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Industrie 4.0: An Overview

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Abstract-*In present situation, every industry is trying to expand their arms all around the globe, to make themselves as a strong competitor in industrial world. Making profit, the industries are also concern with customer satisfaction, product customization, quality of the products. All these factors should be taken care along with the factor of cost of products. Beside it, the life cycle of the product is getting shorter and the arms of information and communication technology (ICT) is quickly covering every sector including manufacturing worldwide. A vision of tomorrows manufacturing will be products and production systems that communicate with each other effectively and efficiently without direct involvement of men and machines. Products will find their ways independently and all the required machineries will be interconnected wirelessly. The heart of this system will be the cyber physical system, which will be connected with subsystems like smart machines, smart products, smart offices, smart transportation systems, and smart electrical grid to smart factory.*

Key words – Industrie 4.0, Industry 4.0, Industrial Internet, Cyber physical system (cps), Smart manufacturing, Internet of Things (IoT), Internet of services (IoS)

1. Introduction

The Industrie 4.0 is currently a buzzword in many industrial and educational conferences worldwide, but there is no universally accepted clear definition has been emerged yet. [4] The industrie 4.0 is also termed as industrial internet (GE) or advanced manufacturing (USA) [4] etc. Figure (1) shows the worldwide investment for transforming the existing technology into a new one in the field of manufacturing. The term industrie 4.0 was introduced by German government as one of its “strategic initiatives” adopted as part of the High-Tech Strategy 2020 Action Plan in November 2011 at a Hanover fair. [2] It was proposed and explained in January 2011 co-chaired by Siegfried Dais of Robert Bosch GmbH and Henning Kagermann of acatech, the communication Promoter Group of the Industry-Science research Alliance (FU) [1]. It is a vision, an idea which was firstly explained by industrie 4.0 working group. The number 4.0 in Industrie 4.0 indicates the forth industrial revolution. The previous revolutions were first revolution, second revolution and third revolution.

The first industrial revolution started in around 1780s after the invention of steam engine and those mechanical devices was first used for fabric production.

The second industrial revolution started in around 1870s after the electricity development, with the use of this the conveyor system established in Cincinnati slaughter house. This was the time when mass production and division of labor were introduced in industries.

The third industrial revolution was due to the electronics and IT which helps the second industrial revolution which was depend on human effort to turn towards the automation. The first programmable logical control, Modicon 048 was used in 1969. Figure (2) shows the various industrial revolutions along with the main driving force or innovations.

These revolutions came because of many factors, Such as increasing the Degree of complexity in industries, improvement in productivity, increase in demand due to increased population, shortage of skilled labor etc. Industrial revolutions first, second and third were observed situation while this forth revolution Industrie 4.0 is a prediction.

1. Design Principles

For effective implementation of Industrie 4.0 in real world practical situation, six design principles were proposed. Those principles, as proposed by [4], are: -

A. Interoperability- The ability to communicate between cyber physical systems and smart networks by effective connectivity with the support of IoT/S.
B. Virtualization- Creating virtual copy of a physical world in the form a virtual plant model or a simulation model. [4] This helps in effective monitoring of physical processes from anywhere.
C. Decentralization- Ability to make own decision because of cyber physical system. It helps in effective globalization without any central planning.
D. Real time capability – Every step in Industrie 4.0 is identified and recorded in real time. It increases flexibility and helps in real time customization.

E. Service orientation – Services can be no longer a part of a centralized system. Services can offer within a system or outside of system boundary by IoS.

F. Modularity – The complete system should consist of smaller subsystems which can be reutilized for other purpose also. It provides individual modules which can be easily upgradeable and have a plug and play capability.

These principles will provide the rough estimation or a frame work for Industry 4.0 practical implementation. [4]

Figure (1): - Industrie 4.0 worldwide [3]

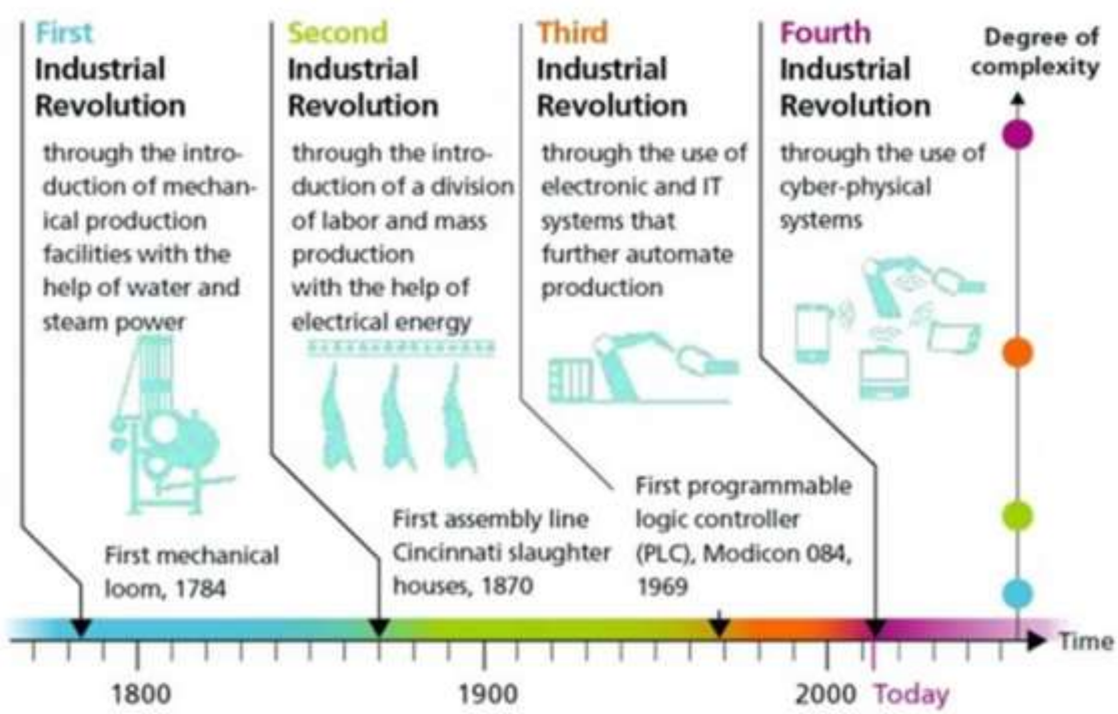

Figure (2): - Evolution of industrial revolutions
Source: - DFKI (German Research center for artificial Intelligence) 2013

2. Definition of Industrial Internet and Industrie 4.0

The term Industrial internet is defined as "The integration of complex physical machinery and devices with networked sensors and software, used to predict, control and plan for better business and societal outcome". (Industrial internet consortium 2013)

The term Industrie 4.0 is defined as "A collective term for technologies and concept of value chain organization. Within the modular structured smart factories of Industrie 4.0, CPS monitor physical processes, create a virtual copy of physical world and make decentralized decisions. Over the IoT, CPS communicates and cooperates with each other and humans in real time. Via the IoS, both internal and cross organizational services are offered and utilized by participants of the value chain." [4]

3. Basic components of Industrie 4.0

The basic components ([1], [4]) of Industrie 4.0, shown in figure (3)

A. Cyber Physical system
B. Smart technology
C. Internet of things and services

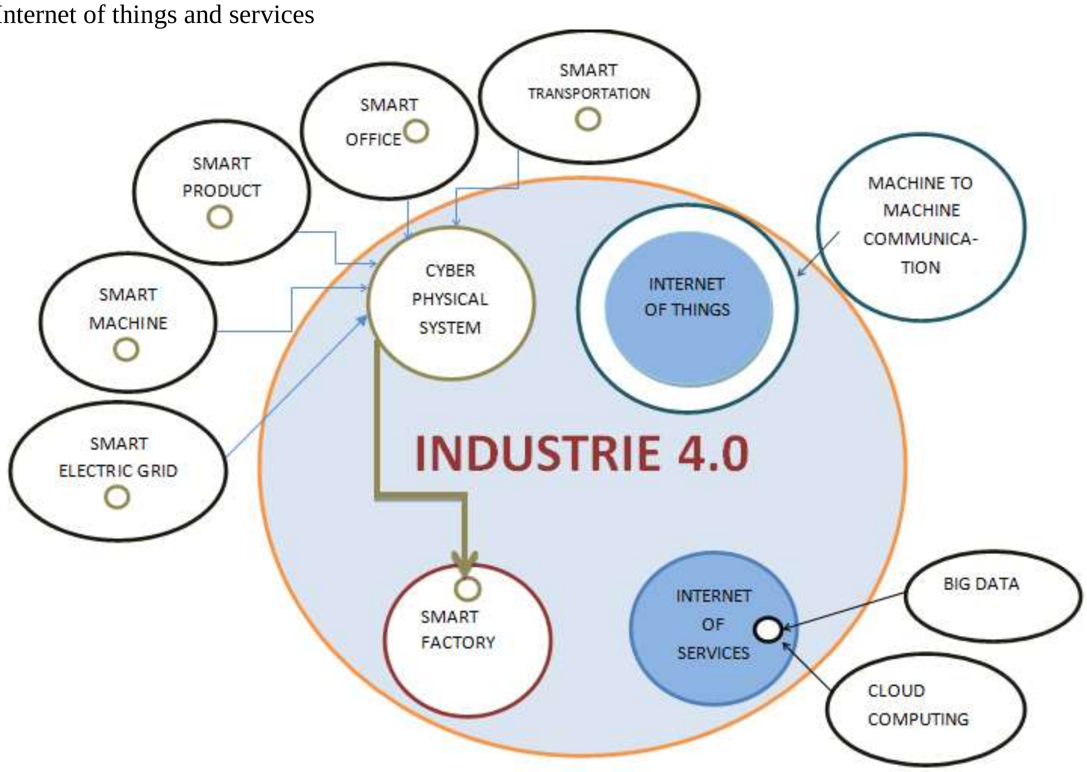

Figure (3): - Basic components of Industrie 4.0

Cyber physical system- Cyber physical system is a core component of I4.0. The classical separation (at a conceptual level) between a sensor and an actuator is becoming narrower and narrower every day with the upcoming of CPS. We believe that arguably such conceptual separation will eventually disappear when CPS will be broadly used in manufacturing facilities. [7] The integration of virtual world (designing, coding, simulation etc.) and the physical world (manufacturing, logistics) as shown in figure (4) with the help of embedded computers, internet network, control system and feed-back loop, [8] as shown in figure (5).

Embedded computers only perform predefined functions. They do not do any data processing. Internet networking unit consist wireless, IPs, modem. Control system usually have sensor, actuators, control processing unit and communication devices. [8] The main challenge is to protect it from cyber-attacks.

The development of CPS is characterized by three phases. The first generation of CPS includes identification technologies like RFID tags, which allow unique identification. Storage and analytics have to be provided as a centralized service. The second generation of CPS is equipped with sensors and actuators with a limited range of functions. CPS of the third generation can store and analyze data, are equipped with multiple sensors and actuators, and are network compatible. [4]

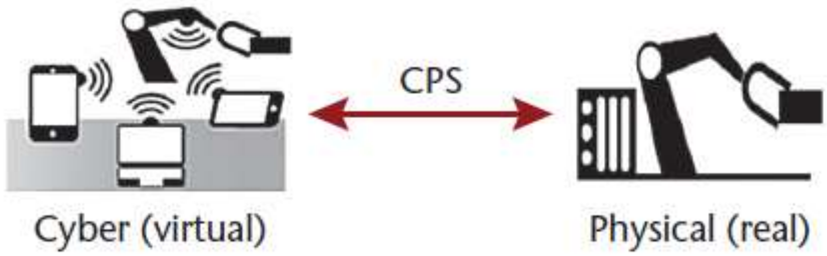

Figure (4): - Integration of virtual and real world [7]

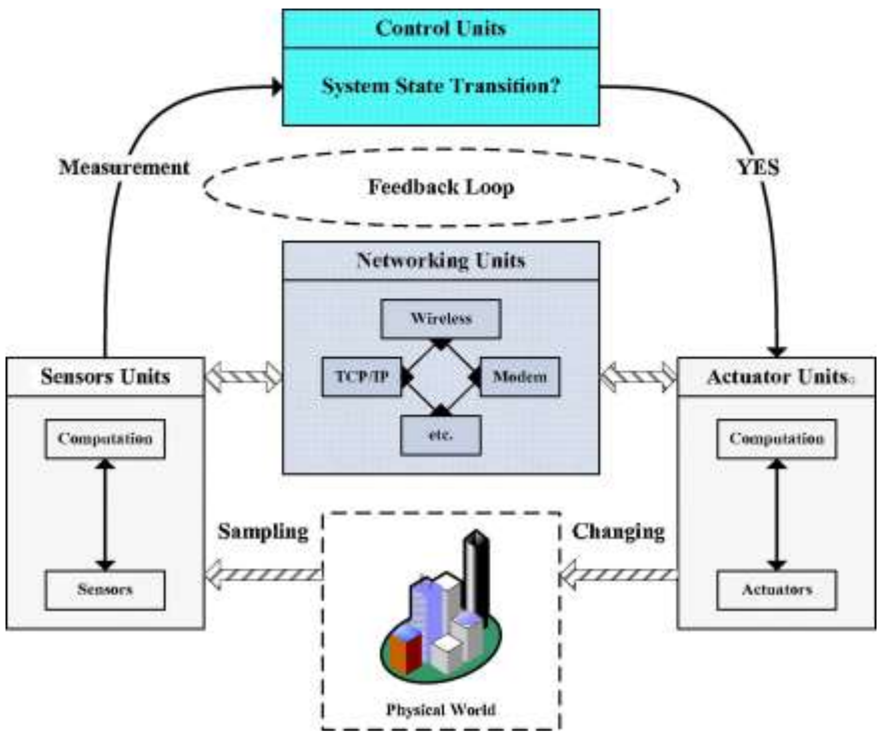

Figure (5): - prototype of cyber physical system [8]

Smart technology – Smart technology is "Technology with ability to sense changes in their circumstances and executes measures to enhance their functionality under the new circumstances offer enormous benefits in performance, efficiency, operating costs and endurance". [10] Smart technology communicates through IoT/S under the smart factory which will assist people and machine in the execution of their task [4] in a real time situation.

The smart technology includes are smart machine which knows what and when to do, smart product have their own code, product knows how it will transform and what will be his destination, traceable at any stage smart grid when and how much power is required and how it will supply, smart transport which knows where the product will go what will be the alternative route, prior information regarding traffic jams, land –slides what will the effective environment under transportation, Smart office which know the office environment, communication between office executives, these all will communicate via IoT/S to the CPS under the real time situation with their own control systems.

Internet of things and services (IoT/S) - These are the main initiator for Industrie 4.0. The integration of IoT/S in manufacturing allows the real time communication of smart technology to CPS. The Internet of things is every physical thing get senses what they have to do at what time, means that when you enter into the room, room lights get on, the temperature of room set automatically according to weather and according to you when you sit on your chair, your TV gets on and auto tuned your best channel according to time, when you go for shower your water temperature gets adjusted before you turn the shower on. Your car get started when you proceed towards your garage, machine error and its remedies in your palm devices like tablets or mobile phone or maybe in the form of message on your watches.

This IoT/S is possible because of internet protocol 6 (IPv6), a 128-Bit IP addresses which was launched in summer 2012 and replaces the IPv4, a 32-Bit IP addresses, increases number of addresses form 4.3 billion to 340 sextillion. [1] IP provides the single communication fabric necessary to support the devices which is connected through internet. [6]

Internet of services enables service vendors to provide their services integrated with big data technology or cloud services via internet. It helps in Industrie 4.0 for effective globalization and decentralization. Services are offered and combined into value-added services by various suppliers; they are communicated to users as well as consumers and are accessed by them via various channels. This development allows a new way of dynamic variation of the distribution of individual value chain activities. [4]

4. Integration of basic components

These basic components shell integrated in smart industries under the horizontal integration through value networks, Vertical integration and networked manufacturing system and End –to –end digital integration of engineering across the entire value chain. [1]

Horizontal integration as shown in figure (6) refers to integration of ICT within a company's globalized value chain (factors which involve increasing the profit of the company) like energy supplier, material supplier, marketing & distribution [1] which inform and communicate when and how much energy is required, how much material when and where required, what is the customer specification, what is his quality parameter, how much quantity required, what will be the shortest possible route to distribution, distribution according to demand, all these factors will linked end to end under the real time situation.

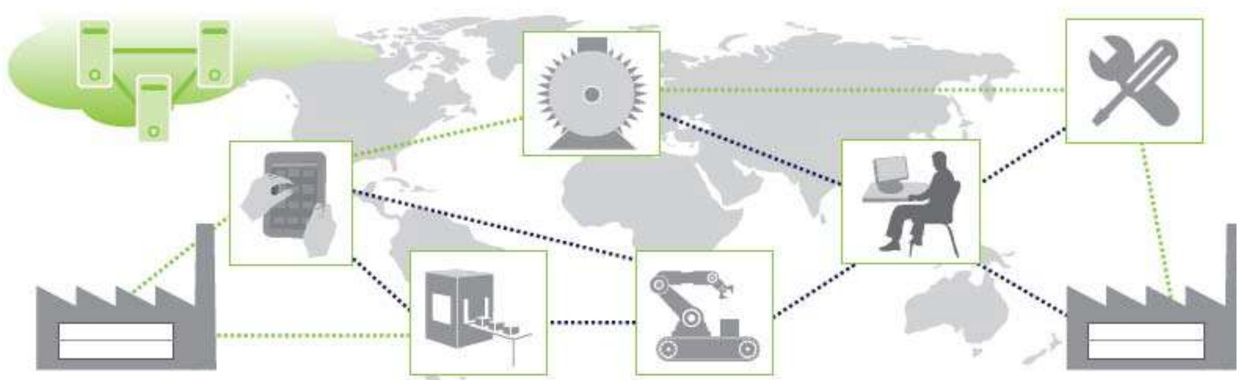

Figure (6): - horizontal integration [5]

Vertical integration, as shown in figure (7), refers to integration of ICT within a company's globalized hierarchical level which involve production planning, sequencing, manufacturing [1] which inform and communicate what material, which machine, what sequence will follow the product, where the product is, in which state, all these factor will linked end to end under the real time situation.

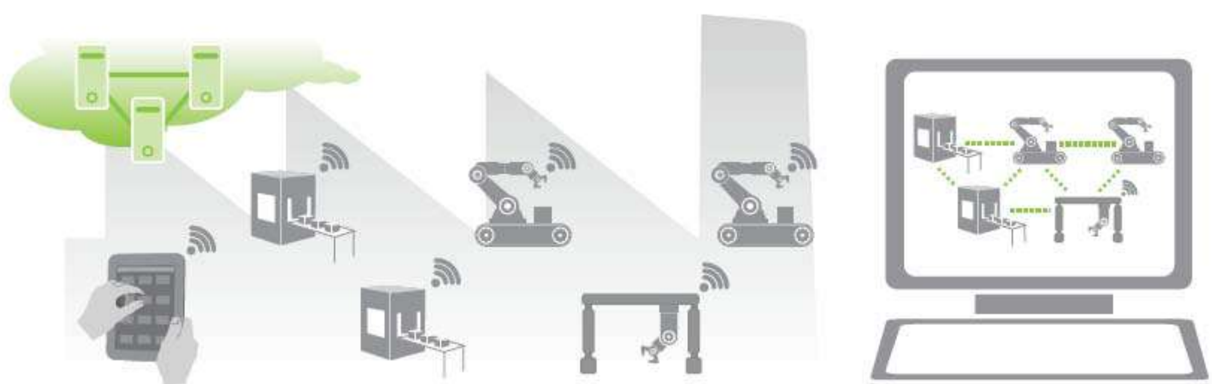

Figure (7): - vertical integration [5]

Through integration in Industrie 4.0 it will transform an existing value chain organization and management across the lifecycle of the product into next level of smart value chain organization and [4]. It will provide greater flexibility, robustness, higher quality under real time situation. It will manage increase complexity in manufacturing due to customization and shorter life cycle. It will also help in cost optimization. The availability of consumable resource will be optimized due to self-organization and control due to end to end integration as shown in figure (6). [1]

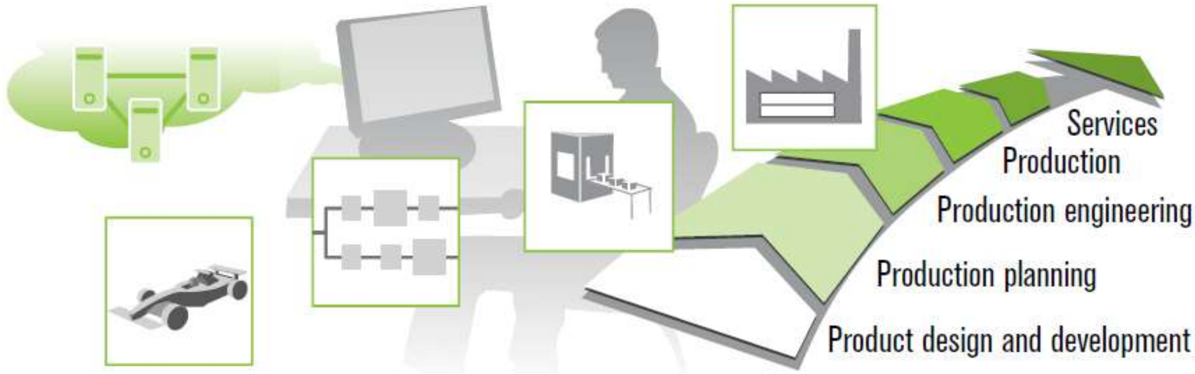

Figure (8): - End-to-end engineering across the entire value chain [5]

5. Proposed Benefits of Industrie 4.0

- Effective globalization
- Leads to innovation
- Optimum utilization of resources (man, material, machine, money)
- Higher resource productivity and efficiency
- Efficient Energy consumption
- Smooth product flow
- Dynamic business model in manufacturing or self-configured
- Autonomous controlling [5]
- Efficient continuous real time tracking
- Close corporation between business partners (suppliers, customers)
- Mutual beneficial opportunity for employees (no effect of ageing)
- Higher employability in tech sector (in the field of IT services, robotics, embedded system, sensor etc.) and create new form of employability like smart data handling
- Meeting Individual customer 's customized product and still making a profit [1]
- Greater flexibility Meeting high level Last minute changes
- Detailed End to end product transparency in real time
- Friendly Working environment which help employees to remain productive
- Better balance between working life and personal life [1]
- Secure and reliable backup system for every step in cloud storage

6. Challenges under implementation of Industrie 4.0

- What will be the effective plant layout
- Supplier of mechatronic system or machineries
- Lack of research and specialist staff [1]
- Strong network infrastructure [1]
- Highly efficient cyber security
- Type of process and work organization
- Training [1]

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