Control of a local energy complex with renewable energy sources

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Abstract. Local energy complexes are characterized by the fact that they do not have as many energy sources as in the Unified energy system. In this regard, it is required to comply with the standard in quality and reliability of electricity. Given the availability of renewable energy sources in the system, the instability of electricity generation must be compensated for with the help of guaranteed energy sources or storage devices. In this paper, various control algorithms for electric power sources with different guaranteed power and inertia are considered. The proposed algorithms are tested on a physical and mathematical model of a local power system.

1. Introduction

In Russia, a historical situation has arisen in which there are territories that are not electrically connected to the united electric network for economic or technological reasons. Such territories are called autonomous or local energy systems.

Currently, in such regions, electricity is supplied using either diesel generators installed back in the 20th century and obsolete morally and technically, or using small gas turbine units. The vast majority are still diesel generators, diesel fuel is delivered either by road, or, in some cases, from sea vessels. Diesel fuel delivery is very expensive, at the rate for 2020, the cost of diesel fuel is more than 60 thousand rubles per ton of diesel fuel.

Due to the high cost of fuel, solar and wind power stations were built in some remote settlements. In addition to them, automated control systems (ACS) are installed in these villages. But they were not brought to constant and reliable operation for a number of reasons, which we will consider in the next section.

2. Problems in the automation of renewable energy complexes

All new equipment supplied to newly designed facilities supports many modern data transfer protocols: IEC-104, IEC-61850, MODBUS. However, old equipment does not have such capabilities and is often manually controlled at the facility. Even on new equipment, protocols and data transfer interfaces may differ, which can cause serious problems in the automation of such energy networks. In this regard, it is better to design such complexes completely, the equipment of the diesel generator set should cover all the needs of consumers with disconnected RES sources. In the best case, a diesel generator should operate in the range from 30 to 75% of its rated power, otherwise it will suffer accelerated wear.
Another really serious problem in RES complexes is the personnel serving this complex. Due to insufficient automation, the technician must constantly monitor the operation of the wind or solar power station, periodically making various switching and operations. Unfortunately, the field usually employs older people as technicians who can dishonestly perform their duties and simply turn off WPP (Wind Power Plant) or SPP (Solar Power Plant), since it is easier for them to control an old diesel generator. To do this, it is necessary to ensure the impossibility of uncoordinated penetration of people into the work process.

For full coordination of the work of all generators, controlled load and consumers, it is necessary to provide for all of them a single top level of automation. The middle and lower levels remain at each of the sources of electricity.

Providing a single top level will reduce losses and practically negate malfunctions. It is necessary to strive to consolidate the data on all such remote villages and cities into one central control center (Network Management Center). The NCC may have the authority to receive and process signals and measurements, as well as manage the network in the event of an emergency. Thus, it is possible to implement the so-called hybrid system for managing complexes in various regions, while reducing the human factor to a minimum.

3. Research complex - physical and mathematical model of a local energy network

When developing power system control algorithms, it is necessary to test and test them on the power grid model, which allows you to simulate various operating modes. The model contains the following blocks:

- Model of a wind power plant;
- Pumped-Storage power plant model;
- Model of a solar power plant;
- Consumer model;
- Model DPS (Diesel Power Station);
- Distribution substation model.

Data from the modules described above is transmitted via Ethernet, USB, RS-485 interfaces via MODBUS RTU protocol. All models are connected to one system using a distribution substation and operate synchronously. The distribution substation also has a connection to UES, however, this algorithm is not used for the operation of the algorithm, since this is not necessary. The electrical connection diagram of the models is shown in Figure 1:
4. Algorithm description

Due to the constant change in wind speeds, WPPs have practically zero guaranteed power, because of this, the system must have either energy stores or guaranteed sources.

In this complex, the wind farm is networked, not autonomous. It is necessary to strictly comply with the requirements for frequency and voltage exiting the wind generator. The frequency of the electric current supplied to the network is controlled by the DC insert in a DFIG dual-power machine. The generator speed range in which it is possible to adjust the frequency of the electric current to the industrial frequency (50 Hz) lies from 1000 to 1800 rpm. However, in the super-synchronous mode, synchronization may not occur despite the operation of regulatory devices.

Adjustment of the generated power of the wind generator can be done in different ways:

• Regulation of the angle of rotation of the blades;
• Regulation of a passband of an insert of a direct current;
• Change in generator excitation.

Consider the second of the proposed methods. There is such a parameter as Derating, its value can vary within (0 ... 100)%, where 0% means the minimum resistance of the DC insert, and 100% completely blocks the power output.

When this parameter reaches a value of 100%, the rotation speed drops significantly, until the synchronization with the network exits. When you exit synchronization, the Derating indicator is reset to zero and the generator stops braking. Given that synchronization is lost, the generator can quickly accelerate. In cases where the generator does not have time to synchronize with the network during acceleration, the mechanical speed may exceed the upper limit of the synchronization range and acceleration of the generator rotor above the rated parameters may occur.
There are various approaches to regulating the parameters of a wind generator (as well as a controlled consumer):

- Iterative method;
- Dependency method;
- Forecasting method based on meteorological data;
- Advance adjustment method based on load data.

Consider the simplest method - iterative. Its block diagram is shown in Figure 2:

Figure 2. Iterational algorithm of WPP

When controlling a wind generator, it is also necessary to take into account wind gusts so that the algorithm does not react to them and has a free run. The change in the power of the wind farm occurs
with some inertia, which also needs to be taken into account in order to avoid problems with long oscillatory processes. An improved experimental relationship can be seen in Figure 3:

![Graph showing wind power plant, system, and consumer with derating.](image)

**Figure 3. Dependence of WPP power and power consumption experimental (progressive change)**

Using this algorithm allows you to manage many types of WPP, regardless of model, location and needs. It has several disadvantages, for example, fluctuations in changes in the required power. In this case, this happens for several reasons:

1. The discreteness of measurements by counters is too large, because of this there is a lag in real values;
2. Inaccuracy and magnitude of the settings. Due to imperfection of the equipment, a large free play occurs. This can be eliminated with detailed adjustment for a specific unit, which will allow for operational adjustment of the parameters.

**5. Conclusion**

Using intelligent algorithms for managing local networks will save a large number of fossil resources, but this requires modern equipment and qualified personnel. Such systems are safe and efficient, which allows them to be located in many remote areas around the world. With the right approach, it is possible to abandon guaranteed sources and work with energy storage, but in this case, the economic model changes and additional justification is required.
6. References

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