SC D2- Information systems & telecommunication
PS1 The impact of emerging information and communication technologies on electric power utilities

Development of intelligent control systems for decentralized distributed energy resources based on a digital platform

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Current trends in energy sector development predetermine the wide use of distributed grids (including autonomous ones) with distributed energy resources (DER) and energy storages. The operating of such grids requires the deployment of automated intelligent control systems for DER coordination, smart metering and demand response support, operation together with an external power system in the parallel mode as well as local balancing. Such automated intelligent control systems for DER are proposed to be constructed on the basis of the software platform which is being developed as a part of the digital transformation programme of the power sector in Russia.

The platform provides mass prosumers with high-quality and cost-effective mechanisms and tools to access capabilities and functions of large-scale energy industry players: from generation and storage of energy resources to integrated asset lifecycle management, based on artificial intelligence and other advanced digital technologies.

The main functions of the platform are as follows:
- integration and coordinated operation of software products and equipment from diverse developers and manufacturers in the distributed energy infrastructure;
- reduction of time to market and costs of new products development in the field of distributed energy;
- implementation of machine learning and artificial intelligence potential in the efficient management of distributed power systems;
- implementation of a peer-to-peer transactional model of the energy market based on blockchains and smart contracts;
- automation of control and mode management of power systems with the DER;
- compliance with information security requirements in a decentralized distributed environment with diverse parties;
- logical centralization of the functions of configuring the energy infrastructure, health monitoring, collecting and analyzing large ammount of measurement data, maintaining the information model and digital twins of energy facilities.

It has been established that software platforms existing on the market do not allow for the solution of these tasks to the extent required by the stakeholders, therefore it is necessary to develop a new software product.

Due to the complexity of the tasks to solve, a full cycle of requirements engineering for the platform in accordance with the standard ISO / IEC / IEEE 29148: 2018 has been carried out.

Major platform stakeholders were identified, including various categories of users, developers, builders, maintainers.

The following platform operation scenarios groups were described:

- energy transactions (scenarios of principal activities of energy facilities owners, various operators, aggregators, and service providers, consisting in the exchange of electricity between parties);
- modeling and optimization (scenarios of formation, updating and application of the information basis of the platform);
- life cycle (scenarios of activities of the equipment and software products life cycle technical processes owners, except the functioning process)

The System Requirements Specification for the platform has been composed; in accordance with it, a set of architecture views of the platform, compliant with ISO / IEC / IEEE 42010: 2011, has been constructed.

A functional platform architecture has been developed, which consists of six subsystems:

- Internet of things (**IoT**) subsystem;
- subsystem of energy facilities intelligent control (**FIC**);
- transactive energy (**TEN**) subsystem;
- subsystem of formation and updating of ontological models, information models, and digital twins of energy facilities (digital twin support, **DTS**);
- electronic document management (**EDM**) subsystem;
- subsystem of state monitoring and diagnostics (**SMD**) of platform components and applications.

The constructed information architecture of the platform describes a heterogeneous storage structure of information of six types:

- ontological model;
- digital schemes and maps;
- online documentation;
- information models;
- real time data;
- mathematical and simulation models.

The software architecture of the platform has been built. According to it the platform is divided into microservices, viz. as small as possible, loosely coupled, and easily changeable modules that interact using cost-effective REST-style communication protocols. The platform also implements larger typical units of applied functionality, composed from microservices and accessible via the same protocols. Microservices include fragments of basic software components and platform aspects that perform the following tasks:

- administration and configuration management;
- provision and display of information;
- data storage;
- information exchange (events, data, command words);
- information security;

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- information exchange with external systems;
- API publishing.

The microservice access interface is published via the API gateway for calls from applications on the platform. Thus, any application consists of calls to microservices in the order determined by the business task being performed. An application may also contain fragments of its own functional logic, provided that microservices for it are not implemented in the platform or are considered unsatisfactory for some reason (the specifics of the application domain, performance, etc.).

The platform implements a full set of microservices, sufficient for reference implementation of platform operation scenarios in applications without non-trivial functional logic. The examples of platform applications are:

- demand responce management system;
- an electronic marketplace that supports auction and other models of energy trading;
- coordinated control system for a fleet of electric vehicles charging stations.

The hardware architecture of the platform was built. It provides the capability to deploy applications and fragments consisting of microservices and basic components on the stakeholder's computing devices (including controllers of individual energy facilities owned by the facility owners), according to the "fog computing" concept. However, intelligent modeling and analysis functions covering the energy infrastructure as a whole are centralized in a cloud environment.

Particular attention is paid to the design of intelligent control modules as a part of the platform. Along with traditional electrical statistical and optimization algorithms, the platform implements modules based on deep learning neural networks (mostly recurrent) to predict the load, optimize the load distribution, forecast of the electricity price, evaluate and forecast of the equipment health, faults and accidents diagnostics. A large functional unit is assembled from a set of modules for automatic assessment of the technical feasibility of tentative smart contracts and verification of the actual execution of committed smart contracts. The adopted ontological model, which forms the basis of the information layer of the platform, is sufficient for using as an ontology interaction of agents as part of multi-agent applications on the platform, allowing for the effective implementation of multi-stakeholder business models of distributed energy.

A prototype of the platform was implemented at the pilot facility.