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ACHIEVING SHOP FLOOR CONNECTIVITY OF LEGACY MACHINES FOR INDUSTRY 4.0

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ABSTRACT

The Phrase Industry 4.0 was introduced first in Germany in 2011 by a representative's group from various fields such as academia, politics and business etc to advance German manufacturing industry competitiveness under an initiative. High technology strategy for 2020 was the idea considered by The German federal Government. In order to proceed with the implementation of Industry 4.0 a group was formed for the advice. This technology combines cyber physical systems, software, hardware, connectivity and communication. This technology also enables us to visualize and control the process from a remote location. Industry 4.0 solutions provide interoperability, virtualization, de-centralization, real-time capturing, etc. Incorporating this technology optimizes the process and increases the efficiency of a manufacturing plant.

In this paper we will briefly discuss how to achieve connectivity with the legacy machines and transmit the acquired machine data using IIoT communication methodologies. This is one of the basic and important steps for converting a normal factory to Smart Factory. Capturing, collecting and displaying the data is very essential to provide any solution. This process includes collection of data from the Programmable Logic Controller by using a Device bridge Application and the data from the Application is sent to Device Bridge Server. An XML format file is generated after the data is captured by the Device bridge. The data from the device bridge collector is sent to the database through an adapter.

There is a need for maintenance solution to be developed in order to reduce the down time in industries. Incorporating maintenance solutions makes work easier by early detection of problem. Solutions for maintenance, data capture, storage and MES solution were implemented into. A database was used for storing the data in which the data related to manufacturing was stored. Encryption methods can be added to store the data. The data can be transferred to a remote location and also the machine can take the inputs from a remote location.

Keywords: Iiot, PDA, MDA, M2M, Shopfloor, Manufacturing, Open-Source Software, OPC-UA, Gateway.

I. INTRODUCTION

The computerization in traditional manufacturing process, a project discussed in 2011 for high technology strategy for the German Government coined the term "Industry 4.0". This technology combines cyber physical systems, software, hardware, connectivity and communication. The design principles of Industry 4.0 help manufacturers to bring a potential transformation in smart manufacturing technologies.

Industry 4.0 is Manufacturing optimization = Connectivity + Technology.

The fourth industrial revolution is the integration of various major technologies and innovations all working and maturing together that will take manufacturing industry to new heights. The various stages of industrial revolutions are shown in figure 1.

The technologies of Big data analytics, cloud computing, artificial intelligence, advanced robotics and sophisticated sensors all of these are present in the Industry in one form or another and they are all interconnected with each interlinking virtual and physical worlds which will transform the business. Even though in its beginning stage, Industry 4.0 is transforming manufacturing industry by giving better agility, transparency and responsiveness to the customers with cost savings

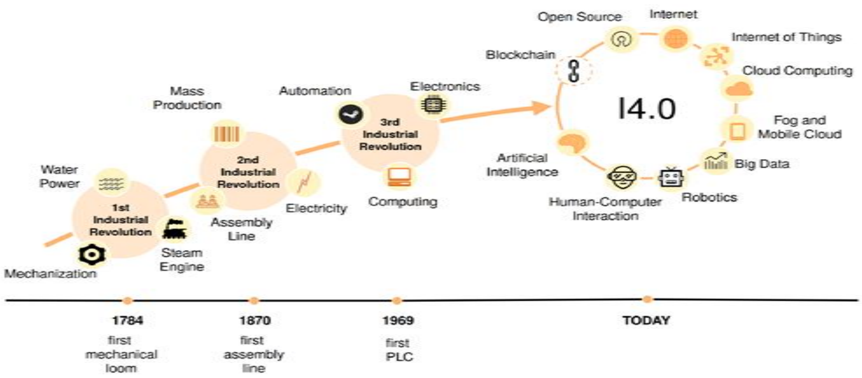

Fig 1: Evolution from I1.0 to I4.0 [1]

The Industry 4.0 main objective is to make manufacturing faster, more customer centric and efficient driving optimization and automation discover new opportunities for business models. Coming few years, we can see major changes in manufacturing industries.

Data capturing today is more than ever before which has been only possible because of machine-to-machine technology, advanced connectivity and scanning. The automated data collection technologies where data is collected from sensors, machines, humans and computer are used to analyse and store on cloud which are used to make new products and services. The figure 2 shows the smart factory architecture.

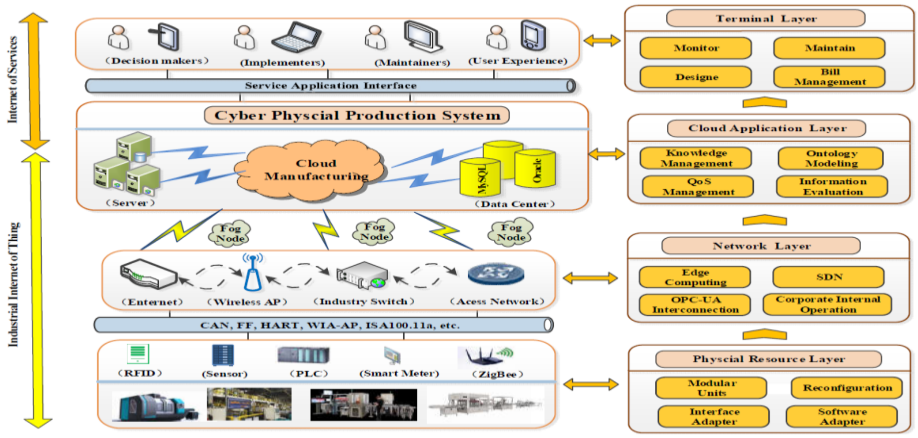

Fig 2: I4.0 Architecture [2]

The industries have to adopt these new technologies to be relevant and to be very competitive in the market. The new digitalization and integration in manufacturing industries is encouraging manufacturers in capitalizing these innovations. Major manufacturers like BOSCH have already begun transforming their strategy to new automation trend. Some of the major trends include the following.

1) Through IIoT backed by good cloud technology.
2) Implementing modern connectivity methodologies to increase productivity, process and data collection.
3) Converting traditional shop floor to smart factory by sensor data collection, new automation technologies, mobility and machine to machine integration.
4) Implementing complete supply chain visibility.

II. METHODOLOGY

The traditional machines operating today in many parts across the world are in good working condition from their day of commissioning to work which would be around 20 years to 5 years recently. So, replacing these good machines with new updated modern machines would cost a fortune to the any company. Also, these machines will be in good condition on proper maintenance for minimum of another 20 years approximately.

So, by implementing the methodology explained here, it will easy to upgrade the communication system of the traditional machines to be adaptable to new technology so as to upgrade the traditional manufacturing plant to Industry 4.0 and also save a lot of fortune to the companies as well.

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2.1 PROPOSAL

The core of this work is to transform a traditional manufacturing plant to Digital plant or smart factory. The traditional plants consist basically legacy machines. Here the smart factory that we discuss is till level 2 of smart factory architecture in which internal process are interlinked and exchange information

Figure 3 shows the proposed flowchart in digitalizing the old shop floor to improve manufacturing process based on continuous improvement process.

The below mentioned flow shows the data collection and operative monitoring phases at level 0 which we have to improve continuously to upgrade to smart factory [11]:

1) Defining of management indicators: The foremost step is for evaluating the process we need to select the indicators.

2) Defining of inputs: After defining the indicators we have to decide which signals to be used for the purpose.

3) Inputs of the process: With the input signal chosen we have to choose properly the signals and sensors that are going to be digitized in order to know which legacy machines needs measuring instruments and what ways these are mixed and linked with those coming from new machinery which already has capacity to obtain data.

4) Data sources selection: After selecting the required measurements and inputs we need to feed the indicator by identifying the data source and once again machinery need to be integrated with proper sensors.

5) Legacy machine upgradation: Once done with the initial stages of inputs sensors and measurement proper equipment must be chosen to make machines perform the task independently according to defined parameters. Equipment's may be PLCs, screens, HMIs etc.

6) Dedicated networks: For smooth operating of machine, transfer of data and control signals, a dedicated network of process from IT has to be established in order to avoid conflicting of data and establish proper data exchange and communication with other machines and systems. In this communication network all are dedicated and is permanent like not only between computers and servers but also between sensors, actuators and controllers.

7) Alarms in the process: Proper alarms have to be generated if any changes and faults in the process that will make operation efficient such as closing od valves, and vapours, shutdown of motors etc. by means of mechanical and hydraulic actuation.

8) Process monitoring and feedback: For the effective monitoring and working of the process, we need to have a data collection and monitoring software which is used to acquire process data (PDA) and machine data (MDA) like production, problems, errors, operation etc. and store it in a database. These data are sent to the ERP (Enterprise resource planning) as feedback where it is analysed and required corrections are applied in the process and used for future analytics.

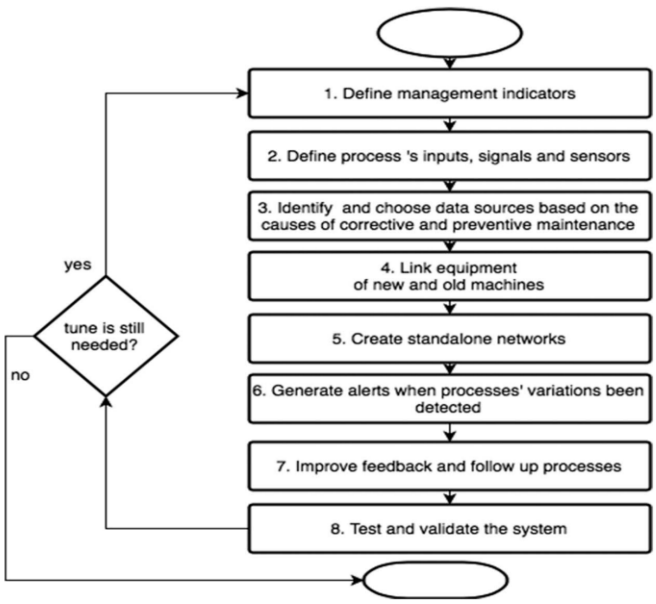

Fig 3: Process of Digitizing Traditional Factories [11]

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9) Testing and validation: The cycle duration of the process must be clearly defined. SCADA systems must be integrated. The data collected from multiple sources currently and historically must be analysed for correlation of variables. Therefore, tactical monitoring and data analytics should be combined and supported by business intelligence software to testing of the design for required results and validate it.

III. DESIGN

The figure 4 shows the shopfloor mapping to the final viewing unit (MES, ERP). Here the machines in the shopfloor are integrated with PLCs. PLCs control the machine operation with their integrated sensors to the input module and actuators to the output module. In order to visualize this data of input and output variables and PLC alarms we have to achieve the connectivity of these PLCs with the server as shown in the figure 4.

Modern machines have the ability to communicate directly with the server as many of them support server communication protocols. Challenge is to achieve this connectivity with the Traditional machines. These old machines also use PLCs for their operation but do not support communication with the server. Also, network security is a challenge. Considering these constraints, we have to adopt a methodology which is cost effective and also easy to implement for the rapid deployment in the shopfloor. The Industry 4.0 initiative in Germany recommends Open Platform communication Unified Architecture (OPC-UA). The OPC foundation manages global organisation where vendors and users collaborate to create standard for multiple vendors, secure reliable and multiplatform.

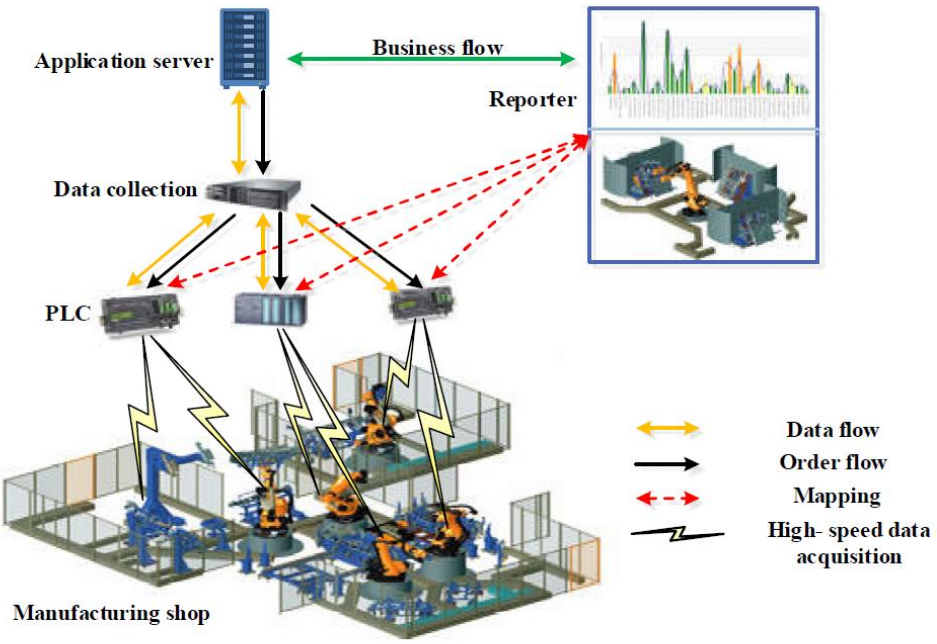

Fig 4: Legacy machine connectivity for I4.0 [2]

All this is important because automation systems need to evolve from where there is separation in Information Technology and Operational Technology to flexible, flattened dynamic and merged infrastructure enabling easy collection of data signals from shop floor level 0 to the business systems. This help in strong product customization and rapid production.

The above figure shows the implementation of OPC-UA on OPC-UA compatible PLCs and non OPC-UA compatible PLCs. The figure also shows the various points in the network where potential cyber-attacks can be found.

3.1 GATEWAY

In computer networking, gateway is a passage which joins two networks together which will have different network model. It takes data from one system, interprets it and then transfers them to other system. It is also called as protocol converter as shown in figure 5. At any network layer it can operate. They are complex when compared to switches and routers.

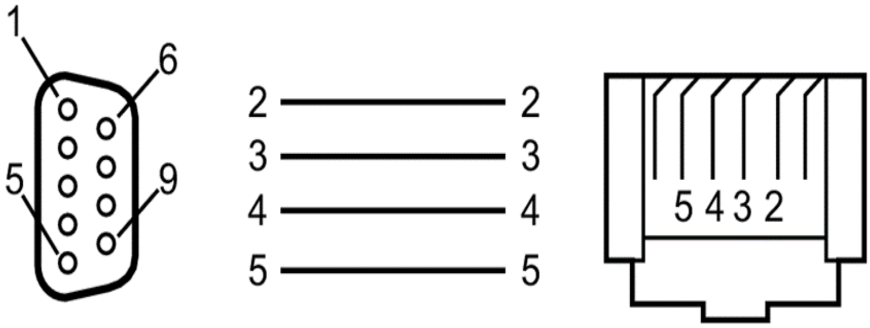

Fig 5: Protocol conversion mapping

Our discussion now comes to the PLCs not compatible with OPC-UA. As OPC-UA supports ethernet connectivity it is necessary to convert the signals to Ethernet transferrable form and for this we have to use an external gateway in between PLC and Ethernet connection which converts PLC signals to Ethernet transferrable form. Then this can be connected to a bridge for data collection as show in the figure which is in turn connected with the application server. The Application coverts the data from PLC to a language in which server can communicate.

3.2 OPC UA and SECURITY

OPC developed OPC-UA which comes from the world of automation OLE for process control protocol. It is standardized under IEC-62541 identifier and contains 14 parts. It can be used in M2M architecture enabling interconnection of applications at shop floor, PLC's, field devices and sensors.

It can also be implemented in various kinds of systems such as SCADA, MES at enterprise level. It is an application protocol which is client/server based. It acts as a IoT Gateway. On top of TCP/IP stack it is implemented [10].

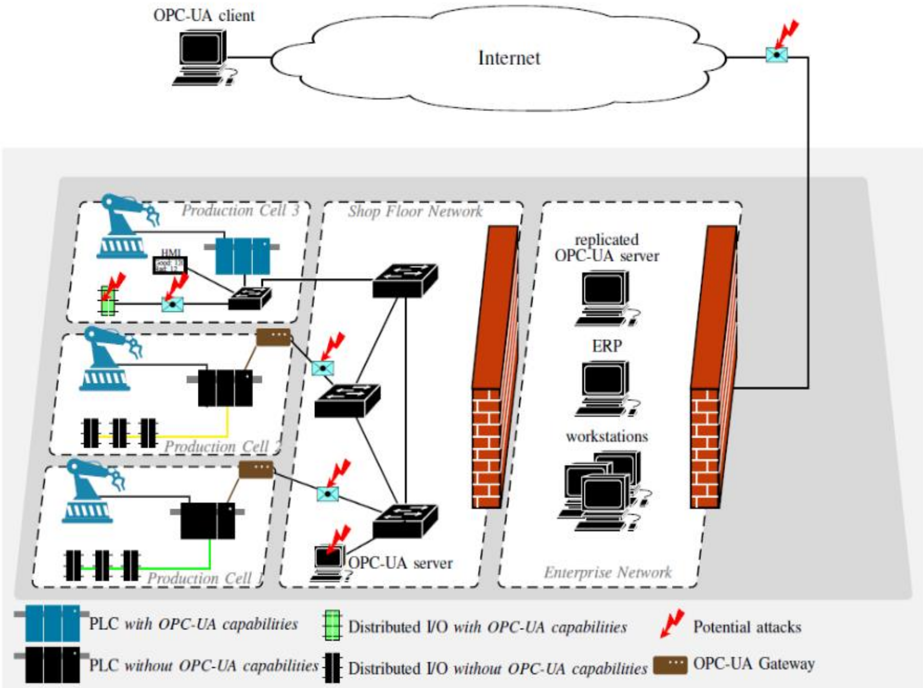

Fig 6: Traditional shop floor converted into Smart factory [10]

OPC-UA defines the interface between Servers and Servers, as well as Clients and Servers, also with access to real-time data, access to historical data, monitoring of alarms and events and other applications. Inculcating this methodology would help many manufacturers and industries to rapidly convert their shopfloor into smart factory and integrate their machines with the MES.

Instead of investing huge amount in buying modern machines, this simple cost-effective methodology can be adopted to upgrade the traditional machine and collect data.

IV. CONCLUSION

The PDA/MDA (Process Data Acquisition and Machine data Acquisition) are very important data required in smart factory as it shows downtimes in organization and operating periods of machines and their malfunctions, which when analysed helps in implementing maintenance measures and continuous evaluation. Applying this methodology, the PDA/MDA (Process Data Acquisition and Machine data Acquisition) can be seamlessly acquired from the machines which are not directly compatible with modern communication systems. An important prerequisite for successful implementation of Industry 4.0 is shop floor integration. Robust networking and flexibility of configuration highly support the modification in production. Only by interconnecting all machines and systems in both horizontal and vertical topology, it is possible to achieve clear and successful communication in real time.

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