Distributed energy system's is the future of the world's power industry

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Summary - The development of renewable energy sources (RES) has a significant impact on traditional generation, in particular to ensure the reliability (guarantee) of the power supply and static stability of power systems. The reason is that non-guaranteed power supply from the generators of intermittent power requires an always-on reserve capacity in power systems does not exceed 20%. This required alignment of the variable operation mode of the installations based on renewable energy in two possible ways:
1. Smoothing power spikes with energy storage of various types;
2. Redundancy generated by RES facilities guaranteeing power source (installing from the accumulated stock of energy resources);
3. The balance of power of the power system regulation of consumption of electric and thermal energy.
The most common way for power is the second that has given rise to numerous power generation complexes consisting of installations based on renewable energy (most likely wind power) and diesel (diesel, gas etc.) electric generators.
For heating most often used the first method: the accumulation of heat different thermal batteries.

Keywords: Power systems; generator; consumer; accumulator; optimal structures; units based on renewable energy sources.

I. INTRODUCTION

The development of the energy system, including installation based on renewable energy requires the application of the principle of distribution, not just generation, but also of consumption. Thus, the principle does not depend on the mesh size and is applicable for Large power systems and Micro power systems "Autonomous generator-Autonomous consumers".

Modern power engineering is based on thermal, nuclear and hydraulic power plants of high power, connected to electricity consumers by high voltage transmission lines of sufficiently large length. Everyone understands that it is economically more profitable to produce electricity at one powerful power station than in many small power stations with the same total capacity. Concentration of large power plants in places close to sources increases their economy by reducing the cost of transportation or transferring fuel from the place of its extraction to the place of use.

The location of electricity consumers is associated with other reasons. Therefore, consumers of electricity are distributed throughout the territory of countries outside of the connection with the proximity of energy resources.

For reliable power supply to consumers and their connection with power generators, electrical networks of different voltage levels and different structures are used. The more complex the electrical network, the more different generators in it, the more important are the questions of choosing a stable mode of its operation. In this case, the network of each level has its voltage level - the larger the network, the higher the voltage, the more complex the communication between networks of different voltage levels and their management. Ensuring the survivability of a large electrical system - a complex of generators, networks and consumers - is achieved by dividing this system into smaller components, and the part in which the emergency occurs is separated from the rest of the system. This allows you to save most of the power system, but leaves the separated part one-on-one with the problem of restoring efficiency and in these conditions with the reliability of electricity supply to consumers. This means that the separated part of the energy system becomes an independent microsystem at the time of accident elimination and restoration of the operability of the failed equipment.

Reliability and guarantee of power supply to the consumers of the microsystem will be completely determined by its structure: the composition of the generators, the electric network scheme and the type of electricity consumers - the less the guaranteed capacity of the generators, the lower the guarantee of uninterrupted power supply. With a low guarantee, mass fan trips are natural, i.e. partial deprivation of their access to electrical energy in separate hours of the day or complete loss of power.

Thus, it is quite clear that the guarantee of the uninterrupted power supply for consumers of microsystems when they are separated from the common network is uniquely dependent on the structure of the generating capacity of this microsystem.

2. ENERGY SYSTEM’S WITH UNIT’S, BASED ON RENEWABLE ENERGY SOURCES

In recent years, power plants on renewable energy sources (RES), primarily solar, wind and small hydropower, have become widespread [1], [2]. Power plants based on these types of energy do not have their own means of accumulating energy resources, such as coal storage, oil or gas storage of hydrocarbon power stations or reservoirs of large hydroelectric power stations. Consequently, they do not have a guaranteed capacity, i.e. power, which is transmitted to the consumer of electricity with a given guarantee of continuity (usually (95-97)%). This means that the consumer does not receive the required capacity in the considered time period only in (3-5)% of cases. Reducing the guarantee of continuity of electricity supply causes an increase in the number and duration of power outages of consumers. Power consumers from power plants based on RES have a guarantee equal to the guarantee of the receipt of the relevant energy resource to the generating capacity of the power plant, i.e. practically equal to zero. Based on this provision, all renewable energy installations are considered as sources of duplicating capacity, which is duplicated by the capacity of the guaranteeing electricity supplier (thermal, nuclear, geothermal, etc. types of power plants). The exceptions are those areas of the world where the supply of solar radiation, for example, has a guarantee (90-94)%, which corresponds to 320-340 sunny days per year (the Arabian Peninsula, Egypt, Equatorial Africa), but in these regions the sun shines only in daytime. In Europe and America, the guarantee of the arrival of solar energy per year does not exceed 50%. From the above it is clear that the power of non-duplicated generators based on RES can not be greater than the reserve capacity of a large electrical system, and their use in microsystems (Microgrid) deprives consumers of these systems of guaranteed power supply, as happens in the emergency separation of such a microsystem from a large power system.

Ensuring the reliability and continuity of power supply to consumers of a large power system (LPS) requires significant investments in network equipment, emergency control and other dispatching systems.

The cost of emergency control can be significantly reduced when building a LPS based on the distribution of generating, transmitting, regulating, protecting and consuming elements over several nodes of the power system that become independent microsystems (MPS). But such a construction of a LPS - regional, national, continental or intercontinental - will require a different application in comparison with the existing paradigm: the construction of a distributed energy system with self-balancing power nodes - microsystems. The management of the LPS, consisting of the MPS network, will be much simpler, and commercial calculations, which are especially important for inter-national energy systems, will become more transparent and simple. In the case of mismatching the regimes of the parts of the LPS, it is divided into independently operating MPS, each of which restores the operability independently, and calculations are conducted only in terms of the amount of inter-system power flows.

When using a distributed energy paradigm, planning for the optimal structure of autonomous (local) power nodes and LPS becomes similar to each other [3], [4]. As a matter of fact, the MPS of the optimal structure becomes a structural invariant of LPS when observing similarity rules when they are equivalent. In this case, the task of optimizing the structure and parameters of the MPS using RES installations becomes the basis for determining the optimal structure of the LPS.

Determination of the optimal structure of MPS with RES installations will be formulated as follows: to find such a combination of consumers of electrical and thermal energy of various types and a combination of sources of electric and thermal energy, in which the degree of duplication of generating capacity will be minimal, and guarantee the continuity of energy supply to consumers by all kinds of energy required by them will be maximum. Maintaining the balance of power in each time interval is effected by the action on generators, energy storage devices and control devices adjustable by users. Generators, storage, control devices and consumers are distributed among the nodes in accordance with the optimal MPS structure.

An example of the structure of MPS, including generators based on RES: F - photovoltaic installations, W - wind-electric installations, H - hydropower installations, guaranteeing an energy source - D (diesel electric installation); consumers of direct(=) and alternating (~) current connected to the buses of direct and alternating current, connected by inverters, is shown in Fig.1.

The structure shown in Fig. 1 can be supplemented with installations for the production, accumulation and use (consumption) of heat, mechanical and other types of energy.

The given block diagram reflects the virtual model of MPS, which when designing a real power supply system is transformed into a technical model, within which real technical devices and their connection schemes are selected, as well as ways and means to control their operation mode.

The final choice is made on the basis of an economic evaluation of possible technical realizations of the virtual model considered.

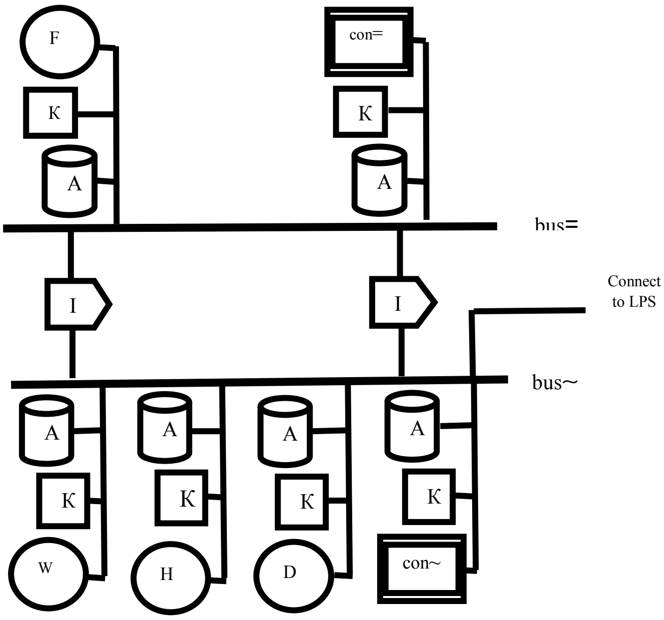

Fig.1 - The structure of a virtual MPS, as a LPS node, with RES-based generators, consumers (con) at a direct(=) and alternating (~) current and communication with other LPS nodes. In the figure: A is a virtual energy battery; К - controller of charge A; F, W, H - photovoltaic, wind- and hydropower installations; D - guaranteeing power installation (for example, diesel electric installation); I -devices of communication of power supply systems on direct and alternating current.

3. THE METHOD OF CHOOSING THE OPTIMAL STRUCTURE OF MPS

The method of choosing the optimal variant of the structure and parameters of an autonomous MPS by the criterion of the maximum of the net discounted income of a power complex on the basis of RES was approved for a number of typical consumers of electric energy [5]. The sequence of solving problems when choosing the optimal structure of MPS is as follows:

– The schedule of consumption of electric power by MPS consumers is determined;

– The calculation of the MPS power balance is carried out with the consequent addition of plants of various types of renewable energy sources to the composition of generating sources with increasing their number (the method of successive approximations);

– Technical and economic characteristics of MPS equipment are determined;

– The infrastructural factors affecting the deployment of RES in the region are assessed;

– The optimum structure and parameters of MPS generating elements are calculated by the criterion of the minimum of the total discounted costs for the life cycle of the MPS project.

Practical applications of the described methodology show the effectiveness of its application for optimizing the structure of MPS with installations based on RES. And the invariance of the structure of MPS and LPS, built on the principle of distributed systems, makes it possible to assert the possibility of constructing effective energy systems with RES installations both in local energy areas and in the zone of operation of centralized power supply systems.

4. CONCLUSION

Energy systems of the future should be economical, reliable and safe, should ensure the maximum continuity of energy supply to energy consumers in all regions.

This can be achieved only with the development of energy systems with installations based on RES based on the paradigm of distributed energy systems.

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