Digital platform as a means of process optimization of integrating electric vehicles into electric power networks

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Abstract. In this paper, we consider the need to create an algorithmized digital platform for the development of electric charging networks of road transport and to optimize the load on the current power grid complex. In modern conditions, this platform can become an example of a mechanism for public-private partnerships and the development of environmentally friendly transport. The purpose of the platform is to provide users with up-to-date information about the state of the electric vehicle battery, reduce the cost of creating a network charging infrastructure for electric vehicle transport, automated resource accounting for power supply companies, and other services. The use of information technologies to combine the processes of economic relations in the field of energy sales services will attract funds for infrastructure development by increasing the load factor of generating capacities and unloading power centers. In the article, the authors propose a digital platform architecture using modern technologies such as IoT, Vehicle to Grid (V2G), Machine learning, Big Data.

1. Introduction
The General trend towards digitalization of energy systems and the use of energy-saving technologies based on information technologies is gaining momentum in the world [1]. Digitalization and intellectualization of electricity distribution and consumption processes are both the basis of the energy transition at the level of the average user and at the level of enterprises. In the last five years, there has been significant development of digitalization technologies [2]. Information technologies are widely used in various industries, and due to their advantages, they become the main technologies of modern society and agglomerations. The introduction of IoT and digital technologies contribute to the transformation of cities into smart cities that improve health care, traffic and transport, power grid management, people's daily lives, and agriculture [3].

There is a need to integrate renewable and distributed energy sources along with an intelligent demand-side energy management system for efficient energy use. The creation of stable and secure information and telecommunication infrastructure is required for high-speed transmission, processing and storage of large amounts of data, access to all organizations and households [4]. Similar large-scale government programs have aimed at the introduction and development of digital technologies in the field of energy that adopted in Russia, the United States, Europe, and Asia [5, 6].

Comprehensive modernization of the power grid complex as a response to increased consumption is a poorly managed and not actually rational process, provided that the latest information technologies not used during modernization. In large cities, to improve air quality, the state calls for the abandonment
of personal and public transport that runs on fuel. As a result, electric vehicles, both public and private, are increasingly common on the road. [7].

In this regard, the load on the current electric grid complex of modern cities is increasing. As of the end of 2019, 123 companies were included in the list of electricity transmission enterprises that were assigned high and significant risk categories [8]. It proves the high level of wear and tear of the existing power grid complex. According to the International Monetary Fund (IMF), the Russian Federation is a country in transition and has problems with worn-out infrastructure similar to those in both developing and developed countries. The main internal challenge of the Russian fuel and energy sector is the need for deep and comprehensive modernization and overcoming the wear and tear of the infrastructure. One of the strategic goals for the development of the Unified National Electric Grid (UNEG) is to overcome the ageing of fixed assets of electric networks and power grid equipment by increasing the scope of work on their reconstruction and technical and technological re-equipment, implementing a unified strategy for investment and capital raising to address the strategic goals of the development of electric networks. The development of digital platforms will help link the actively modernizing industries: economy, ecology, transport and electric power industry.

2. Platform solutions in the electric power industry

In world practice, there are real cases of companies that are somehow interested in creating intelligent systems based on digital technologies.

It is worth to note the experience of the American company TESLA, or rather their project called TESLA Virtual Power Plant (hereafter VPP). VPP is a high-tech system that aggregates electricity from several producers or consumers at once. It can be said that VPP controls the behavior of both producers and consumers. TESLA VPP deployed in a pilot mode in Australia, but already at the initial stage of implementation, the project proved its effectiveness, preventing several serious system accidents. Figure 1 shows a graph of frequency changes in the network. It should be noted that changing the frequency in the power system can lead to a system accident with subsequent disconnection of consumers and disabling of generating equipment.

Figure 1. SA VPP FCAS Response to Contingency Event on 09 Oct 2019.

Figure 1 shows the reaction of the VPP to changes in the power system, and it was the speed of the reaction that helped prevent a system accident. A virtual power plant can include not only small-scale generation facilities such as solar panels, wind turbines, mini and micro HPPs, but also electric vehicles.
With the help of V2G technology, an electric car is able not only consume energy from the network, but also give it back to become a kind of object of small-scale generation.

It is worth noting that the virtual power plant project implements without a comprehensive modernization of the power grid complex. Nevertheless, its intermediate result was a reduction in the load on the power grid.

Optimization of the process of distribution and consumption of electricity was shown in the work of Swedish researchers. Their research was devoted to evaluating the effects of the introduction of V2G technology, by which an electric vehicle became an object of small generation. The effect of such an implementation will be the unloading the air and cable lines during the morning and evening peak loads.

Overloads of power centres are concentrated at the end of the day and in the evening. This is reasonable, since the area under study is mostly residential, so people work during the day.

V2G integration helped reduce congestion by reducing peak demand. Almost all power centres are completely free of overloading with the new system. This means that at a 100% level of replacement of classic vehicles with electric vehicles, the discharge of batteries into the network can cover the amplitudes of critical power peaks [9].

3. Analysis of the impact of V2G on the power grid complex

In the example considered earlier, small-scale generation facilities use as power sources for the entire virtual power plant, which is advisable for the owners of the household. For example, there is an opportunity to organize a scheme with solar panels and energy storage as a backup or (at a low load level) the main power source in a person's country house. However, it is necessary to take into account the factors of decreasing generation efficiency described in [10] high ambient temperatures can accelerate the wear process. In any case, the micro SES on the roof is an object of small power generation. In the case of a large city, where multi-apartment buildings are typical, the object of small power generation can serve as an electric car.

Electric vehicles as an energy storage device can cover fluctuations in the consumption schedule (figure 2) using V2G technology. However, for efficient operation and distribution of vehicles, their integration is necessary not only in the electrical system but also in the information space of smart city management.

The information system will send requests to charging stations to return electricity from the connected car to the network when demand is high (in the morning and evening) and consume electricity when demand is low (in the middle of the night to night) [11].

![Figure 2. Schedule of daily consumption of the united energy system (UES) of the North-West.](image-url)
It is well known that the power system has daily maximums of consumption (in the morning and the evening), the implementation of the platform implies changing the grid of electricity tariffs up to hourly instead of day and night as it is now. Thus, in the evening, during the maximum consumption, when the user arrives after work on a semi-charged electric car, he will connect it to the charging station. However, instead of the charging process, the battery will be discharged. Thus, the electric vehicle will reduce the load during peak loads and help to create a power reserve. It is worth noting that this is only one of the proposed scenarios.

The difficult situation with the available network capacity of the power sources underlines in the studies of cities such as Saint Petersburg. Charging infrastructure services that not integrated into the information space of electric distribution networks may worsen the situation or lead to unnecessary spending on expanding infrastructure capabilities, which will lead to a low load factor. With the help of electric vehicles and V2G technology, it is possible to redistribute consumption volumes between the night minimum and highs and thus smooth the consumption curve. In addition to distribution by day zones, platform-based solutions can achieve territorial distribution based on the load factors of power centres.

Using the example of the North-Western region of the Russian Federation, the volume of possible displacement and redistribution of consumption, taking into account the use of electric vehicles, was estimated. The projected daily consumption schedule shows in figure 2, where the red line shows the level of average power consumption, and the green line is a similar straight line, only in the scenario using electric vehicles[12].

4. Platform participants interaction architecture
The platform architecture is formed as a Diagram of interactions within a digital platform shown in figure 3 for forming rules and build interaction algorithms.

The figure shows that the information exchange between the power system and the consumer will be carried out by transmitting information from sensors that read such indicators as power consumption and power generated (if available), intelligent devices such as power converters, and "connected" electric vehicles integrated into the system.

By using 5G high-speed data transfer technology all data in encrypted form will be transmitted to the main server, where a digital twin of the power system will be formed based on the incoming data, this
allows predicting and prevent system accidents in the future. The high-speed communication channel from the main server to the information server receives actual data on a load of power centers and the power grid complex as a whole, as well as data on road traffic. On the other hand, the user selects a destination in the mobile app and data on the destination. The state of the electric car is sent to the computing server, where the algorithm selects and reserves a Parking space for the user next to the destination. An information server is also needed to collect data about each user's trips and daily routine to create an individual profile of electricity consumption. A significant role in the architecture is played by the localization of the user in the cyber-physical space to predict his actions since actions generate consumption [13, 14]. This will help optimize the user's interaction with the platform in the future. At the same time, it is necessary to assess the reliability of the rebuilt network model in terms of redundancy and load management, as well as the stability of the system with a distributed generation [15, 16]. An important aspect of network reconstruction and assessment of its condition is to maintain the quality of electrical energy in the distribution complex, which contains a significant part of the nonlinear load in the form of power converters, and the presence of intelligent devices will allow determining the sources of harmonic distortion and their contribution [17, 18, 19].

The open asymmetric network Protocol MQTT, which provides caching of the aggregated IoT measurements, can serve as an information and telecommunications infrastructure capable of providing reliable and secure data transmission [20, 21, 22]. Data is exchanged in this Protocol between devices that are using the publisher-subscriber model and a broker, which is responsible for connecting pub/sub and filtering information. Since the message format is not limited, MQTT is able to be used for transmitting messages at all levels of energy-informational interaction, but only if the data format is agreed upon. For example, information coming from the main server referred to as a publisher, and the mobile app user referred to as a subscriber, who subscribes to the topic generated by the publisher. As an example, it is possible to use the following topics in this platform: battery status of an electric car, reserved Parking space, resource accounting for energy sales companies, and tracking expenses. In turn, a subscriber can also act as a publisher when an app user sends data to the server about their destination. Messages are protected by client authentication: the connection is made using the TLS / SSL cryptographic protocols, which make it possible to establish a username, password, and transmit Client IDS. The reliability of messages is provided by the Quality of Service function, which is selected by publisher and subscriber. Besides, the system provides the Last Will and Testament function: in case of unplanned disconnection of the client, the data that supposed to be sent will be delivered in a single copy. Recently, MQTT 4 has received close attention due to its functionality, and most importantly, its ability to integrate with 5G with MEC support. Scenarios for using the MQTT Protocol in the systems of information-oriented smart city networks with 5G support, deployed around the world, are already being considered. [23].

Data can be integrated with systems for predicting the state of Electromechanical equipment and determine the need to use the vehicle by taking into account its remaining life [24, 25]. At the same time, it is important to evaluate and forecast the state of power grid equipment by taking into account the load of which it is necessary to distribute in real-time [26, 27]. When the user arrives at the destination, the car is connected to the power system and the most profitable scenario for further consumption is calculated using algorithms, as a result, the electric car becomes either a consumer or a generator.

It is obvious that situations when it is necessary to get somewhere urgently, and the electric car is discharged will be excluded even at the stage of the algorithms.

5. Conclusion
Today, it is not enough to focus only on physical interactions, especially when implementing cybersecurity mechanisms and managing big data to manage energy savings in smart cities. Transformation and digitalization require new methods and technologies for successful interaction and understanding of the entire cyber-physical system. Formation of system of development management and distribution of generation and consumption of the electric vehicles should be based on the following
principles: reducing the burden on infrastructure, increase the utilization of the statutory maximum generation, maintaining the reliability and safety of the electric network, maintaining the quality of electrical energy, increase the life cycle of infrastructure and equipment, ensuring information security, platform and data.

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