Estimation of the Potential Impact of Electric Vehicles on the Distribution Network's Operation Modes

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ABSTRACT. The potential of electric vehicles as load-regulators on the base of analysis of typical consumers power diagrams in distributed networks is estimated by the development optimal patterns of operation modes in case of rational implementation of V2G/G2V technology. It is justified the prospects of the use of electric cars as consumer-regulators in distributed power grid 0,4-10 kV of urban and rural areas in Ukraine. It is proposed the step-by-step algorithm of estimation the potential impact of bidirectional use of EVs batteries for typical power consumers of transformer substations 10/0,4 kV with similar daily load curves. It is shown that rational integration of EVs in power grids allows even to decrease existing level of active load that affords the increase of efficiency of power equipment use as well as enhancing of ecological state in the country.

1. Introduction. One of the most important directions in the development of the transport system is the gradual replacement of cars with internal combustion engines with electric cars in order to reduce CO_2 emissions. Many European countries support the development of electric vehicles at the legislative level and determine the requirements and conditions for the implementation of the integration of electric vehicles [1]. The increase in the number of electric vehicles makes them an important component of the power supply system at the regional level and at the level of whole country.

Development of energy systems and Smart Grid Technology for Electric Vehicles (EV) requirements and limitations should be considered electric vehicle charging modes for efficient integration to a hybrid power supply system [2, 3]. The integration of a large number of electric vehicles in the network opens up new opportunities for providing flexibility in power management in distribution networks. In particular, in addition to their typical functions as loads on the power grid, battery systems of electric vehicles can serve as a distributed energy store for power grid control. Vehicles can be charged mainly during off-peak periods, and the generation of energy from the battery to the mains during peak periods. This load management allows utilities to reduce the demand for electricity during periods of peak load, which in turn can eliminate the need for peak power plants and help reduce harmful emissions, starting with peak power plants or standby generators. A sufficient number of electric vehicles working together to control the load can lead to the same benefits for the power system as a pumping power plant, including reducing CO2 emissions [4]. When properly managed, electric vehicles can potentially increase the reliability and stability of power grids, support the integration of generations of renewable energy sources and increase the overall efficiency of the system, which leads to the concept of a vehicle to the network.

Today, the efficiency of the production, distribution and consumption of electric energy processes in Ukraine is at an extremely low level in comparison with the developed countries of Europe. The energy dependence of our country on imported energy resources, the lack of internal energy resources

and low efficiency of generating capacities of power plants and networks give rise to the urgent need for the development and implementation of advanced scientific and technical solutions in the electric power industry. The proposed research addresses the above-mentioned problems of ensuring energy independence and security of country, a comprehensive increase in the efficiency of the electrical engineering industry operation through the rational use of the combined power supply system's potential, based on electric vehicles as decentralized high-maneuverable and environmentally-friendly energy sources of cities and also as consumers-regulators of the power system load curve. This will be achieved through the development of scientific and technical decisions to justify the economically feasible modular structure and parameters of energy sources for the construction of appropriate decentralized energy supply systems in the cities, as well as the development and implementation of rational charging/discharging modes of electric vehicles batteries with the introduction of Smart-technologies Vehicle-to -Grid (V2G) and Grid-to-Vehicle (G2V), which will enable efficient management of generation and consumption processes.

2. Analysis of the existing load diagrams of typical consumers.

The use of electric vehicles affects the existing power supply system of consumers, in particular - the operation and deterioration of transformer equipment, capacity of transmission lines, switching equipment, technical implementation of monitoring and control, which should be taken into account when evaluating the change in the parameters of the operation mode and particular topology of the network under studying.

Thus, in order to estimate the expected technical impact of electric vehicles as consumers regulators in urban (suburban) electric networks, it is necessary to analyze the real graphs of electric load (GEL) of the communal sector consumers, operating modes of the main electrical equipment, which will allow to adequately estimate the predicted advantages and disadvantages of introducing the technology V2G and G2V .

In this case, two variants of implementation of the decentralized source should be considered:

1) distributed generation (private station) taking into account the parameters of the current operation of the transformer-consumers network in the main network configuration;

2) group generation (parking charging station) taking into account the parameters of the current operation of the network "transformer substation - consumers" in the radial configuration of the network.

The 2nd option is investigated in this research. In order to substantiate the expediency and necessity of introducing decentralized electric energy sources based on electric vehicles in municipal electrical networks, it is necessary to analyse the graphs of electric load (GEL) of typical city objects taking into account the possibility of placing on their territory and connecting to the power grid stations of charge-discharge stations. According to the GEL of typical consumers (Fig. 1-3), in the case of their power supply from a separate TP, it is possible to determine the expedient power (number of points) of connecting electric vehicles to a specific object (adjacent car parking).

In conditions of low quality and high tariffs for centralized supply, more consumers are switching to domestic heating or using alternative energy sources to reduce the cost of using electric or thermal energy. V2G technology, along with alternative energy sources, can be very useful for the introduction of power supply organizations from the standpoint of which energy networks have been experiencing a significant increase in loads recently, which necessitates a global reconstruction and modernization of electric equipment that requires significant investment. The use of V2G technology can be a "savior" measure for such cases, since the increase in electrical load can be offset by distributed generation from decentralized sources (electric vehicle batteries).

Calculations of irregularity factor K_{ir} are presented below for both variants of typical GELs:

$$K_{ir} = Pmin/Pmax$$

Type of main consumers	Irregularity factor K_{ir}
Houses equipped with natural gas stoves	0,15
Houses equipped with electric stoves	0,25

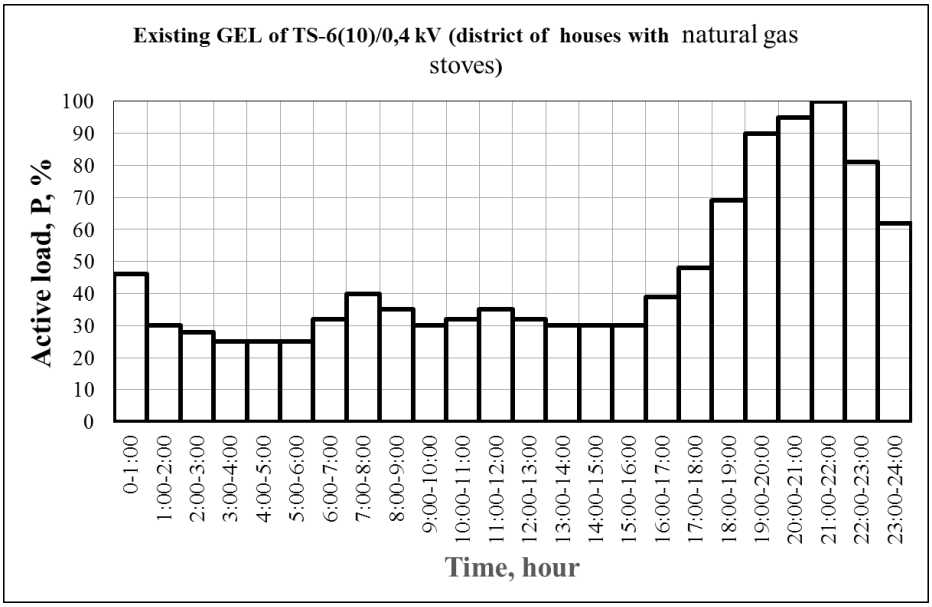

Fig. 1. Typical GEL of transformer substation 6(10)/0,4 kV of district with houses equipped with natural gas stoves

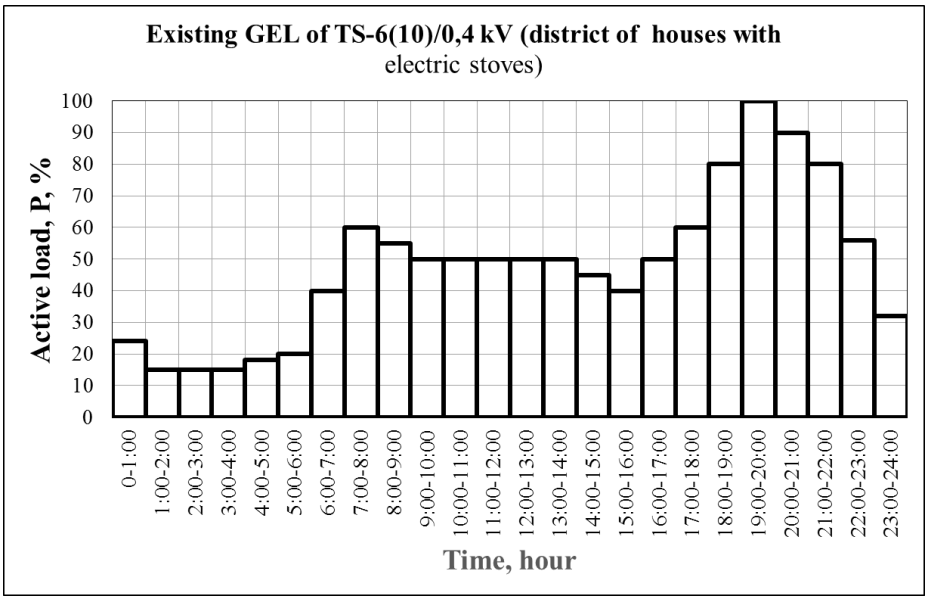

Fig. 2. Typical GEL of transformer substation 6(10)/0,4 kV of district with houses equipped with electric stoves

Public (group) stations of charge-discharge electric vehicles are relevant in the case of using the car for their intended purpose - transportation of the owner (family) to the work place (morning run) and return home (evening run) and smart charge-discharge battery in the period of the daily interval between exploitation.

The location of the group's charging / discharging station is tied to the city TS-6 (10) / 0.4 kV, as the transformer substations are at the centres of the electrical loads of consumers receiving power from them (centralized power supply), which is fair in the case of generation electrical grid into the grid (decentralized power supply), since this will ensure the minimum electric distance from the consumer / generator to the power supply / power point and, accordingly, the minimum power losses, as well as indicators of electrical energy quality for voltage deviations.

3. Modelling of rational patterns and operation modes for V2G/G2V-tecnologies implementation. In order to justify the alignment of the GEL of typical consumers with the help of electric vehicles, it is necessary to perform the following actions:

1) Performing the operational measurements of the working day and day off for TS-6 (10) / 0,4 kV, connected to the charging/discharging station of the electric vehicles;

2) Determination of the manoeuvring part of the GEL, which is expediently compensated by the electric vehicle;

3) Determination the required number of electric vehicles for the implementation of technology V2G with slow discharge to the network;

4) Estimation of the growth of the base part of the schedule of electric loads is performed at slow charging of electric vehicles in accordance with the templates;

5) Verification of the capacity of the technical parameters of the station to meet the needs of rapid charging a certain number of electric vehicles.

Taking into account the above mentioned algorithm, the simulation of the technology V2G / G2V for two typical residential areas was performed.

Assumption:

- simulation is carried out for identical Nissan Leaf electric vehicles:

- EVs have the same typical template of use;

- the use of an EV as active consumer-regulator/generator takes place in the mode of slow charging / discharging (based on the power of 6,6 kW) in order to reduce the negative impact on the accelerated degradation of the traction battery.

Daily rational use of EVs with V2G/G2V-technologies are shown in Figures 3-4

Modelling results for alignment of typical consumer GELs are presented in Figures 5-6.

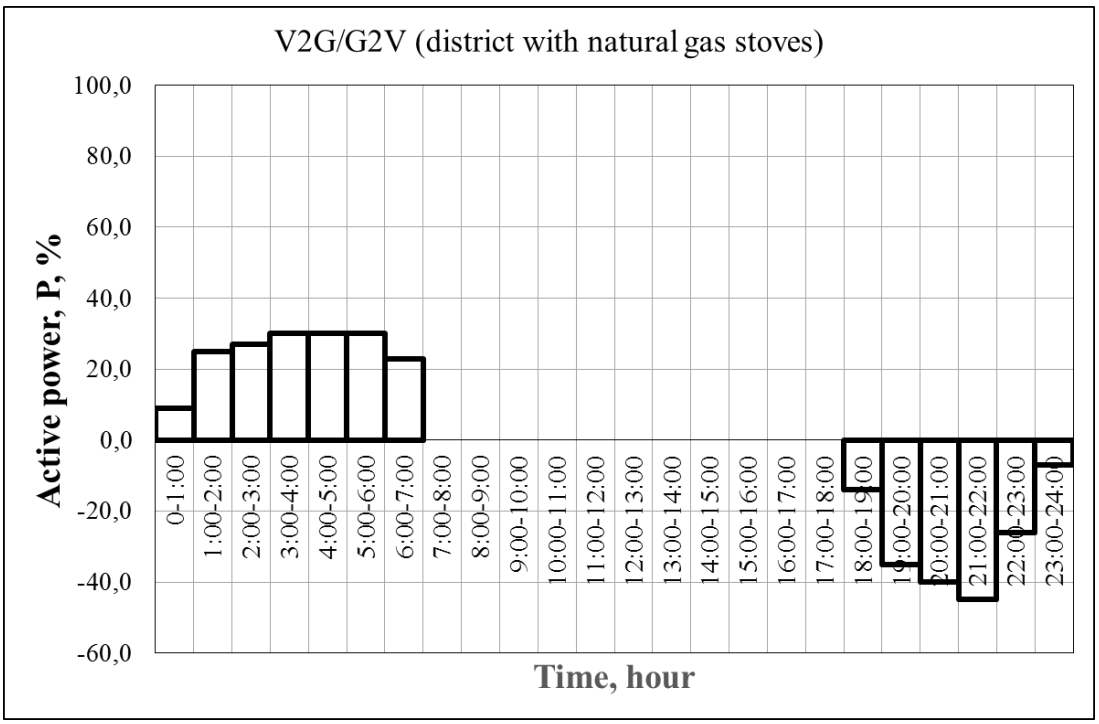

Fig. 3. Effective template for the use of electric vehicles (houses with natural gas stoves)

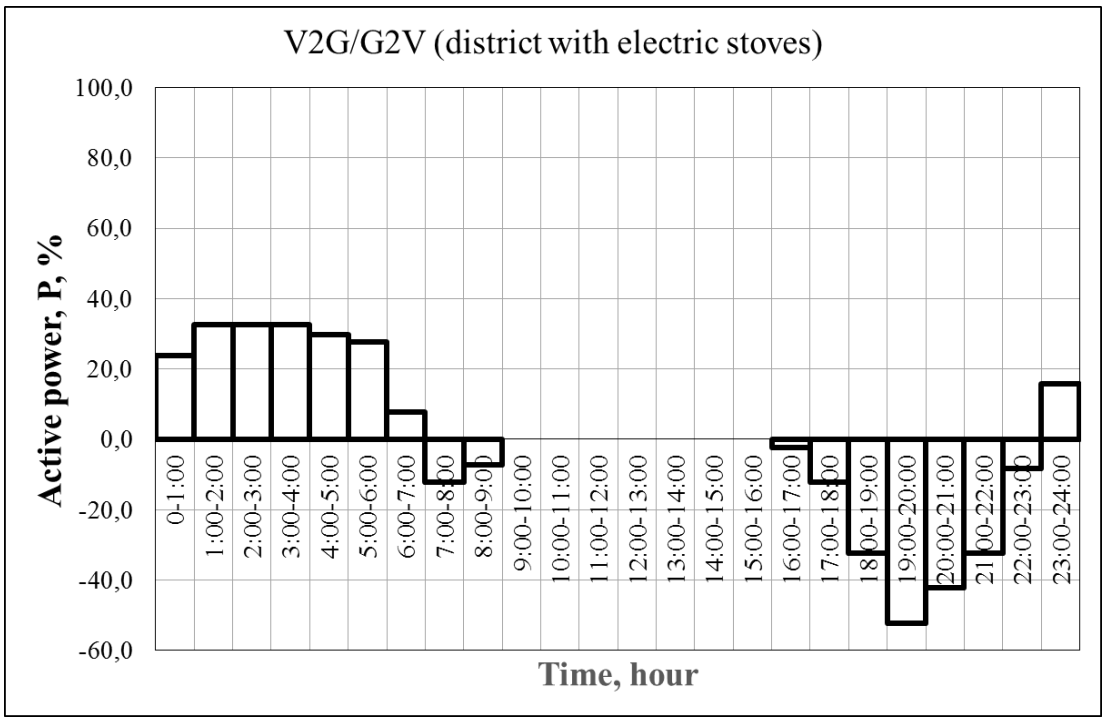

Fig. 4. Effective template for the use of electric vehicles (houses with electric stoves)

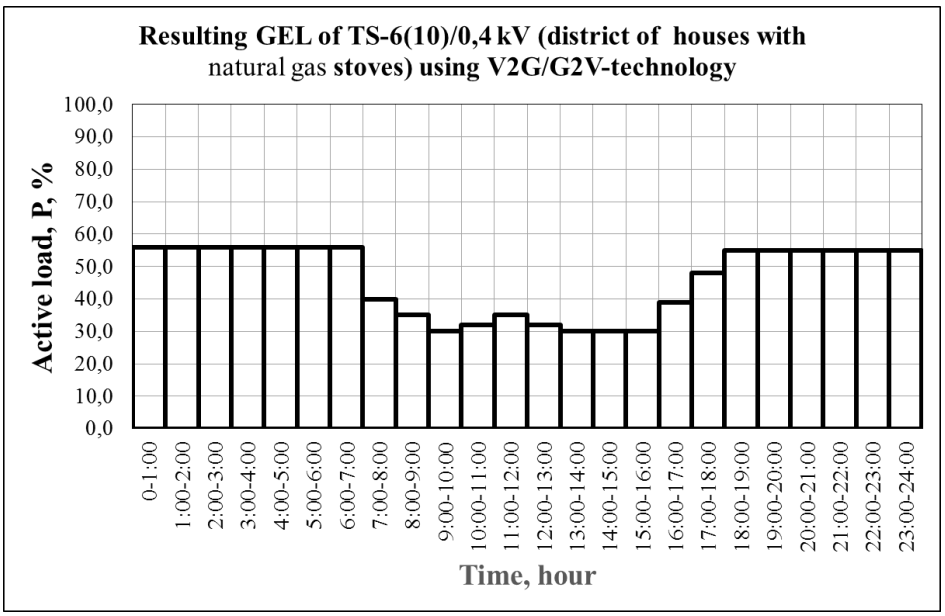

Fig. 5. Resulting GEL of transformer substation 6(10)/0,4 kV of district with houses equipped with natural gas stoves + V2G/G2V-technology implementation

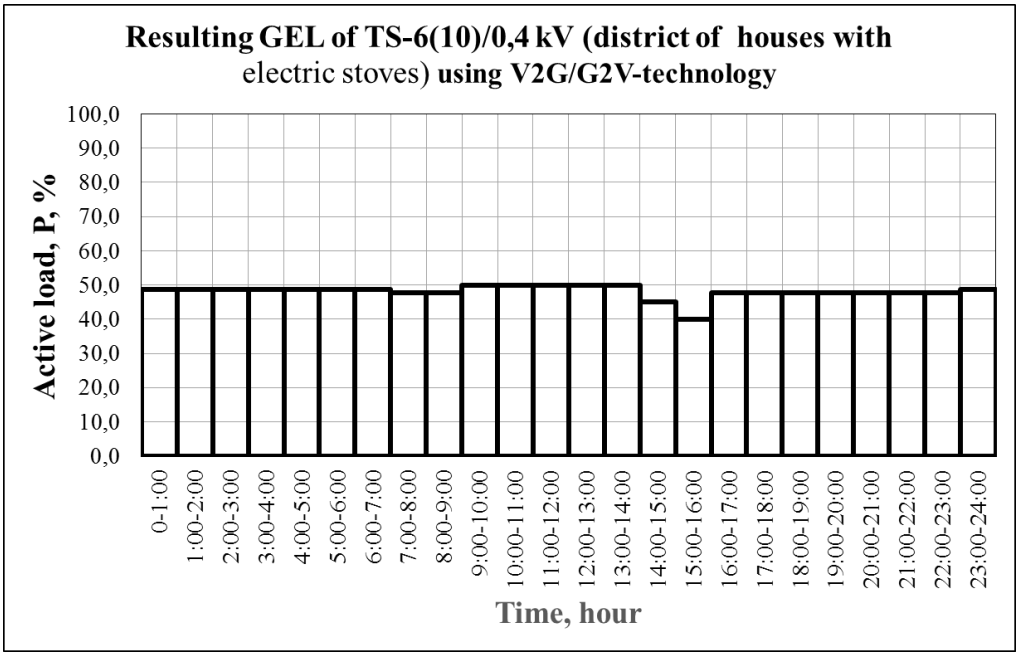

Fig. 5. Resulting GEL of transformer substation 6(10)/0,4 kV of district with houses equipped with electric stoves + V2G/G2V-technology implementation

Summary. As a result of modeling and calculations of the modes of using electric vehicles for smart technologies V2G / G2V, it is proved to reduce the calculated maximum load of the power grid, which will create the preconditions for effective choice of network equipment and its subsequent use in accordance with the nominal parameters.

The obtained results represent the scientific novelty, since the use of the proposed principles allows to reduce the maximum load, increase the transmission capacity of electrical networks from 45 to 55%, which will reduce the investment in electric networks.

Implementation of the developed scientific and technical solutions will increase the efficiency of the electrical distribution networks operation by reducing losses of electricity and rational use of the

power supply systems elements nominal parameters, obtaining a significant resource-saving, environmental and social effect by reducing fuel consumption and harmful emissions on generating blocks of thermal power stations. An additional result of the scientific work will be the conceptual definition of a set of prerequisites for the development of a legislative framework for the introduction of Vehicle-to-Grid and Grid-to-Vehicle technologies taking into account the technical, economic and legal aspects of the electricity market.

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