Designing of architecture of an intelligent management system for assets by using hydrotreating process as an example

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Abstract. The article suggests the architecture solution based on the digital twin object model. The solution is based on a synthesis of relevant knowledge about international concepts of digital transformation of production systems. The design model is an information object model. The architectural concept is based on that the state of values of properties material assets, petroleum products, is affected by the state of the values of the parameters of the role equipment. On the one hand, the process control contour boundary is a cost center, on the other hand – is a profit center. The presented model is a digital twin of the hydrotreating process. The architecture solution can be replicated for other technological processes (or their segments) of production, which have continuous production in their life cycle. The architecture is consistent with the architecture of IoT, provides the ability to use synthesized machine learning technologies, takes into account landscape interoperability, provides business logic SAP ERP. Designing model approach as part of a software solution bases on the principles of system engineering (Model-based systems engineering, MBSE, system modeling notation SySML).

Keywords: Architecture Solution, Assets, Digital Twin, Hydrotreating, System Engineering, Neural Network Technology.

1 Formulation of the problem

The main focus of the article is the management system for assets as a result of the business activities of a vertically integrated oil and gas company (VIOC) at the stage of refining petroleum products at the hydrotreatment process.

The Design of digital twins in I4.0 solutions is a main way. There are different points of view on this question. A digital twin is a synergistic mathematical model that aggregates knowledge about an object and / or a system of objects [1]. Accept the fact: «one of the most important steps in engineering design is the choice the structure of the designed system or analysis of structural representations of the behavior and the system activity. Even, if we have a detailed mathematical model, it does not fit for this purpose» [2]. The question is one of priorities.

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Let's accept that the system view of the digital twin complex manufacture control system [3, 4]. The chosen approach is consistent with Gartner agency definition of a digital twin, which based on the consolidated opinion of experts: «A digital twin is a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person or other abstraction. Data from multiple digital twins can be aggregated for a composite view across a number of real-world entities, such as a power plant or a city, and their related processes» [5].

To design the digital twin for state assets management, the hydrotreating process as an example, we use a model-based methodology of system engineering – MBSE [6-8]. This methodology has a high development rate today in practice [9-12].

SySML technology, as part of the MBSE methodology, will be used as the main design tool in the study of complex systems of various nature, which should include a hydrotreatment system [12].

2 Design of structural view of the behavior and activities of the hydrotreatment system

The concept of Digital Transformation of Petrochemical Production was proposed in [3]: «The main object of management in the new client-driven dynamic business model I4.0 is the product. As the unit of management, the state of the product is taken at a certain stage of its life cycle. This concept solves one of the key problems of the disagreement between the principles of continuous production with a multitude of simultaneous parallel production processes determined by petrochemical technologies and the discrete nature of all software systems (SS)». Particular attention is given to the digital reference architecture transformation concept [3].

As the main material asset, we denote control object – real oil state overall value chain of the production process from crude oil to marketable products of various nomenclatures – digital twin based on actually measured [4].

Assume a feature point of view: value chain – corresponds to the stages of the material asset life cycle, oil, at the production stage (provided that the oil product is a system [3, 13, 14]); production stage is a set of technological processes: process segments, operation, operation segments [15]; process boundaries determine where profit center according (SAP logic) [16].

To ensure the required actual condition of the control object, the oil product requires resources. Denote the asset systems that provide the required state of material assets at the process boundary. These are resource objects – equipment, staff and other (not related to the place of the Profit center according). Assume a feature point of view: object resource equipment at the stage of its operation (provided that the equipment is a system [3, 13, 14]); production stage is a set of technological processes: process segments, operation, operation segments [15]; process boundaries determine where cost center accounting (SAP logic) [17].

Conceptual view of technological process management system (see Fig. 1). We use the domain approach [15]. To describe structure of technological process management system was used structure diagram, which designing according SysML [18].

The conceptual view of product is represented on Fig. 2. It consists list of products from hydrotreating process [19]: diesel, hydrocarbon gas, hydrogen gas, MEA, gasoline, sour gas. Also, it shows connection (dependences) between products. The block diagram is represented on Fig. 3, which is the object model of structure. Conceptual view of equipment of the hydro treating process: ReactorBlock, StabilisationBlock, CleaningGasBlock, GasolineCleaningBlock.

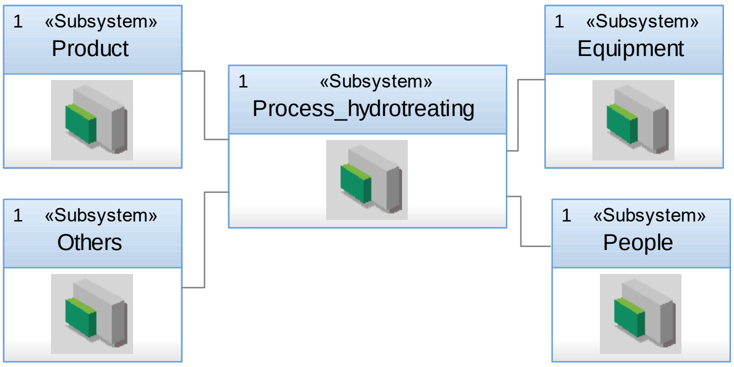

Fig. 1. Conceptual view of technological process management system (Structure diagram technological process management system)

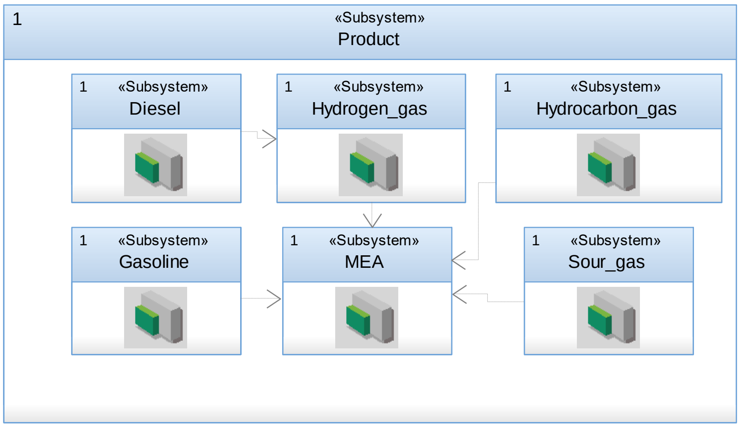

Fig. 2. Conceptual view of oil product subsystem (Structure diagram oil product subsystem)

Assume a feature point of view: accept the fact that the equipment is divided into equipment and role equipment [4, 15]; the state of the values of the parameters of the role equipment affect the state of the values of the properties of the material asset, oil product.

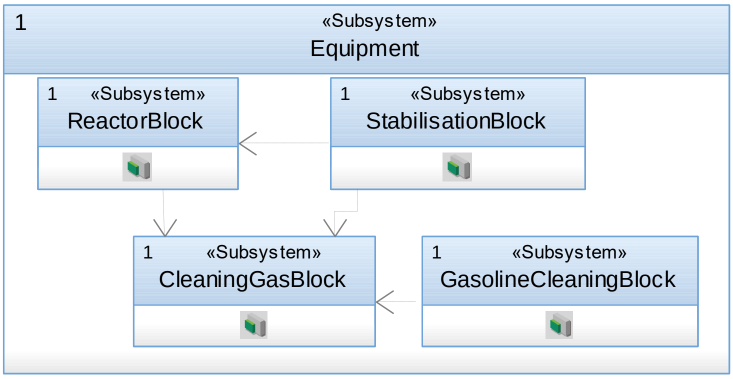

Fig. 3. Conceptual view of equipment subsystem (Structure diagram equipment subsystem)

Conceptual view of subsystem equipment gasoline cleaning block is shown on Fig. 4. Assume a feature point of equipment view: the equipment is divided into segments according to technological process. Denote the block for moving the monoethanolamine to the other block – MEAPumpInBlock, which include role equipment: MEA transferring pumps: H_5_1, H_5_2. Denote the unit for extraction process – ExtractorBlock that consist extractor K_6 и tank E_6. Denote the block for moving the monoethanolamine from the other block – MEAPumpOutBlock: MEA transferring pumps: H_6_1, H_6_2; Denote the block for moving the gasoline out – GasolinePumpOutBlock: gasoline pumps H_3_1, H_8_1; Denote the gasoline production block – GasolineProductionBlock – the source of raw material – L_24_6, L_24_7. GasolineProductionBlock is an outside system of equipment, which transfer gasoline for cleaning technological process as a one of the material asset.

Conceptual view of subsystem equipment stabilization block is shown on Fig. 5. Assume a feature point of equipment view: the equipment is divided into segments according to technological process. Stabilization block is the next stage, several technological processes, after Reactor block, which include hydrogenation process – purification of diesel fuel from harmful impurities oxygen, sulfur, nitrogen, by using hydrogen and catalysts, reactions occurring under certain technological state. Separated hydrocarbons are sent to stabilization block. According to technological operations, the equipment included in this unit divided into groups: StabilisationColumnBlock, SeparationBlock_of_StabilisationBlock, GasolineOutPumpBlock, DieselOutCoilsBlock. Marked block for stabilization process of diesel fuel – StabilisationColumnBlock. It consists stabilization column K_1 and related equipment – irrigation pumps H_3_1, H_3_2; kilns for heating diesel in the boiler P_2_R, P_2_L; diesel pumps for movement part of the fuel to the boiler and other part out H_2_1, H_2_2, H_2_3. Next block is needed for separate substance, one of them direct to K_1, part of them go out, and gas move to the other technological block. Denote the separation block, which divide substance into several layer – SeparationBlock_of_StabilisationBloc. In include some technological equipment: for substance cooling two air coils XK_1_1, XK_1_2, and one liquid coil – X_10, and separator C_5; Denote the block, which responsible for the withdrawal of stable gasoline from process – GasolineOutPumpBlock. This block consists two diesel pumps H_3_3, H_8_1. Denote heat exchange block – Dieseloutcoilsblock. This group of equipment is a place of interaction with other blocks – Reactor block and cleaning gas block. There are exchangers for MEA – T_4; diesel exchangers T_2_1 _n, T_2_2_n, T_2_3_n, T_2_1_v, T_2_2_v, T_2_3_v; exchangers between new diesel and diesel after hydrotreating T_26, T_27; and the last air cooler for diesel X_5_1, X_5_2, X_5_3.

Assume a feature point of view: equipment – an object of management; equipment can perform certain technological functions – it is role-playing equipment. To make managerial decisions, we will consider only those parameters that affect the properties of the main material asset, oil product.

Consider the properties of role-based equipment using object – compressor PK_1_1 as an example. First, we highlight the technological parameters: temperature and pressure in the compressor row. For a material asset, diesel and gasoline, it is necessary to maintain the required properties, which are achieved by the required chemical composition of the substance under certain environmental parameters, which are provided by a certain value of the role equipment parameters. Therefore, we identified two main parameters of the compressor.

To maintain normal parameters, it is necessary to maintain a certain, operational condition of the equipment. The condition of the equipment greatly affects its operation, and as a result, the main material asset. The compressor is a dynamic equipment. Dynamic properties of compressor: vibro movement, vibro speed, vibro acceleration. The listed characteristics are measured on the crankshaft of the compressor. The rotation of the shaft and its vibrations are affected by bearings. The condition of the bearings can be monitored indirectly by measuring their temperature. Therefore, six more parameters are added according to the number of bearings. It is possible to control the compressor through a system that squeezes the suction valve when compressing gas. Therefore, the parameters in this row will change differently, which also affects the output state of the properties of the material asset.

So, the state of the values of the parameters of the role equipment affect the state of the values of the properties of the material asset, oil product. So, compressor like role equipment has some parameters: activity – one, two, three or four line, bearings temperature: first bearing, second bearing, third bearing, fourth bearing, fifth bearing, sixth bearing; line parameters (temperature, pressure), vibro acceleration, vibro movement, vibro speed.

On the next stage, parameters are divided from equipment. For example, get object – compressor PK_1_1. We can see the object, which describe parameters of the compressor on the Fig. 6. Each object is a specific compressors parameter. Let's divide substance properties and parameters of the equipment that we will have a properties layer. So, we can see equipment parameters of the compressor. This layer will be used in the neural network.

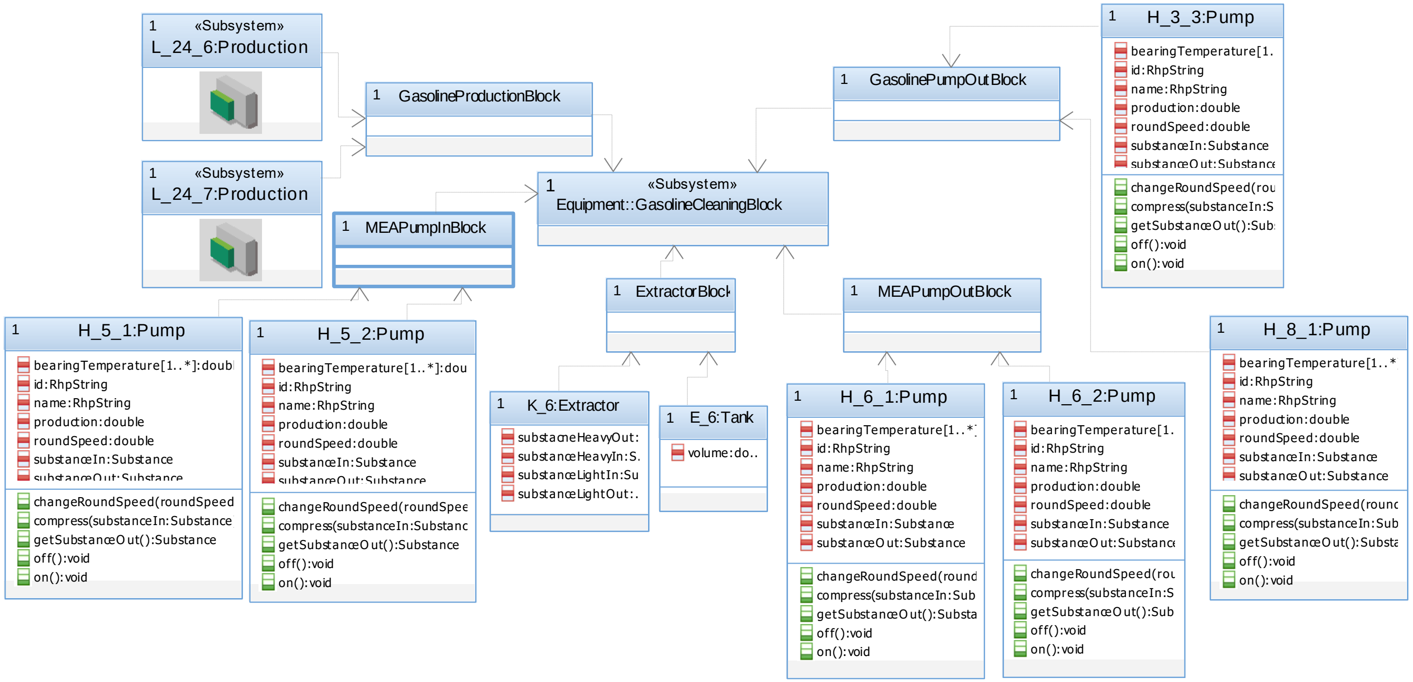

Fig. 4. Conceptual view of gasoline cleaning block (Block diagram subsystem equipment gasoline cleaning block)

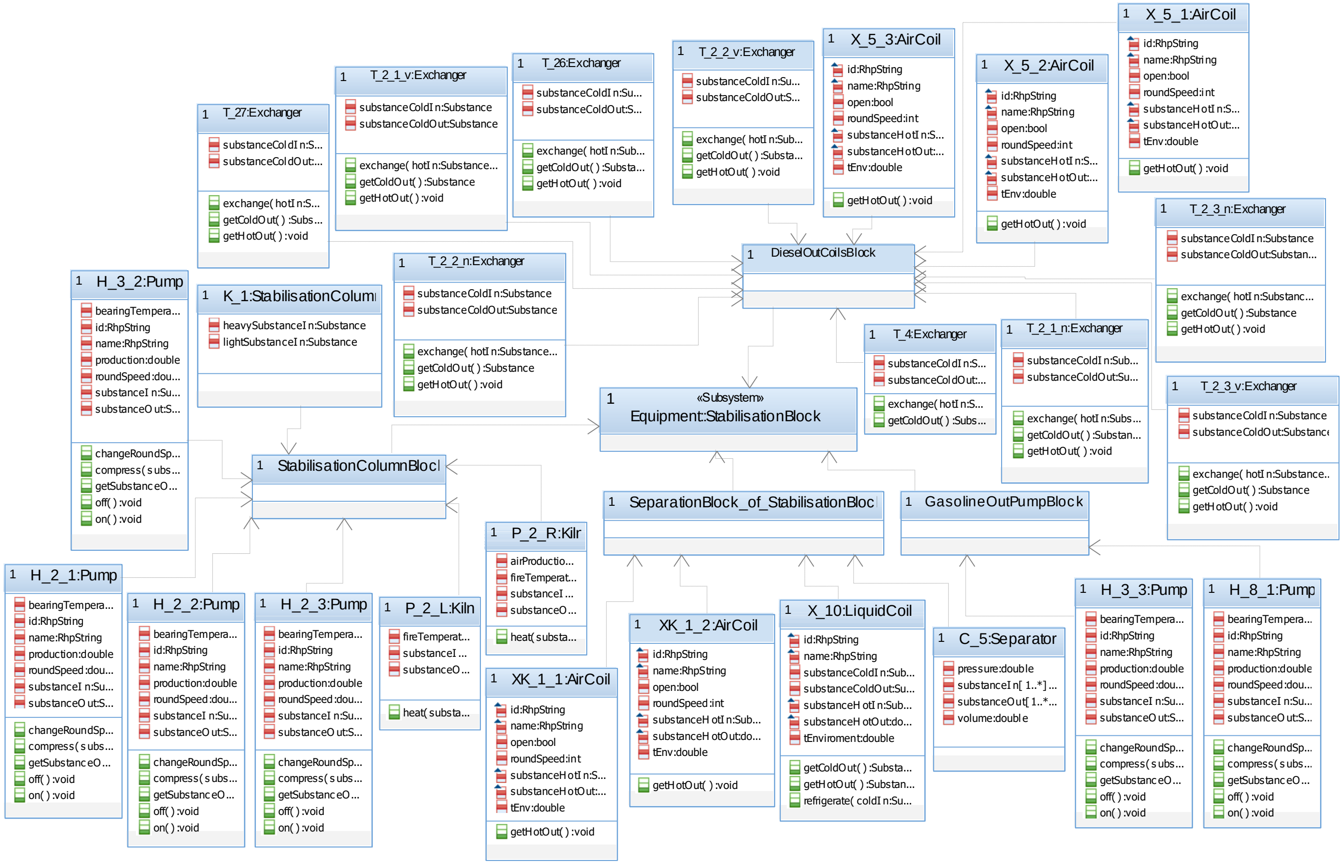

Fig. 5. Conceptual view of stabilization block (Block diagram subsystem equipment stabilization block)

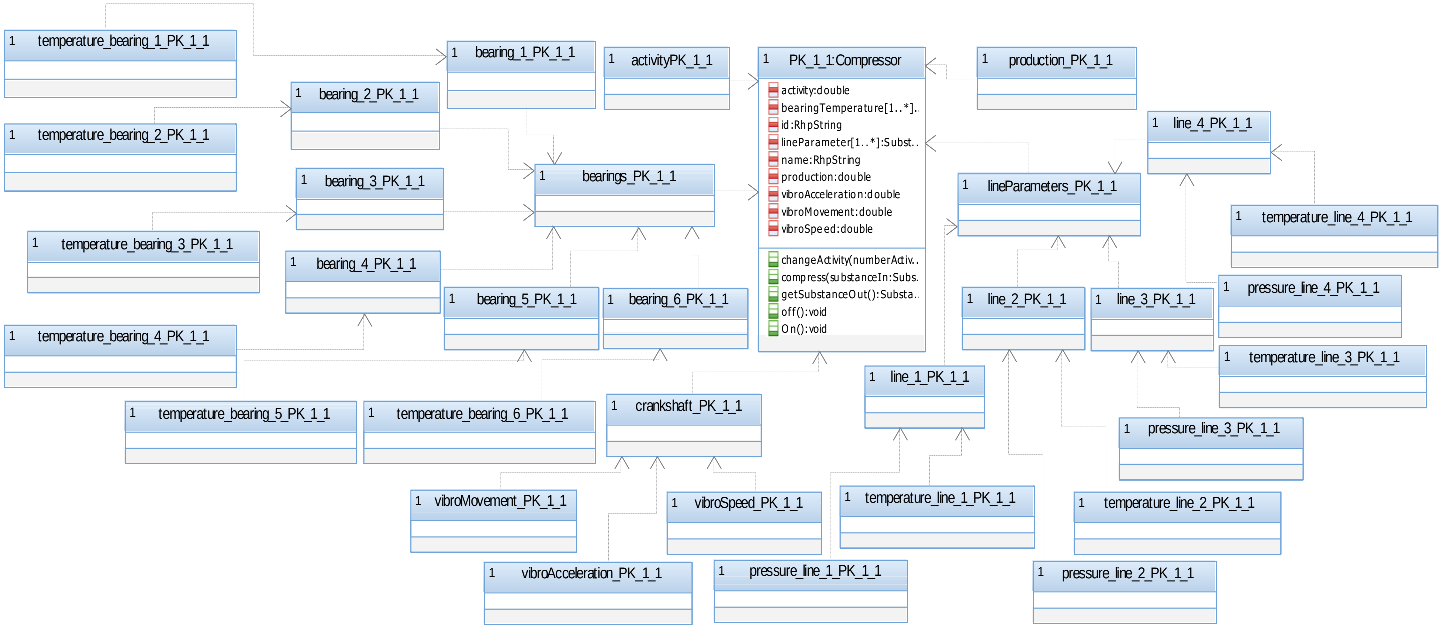

Fig. 6. Conceptual architecture of compressors parameters

Take hydrogen gas as an example, because it interacts with the PK_1_1 compressor – resource object, which described above. We distinguish the following properties of the substance destiny, fair temperature, sour percent (special quality, that not included in the physicochemical properties of substances, but isolated and important) boiling temperature, autoignition temperature, ignition temperature, flash point, heat capacity. The achievement of the required properties values of substances described earlier is the goal of controlling the values of equipment parameters. To identify complex dependencies between the values of the equipment parameters, – the resource object and the material asset, – oil property values, consequently, neural network technologies will be used to calculate the control action. Neural networks are widely used for decision-making based on the analysis using technology data mining [20, 21].

The equipment parameters obtained from sensors and the state of oil products provide to the input layer of the NN. We use a multilayer neural network to identify complex hidden relationships between input and output vectors. At the output, we get a vector that describes the state of the oil product – the main asset, based on which, through communications, we will determine the most influential equipment and manage it.

The target system is divided into five stage. The data from the sensors, that describes real equipment, must be collected and processed. The first component will collect data from sensors. The second component should sort into two parts: negative and positive example. Then several data problems should be solved. Firstly, some parameters or properties are analyzed once during a day or week. Second, data dimensions are various. So, temperature is measured between minus 70 and plus 700 ^{o}C, but pressure is measured between 0,1 and 6 MPa. It is a problem for NN training.

Management system – is a deep neural network, which has input vector and output vector. Input vector is a data, which describes real substance property, property, that we wish, and the ideal property. Output vector is a data, which describes parameters of the equipment; owing to we can reach necessary property.

3 Summarize

The main distinctive features of the proposed concept of the digital transformation reference architecture are the following. The article presents the architecture solution based on the digital twin object model. The architecture solution can be replicated for other technological processes (or their segments) of production, which have continuous production in their life cycle. The architecture is consistent with the architecture of IoT, provides the ability to use synthesized machine learning technologies, takes into account landscape interoperability, provides business logic ERP SAP. Designing model approach as part of a software solution bases on the principles of system engineering (MBSE, SySML).

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