ТЕХНІЧНІ НАУКИ

USE OF POWER TRANSFORMER WITH IMPROVED PERFORMANCE FOR RURAL ELECTRIC NETWORKS WITH ANYMMETRIC LOAD

Zeliankevich Aliaksandr,
Senior Lecturer,
("Belarusian State Agrarian Technical University", Minsk, Republic of Belarus)

The problem of providing consumers with electrical energy of proper quality becomes more and more urgent with an increase in electrical loads. This problem is especially acute in rural electrical networks, which is due to their large length and ramification, the connection of a large number of single-phase and non-linear loads.

The choice of means and methods to ensure the quality of electricity is a complex technical and economic task. In electrical installations of the agro-industrial complex, it is advisable to use devices that are relatively simple in design, reliable, relatively inexpensive, and easy to operate. One of these devices are power transformers with special winding connection schemes. For example, to increase the symmetry and sinusoidality of voltages at consumer transformer substations with a voltage of 10 / 0.4 kV, power transformers are used with a "star-zigzag with a neutral wire" winding connection scheme, with an 11th group of winding connections that cannot work in parallel with transformers brands TMG and TMGSU with winding connection schemes "star - star with a neutral wire" and "star - star with a neutral wire with a balun" having a zero group of connections. The use of a power transformer developed by the authors with a "star - double zigzag with a neutral wire" (Y / 2Zн) connection scheme with a zero group of winding connection allows to solve this problem. This power transformer is resistant to load-side influences that distort the voltage quality and is capable of providing a high level of symmetry and sinusoidal voltage, as well as parallel operation with commercially available transformers of the TMG and TMGSU brands.

The transformer consists of a magnetic system, high (HV) and low (LV) voltage windings with their insulation, tank and fittings. HV windings are located on the rods of a three-rod magnetic circuit and are connected according to the "star" scheme. Low voltage windings, consisting of three parts, which are placed on the rods of different phases and connected in series. In this case, one half of the phase secondary winding is located on the same rod of the three-rod magnetic circuit of the transformer as the primary winding of the same phase, and the other half, which consists of identical parts, is located on the other two rods of the three-rod magnetic circuit. The ratio of the number of turns in parts of the phase windings a1 / a2 / a3, b1 / b2 / b3, c1 / c2 / c3 is 0.5 / 0.25 / 0.25. The secondary voltage of the transformer will be equal to the vector sum of the voltages of the three parts of the secondary winding, which are located on different legs of the magnetic circuit of the transformer.

In no-load mode, the supply voltages cause currents to flow only through the phase windings of the primary side of the transformer. Since the transformer works with a saturated magnetic system, it is a nonlinear element of the electrical circuit, therefore the no-load currents will be non-sinusoidal, that is, they contain the highest even and odd harmonics, except for harmonics that are multiples of three, for which in the primary winding, connected according to the "star" without a neutral wire, there are no paths for their flow.

The reactive components of the no-load currents of the primary winding create an alternating magnetic field and phase magnetomotive forces (MMF). Phase MDS create the corresponding magnetic fluxes, the curves of which, due to the nonlinearity of the magnetic characteristics of the steel of the transformer, differ from the sinusoid and contain higher harmonics that are multiples of three, which are absent in the magnetizing current. The main magnetic fluxes of the first harmonic are closed along the path of the least magnetic resistance in the magnetic circuit. Magnetic fluxes caused by higher harmonics in multiples of three are forced to close from yoke to yoke through air and structural elements with significant reluctance. Therefore, they are small, they can be neglected and the magnetic fluxes created by magnetizing currents can be considered sinusoidal.

When a transformer operates with an unbalanced load, its phase voltages of the HV winding, which is connected according to the "star" scheme, may contain components of the direct, reverse and zero sequences. Since there are no paths for the zero sequence currents in the HV winding, they are equal to zero. The phase currents of the HV winding are equal to the vector sum of the positive and negative sequence components. The system of phase currents of the HV winding is balanced, and their vector sum is equal to zero. Phase voltages and currents of the LV winding of a power transformer connected according to the "double zigzag with a neutral wire" scheme may contain components of all sequences. The components of the positive and negative sequence of currents flow through the LV phase windings and are closed through the load of the transformer. Their vector sum at the neutral point of the HH side is equal to zero. The magnitude and direction of the secondary zero sequence currents are the same in all three phases. They create three times the current in the neutral wire, closing through the neutral conductor and the load. The MDS they create are also zero. Flowing through the parts of the LV phase windings, the zero sequence currents create in the halves of the windings a1, b1, c1 equal in magnitude and in the phase of the MDS, as well as in the quarters of the windings a2, b2, c2, a3, b3, c3 equal to each other MDS. In the halves of the phases of the LV windings a1, b1, c1 and the quarters a2, b2, c2, a3, b3, c3, located on each of the cores of the magnetic circuit, zero sequence currents flow in opposite directions, taking into account the direction of winding and marking of the winding terminals. In the rods of individual phases, the magnitudes of the zero-sequence MDS will be zero, i.e., they are compensated, the magnetic fluxes caused by them in the rods of the magnetic circuit will also be zero. The LV winding balances its own magnetizing forces of the zero sequence independently, while eliminating the additional magnetization of the magnetic core steel by them. EMF in the windings, which are created by zero sequence magnetic fluxes, will also be zero. The transformer will not create a zero sequence voltage in the mains supply. In the HV winding, the phase voltage asymmetry is due solely to the presence of negative sequence components. In the secondary winding, the zero sequence voltages will be caused exclusively by voltage drops across the phase resistances from the corresponding currents. The inductive resistances of parts of the windings to zero sequence currents are largely mutually compensated, since on each of the cores of the magnetic circuit, half a1, b1, c1 of the secondary phase windings are wound counter to the quarters a2, b2, c2, a3, b3, c3 and the active component of the resistances prevails.

Conclusion. A three-phase power transformer with a star-double zigzag with a neutral wire winding connection scheme has a zero connection group, which allows it to be connected in parallel with widespread star-star transformers with a neutral wire in order to increase the load capacity of electrical networks and the quality of electricity. The magnitude of the resulting magnetic field of the transformer and the EMF generated by it in the windings does not depend on the magnitude of the load. The voltage imbalance of the transformer is caused by the presence of positive and negative sequence components, which are converted from the secondary to the primary side, and vice versa. The decrease in voltage unbalance is due to the compensation of the zero sequence components. Minor voltage drops are caused by zero sequence currents on the active resistances of the LV winding phases.

The use of this power transformer with improved characteristics will ensure a high level of symmetry and sinusoidal voltage in rural electrical networks, as well as parallel operation with commercially available transformers, which will reduce losses, increase the service life and efficiency of electrical equipment, and increase the reliability of power supply.