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A Review on the Approach Towards Cyber Physical Manufacturing System Architecture for Mining and Production Industries

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Abstract

Conceptualization of Cyber-Physical Manufacturing System (CPMS) is a comprehensive zone of engineering which provide supports in terms of applications across mining sectors and any manufacturing domains metal industry, air transportation, mining activities, critical infrastructure, health care and medicine, intelligent transportation, robotic for service, and special smart manufacturing etc. CPMS is an emerging technology in facilitating the conversion from conventional to automation and is translating complete scenario of manufacturing. This paper deals with a review on an approach towards the CPMS architecture based on smart services for manufacturing systems like mining and metal industries. This paper introduces the review on an implementation example of an approach in mining and manufacturing industries, instantiating the conceptual architecture using unique technologies.

Keywords: *CPMS, Intelligent Service, Metal, Mining, Manufacturing*

1.0 Introduction

Conventional manufacturing systems have been converted totally into real time system with some multifaceted domain due to faster technological update and globalisation[1,2] which progressively bank on to computer technology to direct manufacturing activities and provide information to the right place in the method. It's quite tough to rectify the essential software and its tools and thus in turns have inadequate help for solving the complexity of the problem. Now a days, attentions have been achieved by the service industry based on the technology which provides the platform for everyone to gain the benefits without compromising the interface standards of the company[3]. But still the level of complexity is limited due to their small approach onto their platform which in turn badly impact the features like coordination, composition etc[3]. Mass production manufacturing companies like metal industries, automobile industries face the challenges at the very beginning stage of design itself but at a later stage when the production start, its stable. Job shop production like aircraft and ships, on the other hand, required rigorous changes in its design characterization with maximum degrees for each product. The distribution of supply chains is higher, and this is due to varied suppliers in different countries. And

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at this point of time the delivery of product is uncertain pertaining to production. In any supply chain, when any manufacturing industries are moving with customization, then flexibility should be there in terms of software, coordination, decision etc. which support the system. Taking the efforts in line with the latest software which in turn provides flexibility with the help of IOT already exist in its specialization[4]. Using its capability with the help of IOT, still they face challenges in terms of updating the software with respect to customization. So, to deal with changing needs and flexibility in any manufacturing industries, we need to amalgamate the IOT with hardware along with intelligent coding or services. As we know that CPMS is an upcoming and very intelligent services to manufacturing industry but still it is lagging its features and utilization in terms of deployment and some formal techniques. So, to overcome this problem, we need to discuss both the existing and emerging requirement with relate to CPMS[5-8].

In this paper we are going to understand the present scenario in the domain of Intelligent services for initiating the information systems in manufacturing process specially for job shop production. Paper deals with the need to understand the architecture of CPMS and then to find out the challenges in this field which relates to customization of production in present time. After that, a schematic framework is shown to get the familiarity of Intelligent services in any manufacturing processes. This paper also concludes that CPMS leads to few important aspects which are optimization, prediction, diagnosis, flexibility in operation, controlling and managing the machines remotely across manufacturing sectors like metal industry and mining sectors.

2.0 Cyber-Physical Manufacturing System Components

To construct CPMS architecture, five components are required. These components are connectivity, data conversion, internet, decision, and feedback. Bringing all these together is itself a challenge. Let us first discuss about the connectivity. Here it means connecting the machine with its parts or components to achieve information or some reliable data which should be good enough to work upon it in developing Cyber-Physical Manufacturing System[9] for Industry 4.0. Various actuators and sensors are being considered to get all these data like pressure, temperature, speed, volume, velocity, acceleration of the machines and their parts. It is also important to take the videos and images of the same. Data from several sources are taken and stored for its testing and reliability. Even some of the parameters like humidity, voltage, current, vibration etc are also noted with the help of sensors or devices. Some of the data are obtained from Coordinate Measuring machine, Programming Logic Controller, lathe machine, gear cutting machine and many more to establish the sufficient data bank. And these data are used to understand the protocols of internet/cyber. Now these data are considered as an information to bridge the gap. To fill this gap conversion of data must be taken place at various level. Different mechanism is utilised to convert the available data into useful information. Few mechanisms are built for diagnostic and maintenance of machine and its parts. It provides the independent nature to the machine which are under working condition. In CPMS internet plays an important role to complete this architecture. All the data which are obtained from machine, or its part are then utilized to create a network. After creating the central network of machines, now it's time to extract the gap or lag which is still there. After this, a better understanding of machine or parts is provided which itself is part of analytics. This analytics gives us the autonomous comparison between number of machines which reflects its capability, performance and thus rating can be obtained at the same time. It also allows us to predict the nature and future working ability of machine based on the information gathered all together. Virtual machine network is helping Industry 4.0 in getting success. Further in an architecture of CPMS, decisions must be taken based on the analytics provided herewith. In terms of significance of the tasks for predictive maintenance could be realised at an early stage based on the data availability. Already these data are compared and specific machine or its parts information is there. So, on this basis a decision is made for readiness. Last but not the least, a closed loop of a virtual machine network is of utmost concern. Getting feedback at appropriate time with the help of connectivity, data conversion, and internet, help the CPMS to improve its output and efficiency. When the physical part is getting feedback from the internet,

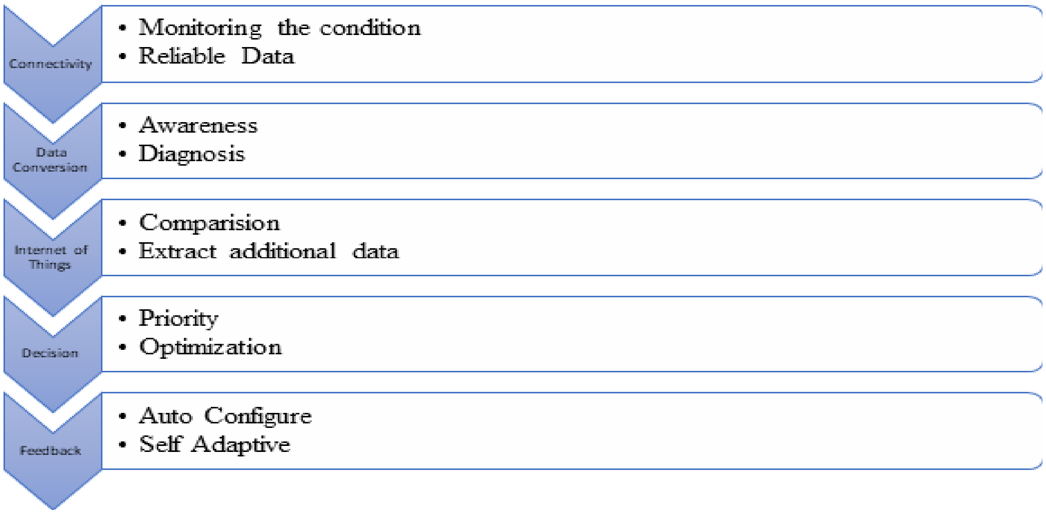

Figure 1. Components of CPMS architecture.

it assures that some rectification is required over there and sorted out within due course of time. At this point autonomous configuration and self-repairing is taking place which reflects the control over the mechanical mechanism. It acts as the Resilience Control System (RCS) to apply the controls corresponding to the decisions made with respect to machines. Figure 1 given below shows the components of CPMS architecture.

3.0 Challenges in Cyber-Physical Manufacturing System Components

Some of the literature discuss about the problems pertaining to integration of machine with internet, data segregation[10,11], compliance with international standard. Furthermore, challenges are encountered in CPMS architecture related to novelty in design and services, diversity in products, customer satisfaction[12], quality and support services[9]. As per the de-facto standard IEC 61131 an Industrial Automation Systems (IASs) is being established[11]. To eradicate the restriction of the above-mentioned standards, the updated version of the same have been introduced to solve the problems pertaining to Complex Industrial Automation (CIA). Though, to overcome all the challenges in CPMS architecture, maximum work is required to disrupt the standardization currently available[13].

4.0 Purpose/Function of Standards in CPMS Architecture

Some of the existing types of standards pertaining to the CPMS architecture is provided below in Figure 2.

To make sure that products, materials, processes, and support services suitable for their objectives should be utilised constantly provided with their appropriate specifications, characteristics, requirements etc. is a part of document named as standards. So as to achieve an effective growth and deployment of technology elements in an Industry 4.0, several categories of standards have to be applied with different roles and functions which are needed for different categories. Therefore, it is necessary to identify the appropriate standards as per the requirements in development of technology elements and complex interactions which let us to know about the machine components mechanics[14]. Figure 3 specifies function of the standards pertaining to the CPMS architecture.

Fusion of knowledge among various technology elements is very important when these standards are utilised in providing the details related to products, materials, processes, and support services. When fusion of knowledge among various and across the technology elements takes place then it helps to bridge the gap between market and research products. With the help of various kinds of standards available with respect to CPMS architecture, it is quite easy to understand the gap and be able to fill this gap by amalgamating scientific research

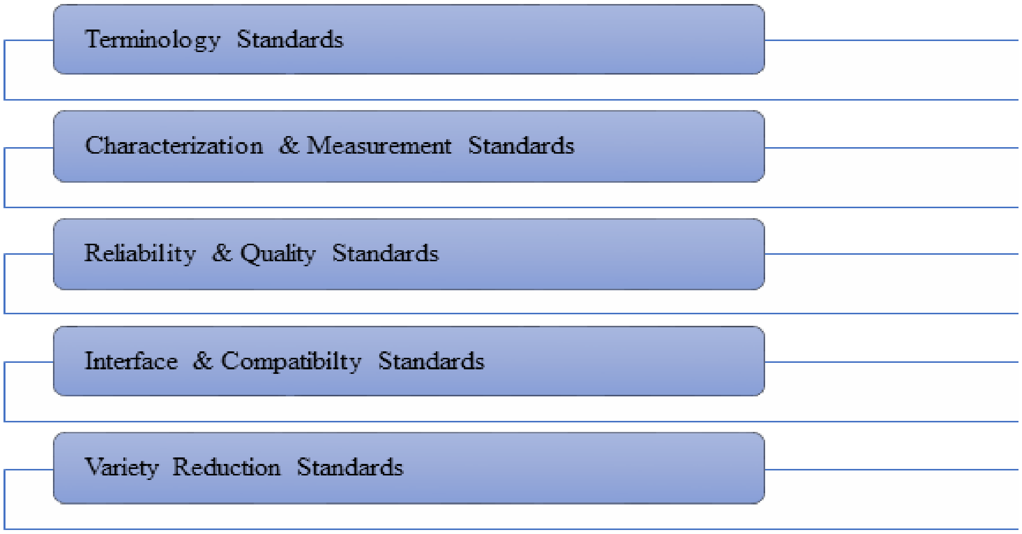

Figure 2. Standards pertaining to the CPMS architecture.

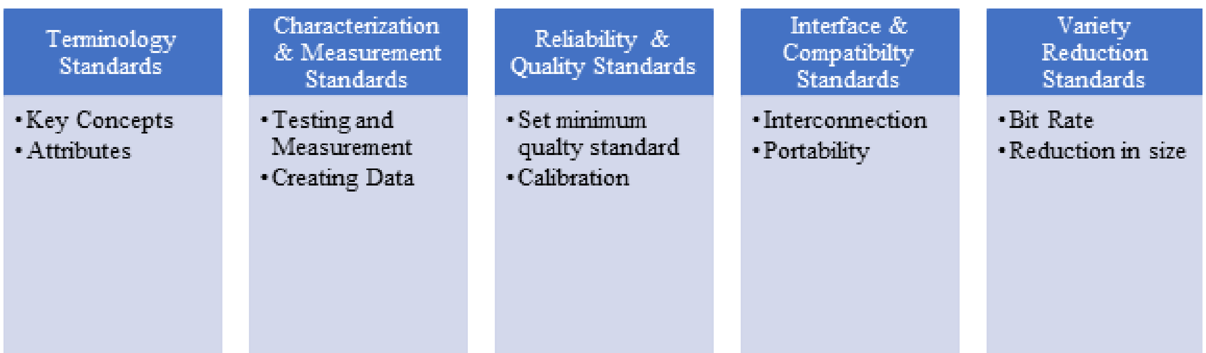

Figure 3. Function of the standards pertaining to the CPMS architecture.

and technology elements into market. First components of CPMS architecture are smart connectivity. Under this level data from physical machine components is achieved. And for these various techniques are there under the standards format and the most peculiar is the usage of Automatic Identification and Data Capture (AIDC). Under these techniques some standards specify the exceptional recognition for listing methods, general guidelines, separate carrying components, particular products, and product bundles, different returnable carrying items, and combinations[14]. In CPMS sensors plays an important role in obtaining the data from the machine elements. At the same time these sensors are to be monitored and handled precisely.

Conversion of data into information is the second components of CPMS architecture. Under this level managing the data of machine elements from the smart connectivity level and then it is being analysed individually. This component has some standards which is used to explain the characteristics of machine elements. Various series of the standards under this level provides the source for examining the behaviour, types of elements, data and the interconnectivity which is not clear and precise. One of the series of the standards under this level offers exchanging of data under unified data format which is also called as Automation Markup Language (AML). Furthermore, series of the standards also setup a cutting edge featured system to understand the environment for the Internet of Things. But apart from these functions, there is an issue pertaining to the security of data or information in CPMS architecture. So, in this regard, international standards organisation also provided the control mechanism and securing the risk of data breaching in CPMS architecture. And even series of the standards under this level offers extensive protection of data security comprising of control and automation systems[14]. When communication is required in the third level of CPMS architecture at that time internet is necessary components. Exchanging of information and data achieved from machine elements required a series of the standards under this level also which is already there in the form of wireless communications. To explain Local Area Network (LAN), there is collection of international standards, and it must work based on real time distributed network protocols. Monitoring, handling, measurements, and control of information in CPS system is taken care with utmost concern by utilising the certain set of standards[14]. It has to be ensured that quality and support services for carrying the information and data through distributed network protocols is handled under these components of CPMS architecture. Storage of data and managing the information is allowed with certain interface which is again under a specific series of standards. So, integration of devices with IOT is the crucial layer under which refinement is done to act accordingly with the available and additional data which has been accumulated under second level of CPMS architecture. Fourth level in CPMS architecture is to make decisions based of the data available. After examining the information floated in the channel, it allows the system to take decisions while processing and communication. It amalgamates all the information and data and help the system to finalise the required commands to be delivered in the distributed network of CPMS architecture. Last but not the least, the closed loop of CPMS architecture is very useful in making decisions among the machine elements with the existing interface. With this level, auto configuration and self-adaptive nature of machine elements comes into scenario. Once the integration done in any system, the chances for standardization and reliability gets reflected. Some series of standards under this level also exists which minimizes the flaws, cost and threat which are coupled with the interface of distributed network. However, few series of standards also guarantee the life cycle safety for automation control and improves the protection level[14].

5.0 Needs of Job Shop Production based on Intelligent Services

At present scenario, a lot of diversity has been encountered in customer's requirements. Thus, customization will play a big role in managing the production activities to meet customer's requirements. Therefore, it is quite challenging for mass scale production industry to excel the men and machines at an efficient scale[15,16]. To fulfil the customer's needs at various manufacturing industry like aerospace, frequently build a substantial number of different aero models. Such types of challenges in an engineering industry leads towards the maximizing the efforts for planning and control in any production activities. Repeatedly having errors in production line, design related flaws, supply chain and logistics, information technology, vendors etc. are reflecting that they are not prepared even at the early stage itself. When industries like aerospace work upon customization, then it means really that they are adding values to their products. They usually deal with the assembling activities which are manufactured by a very extremely concentrated supplier. So proper planning and control measure has to be taken with respect to vendor network or suppliers. In general, at job shop production, maximum customisation of production leads towards the five factors which fulfil the information system in supporting the CPMS. First one is an individual idea or decision at micro levels in various departments. With reference to this, few decisions have to be taken at any step of planning and control of production activities by the labour which should in line or getting support with their operation managers. In an automated production activity, it is noticed that production planning and control commands are very rigorous in terms of labour[17]. At every small step they are supposed to take decisions and it help in rectifying the schedules of production manually. Thus, proper man-machine user interface is extremely advantageous in developing CPMS architecture. Second one is based on confined data for the scattered facilities available in manufacturing industry. As it is known that complete manufacturing process and system is divided into various groups of assembly station. And these stations are decomposed part of an overall production system comprises of scattered facilities of assembly lines. So, these scattered facilities have some local or confined data which is to be utilised to take decisions in any CPMS architecture[18]. When altering scheduling challenges comes at several points of time then the support of confined data of scattered facilities is required to solve the problems to have better control and planning mechanism in manufacturing process. Third one is the management of schedules based on Arbitration. As per customisation of any product, a single window is open as per production planning and control mechanism. Subsequently parallel schedule has been utilised to find the objectives of individual customer requirements. So based on the ongoing schedule management, development of the customer's order is examined and monitored very precisely. Further skilled groups of workers carry out appropriate task which are assigned by the operation manager after dividing the work into small packages. A Resource Constraint Project Scheduling Problem (RCPSP) in multiple mode is designed to overcome the difficulty during the scheduling on the task level[17,19]. Under this RCPSP, a particular bundle of modes is designated to individual task to be performed. And this mode is provided with specified skills to a particular number of workers. Thus, completion of work time varies with respect to the number of workers. The numbers of worker should be less when they are allocated to a particular workstation at any point of time. So, for a particular period as per RCPSP, specific number of skilled workers are required at each workstation. Therefore, assembly line balancing helps to find the numbers of worker at a particular workstation[18,20]. As per RCPSP, it has mainly two scopes in terms of decomposing the overall work either in several shits or in weeks, months, or years. However, RCPSP can be modelled for an individual station which might be useful, and it will lead towards the betterment of the scheduling and planning while developing the CPMS architecture[21]. Fourth one is the amalgamation of execution systems with production activities. Proper integration of software with machine elements and its execution plays an important role for making decisions with respect to scheduling and production planning. Due to its constraints, it's very tough to implement in mass production activities[19,20]. Fifth one is self-adapting or self-configuration in the CPMS architecture which makes the system a closed loop. In Industry 4.0, frequent changes are common in terms of customization of work orders. And for this there should be provision to any production activities pertaining to planning, scheduling, and control to adapt the repeated changes in the system even for the complex processes. Few changes or disturbances in CPMS architecture includes design, information services, machines, tools etc are existing. When there are huge disturbances during production activities, then even information services like Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES) are not applicable to rectify the problem at real time. Therefore, by having only compatible interface won't work to resolve the problems or challenges faced in a highly complex environment of manufacturing[17].

6.0 Intelligent Services based Architecture as a key for CPMS.

While discussing about the needs of job shop production based on Intelligent Services, a CPMS architecture is developed utilising the intelligent services for helping small production activities where lot of customization is required. Thus, as per one of the literature Intelligent Enterprise Service-based Bus (iESB) is developed which acts as an autonomous software which are supposed to deliver the very specific results. The decomposed physical machine components are incorporated with scattered Intelligent Services which are intended to request the support from other Intelligent Services. In some of the literature it has been found that there is a lot of difference between an Intelligent Web Service and an Intelligent Service[22]. Intelligent Web Service is an amalgamation of agents pertaining to software and the services provided by cyber. These agents are used to incorporate the artificial intelligence into the cyber which help in changings the details of machine components during its production activities[22]. Let us understand the individual idea or decision at micro levels in various departments and confined data for the scattered facilities available in manufacturing industry. It refers to facilitating and synchronizing all the activities taking place in an architecture of CPMS. The instruction provided to support the distributed intelligent processing takes place with the help of software and by amalgamating scattered capabilities of machine elements or components. To get these characteristics in an architecture of CPMS, enterprise service bus architectures have to be incorporated which provides the full proof output, registering and distribution of message in a system. And for this integration of enterprise service bus and Intelligent Services act as a solution to improve the issues pertaining to communication while implementing the Intelligent Services into CPMS architecture[23]. Thus, enterprise service bus helps in transporting the communication which are transferred by Intelligent Services. Notification has also been registered in the form of messages whenever actions of interest happen in CPMS. Establishing the management of schedules based on Arbitration is also being supported by the Intelligent Services based Architecture. The coordination between the global and local information takes place by using the management of schedules based on arbitration which is very effective to provide overall support. And this is because of the appropriate messaging being guided by the enterprise service bus and Intelligent Services. It assures the delivery of communications with a definite mechanism. When data has to be extracted at an extreme level from the CPMS architecture then at that time arbitration helps in managing the information available within the system. For this communication layer act as a solution to guarantee the transportation of information within the CPMS. It has some limitation towards the scheduling and planning support at a certain level. That's why local data in a distributed network is utilised and at each level decisions must be taken to solve the problems available in CPMS. As per the constraints, time, resources, and events which are unexpected, optimize the overall process with the help of management of schedules and planning. But both are different with respect to time. Planning dealt with the work which is going to take place in a month or weeks and scheduling refers to the immediate, forthcoming, and pending tasks. Uneven process, breakdown, lack of manpower leads towards the unexpected events which should be rescheduled, and self-adaptation should take place within the CPMS. To handle these situation enterprise service bus and Intelligent Services works according to the arrangements available in the manufacturing industry along with different types of activities going on over there[24]. Thus, officer has to provide the information of all the activities taking place in an industry with proper details pertaining to the man, machine, materials etc. Therefore, Intelligent Services helps in initiating the process within the system with the help of officer who is going to specifies the activities themselves. Now it's time to integrate the execution systems within production activities. And for this interface between different activities and software agents has to be provided with the help of Gateway service functions. It leads towards the interchanging the amount of data within the system. This interface also exchanges the data with external system like ERP, MES, SCADA, etc. Gateway service functions is not only used to send the information but also been utilised to receive the information whenever it is required. Thus, the CPMS has sufficient data from all the sources (within the system and external) which are registered into intelligent services and thus utilising it, just after getting the notification. Self-adapting and self-configuration is one of the most concerned aspects of CPMS architecture. It reflects the frequent changes in the technology. With this frequent changes, it differentiates the various production activities, organisation, and technologies available in the global market. It provides a wide range of adaptability to reschedule and replan the activities or techniques to redesign the architecture of CPMS as a whole system. Scattering of data, establishing the management of schedule on arbitration basis, integration of execution systems and last but not the least novel ideas in the field of manufacturing has the scope to rebuild the architecture of CPMS in such a way to have a very different characteristics which could sustain very easily. The architecture involves intelligent services and enterprise service bus. Registering the service and Node Manager are other two components of architecture in a CPMS. Connection between two architectures should be establish with the help of Node manager. Various locations have its own manufacturing units, and it must control and monitored from remote place. Thus, to initiate the exchange of data between internal and external sources potential consumption of same must take care. Overall process leads towards the distribution of data to the network in an effective way. While distributing the data into the system, all the information is registered and help in coordinating with each node. Each node has nodal manager who provides the availability of data in the service registry at a particular node in the distributed network. To cope with the changes in the domain, the newly developed architecture depends on the meta data for re designing the different concepts of architecture in CPMS. One of the literatures based on metadata is available to understand the concept[25]. Thus, the unavailability of information in the models leads towards the development of conceptual architecture in CPMS where interface between machine and software agents is lagging. Using metadata, it helps in modelling a finite architecture for CPMS which is going to approach towards the real-world activities along with the standards or policies[26]. Thus, inculcating the proposed architecture will help in finding the dependent territory in any manufacturing industry.

7.0 Conclusions

In this paper, how intelligent services and enterprise service bus has been incorporated to develop a novel architecture in CPMS for job shop type production in metal industries and mining sectors has been discussed. These two services in an architecture plays an important role in any manufacturing industries to be effective enough. It focusses on replanning and rescheduling of the activities along with exchange of information to build autonomous system. Software agents with internet of things leads towards the transportation of information in a distributed network. Thus, scattered facilities in a distributed network works as an independent territory. As an overall in providing support to system an Intelligent Enterprise Service Bus (iESB) is utilised to strengthen the complete system with various tools. At present CPMS in itself plays an important role in developing the manufacturing system with problem solving attitude in real time. And for this Industry 4.0 is an upcoming technology with lot of characteristics to cope with real time problems. One more aspect has been dealt in this paper pertaining to standardization. This paper also concludes that CPMS leads to few important aspects which are optimization, prediction, diagnosis, flexibility in operation, controlling and managing the machines remotely across manufacturing sectors like metal industry and mining sectors. This paper encompasses review on CPMS architecture along with its purposes.

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