Industry 4.0 – An Introduction in the phenomenon

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Abstract: The goal of the paper is to introduce specialists from industry into the important phenomenon of the recent technology and to explain cyber – physical and informatics background of the platform Industry 4.0 and basic steps in any design and implementation of the Industry 4.0 systems. Authors introduce readers in both the RAMI 4.0 as well as the Industry 4.0 Components models which represent necessary initial background of any Industry 4.0 application. The main stress is given to the Industry 4.0 components model, which enables designers from firms to understand already existing Industry 4.0 case studies and to develop their first Industry 4.0 case studies applications.

Keywords: RAMI 4.0, Industry 4.0 component, administrative shell, communication, virtual

1. INTRODUCTION

It has been said and written much and much about the Industry 4.0 in different workshops. An opinion of authors of this contribution is that it was probably necessary in the first years of the new technological revolution, but they are convinced, that now is already the right time to help praxis in better understanding of the system - technical background of the Industry 4.0 platform and make engineering steps towards Industry 4.0 applications. The key issue of any design and system development in the recent engineering work in Industry 4.0 will be a proper implementation of both, the RAMI 4.0 (Reference Architecture Model Industry 4.0) and the Industry 4.0 Components models. Authors will explain the models in more details. Let us, please, to repeat shortly only the initial Industry 4.0 terms.

The Industry 4.0 is used for three, mutually interconnected factors:

1) Digitization and integration of any simple technical – economical relation to complex technical – economical complex networks
2) Digitization of products and services offer
3) New market models

All these human activities are interconnected by a lot of communication systems in the moment. The most promising technologies will be Internet of things (IoT), Internet of Services (IoS) and Internet of People (IoP).Thanks to these communication technologies, communication entities will be able (in the Industry 4.0 environment) to communicate with each other and utilize data from the production owner during the all life cycle of systems without respect to border among enterprises and countries. All entities of the whole production – market network will be able to have relevant data as well. It will be very helpful for all entities while producers will be able to work out systems with features of very modern components which will be even in the design and testing phase.

Such a digitization of industrial production can create quite new digital market models. On the basis of the data (accessible in cloud) users will be able to predict a shutdown of production of some of production entities etc.

For purposes of such a complex production – market networks the leading institution and firms in Germany – the leading country of the Industry 4.0 activities and ideas - developed and published the RAMI 4.0 (Reference Architecture Model Industry 4.0) and the Industry 4.0 Component models in the last year. Because of the above mentioned three interconnected factors, the 3D graphical model RAMI 4.0 has been developed.

2. RAMI 4.0 (REFERENCE ARCHITECTURE MODEL INDUSTRY 4.0)

Authors of the RAMI 4.0 model are BITCOM, VDMA and ZWEI. They decided to develop a 3D model because the model should represent all different manually interconnected features of the technical – economical properties. The model SGAM, which was developed for purposes of communication in networks of renewable energy sources seamed to be as an appropriate model for the Industry 4.0 applications as well. The RAMI 4.0 is a small modification of the SGAM (Smart Grid Architecture Model). Because into the SGAM as well as into the RAMI 4.0 enter approximately 15 industrial branches, the RAMI 4.0 model enables looks from different aspects. That’s why layers in the vertical axis represent the look from different aspects (a look from the market aspect, a look from a perspective of functions, information, communication, a look from an integration ability of the components) (Manzei, Schleupner, & Heinze, 2016),(VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik, 2016)(VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik, 2015).

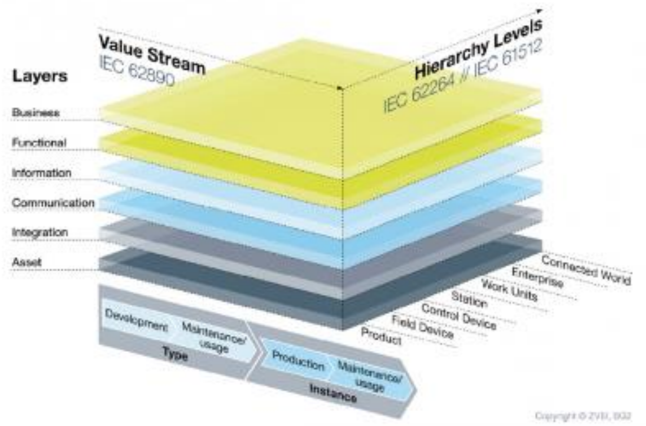

Fig. 1 RAMI 4.0 model
(VDI/VDE-Gesellschaft Mess- und
Automatisierungstechnik, 2016

Very important criterion in the modern engineering is the product life cycle with the value stream which it contains. The left – hand horizontal axis displays this feature. There are expressed e.g. constant data acquisition throughout the life cycle. Even the totally digitization of the whole development – market chain offers great potential for improvement of products, machines, and other layers of the Industry 4.0 architecture throw-out the all life cycle. This look corresponds well with the IEC 62890 draft standard.

The next model axis (right in the horizontal level) describes function position of the components in the Industry 4.0. In this axis, there is specified the functionality of the components, no any specification for implementation but the function assignment only. The axis respects both IEC 6224 and the 61512 standards. But the IEC 6224 and the 61512 standards are intended for specification of components in a position in one enterprise or works unit only. Therefore the highest level in the axis horizontal right is the Connected world.

3. RAMI 4.0 IN MORE DETAILS

The individual layers and their interrelationships are described as follows (Platform Industrie 4.0, 2014):

3.1 Function of layers in vertical axis:

Asset Layer
Represents reality, e.g. physical components such as ideas, archives, documents, linear axes, metal parts, diagrams. Also human being is a part of the Asset Layer. They are connected with the virtual reality world by the Integration layer. Passive connection of the assets to the higher Integration Layer is done by for instance means of QR codes.

Integration Layer
This layer makes provision of information on the assets (HW/SW, components) in a form which is available for computer processing. It makes also computer control of the process, generation of events from assets and it contains elements, which are connected with IT (RFID readers, sensors, HMI, actuators, etc.). Integration of persons is a part of Integration layer functions as well – (via HMI).

Communication Layer
This layer provides standardization of communication by means of uniform data format in the direction of the Information Layer. It provides also services for control of the integration Layer.

Information Layer
Provides run time for preprocessing of events, execution of event-related rules. It enables formal description of the rules and event pre – processing. Next functions of the Information layer are: Ensuring data integrity, consistent integration of different data, obtaining new, higher quality data (data, information, knowledge) provision of structured data by means of service interfaces. It also receives events and transforms them to match the data which are available for the higher layer.

Functional Layer
Functional Layer enables formal description of functions and creates platform for horizontal integration of various functions. It contains run time and modeling environment for services for support of business processes and a run time environment for applications and technical functionality. Rules and decision – making logic are generated in the Functional Layer. Some use case can be executed in lower layers as well. But remote access and horizontal integration can take place within the Functional layer only because of the necessity of data integrity.

Business Layer
The layer ensures the integrity of functions in the value stream, enables mapping business models and the resulting of the overall process. It contents legal and regulatory Framework conditions, enables modeling of the rules which the system has to follow. The layer creates also a link among different business processes.

3.2 Function of layers in the horizontal left axis:

The left – hand side horizontal axis represents the life cycle & and value stream of industrial production. This axis is divided to Type and Instance. A type of any product, machine or SW/HW represents the initial idea. This covers the placing of design orders, development and testing up to the prototype of production. After all tests and validation, the type is prepared for serial production. On the other hand, the type of any component, machine or HW/SW etc. creates a basis for the serial production. Each manufactured product represents an instance of that type, for example has a unique serial number. The instances are sold and delivered to customers. For customers are the products initially once again only types. They become instances when they are installed in a particular system. The change from type to instance may be repeated many times. The fine structure of the life cycle and value stream look in the RAMI 4.0 over the axis left hand horizontal shows a division of the Type to Development and Maintenance/ usage, but due to the physical character of the problem – instances consist from Production and Maintenance/usage. The function of layers in the horizontal left axis can be explained in following simple example:

The development of a new electrical drive represents creation of a new type of an engine. The drive (controlled engine) is developed, initial samples are set up and tested and a first prototype series is manufactured and validate. After successful testing, the new drive type is released for sale (product designation in sales catalogue of the producer). In this moment a first serial production can be started. Each drive in the serial production has its serial number (a unique identification) and is an instance of the previously developed electric drive. Feedback from customers to instances of the type may lead to corrections in the mechanical part of the drive and correction in the control SW. Such modification are modification in the type, i.e. they are applied as amendments to the type documentation and new instances of the modified type are produced. The left hand side of the RAMI 4.0 model represents the value stream as well. Digitization and linking of the value stream (in the Industry 4.0 idea and praxis) big potential for improvement of produced types. Logistic data can be used in assembly, purchasing sees inventories in real time and know were parts from suppliers are at any moment, customers sees the completion status of the product during production etc. The value stream in the totally digitized production enables linking of purchasing, order planning, assembly, logistic, maintenance, the customer and suppliers and so on. It provides great improvement potential .The life cycle can therefore be viewed together with the value- adding processes which it contains and not in isolation as it is in the present production (Platform Industrie 4.0. (2014)).

3.3 Hierarchical system architecture in the Industry 4.0

Industry 4.0 brings changes also in the architecture of the classical control pyramid of production complexes as well technological processes. In the Fig 2 there is described the „new"Industry 4.0 architecture of hierarchical level. The Fig. 2 is no implementation scheme, but it shows solely a functional assignment of components of the Industry 4.0. The Fig. 2 shows the axis right horizontal of the RAMI 4.0 model (Elektrotechnik & VDE, 2016).

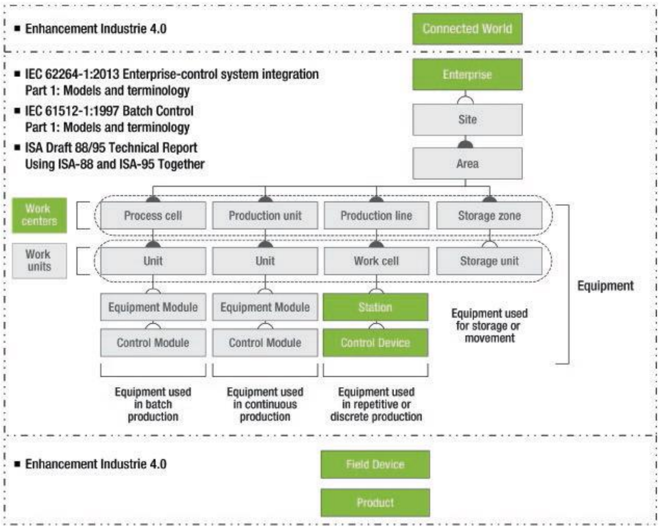

Fig. 2 New control pyramid of RAMI 4.0 (VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik, 2015)

This axis within an enterprise or factory follows the IEC 62264 and IEC 61512 standards. But it is clear from the Fig.2 that not only control devices are decisive , but also consideration within a machine or a system. The collared blocs correspond well levels of the axis right horizontal of the 3D RAMI 4.0 model. The other blocs represent different type of production (batch, continuous processes and repetitive or discrete production. The level over and below the IEC standards area represents steps further and describes also groups of factories, collaboration within external engineering firms, component suppliers and customers. It is the Connected World area of the new architecture „pyramid".

4. INDUSTRY 4.0 COMPONENT MODEL

The second very important model for purposes of the Industry 4.0 that has been developed by BITCOM, VDMA and ZWEI during the last one year is the Industry 4.0 components model. It is intended to help producers and system integrators to create HW and SW components for the Industry 4.0. It is the first and the only (in July 2016) specific model which goes out from the RAMI 4.0 model. It enables better description of cyber – physical features and enables description of communication among virtual and cyber – physical objects and processes. The HW and SW components of future production will be able to fulfil requested tasks by means of implemented features specified in the Industry 4.0 components model. The most important feature is the communication ability among the virtual objects and processes with real object and processes of production while this model specifies the conform communication. Physical realization of it is that any component of the Industry 4.0 system takes an electronic container (shell) of secured data during the all life cycle. The data are available to all entities of the technical – production chain. Therefore this model goes out from a standardized, secure and safety real time communication of all components of production. The electronic container (shell) of data and the all Industry 4.0

component model is specified in the Fig.3 (VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik, 2015).

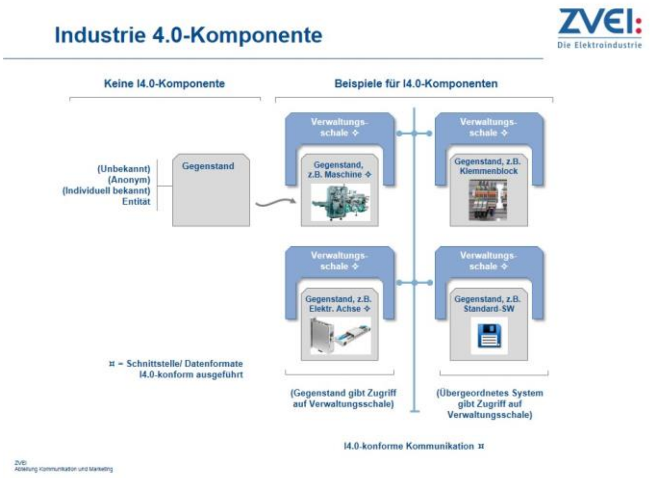

Fig. 3 Industry 4.0 components model (VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik, 2015)

4.1 Specification of the Industry 4.0 component model

The initial condition of the Industry 4.0 platform is that different objects with different communication abilities have to be implemented as Industry 4.0 components. Fig.3 shows how an object of production becomes an I4.0 component. The object (thing) is a standard technological object (component of a machine, machine, SW, etc.) still without I4.0 component's features. Only when the object (thing) is surrounded by an administration shell (data container), can be described as an I4.0 component. The administration shell covers both the virtual representation and the technical functionality of the object (thing). There are 4 examples of implementation of I4.0 functionality of the object (thing) to become the I4.0 component in the Fig. 3:

1. An entire machine can become an I4.0 component above all as a result of its control system (e.g.PLC). This is done for example by the producer and PLC integrator.
2. A strategically important assembly from a supplier can be regarded as an I4.0 component, so that it can be registered separately but asset management and maintenance system. It can be done by the component manufacturer.
3. A terminal block can be considered as an I4.0 component as well. For it can be important to retain the wiring with individual signals and keep it up to date throughout the life cycle. This embodiment can be implemented by the electrical engineer.
4. Also the SW supplied can represent an important asset in a production machine. Such SW could be a standard for larges set of machines (development SW). It is also possible, that supplier may wish to sell a library of extended functions for his products separately.

In the development works of the Industry 4.0 components model there were defined following requirements (VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik, 2015):

A. A network of I4.0 components must be structured in such a way that connections between any end points (I4.0 components) are possible. The I4.0 components and their contents are to follow a common semantic model.
B. It must be possible to define the concept of an I4.0 component in such a way that it can meet requirements with different focal areas, i.e. office floor and „shop floor".
C. The I4.0 compliant communication must be performing in such a way that the data of a virtual representation of an I4.0 component can be kept either in the object itself or in a (higher level) IT system.

As mentioned above, the communication ability in the Industry 4.0 systems has a high importance level. Therefore if the properties of an I4.0 component are to be made available, at least one information system must maintain a connection with the object. This requires at least passive communication ability on the part of the object, which means that an object does not necessarily have to have the ability of I4.0 compliant communication as set out by GMA Technical Committee 7.21. Existing object can be extended to constitute I4.0 components. In this way for example a Profinet device can become an I4.0 component (VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik, 2015).

Next key word of the Industry 4.0 ideas is the „virtual representation". It takes place in the Information layer of the RAMI 4.0 model. The virtual representation contains data of the object (thing). These data can either be kept on the I4.0 component itself and made available to the outside world by I4.0 compliant communication, or they can be stored in an IT system which makes them available to the outside world by I4.0 compliant communication.

One important part of the virtual representation is the „manifest". Manifest can be regarded as a directory of the individual data contents of the virtual representation. It contains meta – information. Furth more it contains obligatory data on the I4.0 component. Further data in the virtual representation include data about individual life cycle phases e.g. CAD data, terminal diagrams or manuals. The I4.0 component is specified in the Fig. 4 (Ergebnisbericht der Platform Industrie 4.0, 2015)

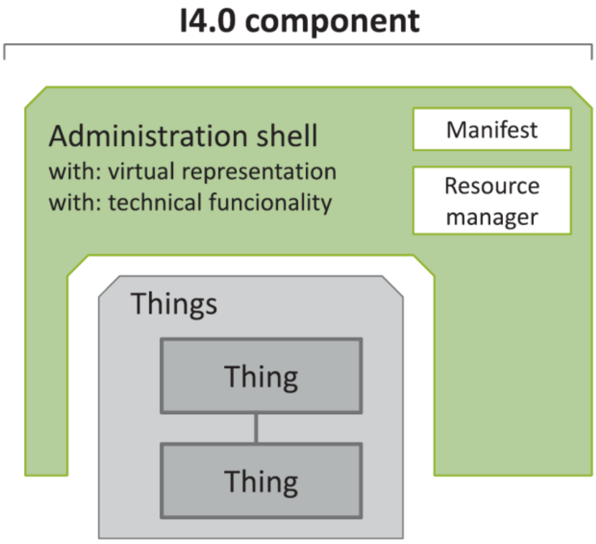

Fig. 4 I4.0 component (Ergebnisbericht der Platform Industrie 4.0, 2015)

Virtual representation of an object has to be data – structured. That's why the administration shell of any I4.0 component has to contain specific information expressed in a proper Industry 4.0 vocabulary and in an Industry 4.0 format. For different purposes the I4.0 component can have more than one administration shall.

Important is, that an I4.0 component can also, apart of data possess a technical functionality. It can be, for example, SW for local planning in connection with the object (thing), SW for project planning, configuration, operator control and services. It can also contain value added to the object and further technical functionalities. The technical functionality takes place in the Functional layer in the RAMI4.0 model.
Deployment of I4.0 components in the future, digital factory, is shown in the Fig. 5. Components are mapped by means of their administration shells and their mutual connections into the repository. The physical factory is then represented in the digital form in the repository (digital factory) during administration shells and their connections (respiratory) by means of dynamic actualization during the life cycle of the factory (Manzei, C., Schleupner, L., & Heinze, R. (2016). *Industrie 4.0 im internationalen Kontext*.).

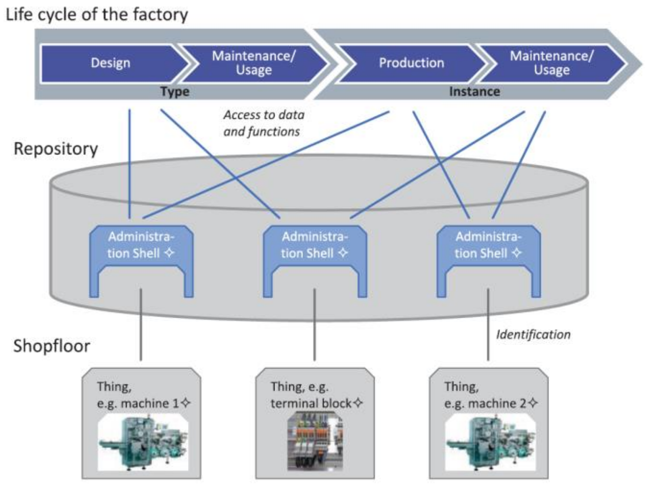

Fig. 5 Repository of the digital factory (Ergebnisbericht der Platform Industrie 4.0, 2015)

The I4.0 components are to be capable of entering into and initiating all possible cross – connections within the I4.0 factory.

5. CONCLUSIONS

Contribution deals with technical background of the Industry 4.0 platform. It goes out from information of German institutions ZVEI and VDI/VDE and from presentations and panel discussions in SPS/IPC/Drives 2015 in Nuremberg and local conferences and workshops concerned to the topic Industry 4.0. Authors give the main attention to explanation of two basic important models of the Industry 4.0 platform, hence the Reference Architecture Model Industry 4.0 (RAMI 4.0) and particularly to the Industry 4.0 component model. The second one offers technical solution of Industry 4.0 components and can enable creation of Industry 4.0 case studies and first I4.0 applications

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