Virtual source of reactive power in electricity supply systems of household consumers

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Abstract - The principle of distributed generation of reactive power is proposed in the structure of the basic principles of constructing smart grids for civilian objects. For its implementation at points of final distribution of electricity networks of buildings and structures should provide for the installation of individual reactive power compensation devices.

Keywords – electricity supply systems, reactive power, virtual power plant, virtual reactive power plant, reactive power compensation.

Introduction

Virtual Power Plant (VPP) is an efficient resource at the disposal of the smart grid operator to solve the problem of balancing active power. VPPs are formed on the basis of the following resources: a) Distributed (decentralized) sources of electricity, mainly, renewable sources of consumers; b) distributed resources for the accumulation of electricity (electric power storage); c) controlled electric receivers.

An important task of the operator of a smart grid (microgrid) is to provide a balance of reactive power and appropriate levels of voltage in the grid that meet the requirements of quality, cost effectiveness and reliability of electricity supply. In the event of a deficit of reactive power in the power grid, regimes with reduced voltage level come in, which reduces the stability of the work of electric motors of technological installations of consumers and worsens the quality of electric energy. In addition, the flow of reactive component currents leads to additional energy losses in the elements of distribution networks.

The principle of creating virtual power plant.

As a reactive power resource, it is expedient, by analogy with VPP, to create virtual reactive power sources (VRPP) that will accumulate the power of distributed reactive power compensation. The sources of reactive power in the final distribution networks (fig. 1) are usually based on the principle of individual compensation and are regulated according to the load schedule of the given node, that is, on the consumer's demand. To improve the economic performance of power supply systems in such networks, discretely regulated static capacitor`s batteries or reactive power generation by synchronous motors of process plants are installed. To obtain an additional reactive power resource by the operator of the distribution network (DSO), it is possible, by analogy with VPP, to attract a distributed compensation resource at the DSO at the voltage 0,4 kV, which can be described as a virtual source of reactive power.

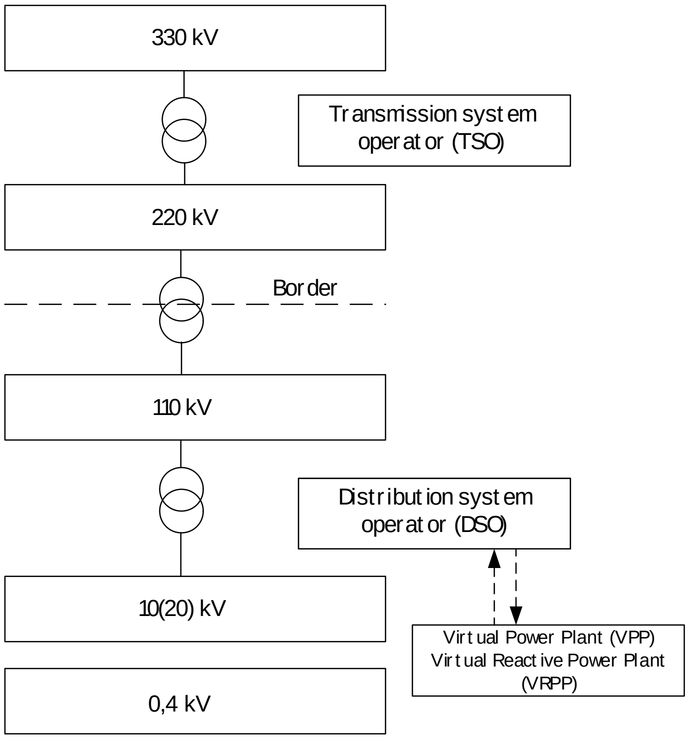

Fig.1 Network operators in Different Voltage Levels in Ukraine

Creating VRPP based on the resources of non-residential consumers is not fundamentally problematic, since the principle of distributed compensation of reactive power is widely used in non-residential power supply systems. For objects of consumers with a permitted power of 16 kW or more, if the volume of reactive energy of generation or consumption during the accounting period is 1000 kVA · h or more, a charge for the flow of reactive electricity in accordance with the "Methods for calculating the charge for the flow of reactive electricity ", approved by the order of the Ministry of Energy and Coal Industry of Ukraine, 06.02.2018, No. 87 [1]. The consumer is encouraged to install PFM devices with automatic regulation and means of accounting for consumed and generated reactive electricity. The creation of VRPP for such facilities means the provision to the distribution network operator of the customer's devices to solve the problem of reactive power balancing.

The problem of compensation of reactive power in the distribution grids of civilian objects

At the moment, existing regulatory framework does not oblige and does not stimulate household consumers to install reactive power compensation devices. According to [3], the domestic consumer of electrical energy is a natural person who uses electrical energy to provide his or her own household needs that does not include professional and commercial activities, based on an electricity supply contract with an electricity supplier. In accounting systems for the consumption of energy in the electricity grids of such consumers, there is still no account of reactive energy, mainly due to the small volumes of distributed consumption compared to industrial objects, the occasional nature of electricity consumption by a significant number of single-phase electric receivers, a relatively small unit capacity of consumers who pay for electricity, the complexity of the phase control of reactive power compensation devices, that is, due to technical and economic inexpediency.

Recently, a number of publications appeared in which justified the expediency of compensation of reactive power in the distribution grids of civilian objects, and in the residential sector in particular. This is due to the increase in the density of communal loads, the increase in the electrical load of civilian objects, the increase in the consumption of reactive electricity by dwellings of increased comfort, etc. But the main argument in favor of the use of individual SMP in the domestic sphere is the opportunities that arise as a result of the construction of power supply systems as active (intelligent) distributive networks (microgrid). Such systems are built In such systems, install intelligent meters and means of regulating electricity consumption.

As an illustration, we present the results, performed according to the current method of State Buliding Codes [2], calculations of the level of reactive power consumption of typical typical buildings of modern civilian development. Three types of apartment houses: a) 9-storey 6-section residential house with gas stoves for 210 apartments (1st type housing in terms of household appliances and I-level electrification according to the estimated specific load in accordance with [2]); b) 16-storey two-section house with electric stoves and 2 elevators per section (2nd kind, III level of electrification) for 126 apartments; c) 24 storey two-section high-rise residential house with electric stoves and 2 elevators per section (2nd and 4th level electrification) for 112 apartments and a shopping center with a total area of10,000 m^2.

For residential buildings, the calculated active load:

$$P_p = p_{spec} \times N_{app} + 0{,}9 \times K_d \times n_{el} \times p_{el} \qquad (1)$$

where p_{spec} - specific calculated electrical load; N_{app}- the number of apartments; p_{el}- Installed power of the electric motor of the elevator; n_{el} - number of elevators; K_d- coefficient of demand for lift load.

2. For the office center:

$$P_p = M * p \qquad (2)$$

where M - total area of premises; p- specific power of electrical equipment for $1m^2$.

Taking into account these expressions the value of the total load capacity is calculated, respectively, for a 9-storey 6-section residential building with gas stoves for 210 apartments; A 16-storey two-section residential building with electric stoves (with 2 elevators per section) for 126 apartments; 24-storeyed two-section residential dwelling house of high comfort with electric stoves (with 2 elevators per section) for 112 apartments(Eq.1), as well as a large office center with a total area of 10, 000 m^2 (Eq.2):

$P_{\max1}$ =210×0,86+0,9×0,65×6×7= 205,2 kW,

$P_{\max2}$ =126×1,96+0,9×0,65×2× (7+9)= 267,2kW,

$P_{\max3}$ =112×2,48+0,9×0,7×2×(7+9)= 298 kW ,

$P_{\max4}$ =10000×0,2=2000 kW.

Estimated reactive load:

$$Q_p = P_p * tg\,\varphi_{norm} \qquad (3)$$

Where $tg\varphi_{norm}$ - the normative factor of reactive power.

Q_{max1}=180,6×0,43+28,14×1,17=110,6 kVar,

Q_{max2}=247×0,4+18,7×1,17=120,7 kVar,

Q_{max3}=277,8×0,4+20,2×1,17=137,6 kVar,

Q_{max4}=2000×0,62=1240 kVar.

The average reactive power factor for a typical block with these typical buildings is: 0,58.

Consumption of such volume of reactive power leads to additional losses in the low voltage distribution network, which is an incentive for the application of compensation.

This is especially relevant for power supply built on intellectual principles, with the installation of smart meters with their capabilities to monitor consumption, quality of energy, and consumption management.

Our proposals for Micro Grid for household objects:

1. At the regulatory level, provide for distributed compensation of reactive power for each consumer by installing condenser batteries for compensation of reactive power, which will be managed by an information structure based on an intelligent counter.
2. To provide for the standard setting of condenser batteries in each surface switchboard for compensation of reactive power, which will be controlled by an information structure based on an intelligent counter.
3. The received resource of sources of the distributed generation of reactive power to transfer to the disposal of the distribution network operator for its use as a virtual source of reactive power.
4. In the era of the introduction of intelligent power supply, characterized by distributed generation, distributed accumulation and control of the work of electrical equipment, compensation of reactive power should be mainly based on the principle of distributed generation. Our proposals for Micro Grid for civilian objects:

Conclusion

In this paper the problems of consumption of reactive power by domestic consumers are considered. The calculation of reactive power consumption by typical buildings in the new residential quarter is calculated, and ways of solving the problem of unbalance of reactive power in distribution networks of domestic consumers are proposed, by installing condenser batteries and combining them into virtual reactive power plants.

References

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