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A case study of industry 4.0 implementation in manufacturing industry.

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Abstract

The manufacturing world had undergone four separate industrial revolts. Industry 4.0 is a most recentchapter in the Industrial revolt story that pivotedmainly on manufacturing automation, live data capturing, smart machines, and internet connectivity with key objectivesof productivity rise, optimization of available working hours, and increased organization competitiveness. This research paper studiesthe industry 4.0 through the survey of available literature in a sequential manner that started with understanding the development of the manufacturing industry from industry 1.0 to industry 4.0, the nine key foundation blocks of the industry 4.0, the cyber-physical systems, the Smart factory concept,industry 4.0 application strategy guide step by step, Industry 4.0 benefits, risk, and challenges. We applied the Industry 4.0 concept step by step as a pilot project as per the Industry 4.0 application strategy guide atthe bus bar trunking production factory with the target of delivering the demand of customerswithin committed or shorter lead time from the bus bar manufacturing shop and discussed the outcomes briefly. We concluded that Industry 4.0 helps to improve operator work-life, overall productivity, and to reduce the operating cost of production drastically in mass manufacturing processes. Industry 4.0 is also a boon in today's changing work culture after the CORONA pandemic through its core concepts of digitization, paperless work, networking, and maximum internet usage. It also guides to adopt automation and smart machines that are communicating in real-time with its customer. We also observed that its application is costly in terms of investment to deploy for small or middle scale manufacturing plants, but they shall implement partly to get the benefit from it.

Keywords: Industry 4.0, Smart Factory, Digitization, Manufacturing automation, Internet of Things.

1. Introduction

1.1 Background

The German word "Industrie 4.0" came from a German government's high technology-oriented project which is promoting the computer base production. This word was revived in the year 2011 at the Hannover event. The manufacturing world had undergone four separate industrial revolts. The first industrial revolt had consisted of steam-powered machine operations, the second industrial revolt involved the electricity-powered mass manufacturing assembly lines, the third revolt updated the industry with computer and manufacturing automation integrations, and the industry 4.0 is a most recent chapter in the industrial revolt story that pivoted mainly on manufacturing automation, live data capturing, smart machines, and internet connectivity with key objectives of productivity rise, optimization of available working hours, improvement in the customer satisfaction, and increased organizations competitiveness (bcg, 2020).Industry 4.0 also frequentlycalled smart production that integratesevery work station or process of operation with digitization, machine study, and data mining to prepare a detailedexplicable and interconnected system for organizations that improve operations and supply chain efficiency (epicor, 2020).

1.2 Definition

Industry 4.0 officially can be defined as "nomenclature for the recenttechnology of manufacturing automation and data-based communication that includessmart machine systems, cloud database, the internet networking, and cognitive data analysisto build the smart manufacturing industry" (I-scoop, 2020).However, some people consider industry 4.0 as only a marketing hype strategypracticed

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in production management that trying to seek our notice (Bernard Marr, 2018).

1.3 Objectives

a. To understand the detailed Industry 4.0 application process.
b. To apply the Industry 4.0 to a pilot work area in a manufacturing process and analyze the outcomes.

2. Literature review

2.1 Development of manufacturing industry from 1.0 to 4.0

The Manufacturing industry got developed in four separate revolutionary phases across the world. The development of manufacturing industry from 1.0 to 4.0 phases is explained below:

a. Industry 1.0: The first revolution in the manufacturing industry hadcome offin the early 1800s. Human or animal labor got replaced by steampower-based mechanisms or machines during this period.
b. Industry 2.0: The second revolution in the manufacturing industry had come off in the early part of the 20th century; the steam power got replaced by electricity-driven work in manufacturing factories. The machine's efficiency and mobility both improved with the use of electricity.Mass production-oriented manufacturing assembly lines had introduced during this phase.
c. Industry 3.0: The third revolution in the manufacturing industry had come off in the late 1950s;in this phase, the electricity triggeredmachines are updated with the electronicand further computer-based technology in the manufacturing industry, also the mechanical and analog technology used in the machines slowly got replaced by automation and digitization.
d. Industry 4.0: The fourth revolution in the manufacturing industry had come off in the past few decades; Industry 4.0 is based on more advanced digitization and communicationvia the Internet of Things (IoT), real-time data control, and the smartmachines. Industry 4.0 joins actual with digital and ensures better communication and controlbetweencomplete value chains (epicor, 2020).

2.2 Foundation blocks of the industry 4.0

There are nine key foundation blocks in the implementation journey of Industry 4.0; many of them had been used by the manufacturing industry but collectively they are capable of changing the production bar by fully integrating, automating, and converting them into the optimized flow of production. We shall see this one by one as below (bcg, 2020):

a. Big data and analytics: In the industry 4.0 scope, capturing and analyzing the manufacturing data from different locations, machines, and people will help to take actual time decision making. For Example, Infineon a semiconductor manufacturing industry reduced their rejection at the final chip testing work station by data captured at earlier wafer stage in the manufacturing process, thus Company identified the product failure in the early stage by real-time data study.
b. Autonomous Robots: Robots of today's time are self-driven, they interact with other robots and work safely in a given work environment. For example, ABB is going to launch both an armed robots named YuMi which is capable of assembling the products on assembly lines along with human operators.
c. Simulation: Earlier simulation extensively used in the virtual product or process design phase, but Industry 4.0 started its use in the actual operation which allows actual data integration with virtual data that help workers to set the plan of next changeover of product in queue results in a major reduction of the changeover time by 80 percent.
d. Horizontal and vertical system Integration:Industry 4.0 integrates Customer, Supplier, the different departments in the industry, and industries with one-goal of optimization.Horizontal integration is the digitization of the full value stream interconnects and transfers the data with suppliers, customers, and factory.Vertical integration is an integration of the IT process at a different hierarchical production level. These hierarchical levelscan be a field that is*interconnected with the manufacturingby sensors*, the machine managing level, or actual manufacturing process level *that should be controlled*, further,the *production planning, quality control,and so on* and *order capturing and processing, the complete manufacturing planning.*
e. The Industrial Internet of Things: Industrial Internet of things helps the machine, sensors, and devices to communicate with each other and with centralized servers to decentralize the decision-making process that allows actual-time replies to

the manufacturing issues. For example, Bosch applied this concept in its valve manufacturing facility where products are recognized by RFID and its work station to know which production step should be done next for different specification products on the same line at the same time.

f. Cyber-Security: As the internet-based data usage and its integration with manufacturing lines are increasing the data handling creates an issue of theft or data fishing. Cyber-security is a Good solution to answer these problems.

g. The Cloud: The data count is increasingafter the addition of the real-time manufacturing data; this problem needs data storage locations that are clouds and its efficiency in terms of reaction time and data storage capacity.

h. Additive Manufacturing: Additive manufacturing such as process of the 3D printing will be commonly deployed to produce pilot batches of tailor-made products that give benefits like less weight, less inventory, and reduced material handling while manufacturing.

i. Augmented Reality: This system supports warehouse part identifying, machine repair, and maintenance information passing on the mobile. Real-time data sharing of such issues helps in quick decision making. For example, augmented reality glasses display machine repair standard operating procedures at the location.

2.3 Cyber-physical systems (CPS)

Cyber-Physical Systems integrates the actual and virtual systems to build an interconnected or networked manufacturing process in which devices, machines, and servers communicate with each other artificially. It allocates the foundation for the internet of things; further integrates embedded software-based systems and user interface into a digitized network that easily communicates with each other, modern mobile phones are perfect examples of this concept.

2.4 The smart factory

Cyber-physical systems application in the actual production gives birth to the smart factory as shown in the below figure.

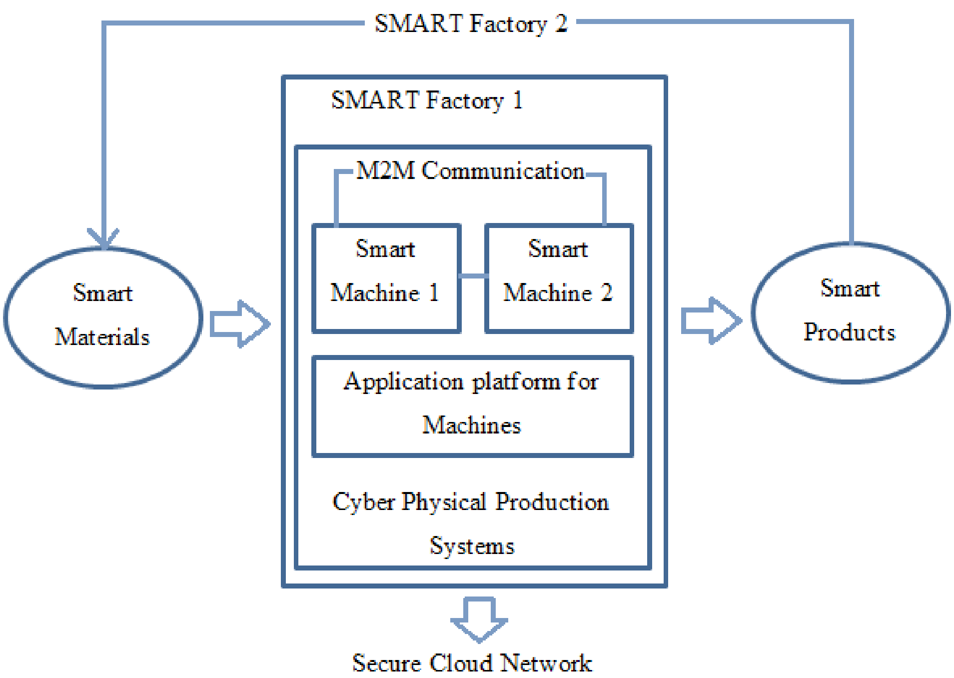

Fig. 1: The Smart factory Structure (Secure Cloud data Based Network)

Flexible secure cloud data-based network of the cyber-physical systems made possible the complete automation in the production system in the industry. Flexible data network helps to optimize the production flow to the great extent that helps to reduce cost and time consumption in the manufacturing process (I-scoop, 2020).

2.5 Industry 4.0 application strategy

Industry 4.0 applications strategy isshown step by step in the figure below (bcg, 2020),

Fig. 2: Industry 4.0 application strategy step by step

Let us understand the Industry 4.0 application strategy step by step as below,

a. Map out the company's industry 4.0 strategies: Plot the current digital level of the company and make a plan for the next five years. Decide the actions which shall create more value to the company and integrate it with overall all organization business strategy.

b. Develop a new pilot project: Start industry 4.0 applications in a selected product manufacturing line as a pilot project that will help to understand the concept to the entire team member and evaluate the benefit of implementation to the business. This will also help to gain funding from the top management to implement the strategy in other areas of manufacturing.

c. Understand and present the gap or requirements of resource: Map the complete process in the company with the experience of the pilot project implementation and identify the gaps and probable opportunity for digitization application. Industry 4.0 success depends upon the digitization skill of the participating members and their interest; this creates a need of attracting interested and skill full team for the project implementation.

d. Big Data analysis: Big Data communicated by the machine, device, and people should be directly linked to real-time decision making of improving the product quality and manufacturing speed.

e. Change into a digital company: Industry 4.0 concept best utilization needs a complete application to whole stakeholders in a company. Enforce the digital culture or "tone from the top" to ensure every person think digitally.

f. Develop an ecosystem view: Real business growth starts with mapping the consumer behavior and adapting this within the suppliers, consumers, and business partners.

2.6 Industry 4.0 application benefits

a. It makes local businesses more competitive to deal with global competition like amazon who already best performing in optimizing their resources, transport, and supply chain management.

b. As Industry 4.0 is a comparatively new concept hires a new talent and builds a young workforce who raises efficiency, teamwork, proactive and predictive data analysis, and involvesworkers, supervisors, and managers to utilize actual-time data to make better decisions to respondprobableproblems before they create any major failure.

2.7 Industry 4.0 application challenges and risks

The main challenges in an Industry 4.0 application are (epicor, 2020),

a. Definition of exact implementation strategy: Industry 4.0 champion should develop clears implementation strategies to define all the required resources and timelines.

b. Executing successful pilot Projects: Pilot Project is going to build trust in the top management who are going to allocate the fund for complete project execution, hence pilot project success is very crucial.

c. Culture of Company.

d. Skilled manpower acquisition for adapting the digitization change quickly.

The main risk in **an Industry 4.0 application is,**

a. Cyber-security and privacy as the data phishingof the Industrial Internet of Things going to create problems in big data capturing and analysis. Data security is also a concern as product drawing, design, and specification security is important.

b. The endless and very important human riskof future of work availability, job availability, and financial crisis built up based on these aspects.

3. Pilot project application

3.1 Overview

The Legrand facility at Ambad, MIDC of Nasik city is a manufacturing bus bar trunking system commonly used at high rise buildings, Malls, industrial construction, and Hospitals to transfer 630 to 5000-ampere current from transformer to the respective floors. The customer expects thismake to order product delivery at the actual site usually within three weeks after order confirmation. We decided to adopt the Industry 4.0 concept to deliver this demand within committed or shorter lead time from the bus bar manufacturing shop as per the Industry 4.0 application strategy guide.

3.2 Pilot project application step by step

a. Mapping of current bus bar manufacturing process: Bus bar manufacturing involves bus bar and insulating material cutting as per customer requirement, wrapping of insulating material over bus bar, and arranging four bus bar in RYBN shape, assembling it in the casing enclosure, further 100% high voltage testing of this bus bar and manual data-keeping, application of finish good stickers to the bus bar assembled if high voltage test found Ok and shifting it to final packaging, further dispatch of the packed material to the respective customer within three weeks commitment.

b. Selection of the pilot project area: We analyzed the possibility of the industry 4.0 application at the High voltage testing, sticker pasting, and production declaration area and selected it as a pilot project area.

c. Process Gap or Opportunity identification: We further studied this process in detail and found out the opportunities where we shall apply the digitization as below,

1. High voltage testing data is manually entered in the logbook by the operator.
2. Finish good sticker is given by the supervisor to the operator manually.
3. Production declaration of bus bar assembly is done in the ERP system after high voltage ok approval from the operator in the logbook at the day endby supervisor.

d. Resource allocation: We decided following digitization actions on the above gaps,

1. High voltage data will be stored in the testing machine once the operator enters the product detail.
2. We shall deploy the Finish good sticker printer near to high voltage testing machine and link it directly to the testing machine, Printer will only send print if testing is found Ok.
3. We further decided to add barcode of respective product item code on the finish good sticker and we shall deploy the scanner to scan it. The scanner will be directly linked to the ERP system and once the operator scans the barcode the real-time production declaration will happen.All these actions will require the printer, scanner, interconnection of these devices through the Internet of Things, and training session to the operators for this system usage, we sent this entire requirement for management approval and deployed it at the workstation accordingly.

e. Big Data analysis: After the planned process improvement we started receiving the real-time data of High voltage testing and production declaration which improved the traceability, proof, and timeline details of product manufactured even after the dispatch.

f. Complete Digitization: Through this pilot application of industry 4.0 we got confidence in our ability to adapt the change to the digitization and its benefit, hence further decided to extend its scope to other workstations.

g. Ecosystem View: We also explained this improvement to our suppliers, customers, and all the workmen that helped to involve all the stakeholders to create a holistic view of the complete value stream.

3.3 Pilot Project benefits realized

We realized following list of the benefits after actual implementation of the Industry 4.0,

1. Our high voltage testing data is directly saved from the machine to cloud which is very authentic and available in real-time to every stakeholder.
2. This data improved the trust of the customer as this is a 100percent compliance test for all the

products and traceability even after years as the product has a 17 years warranty span.

3. Finish good stickers direct linkage with the high voltage machine resulted in the error-proofing of sticker mismatch.
4. Finish good barcode introduction and real-time production declaration by mere scanning of it resulted in the elimination of supervisor work/ improvement in productivity of manual production declaration in the ERP at the end of every day.

4. Conclusion

We concluded that Industry 4.0 helps to improve operator work-life, overall productivity, and to reduce the operating cost of production drastically in mass manufacturing processes. Industry 4.0 is also a boon in today's changing work culture after the CORONA pandemic through its core concepts of digitization, paperless work, networking, and maximum internet usage. It also guides to adopt automation and smart machines that are communicating in real-time with its customer.

From our Pilot project study, we concluded that Industry 4.0 increases the transparency, trust, and traceability of the finish product data as well as improves the supervisor efficiency. It also does the error-proofing of the mismatch of product stickers which improves the product quality and eliminates customer complain. We also observed that its application is costly in terms of investment to deploy for small or middle scale manufacturing plants, but they shall implement partly to get the benefit from it.

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