Implementation of Cloud Services for Smart Manufacture

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ABSTRACT

At present, manufacturing entering to fourth industrial revolution when people with smart connecting devices and digital factories playing equal part of smart technology. In today's competitive dynamic market observed a clear trend in product personalisation. It means that requirements of flexibility and reconfigurability are increasing for modern manufacturing systems. Hence different technologies, distributed information from Web, field level and top level manufacture information systems should be offer high degree of interoperability. Accordingly, there is necessity to made it possible to integrate distributed comprehensive systems in uniform information environment.

This paper addresses the problems of integration of shop floor and office floor in a single information space involving to use cloud Internet of Thing services, Big Data processing, implementation of industrial data transmission protocols.

1 INTRODUCTION

Thanks to unprecedented development of IT technologies and the simultaneous expansion of opportunities of access to them through smart connecting devices, globalisation has continued to increase to date. Manufacturing continues to change and face with new challenges. Traditional approach to manufacture management ceases to keep expected outcome. Contemporary realities require highly individualized products. That gives rise to the problem that relates how to answer for inquiries of clients quickly and build individual products with high efficiency, quality, and output rates at attractive prices in the shortest time. Otherwise, there is a high risk of losing clients due to the high-level competition in the global market. Modern manufacturing require flexibility of production, designing a united information field and real time decision making in this respect.

Thus today industry is taking its first steps to the fourth industrial revolution. Significant development of the Internet and its entry in the areas where it has never been, has led to the emergence of Internet of Things (IoT) concept. Internet has become a link between the virtual world and the physical objects within the real world. Increasing connectivity between products, manufacturing equipment as well as customers and partners will opens new sources of income which was previously inaccessible.

The fourth industrial revolution, which often called Industry 4.0, establish a new standards for customer care [1]. Greater customer satisfaction will be achieved by product personalisation and high-quality, easy accessible, smart services.

However, it is entails new challenges for industry. Individual customer orders require to manufactures be able to produce a lot size one[2]. It means that production lines should to be flexible, easily reconfigurable and smart for performing customers personal orders. In this circumstances, it is especially important integrate all systems which involves in value chain to maintain quality services. Otherwise, the time to delivery as well as the error rate due to inconsistent data will increase significantly. Integration of shop floor and office floor requires the development of universal standards for data transmission between different automation layers and security.

Nevertheless, transition to the new customer-focused business model have a high profit potential. Integration and data consolidation brings better transparency into the actual processes condition. Comprehensive analysis, statistics, prognosis provides opportunities for much more timely and informed decision making. Bringing together intelligent systems, products, and machines in network for information exchange, causes that decisions makes more and more autonomously. All the foregoing creates better productivity and resource efficiency.

2 AUTOMATION STRUCTURE ANALYSIS

To compete successfully in the global market, companies need to adapt to new requirement of the Industry 4.0, or suffer the consequences. Design of automation architecture is essential in manufacture capabilities of flexible and timely resource management. At first, let's to look at traditional infrastructure pattern of manufacture (Fig. 1).

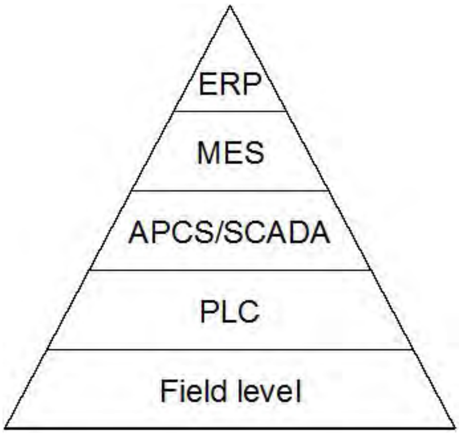


Fig. 1 The pyramid of manufacture automation structure

Automated production management system can be represented by pyramid [3]. Field level is represented by sensors, actuators, engines, valves etc. Next level of the automation pyramid consist of Programmable Logical Computers. PLC is a special digital computer which work with industrial environment signals and operate performing devices. Field level and PLC level are closely physically linked and interact in real time. Level above PLC intended for orchestrating technological process by Automated Process Control System and controlling system states by Supervisory Control and Data Acquisition system. APCS/SCADA level communicate with PLC lever over proprietary bus systems which characterised as robust, secure and well-determined data transmission mechanism that is critically important for production enterprises. Manufacture Execution Systems is a superstructure above APCS for workflow optimisation, mid term production planning and execution. In most cases, data flow between MES and APCS layers is limited causes as to function on separate physical network. As a result this layers in most cases require specific, manual integration and therefore MES generally do not operate with real-time data. Highest Enterprise Resource Planning layer is responsible to perform long-term company resource planning in term of human and material resources. ERP and MES basicly interconnected by Ethernet technology and work closely.

Accordingly, at present, in traditional automation structure of enterprises we can observe that communication between APCS and MES layer is limited by different network environment. As result, MES do not operate real-time data from a shop floor for flexible and timely control of productive capacity and quality which are required for addressing the ideas of the Industry 4.0.

At least, there are three strategies [4] to bringing a gap between shop floor and top floor level:

- Insert Manufacture Execution System into Automated Process Control System. You can import MES functions into APCS. So far, this has not been a popular approach.
- Absorb Automated Process Control System into Manufacture Execution System. Essentially this means that MES takes functions of APCS and starts directly control PLC level. It is interesting in theory, but apparently the differences are too great, because we don't see this happening much in practice.
- Allow Manufacture Execution System and Automated Process Control System to communicate. Companies already have invested huge capital investments to infrastructure of automated systems. This approach implies development of the infrastructure, instead of reconstruction, however, requires new unified data transmission standards.

For now, the third data communication strategy seems to be the favored approach and first have done. OPC Foundation had released new industrial protocol OPC UA for reliable and safe communication among different devices and applications. Moreover, hundreds manufacturers, users and research institutes continue researches and developments for interconnection of products and services.

According the bridging strategy, propose improved automation architecture which is represented in Fig. 2.

For bringing a gap between MES and APCS level we propose to use OPC/Web client-server application for information exchanging between the levels. The application is a client for OPC server by which get real-time data about production line from PLC and then as server prepare the data for secure and semantic support delivery to MES level. Following the Industry 4.0 ideas we clearly understand that we have to efficiently process a big dataflow from the shop floor. IT industry provide powerful solution for data processing by cloud technologies. Hence, we make a proposal for organising MES by cloud services. Thus MES starting work with ERP in a single information environment that enhance collaboration effect of planning tools and manufacture execution. As result we get powerful system which can perform comprehensive planning, analytics and predictions, provide real-time equations and timely send control orders through the OPC/Web server to APCS via Internet network. Additionally, according to globalisation trend, proposed automation structure is matters for world wide spread companies. It gives them a unified tool of flexible and efficient orchestration for distributed plants.

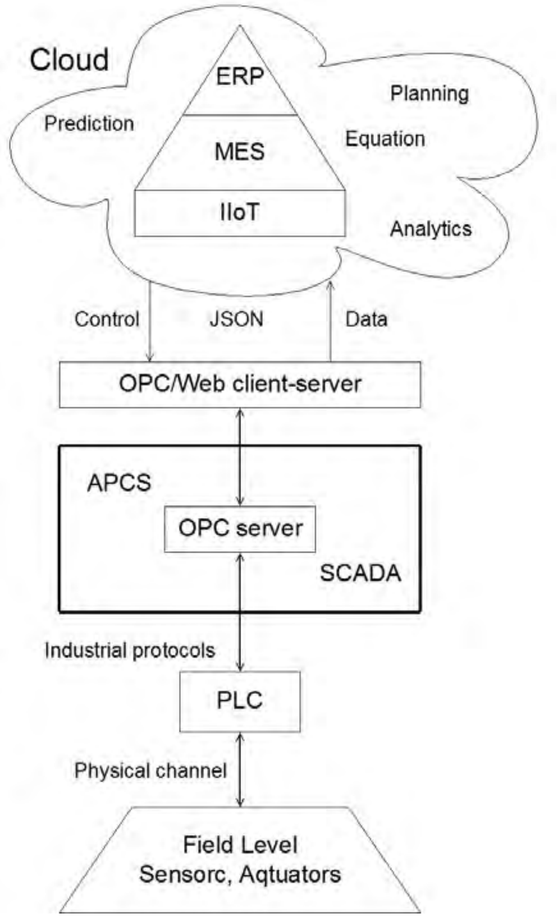


Fig. 2 Automation structure with implementation of cloud services

3 IMPLEMENTATION OF PROPOSED ARCHITECTURE

One of the main implementations of the cloud systems from the Industry 4.0 viewpoint is using cloud as a service at the cases of maintenance of the equipment. The smart services is a new way to manage machine time and one revolutionary possibility to promote productivity factories of the future.

Technically, implementation of IIoT services reconfigures maintenance business model. Service companies are given the opportunity to maintain their equipment more than ever before.

The renewed model of maintenance is presented below (Fig. 3). The devices and equipment have a virtual representation at the service company cloud. It contains clear information about device destination up to location on the plant, needed documentation for repair and maintenance, actual working state and statistics for better servicing of several geographically distributed clients.

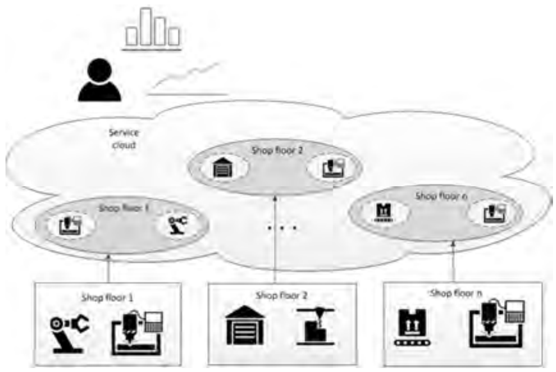


Fig. 3 Renewed model of maintenance

It means that service company have a possibility of remote supervising of real plant equipment state by cloud services. This includes plenty opportunities for the predictive maintenance and advanced service processing in the cloud.

Another big advantage of the cloud concept at the Industry 4.0 is dispatching control (scheduling) of the production line. Potential of Industry 4.0 at this field starts from changing of MES (Manufacturing Execution System) concept with cloud integration and gathering the main data form PLC to the cloud. Now the cloud systems start to change ordinary programs and services (SaaS concept), and from this point of view the concept of cloud MES system seems real. The cloud MES concept has several key advantages those grow from ability of cloud platforms gather and manipulate huge amount of data (Big Data platforms):

- Big Data concept can help at the field of predict failures and maintenance requirements of the devices. With large amount of historical data and ability to cluster and probability analytics, the decision process within the shop floor can take into consideration several other capabilities.
- Quick processing of huge amount of data can take into consideration not only operation data from one production cycle, but ambiguous data dependencies. As a result, the decision process can be totally transformed. The state of the production line consists not only from direct data from sensors and PLC but from historical data at the real time.

- Cloud concept can transform the way of integration of the ERP/MES/CRM systems. Within the transformation of the business and including cloud solutions the service integration becomes easier. Instead of services and on premise solutions, functions of ERP, MES, PLM systems can be integrated and reconfigured at the cloud (Fig. 4)

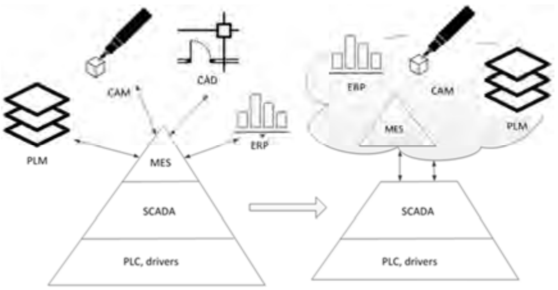


Fig. 4 Reconfiguration by using cloud services

Practically, in this paper, we investigate connectivity capabilities between shop floor and cloud services. Learning laboratory reactor station was chosen as hardware (Fig. 5).

Fig. 5 Learning reactor station

It was selected because the learning station is built with components which are used in real manufactures. Moreover the station works under control of industrial PLC.

Function of this station is heating liquids depending on the recipe selected. Technological process represented in SCADA screen (Fig. 6). Highlighted by red rectangle parameter is a temperature of liquid in the reactor.

For accessing the temperature measurement we use OPC server. Object Linking and Embedding (OLE) for Process Control (OPC) is industrial standard that allows programs to communicate with industrial hardware devices. The server was connected with reactor station PLC via Industrial Ethernet. Thus OPC server can read special tag which contain temperature data from the PLC and share it among OPC clients. On Fig. 7 we can see interface of usual OPC client where shown readed current temperature in the reactor tank.

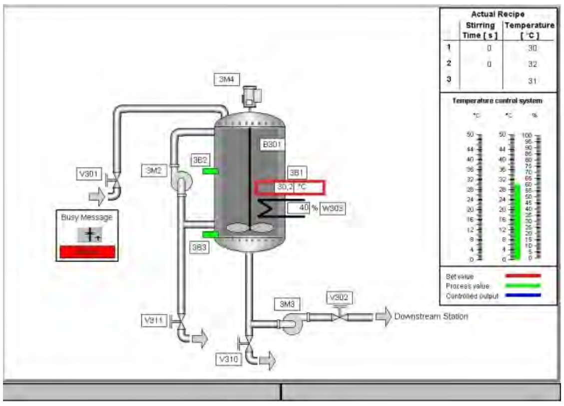


Fig. 6 Reactor SCADA

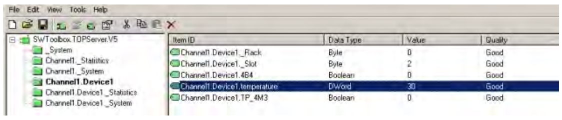


Fig. 7 Common OPC client interface

For transmission temperature data to cloud services we write special OPC client for further processing and analytics.

Cloud is waiting for messages from the client at JSON format. JSON (JavaScript Object Notation) is the text format of data exchange, based on JavaScript developed by Duglas Krockford.

Fig. 8 Comparison of XML and JSON

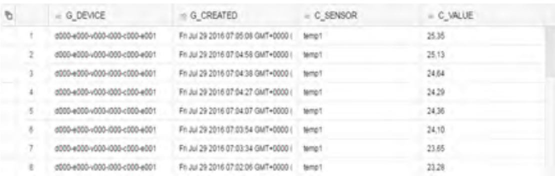
In comparison to XML format (realisation is presented on fig.) JSON is less excess that is critical for the IIoT-interaction. The main disadvantage of using JSON notation is less semantic value.

The interaction between cloud and client based on the WebSocket protocol (wss://) . During the interaction the connection is initiated by the client and keeps until socket will closed.One of the main advantages of the WS-interaction is ability to track network failures. In comparison to HTTP protocol WS allows to eliminate static IP on the device.

4 RESULT

Working on this paper, we implement proposed architecture on Fig 2 and reach following results:

- Read data from industrial temperature sensor;
- Transfer and store data from industrial sensor to cloud by using IoT service (Fig. 9);
- Process the data in the cloud in appropriate way.



	G_DEVICE	G_CREATED	C_SENSOR	C_VALUE
1	d000-e000-v000-i000-c000-e001	Fri Jul 29 2016 07:05:08 GMT+0000 (	temp1	25,35
2	d000-e000-v000-i000-c000-e001	Fri Jul 29 2016 07:04:58 GMT+0000 (	temp1	25,13
3	d000-e000-v000-i000-c000-e001	Fri Jul 29 2016 07:04:38 GMT+0000 (	temp1	24,64
4	d000-e000-v000-i000-c000-e001	Fri Jul 29 2016 07:04:27 GMT+0000 (	temp1	24,29
5	d000-e000-v000-i000-c000-e001	Fri Jul 29 2016 07:04:07 GMT+0000 (	temp1	24,36
6	d000-e000-v000-i000-c000-e001	Fri Jul 29 2016 07:03:54 GMT+0000 (	temp1	24,10
7	d000-e000-v000-i000-c000-e001	Fri Jul 29 2016 07:03:34 GMT+0000 (	temp1	23,65
8	d000-e000-v000-i000-c000-e001	Fri Jul 29 2016 07:02:06 GMT+0000 (	temp1	23,28

Fig. 9 Stored data in the cloud

Result of temperature data processing shown in Fig. 10. At present moment data from temperature sensor represented in bar chart view and available for all remote users of the cloud services.

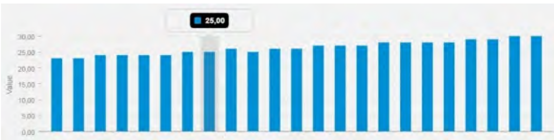


Fig. 10 Temperature bar chart

5 CONCLUSION AND OUTLOOK

The aim of this work is to propose automation architecture of enterprise keeping in mind ideas and trends of the fourth industrial revolution. Based on Industry 4.0 product personalisation trend we target a main challenges for manufacture. Production must become more smart and flexible to able to produce personalised products as profitable as mass products. Bringing a gap of connectivity between field and top is a key. Designed architecture was created based on strategy to build the bridge between Information technology and Operation Technology world. Following this approach we maintain well-established, reliable shop floor structure and enable transparency, efficiency and flexibility of manufacture execution. Take into consideration rising data flow, we suggest to use cloud services of analytics, planning and prognosis for better performance, thus indicating the trend of moving MES to cloud platform. As result of this paper we realised communication of cloud IoT service with learning reactor station equipped by industrial sensors and PLC and making data processing by cloud services tools.

Beyond the scope of this paper there is outstanding issues of security industrial data transmission over Internet, implementation of advances protocols such as OPC UA for unified communication between shop and office floor, supporting semantic meaning of transferred data. Our future research shall focus on issues mentioned above for further architecture development of factory of future.

6 ACKNOWLEDGEMENTS

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