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Computer-aided design of technical documentation on the digital product models of Industry 4.0

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Abstract. The task of organizing project activities in a digital factory is considered. Digital Factory is the industry 4.0 enterprise, operating in the digital environment. The components of a digital enterprise at the physical level of technological equipment (cyber-physical systems) and at the cyber level of cloud services are described. A set of tools that provide information support for the process of designing instrument-making products is offered. The scheme of interaction between the components of the Industry 4.0 digital factory and cloud services for project activities is given.

1. Introduction

The development of modern industry is inextricably linked to improvement of the technological base of the project environment of enterprises. In organizations, new information technologies are being introduced [1-3], to substantially automate the design activities of instrument-making product developers and to carry out the activities of manufacturing enterprises in an automatic mode. Such technologies are cloud technologies, technologies of the industrial Internet of Things (IoT), technologies of cyber-physical systems, etc., implemented using cloud services [4, 5].

Enterprises operating with the use of new digital technologies are now commonly considered the Industry 4.0 enterprises. The concept of “Industry 4.0” is a collective one and describes the transition of industry to a new technological order in a historical perspective. According to the accepted terminology, the enterprises of Industry 4.0 are [6-8]: a digital factory (designing enterprise), a smart factory (production enterprise) and a virtual factory implementing the full life cycle of an instrument-making product.

To organize the design activities of the Industry 4.0 enterprises, the components of their infrastructure must be defined both at the physical level of technological equipment and at the cyber level of cloud services, and the properties of these components relevant to the field of instrument engineering [9, 10] should be determined.

2. The Industry 4.0 digital factory Infrastructure

The scheme of the Industry 4.0 digital factory components interaction, specializing in the field of instrumentation, and cloud services that support the project activity, is shown in Figure 1.

Physical level of the Industry 4.0 digital factory is [5, 6]:
- automated workplaces (AWP) of schematic designer for instrument-making products;
- automated workplaces of text document designers for instrument-making products;
- automated workplaces of drawing designers for instrument-making products;
- automated workplaces of software documentation designer for instrument-making products.

In accordance with the types of individual technical documents developed and drawn up for
instrument-making products, the AWP group and the Industry 4.0 digital factory specialists form:
- research and development department, tasked with preparing of electronic version of circuit and text design documentation for instrument-making products;
- design department, tasked with preparing of electronic version of text and drawing design documentation for instrument-making products;
- chief technologist department, tasked with preparing of electronic version of text and drawing process documentation for instrument engineering products;
- software development department tasked with developing of functioning programs codes and preparing program documentation for instrument engineering products;

![Diagram](image_url)

**Figure 1.** Interaction scheme of the Industry 4.0 digital factory components and cloud services for project activity.

Diagrammatic documentation for instrument-making products includes electrical schematic diagrams, wiring diagrams, connection diagrams, kinematic diagrams, optical circuits, etc. Drawing documentation for instrument-making products includes assembly drawings of parts and assemblies, dimensional drawings, packaging drawings, etc. Software documentation for instrument-making products includes program texts, program data (a component loaded into an instrument-making product), etc.

The entire technical documentation for an instrument-making product prepared at the Industry 4.0 digital factory forms a digital product model. Unlike the electronic model of the product, which requires only the electronic documentation to be made taking into account weight and size characteristics of the product, digital model includes descriptions (at the level of mathematical dependencies) of physical properties of materials and components of the product. The finalized digital model of the product is transferred to the electronic archive of the digital factory for the subsequent transfer of documentation to the smart factory for the series production of the product.

### 3. Cloud services for the Industry 4.0 simulation modeling

The description of instrument-making products in the form of digital models is related to the need of replacing the traditional, expensive physical tests of the finished product conducted at Industry 3.0 enterprises to confirm the quality of technical documentation with virtual tests conducted at the
Industry 4.0 enterprises by means of simulation modeling.

The AWP scheme of the technical documentation designer for digital models of the Industry 4.0 products is shown in Figure 2. The technical support of AWP is formed by an instrumental computer. The AWP grants an access for the designer to the cloud services based on the Internet of Things protocol [3, 4].

Simulation modeling is a process of testing a digital model of a product, performed at an automated site of a designer of technical documentation, in which not only a product, but also test equipment, external operating environment, etc., are presented in the form of mathematical models described at the level of variable parameters. Simulation modeling of a digital product model makes it possible to evaluate the behavior of a future product in actual operating conditions at the design stages when a physical sample of the product does not exist yet. The possibility of changing the values of variable parameters with sufficient accuracy for practice allows determining the limits of applicability of an instrument-making product under expected operating conditions.

To perform the simulation of a product digital model, designer must have the tools implemented in software at the cyber level. These tools are:
- cloud services such as software, computer, platform, infrastructure, providing design development environment (design of technical documentation) and testing of a digital model;
- mathematical models of external influencing factors (the environment expected by the product in
operation), models of materials and components used in the product at the level of description of their physical properties, etc.

- scenarios of statistical tests performed by modeling tools, where in certain sequences (or at the same time) there are simulated environmental effects on the digital model of an instrument-making product;
- test methods, with the parameters of external influencing factors determined at the level of numerical values (high and low ambient temperature, pressure, humidity, etc.);
- standards (regulatory and technical documentation) necessary for the preparation of technical documentation for instrument-making products and virtual test methods.

The result of CAD (Computer-Aided Design) simulation of a product digital model are design solutions drawn up by designers in the form of technical documentation (schematic, text, drawing, software), according to which the Industry 4.0 Smart Factory will subsequently manufacture the product. All design solutions obtained in each virtual test scenario are documented in the cloud storage of a digital factory. The final design decision is a variant (design alternative) corresponding to the optimality criteria given in mathematical models.

4. Conclusion

Practical experience in the preparation of technical documentation for instrument-making products shows that the average product design time is up to a year. In the next few months, the manufacture of a product prototype is carried out and the stage of testing a physical sample begins. The test phase can be performed up to six months.

The test results of the product are the basis for its refinement (in the event of errors in technical documentation and manufacturing defects) and for introducing changes in the design, software and technological documentation. In case of changes in documentation and product, tests on the modified sample product are repeated.

Thus, from the beginning of the product designing stage to the moment of drawing up the technical documentation for the product, where most of the errors are identified and eliminated, it can take three to four years. Only then, the product documentation can be transferred to the serial factory for the production of samples. This design procedure is still the same at the Industry 3.0 design enterprises.

The implementation of tools for simulation of digital models and virtualization of design solutions using cloud services in the design procedures of the Industry 4.0 digital factory allows reducing (up to a year) the development time (design) and improve the quality of technical documentation for instrumentation products.

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