Industry 4.0: ERP and Shop Floor Integration with Manufacturing Execution System (MES) in Sri Lankan Manufacturing Organizations

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Abstract - *Worldwide manufacturing industry started to go with Industry 4.0 and so do Sri Lankan manufacturing industry. For this revolution, Shop floor integration is an essential requirement for implementing concept of industrial 4.0. Considering Shop floor integration, there are two facts according to the manufacturing IT; First Integration of all machines, systems, user interfaces. (Central IT systems - manufacturing execution systems (MES) level) in simple words the MES has to ensure the product is manufactured correctly. In this matter a lower level layer / shop floor integration layer should handle the process. This layer manages the MES, all the details of shop floor control and communication. Second Communication of the systems at the shop floor. The purpose here is the supply of industry standard interfaces and shop floor integration platform PAC is an ideal product for implementing these concepts.*

ERP systems contain information regarding inventory, customer demand and MES control contain how to build it. So, integrating these two could help to increase operational efficiency and enable organizations to become more flexible. In addition, real-time information exchange between the business layer and the production layer could help increase overall efficiency, reduce cycle time and management get more visible information and that helps to improve decision making.

Researchers goal is to find out requirements and possibilities to implement such technologies in line with industry 4.0 revolution in Sri lankan context. In result of surveying conducted among selected manufacturing organizations who already use ERP system or capable of implement ERP systems featuring Manufacturing Execution System, gathered necessary information.

Key words: ERP, MES, Shop Floor, Programmable Logic Control (PLC), Industry 4.0

I. INTRODUCTION

Industry 4.0 as known as 4th Industrial Revolution, it is based on integration of business and manufacturing processes as well as integration of all actors in the company's value chain. In industry 4.0 technical aspects of above requirements are met by application of generic concepts of cyber physical systems (CPS),Internet of Things(IOT) and Internet of Services to the industrial production lines[1], [2].

ERP or Enterprise Resource Planning System is an integrated enterprise computing system that lets an enterprise automate flow of information, resources and all functions within the enterprise on a common database, it's a one database, one Application and a unified interface across the entire enterprise[3].

MES or Manufacturing Execution Systems, it's an information system connecting monitors and controls to manufacturing systems and data flows that take place on a factory or shop floor. Overall target is to make certain that manufacturing operations are effectively executed and improve production output[4].

One of the key important factors in Industry 4.0 is shop floor integration. Since Industry 4.0 is a

new concept still around the world in 2019. Integrating an ERP and Shop Floor Application like MES is Going to have lot of challenges. For an ERP to be an Industry 4.0 Application There are Lot of Requirements, an ERP to Get in to Industry 4.0 it needs those requirements to be full filled. By Taking from Industry 4.0 context an ERP system to be a Industry 4.0 system, it needs to use IOT (Internet of Things), IOS (Internet of Services) and Cyber Physical Systems, By Using These Technologies ERP must be Connected Every Where in an Enterprise.

Industry 4.0 is still new Around the World and to Sri Lanka it is a Completely new and Radical Concept. In Sri Lanka, Manufacturers in the Industry are still adapting to ERP so in this Paper we Discuss ERP and Shop Floor Integration with Manufacturing Execution System (MES) in Sri Lankan Manufacturing Organizations. This highly depends on successful implementation and operation of an ERP System.

II. DEMANDS ON ERP SYSTEMS MADE BY INDUSTRY 4.0

With the industry 4.0 revolution existing and suggesting ERP systems are must uses to be and operate in a Cyber Physical Systems environment. In the path to be it must fulfill a variety of technical and process related requirements as follows.

A. Technical requirements

1) *Data storage:* Simplification of data model **-** Simple table structures for the logical data model of ERP systems. Goal: abandonment of intermediate results (timeliness of data) Decentralized data management **-** Distributed storage of data in different systems. Goal: dynamic, bi-directional (ERP-MES-PLC) loading of data to control processes flexibly

2) *Data exchange:* Connection to legacy systems **-** Exchange (vertical and horizontal) and processing of data with and from different hardware and software systems. Goal: integration of systems for a flexible planning, control and execution. Speed of data access **-**

ERP system should deliver requested data within short response times. Goal: fast reaction to changes which are on short notice.

3) *Data use :* Visualization **-** The user interface of the ERP systems should display information adequately (i.a. display on different devices), understandingly and intuitively. Goal: improvement of human-machine interaction. Integration and Intelligence **-** ERP system should connect data from different sources and hence create new information. Goal: generation of new information. Automation **-** ERP system should use the data to trigger automated processes. Goal: reduction of errors and increase in efficiency.

B. Process-related requirements

Suitability for dynamic planning, control, and execution

1) *Technical connection of ERP Systems to MES and PLC:* Vertical integration to make the production planning and execution more dynamic, Bi-directional exchange and usage of decentralized stored data. Goal: cost-efficient production of a higher variety of variants

2) *Support for an integrated end-to- end process* **-** Technical connection of supply chain partners **-** Horizontal integration e.g. with suppliers and customers. Goal: integrated information and process flow along the supply chain.

3) *Progressiveness of the human-machine interaction in the process* **-** Modern user experience **-** User-friendly, personalized and intuitive human-machine, interaction, Role **-** based and graphical data input and output. Goal: fewer errors and more efficiency in the process execution,

4) *Location-independent control and execution of processes* **-** Use of innovative mobile applications **-** Horizontal integration e.g. with suppliers and customers. Goal: integrated information and process flow along the supply chain

5) *Efficiency of process steps supported by the system* **-** Performance of processes supported by

the system - Faster data processing based on current data. Goal: ad hoc processing of requirements which changed on short notice.

6) *Process improvement through intelligent data analyses* - Effective usage of connected data - Use of all existing data from different data sources, Generation of intelligent reports. Goal: decision support for predictive planning and control of processes and/or the trigger of automated, subsequent processes

III. NEW ROLE OF ERP SYSTEMS IN TECHNOLOGY REQUIREMENTS

Considering Industry 4.0, the ERP systems have to play a new role. Normally an ERP system is the centralized system for data storage in a company to plan, control, and execute business processes. But the ERP system has to be embedded into new business processes and connect system consisting of intelligent components. Still it will be the central part of this entire system but not all data will be stored in the ERP system's database like before. The connections to other IT systems become very important and same happens to the data use. The planner receives intelligent analyses based on real time data which can be accessed using various devices with a modern user interface replacing access to database tables with the help of transactions. All innovative data management, data storage, data exchange and data use are affected by the new role of ERP systems. So suitable concepts should develop individually for each organization to maximize the benefits of Industry 4.0. For example; organization should decide which data should be stored centrally in the ERP system and what data should store decentrally. Static data like material data can stored centrally to avoid redundancies and inconsistencies. Meanwhile dynamic data like transaction data for orders can stored decentrally. That allows flexibility of the transactions. Data exchange with all IT systems should plan carefully and they need to connect with new technologies like sensors and analytic algorithms which are able to make ERP systems more efficient. Some roles and description as follow.

A. *Mobile* - the user is able to access information about production processes at anytime and anywhere and may change control parameters.

B. *Role-based* - the user interface provides functions of ERP systems to the user as needed for the job role and tasks. The Information is displayed and analyzed accordingly.

C. *Simple* - complex functions of the ERP systems are divided into single steps and then user executes one after another. The simplification of the user interface increases the efficiency and reduces the probability of errors.

D. *Personalized* - the user interface provides the user with modern functions which give the impression that the work is supported according to individual needs. This way a bond between the user and the working medium is established.

E. *Agile* - the user interface enables the user to work quickly and without delays with an ERP system. Information can call, processed, and visualized immediately.

In this research, researchers suggest and use as example SAP SE and its software tools, services as the suitable package to implement ERP system for industry 4.0 concept.

IV. CONNECTION OF ERP SYSTEMS TO THE SHOP FLOOR

Production is planned top to bottom from the production planning level in other words an ERP system to the MES (execution level) down to the Programmable Logic Controls (PLC - machine control level). SAP SE responds to this requirement by connecting the ERP system with the MES and then enable the exchange of information between the top floor and the shop floor in real time. Which named as ‘‘connected manufacturing’’.

To do this consisting ERP system's reach needs to be expanded towards the machine layer. So, the machine layer has to be programmed more openly then the middle control layer which integrates the various data sources can manage the production process more autonomously. There are many reasons for performing the balance of production execution in a separate MES using like SAP Manufacturing Execution (SAP ME) or similar applications. If there is a downtime in the ERP system's connectivity because of some reasons but production has to keep running. Manufacturing processes need more detailed execution operations than planned in the routing by ERP systems. In individualized production scenarios, consistent data exchange between product engineering and manufacturing execution plays a major role as the interconnection of these functions forms the start of stable manufacturing processes.

Currently, the Engineering Bill of Materials (EBOM) is handed over to the manufacturing department, where mostly the system based on the requirements from engineering develops the Manufacturing Bill of Materials (MBOM). These routing have fixed pattern. With the intention to be more flexible, SAP launched the SAP Visual Enterprise Manufacturing Planner (VEMP), which permits the manufacturing engineer to create these MBOMs by re-grouping the parts and components and be able to add other parts that are needed for packaging processes.

SAP Manufacturing Integration and Intelligence (SAP MII) and SAP ME use the data from the EBOM or the routing from the MBOM. Both systems complete each other's processes. When considering SAP MII, it integrates shop floor solutions such as SAP ME and other data sources with the ERP system for production, supplier management, plant maintenance, quality management and materials management. Also, it is used to visualize Key Performance Indicators in marketing section, calculated by analyses of the data extracted from the integrated data sources. SAP MII offers an alert framework monitoring the maximum value, minimum value and equal value (threshold values) for any machine and creates preventive maintenance work orders for each threshold breach.

SAP Plant Connectivity (PCo) enables the exchange of data between the MES level, supervisory control, and data acquisition (SCADA - Supervisory Control and Data Acquisition) services, Human Machine Interfaces (HMI) or Programmable Logic Controls (PLC). SAP ME offers full integration with SAP ERP systems out of the box. Nonconformity management is supported by in line sampling and system-guided manual rework processes.

As an example, following use case shows that how shop floor integration and MES works together.

Use Case: Shop floor integration with MES

Description

The bidirectional data exchange from the ERP system to the machine control level (PLC) through an additional interconnection of an MES fosters customer individualization and flexibility in production. This way customer orders may change at short notice and the changes will still be considered during production. (This case study used as an example to explain what it is and how this concept operates.

Benefit

Time and cost savings through greater flexibility in production due to data exchange between the planning, control, and execution levels and hence the possibility of parametrizing machines based on customer requirements. Production efficiency is increased as workers benefit from ex: digital work instructions.

Digital Option #1: Manufacturing – knowledge, skills and culture – digital vision and culture

The production worker is supported by digital work instructions which are stored at MES level and can be accessed on demand.

Digital Option #2: Manufacturing – operational processes – advanced sensors

Machine data such as quality information is collected by sensors during production and sent to MES. This way the production can be adjusted if quality issues occur.

Digital Option #3: Manufacturing – planning and controlling – big data and advanced analytic

The MES also serves as a platform for Big Data analyses. With the help of advanced analytic tools such as SAP MII there is the opportunity to ex: analyze the root causes of errors and non-conformity that led to customer returns.

Digital Option #4: Manufacturing – planning and controlling – advanced manufacturing

The direct transfer of customer orders from the ERP system via MES to PLC permits the production of a lot size of one. With the help of technologies such as SAP PCo which serve as middleware between the MES and the PLC, an individualization of products is enabled and changes in customer requirements can be taken into account during production even at short notice.

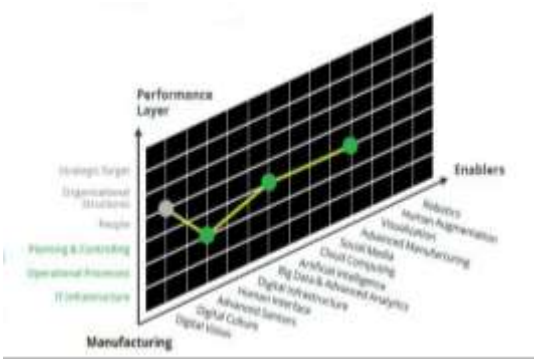

Figure 1. Project experience use case

Source: Deloitte ERP Industrie 4.0 Whitepaper

V. INDUSTRY 4.0 IN SRI LANAKAN CONTEXT: ARE WE READY?

Industry 4.0 brings new technologies to the table like internet of things, ergonomics, autonomous vehicles, 3-d printing, mobile internet, blockchain, energy storage, renewable energy, data science, artificial intelligence, advanced robotics, and advanced materials[1]. As a matter of fact it represents a whole set of interconnected technologies[1].

Being a developing nation it takes a lot of time to adapt to new changes in a country like sri lanka, when considering ERP adaptation, developing countries in Asia region is very low[2]. But when considering recent history can say that sri lanka is very much looking forward to industry 4.0[3]. For many sri lankan industries industry 4.0 is a pivotal point[4]. Industry 4.0 changes the way a traditional industry or manufacturing process in so many ways, it is a very serious transformation[4]. To face this transformation, need drastic changes in many areas in and out of the industry. Present time in every industry, there are leaders who disrupt the way current industry works by bringing new ideas and concepts into the industry, most of these new ideas and concepts have small or big connection to industry 4.0. The reason for this is most of the new ideas and concepts if not all of them have one common thing; technology. Industry 4.0 will change human resources, education, job market,

education, economy, business processes and many other areas, drastic changes will happen in every area but there will be a huge impact on manufacturing processes and related areas like manufacturing execution systems and enterprise resource systems. Once the changes starting to happen, there will be a huge shock throughout the industry in sri lanka. Sri lankan apparel industry is already on the move in using industry 4.0[4]. But the biggest concern is the technology adaptation. Many companies tend to use ERP solutions nowadays but turning to industry 4.0 still doubtful. At the same time some organizations successfully adapt to the technology and others failed to do so. In sri lanakn context small and mid-size companies are not yet ready to go for industry 4.0 integrated with ERP solutions. So that only big manufacturers; in this situation mainly apparel industry, ready / can implement such systems to centralize their business processes.

VI. BARRIERS TO IMPLEMENT

In result of surveying which was conducted among 5 different manufacturing organizations who already use ERP system in their business process or capable of implement ERP systems featuring Manufacturing Execution System. The purpose of this survey was to discover the following barriers to implement such systems in converting process for industry 4.0. The survey was conducted by means of a questionnaire given to the organizations to complete. The first part of the questionnaire dealt with the technology capabilities and the second section was concerned with cultural aspects. From the data gathered the most significant main barriers as follows.Technology sense: Obtaining accurate information about the technologies 20%, Difficulties in coordinating Industry 4.0 activities across different organizational units Concerns about IoT related cyber security 48% Data ownership when working with third-party providers 10% Rapid technology changes and problems with allocating annual cost/ assets 22%

Cultural sense: manufacturers lack the courage to push through an emerging technology transformation 5%. Even though find some solutions for the mentioned barriers inevitably will remain some degree, which means these barriers cannot eliminate but only can mitigate.

VII. CONCLUSION

According to the survey and discussions had with manufacturing organizations, small and mid-size organizations have low possibly to implement ERPs along with industry 4.0 and those organizations must hands on required technology like big organizations. Even in considered big organizations lack knowledge in shop floor integration, MES and SAP ME. Manufacturing industry should more concern in new trending technologies and top management must encourage their employees to learn about them and adapt to them.

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