry 4.0 emphasizes the idea of consistent digitization and linking of all productive units in an economy. There are several technological areas that underpin Industry 4.0, which are horizontal and vertical system integration, the internet of things, cybersecurity, the cloud, big data analytics, simulation, additive manufacturing (3D-Printing), augmented reality, and robot. The figure below shows the technologies related to Industry 4.0

Figure 2: Technologies Related to Industry 4.0

V. INDUSTRY 4.0 DESIGN PRINCIPLES

The design principles allow manufacturers to investigate a potential transformation to Industry 4.0 technologies.In order to assist company in identifying and implementing Industry 4.0 pilot projects, Hermann et al. claim in their working paper [4] that specific design principles are required to be defined. The paper therefore derives six design principles as presented in Table 1. The principles are obtained by an evaluation of the literature review on the Industry 4.0 components.

- **Interoperability**: Objects, machines and people need to be able to communicate through the Internet of Things and the Internet of People. This is the most essential principle that truly makes a factory a smart one.

- **Virtualization**: CPSs must be able to simulate and create a virtual copy of the real world. CPSs must also be able to monitor objects existing in the surrounding environment. Simply put, there must be a virtual copy of everything.

- Decentralization: The ability of CPSs to work independently. This gives room for customized products and problem solving. This also creates a more flexible environment for production. In cases of failure or having conflicting goals, the issue is delegated to a higher level. However, even with such technologies implemented, the need for quality assurance remains a necessity on the entire process.

  - Real-Time Capability: A smart factory needs to be able to collect real time data, store or analyze it, and make decisions according to new findings. This is not only limited to market research but also to internal processes such as the failure of a machine in production line. Smart objects must be able to identify the defect and re-delegate tasks to other operating machines. This also contributes greatly to the flexibility and the optimization of production.

  - Service-Orientation: Production must be customer-oriented. People and smart objects/devices must be able to connect efficiently through the Internet of Services to create products based on the customer's specifications. This is where the Internet of Services becomes essential.

  - **Modularity**: In a dynamic market, a Smart Factory's ability to adapt to a new market is essential. In a typical case, it would probably take a week for an average company to study the market and change its production accordingly. On the other hand, smart factories must be able to adapt fast and smoothly to seasonal changes and market trends.

VI. CENTRALIZED OPERATIONAL DATA THAT MANUFACTURING OFFERS

1. Lean Process Optimization.

Systems will become interconnected and know the exact location of every part at any given time and build in probabilities to have only the parts needed delivered to the line. The system will be able to extend beyond limit of individual factories and interconnect multiple facilities to accomplish goal of lean.

2. Predictive Maintenance.

The main promise of predictive maintenance is to allow convenient scheduling of corrective maintenance, and to prevent unexpected equipment failures. The key is "the right information in the right time". By knowing which equipment needs maintenance, maintenance work can be better planned (spare parts, people, etc.) and what would have been "unplanned stops" are transformed to shorter and fewer "planned stops", thus increasing plant availability. Other potential advantages include increased equipment lifetime, increased plant safety, fewer accidents with negative impact on environment, and optimized spare parts handling.

3. Elimination of Quality Process.

Traditional technology is good at reviewing a defined set of problems, but machine learning techniques could potentially eliminate the process of testing all together by predicting quality early in the manufacturing process and knowing when the system is going to fault.

VII. IMPACT OF INDUSTRY 4.0

The conceptual Industry 4.0 have a high impact and wide range of change to manufacturing processes, outcomes and business models. It allows mass customization, increase of productivity, flexibility and speed of production and improvement on quality product. This mass customization will allow the production of small lots even as small as single unique items due to the ability of rapidly configure machines to adapt to customer-supplied specifications and additive manufacturing. This flexibility also encourages innovation, since prototypes or new products can be produced quickly without complicated re- tooling or setup of new production lines. Thus, it can produce one product and many variants, with a decrease in inventory by using Industry 4.0 technologies [7]. The speed with which a product can be produced also improved where digital designs and virtual modelling of manufacturing process reduce the time between the design of a product and its delivery. In Germany, data-driven supply chains can speed up the manufacturing process by an estimated 120% in terms of time needed to deliver orders and by 70% for the time to get products to market [8].

Integrating product development with digital and physical production has been associated with large improvements in product quality and significantly reduced error rates. Data from sensors can be used to monitor every piece produced rather than using sampling to detect errors, and error-correcting machinery can adjust production processes in real time. This data can also be collected and analyzed using 'big data' techniques to identify and solve small ongoing problems. The rise in quality plays a key role in reducing costs and hence increasing competitiveness. According to [9], the top 100 European manufacturers could save the costs of scrapping or reworking defective products if they could eliminate all defects.

Productivity can also increase through various Industry 4.0 effects. By using advanced analytics in predictive maintenance programs, manufacturing companies can avoid machine failures on the factory floor and results in downtime cut and increase production. Some companies will be able to set up 'lights out' factories where automated robots continue production without light or heat after the staff has gone home. Human workers can be used more effectively, for those tasks which are important.

It is easier to make money today with fewer workers rather than a quarter of a century ago. In a book on the Fourth Industrial Revolution handed to each of the delegates at World Economic Forum [10], Schwab compares Detroit in 1990 with Silicon Valley in 2014. In 1990, the three biggest companies in Detroit had a market capitalization of $36 billion, revenues of $250 billion and 1.2 million employees. In 2014, the three biggest companies in Silicon Valley had a considerably higher market capitalization ($1.09 trillion) generated roughly the same revenues ($247 billion) but with about 10 times fewer employees (137,000). Robotic in Industrial application has substantial economic impact where increasing of productivity can drive economic growth. A recent study estimates that these benefits will have contributed as much as 78 billion euros to the German GDP by the year 2025 [6].

VIII. CONCLUSION

This Paper reviews the concept & trend of Industry 4.0. since the advent of information technology, economies of countries around the world increased dramatically on a global scale to grab the opportunity that presents. Germans with their high-tech strategy 2020 program are leading the way of the new evolution in manufacturing. Many companies, organizations & researcher have taken this opportunity to enhance and spread their knowledge of the new revolution. Internet of Things (IoT), Internet of Service (IoS), and Cyber-Physical System are the main components on which the fourth Industrial revolution are built on. Industry 4.0 covers a wide area of application this helps in achieving many business and operational objectives. Iot plays a crucial role as a match maker between Information Technology (IT) and Industrial Production (IP). This ultimately leads to new level of automation that is tailored for fourth industrial revolution.

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