UDC 621.311.183

ANALYSIS AND RESEARCH OF THE INTEGRATION OF ELECTRIC VEHICLES INTO URBAN POWER GRIDS

Evdokimov D.M., Pavlycheva T.N., Kuligina N.O.

Nizhny Novgorod State Technical University R.E. Alekseeva, Nizhny Novgorod, e-mail: danil.evdokimow@yandex.ru, tamara-p@mail.ru, fedor_ais@bk.ru

Recently, there has been a tendency to expand the scope of practical application of electric power storage devices as one of the ways to balance load schedules. They are considered one of the most important components of the electric power industry of the future, as an integral element of "smart energy systems". The main factors contributing to the greatest attention to energy conservation in the large electric power industry are: a significant increase in the cost of electricity in most power systems during peak hours, high requirements for the reliability of power supply, as well as environmental problems [1]. The main property of storage devices is the ability to accumulate electricity with its subsequent supply to the grid at the right time for the power system. This will significantly save energy costs, as well as smooth out the tops of load graphs. The task of compensating for uneven schedules of electrical loads is typical for each energy system as a whole. This problem is solved mainly in several of the most common ways: by forming the most favorable structure of production capacities in the power system; using flows with neighboring power systems and attracting consumers to equalize load schedules on the power system with the help of administrative (restrictive) and economic (incentive) measures.

Keywords: power supply, network, electric vehicle, storage, charging station, load schedule

The issues of increasing energy efficiency and energy conservation are the main ones in the Russian electric power industry. First of all, this is associated with a rapid deterioration in performance and severe wear of power plant equipment, the need to modernize them or build new power plants using modern methods. The demand for electricity is growing, and the construction of stations or their restoration is currently a very long and rather expensive process. Therefore, it is necessary to look for alternative ways to improve energy efficiency, to encourage consumers to use energy-saving measures. The main way to solve the problem may be a set of programs for managing the use of electricity, which will allow:

a) reduce the load during peak hours of the power system;

b) harmonize the schedule of energy consumption by redistributing the load to the hours of its minimum (night period), as well as introduce technologies that increase energy efficiency; reduction of losses during transportation and distribution of electricity.

In order to reduce the unevenness of daily loading schedules, it is possible to use electric vehicles as equipment for energy storage according to the principle of operation of a hydraulic storage unit (HPP). This program is called V2G (Vehicle-to-Grid).

V2G is a way of two-way use of electric vehicles and hybrids, which involves connecting the car to a single electrical network in order to charge and return "excess" electricity back. This system allows you to:

1) to sell electricity during the hours when the car is not used for its intended purpose, as well as to recharge the battery during those hours when electricity is most affordable, that is, at night;

2) use the battery of an electric vehicle as an uninterruptible power supply. Thus, using this technology, it is possible to realize the possibility of connecting cars to your home and using them as an uninterruptible power supply [2].

Improving the energy efficiency of the production and transmission of electric energy by regulating modes when using electric vehicle batteries as consumers-power regulators, i.e., evaluating the possibility of implementing the V2G system on the example of a residential area to smooth out daily load schedules.

Materials and methods of research

The energy consumption mode is a change in the amount of electricity consumed depending on the day, time of day, day of the week and season of the year. Energy consumption modes are displayed on electrical load graphs and help energy companies to manage electricity consumption more efficiently and prevent overloads in the power grid. In turn, they are characterized by a number of indicators, such as:

1) the load factor is an indicator that is defined as the ratio of the average daily to peak load (it shows how full the daily load schedule is);

2) Annual (daily, monthly) maximum load (maximum power) of the hours used by the

consumer. It is defined as the ratio of electricity consumption for a certain period of time to the maximum load for a certain period of time;

3) The load simultaneity coefficient (or demand coefficient) is the ratio of the total maximum load on an enterprise to the sum of the load on its individual consumers. It shows how efficiently the power is used in the enterprise. These indicators are important for assessing the efficiency of electricity use at the enterprise and allow you to optimize energy costs.

Load graphs are basically a curved line consisting of several segments, with peak loads in the morning (8:00-11:00) and in the evening (18:00-22:00).

The best method of solving the problems of uneven load schedule is the accumulation of excess electricity generated during night outages, with its further use at peak load. To date, there are various types of energy storage devices (batteries). At the moment, in the electric power industry, the most common are storage devices that accumulate mechanical energy.

An electric vehicle is a type of transport that runs on electric motors powered by batteries or fuel cells, rather than internal combustion engines. It differs from cars with electric transmission and urban electric vehicles. An electric car can be of various types, such as an electric car, which is used to move indoors, and an electric bus, which is a bus with a battery [3]. The simplest type of electric car is a car with a rechargeable battery, which is the first of its kind. Cars with a rechargeable battery are the very first and, moreover, the simplest type of electric vehicles. In addition, many countries encourage the use of electric vehicles by providing incentives and subsidies for their purchase and use.

The technical and economic parameters of electric vehicles of this type depend on the characteristics of the batteries used. To determine how far an electric car can travel after one charge, you need to take into account the ratio of the weight of the battery to the total weight of the car. This is called the power reserve. It is important to note that the weight of the battery and the load capacity of an electric car is many times greater than the weight of a carburetor engine and the load capacity of a conventional car. It is necessary to charge the battery after a certain period of operation, which is carried out from various sources both from the outside and from the generator installed on board the car. The second method has one feature – the generator is powered by a simple engine, so such a car should not be considered an electric car, but a kind of hybrid cars.

The battery needs to be recharged after some time of operation, which is carried out both from various sources from the outside and from the generator, which is installed on board the car. The latter method has one feature – the generator is driven by a simple engine, so such a car should not be considered an electric car, but a kind of hybrid cars. In order to store mechanical energy, air accumulators, hydroelectric power plants (pumped storage power plants) are used. Air accumulators use excess energy generated at night to compress and store air in an impenetrable underground reservoir.

The device of an electric car differs from a car with an internal combustion engine, it is somewhat simpler, but also the most reliable, since it has a minimum number of moving parts. In an electric car, the main design elements are: an on-board charger, an electronic system. To provide power to the main traction motor, a powerful traction battery is used in the car. A lithium-ion battery consisting of several connected modules is installed on electric vehicles. The output current of such a battery is approximately 300 watts of direct current, and its capacity fully corresponds to the power of the electric motor.

Traction motor is a series of three–phase asynchronous or synchronous electric machines powered by alternating current. Power from 15 kW and more than 200 kW. If we compare an electric motor with an internal combustion engine (ICE), then the efficiency of the former in relation to the latter is 90%:25%. In addition, the electric motor has the following advantages which are also quite important and in demand, namely:

a) maximum torque can be obtained at any speed;

b) the design is quite simple and there is no need for additional cooling;

c) it can also work in generator mode [4].

Currently, such methods of charging an electric vehicle are used as:

1. Charging from a 220V home network. This is the simplest and most common way. The advantage of this method is that it is widely available to all owners of private houses or garages.

2. Charging stations for electric vehicles with voltage up to 400 V.

The V2V (Vehicle to Grid or "Vehicle to Grid") system is a way for electric vehicles and hybrids to interact with the electric grid. It allows you to connect an electric vehicle to a common electrical network for charging and returning unused electricity back to the network. Thus, an electric vehicle can be used to compensate for surges in electricity generation. To do this, the electric vehicle is equipped with a battery charge management system from the mains and the return of part of the charge to the mains.

The battery of a conventional electric vehicle has the ability to return from one to several kilowatts/hours of electricity to the network. If we take into account that the electric car is mainly located in the parking lot and allows the possibility of connecting to the network for more than half of its existence, it means that there is already a solution to the problem of accumulation of excess electricity in existing energy networks [3].

Owners of electric vehicles and hybrids equipped with the V2G system will have the opportunity not only to return electricity during the hours when the electric vehicle is not in use, but also to recharge the electric vehicle during the hours when electricity is cheapest (this is especially true in those regions where the cost of electricity depends on the time of day). You can also connect a car using this technology to your home and use it as an uninterruptible power supply for your home or office [2,3,5].

The V2G (Vehicle-to-Grid) system will require the creation of a network of charging stations for electric vehicles that can not only charge batteries, but also supply electricity back to the grid. To do this, it is necessary to standardize the interface between the network and the electric vehicle, as well as to create special chargers that can convert direct current into alternating current. This will make it possible to use energy more efficiently and increase the stability of the power grid. V2G technology makes it possible to use electric vehicles not only as a means of transportation, but also as a source of electricity. This can be especially useful during periods of peak electricity consumption when the network is under heavy load. In such conditions, electric vehicles will be able to supply energy to the grid and reduce the load on power plants. In addition, V2G can be used to store energy from renewable sources, such as solar and wind energy, due to the establishment of a significant fleet of electric vehicles, the implementation of the V2G system will make much better use of existing energy production capacities and will open up great prospects for the development of alternative energy.

An electric vehicle used to level the surges of electricity generation contains a battery charge management system from the electrical network and the return of part of the charge to the network.

The batteries of a standard electric vehicle allow you to return from one to several kilowatts hours of electricity to the network. Considering that most of the time the electric car is in the parking area and can be connected to the network for more than 90% of its existence, we can say that the solution to the problem accumulation of excess electricity in existing power grids already exists [3].

Owners of cars equipped with V2G will have the opportunity not only to return electricity during the hours when the car is not in use, but also to charge the car during the hours when electricity is cheaper (in many countries, the price of electricity depends on the time of day). It is also possible to connect a car with this technology to your own home and use it as an uninterruptible power supply for your home or office [5].

Electric cars are considered an environmentally friendly alternative to cars with internal combustion engines [5]. When electric cars and hybrids were just entering the market, environmentalists considered them a salvation for the planet, where there are more and more cars every year.

In addition to the production and damage of power plants that generate their own electricity, the problem also lies in the batteries themselves or their disposal. To date, only 5% of such batteries are recycled. This leads to a high risk of environmental pollution. If the batteries are damaged, toxic elements and gases are released. In addition, the materials from which batteries are made (for example, lithium and cobalt) are found in nature in limited quantities and are not renewable. Their additional production (rather than reuse) leads to an additional burden on the ecology of the planet, since production processes are quite dirty and energy-intensive.

Reuse becomes an alternative option for recycling batteries. The possibilities for reuse are very limited. It is also worth noting that reuse allows you to save very limited. However, with more efficient testing and tuning, batteries that have increased battery life for a second term could successfully compete in systems such as backup power for small electric receivers. Equipped with an inverter and a mains filter, combined into a single system, several electric vehicle batteries are able to power several low-rise buildings or a small small enterprise with backup power at the time of an accident for several hours.

It is expected that this system will balance the energy supply system and even reduce the cost of electricity for consumers. It is believed that the system will encourage owners to charge electric car batteries from the regular grid at night when electricity consumption is low. This makes it possible to optimize the load on the city power grid during the daytime, when the load on the network is maximum.

It will also help to significantly reduce energy costs at home.

General household electricity needs are part of the resource that is spent on maintaining and providing lighting for a high-rise building, beyond the share of electricity that the owner uses within his residential property.

The amount of household electricity needs includes the following list of costs:

1) lighting of stairwells, vestibules, entrances;

2) electricity required for the smooth operation of intercoms;

3) electricity consumed by elevator cabins;

4) electricity for video cameras, if they are installed in the house;

5) technological losses fixed in intra house networks.

The location of the substation is chosen taking into account the convenience of its placement, maintenance and the possibility of mutual redundancy between a transformer substation on a 0.38 kV high-voltage line, which is necessary for consumers of the first category in terms of reliability of power supply, such as: important healthcare facilities (intensive care units, large dispensaries, maternity wards, etc.) and other state institutions; boiler houses, pumping stations the stations of the first power supply which leads to the failure of urban life support systems; traction substations of urban electrified transport; communication installations, control rooms of urban systems, server rooms; elevators, fire alarm devices, fire-fighting devices, burglar alarms of large buildings with a large number of people in them.

Thus, if consumers of the I category of power supply reliability are connected to the outgoing transformer substation 10(35)/0.4 kV of the 0.38 kV high-voltage line, then it is necessary to install two transformers at the projected substation 10(35)/0.4 kV. This is due to the need to provide electricity to category I consumers via two mutually redundant 0.38 kV high-voltage lines from two independent power sources, and switching the consumer's power supply to a backup high-voltage line (or to a backup power source) should be performed automatically.

In residential buildings, in exceptional cases, it is allowed to place only dry transformers, provided that an acceptable level of noise and vibration is provided. In the sleeping buildings of various institutions, in schools and other educational institutions, the placement of built-in and attached substations is not allowed. According to the rule of electrical installations (clause 4.2.85), transformer substations are not allowed to be placed under production facilities with a wet technological process, under showers, bathrooms, etc.

The most convenient places to install parking are public places, such as: shopping malls, office centers, cafes, sports and recreation complexes, and city polyclinics. And also, for the implementation of the electric vehicle charge-discharge program, for the exchange of energy between it and the city electric grid, it is favorable to install parking lots equipped with a charging-discharge station in the courtyards of houses with a high number of apartments, and with sufficient free house territory.

To analyze the feasibility of applying the methodology to the interaction of electric vehicles and urban electric networks, we will analyze the power that electric vehicles need for one hundred percent recharging (25 kW per 1 pc.) and the one that they can return to the network while in parking spaces (about 15 kW).

That is, the system looks like this: at night, when the load on the power grid is minimal and electricity tariffs are low, the electric vehicle is charged. In the morning at peak hours, after reaching the workplace, the driver returns unused energy at a high rate. After lunch, during the hours of medium load, the vehicle can be recharged, and in the evening, the excess energy can be sold at a high rate. Such a simple scheme is not only beneficial, but can also help to stabilize the operation of the city power grid, which is what we need.

The estimated capacity of consumers of transformer substations, the installed capacity of transformer substations, as well as the estimated capacity of consumers with the power consumed by electric vehicles included in it are indicated.

The estimated capacity, including that consumed by electric vehicles, exceeds the installed capacity of transformer substations.

One of the approaches to create an optimal load at each transformer substation is the modernization of the energy system. Due to the increase in the number of electricity consumers, the amount of energy consumed is also increasing, so there is a need to modernize existing power supply devices. it provided substations with the required reliability of power supply and quality of electricity [5].

A whole range of measures is being implemented, including both new construction, expansion, and reconstruction of networks. At the same time, new construction means the construction of new power lines and substations, expansion means the installation of a second transformer with the appropriate equipment at one transformer substations, reconstruction means the replacement of power line wires, the transfer of networks from 6 kV voltage to 10 kV voltage, the replacement of transformers, the installation of reactive power compensation, partitioning, automation, regulation tension [6].

The mass use of electric vehicles as an element of the Smart Grid will allow:

1) significantly increase the efficiency of the use of electric distribution networks due to controlled distributed load;

2) increase the useful vacation to the network;

3) to ensure the alignment of the night “failure” of the load profile

4) power systems.

When implementing Vehicle To Grid (V2G) technology, use electric vehicles as distributed energy storage to cover peak loads of the power system. Popularization of the use of electric vehicles can significantly increase the efficiency of the use of electric distribution networks and increase the useful vacation to create problems in the case of the use of chaotic and suboptimal charging infrastructure.

Results of the research and discussions

In the course of the study, the method of reducing the daily maxima of load schedules by accumulating energy received from electric vehicles, its subsequent delivery to the network, is considered.

A power outage, whether of small, medium, long duration or prolonged, can lead to disruption, damage and downtime, no matter whether it is a domestic consumer or an industrial one. A user of a home computer or a small enterprise may lose valuable data or products when the equipment is de-energized. The losses of an industrial consumer of electricity due to interruptions in its supply are likely to be more serious.

This is one of the main problems that contributes to the use of backup sources of electricity in the power supply system. In our case-the battery of an electric car. The use of an electric vehicle battery as a backup source of electricity for a private home helps to solve issues not only of power outages for a private home, but also allows for economic benefits to homeowners.

In order to get an economic effect from the alignment of the schedule, it is necessary to competently approach the implementation of alignment measures, create conditions to support those consumers who use modern accumulating and generating equipment, as well as use their electric vehicles as a tool for leveling the load schedule, conduct a pricing policy in which consumers would benefit from the use of their vehicles funds.

Conclusion

From the above, it can be concluded that the regulation of electrical loads is understood as a set of targeted measures to reduce electricity consumption and coordinate load schedules.

As a result of these measures, electricity losses in the power supply system are significantly reduced, and when choosing elements of this system, it is possible to reduce its cost and material consumption.

The uneven loading schedule worsens the operation of the networks and requires additional capital expenditures for the construction of new networks and power units of power plants that provide coverage of load peaks.

Concluding the above, it can be inferred that regulating electrical loads involves implementing targeted measures to reduce electricity consumption and coordinate load schedules. These measures lead to a significant reduction in power supply system losses and can result in a reduction of material and cost consumption when selecting components for the system. An irregular loading schedule negatively impacts network functioning and requires costly capital expenditures for the construction of new networks and power plants. The use of V2G technology in the vehicle-to-network system can promote the popularity of electric transport by allowing owners to earn money through the sale of electricity. V2G technology can harmonize the schedule of daily consumer loads and is estimated to coordinate the daily electric load schedule for not only individual neighborhoods but entire cities with a sufficient number of electric vehicles connected to the network.

References

1. Chernetsky A.M. Evaluation of the economic efficiency of the use of electric power storage devices in the power system // Energy. Proceedings of higher educational institutions and energy associations of the CIS. 2013. No. 4. P. 21-28.

2. Okorokov D.A., Nikishin A.Y. Prospects of using the V2G system to equalize the daily load schedule in the Kaliningrad region // Bulletin of Youth Science. 2016. No. 3(5). P. 9.

3. Velikanov A.A., Orlova A.N. Electric car – transport of tomorrow // Technological and economic education: achievements, innovations, prospects: Intercollegiate collection of articles of the XII International Scientific and Practical Conference: in 2 volumes (Tula, February 15-18, 2011). Tula State Pedagogical University named after L.N. Tolstoy. 2011. Vol. 2. P. 38-42.

4. Treskova Yu.V. Electric vehicles and ecology. Prospects for the use of electric vehicles // Young scientist. 2016. No. 12 (116). P. 563-565. URL: https://moluch.ru/archive/116/31697 / (accessed: 01.05.2023).

5. Tusova A., Romanova E., Strielkowski W. Smart grids as the leading concept in the Internet of Energy // 4th International Conference on Social, Business, and Academic Leadership (ICSBAL 2019). Advances in Social Science, Education and Humanities Research // Atlantis Press. 2019. Vol. 359. P. 238-243.

6. Leshchinskaya T.B., Volkova E.A. Choosing the optimal option for the development of 6-10 kV distribution air networks according to a multi-criteria model // Energy security and energy conservation. 2018. No. 5. P. 23-30.