Providing The Quality Of Electric Power By Means Of Regulating Customers' Voltage

Dmitry A. Klavsuts
Graduate student of the Novosibirsk State Technical University, Russia
dklavsuts@gmail.com

Irina L. Klavsuts
PhD in engineering, Associate Professor of Management of the Novosibirsk State Technical University, Russia
ira.klavsuts@gmail.com

Tatiana V. Avdeenko –
DSc in engineering, Professor, Head of Economical Informatics Department of the Novosibirsk State Technical University, Russia
tavdeenko@mail.ru

***Abstract*- The report presents innovative patented method and device of DSM for regulating customers' voltage which allow, to a considerable degree, to normalize electric power parameters for customers and also to control the quality of consumed energy and to economize electric power in electric networks of both high and low levels of voltage.**

***Index Terms*--Power Quality, Voltage Regulation, Innovative Technology, Demand Side Management, Energy Efficiency.**

I. INTRODUCTION

In the world there are standards for the quality of electric power, for example, Standard EN 50160 [1]. Voltage is a most important parameter and it takes the first place in the Standard. If the standards are not met, then it is impossible to guarantee normal work of the equipment connected to the electric grid. In fact, it is quite difficult to meet the standard, as the commutation of customers occurs in an arbitrary way. Generally, the above said refers to grids of 0,4 kV, as more than 65% of all customers are powered from these grids.

There is presented an innovative method and device of demand side management which can be used to power electrical equipment of industrial enterprises, lighting networks, communication systems, automation and remote control, residential and public buildings in order to control the quality of electricity optimization of consumption and conservation of electric power [3, 4, 5, 6].

The essence of the method [3, 4, 5, 6, 7, 8, 9, 10] is in the use of a voltage regulating transformer which capacitance is much less than that of the load. The winding of low voltage (LV) of this transformer switches into the grid phase in chain with the load. The winding of high voltage (HV) switches into the regulating grid. According to Kirchhoff's second law, load voltage is equal to the vector sum of grid voltage and EMF, induced by the winding of high voltage in the winding of low voltage of the above mentioned transformer. Accordingly, load voltage, current and capacitance of the load and in the grid change.

The innovative technology of DSM for regulating customers' voltage [2, 6, 7, 8, 9] is successfully introduced in hundreds of enterprises, in residential and public buildings.

II. THE BASE SCHEME OF DEVICE OF DSM FOR REGULATING CUSTOMERS' VOLTAGE

The base scheme of the device of regulating consumers' customers is represented in Fig.1.

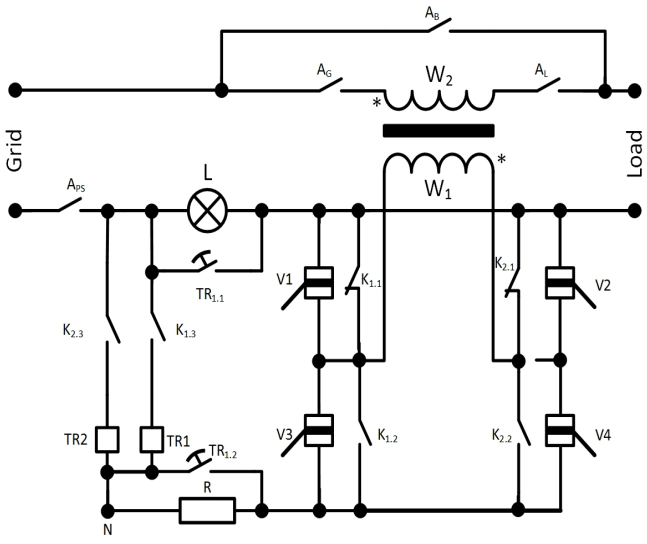


Fig. 1. The base scheme of a regulator of voltage with the device for regulating customers'voltage

The winding of high voltage (HW) W_1 of the regulating transformer is included into the bridge diagonal consisting of consequently connected normally closed $K_{1.1}$ and normally open $K_{2.2}$-, contacts of contactors K1 and K2, control circuit of which is not shown in Fig.1. The power supply of the winding W_1 is applied on the second bridge diagonal through the above mentioned contacts. The power supply of the circuit is carried out from the network phase, through automatic protection switch A_{PS}, shunt L and from a neutral conductor of the network through shunt limiting resistor R.

The control diagram is realized in the following way. Normally open contacts $K_{2.3}$ and $K_{1.3}$ of contactors K1 and K2 are commuted with the phase through automatic protection switch A_{PS}, and from response outputs of the contacts $K_{2.3}$ and $K_{1.3}$ power supply is applied to the coils of

time relays TR2 and TR1 accordingly. The second outputs of time relay coils are switched to the network zero.

Contact $TR_{1.1}$ with time delay for bridging, that belongs to the time relay TR1, shunts L. Contact $TR_{2.1}$ with time delay for bridging, that belongs to the time relay TR2, shunts R.

The power part of the diagram contains the winding of low voltage (LV) W_2 of the regulating transformer,
automatic switch "grid" – A_G, automatic switch "load" – A_L и automatic switch "bypass" – A_B.

The diagram works in the following way:

For a selected phase, the operation mode depends on which of the phases of the grid is applied to the control system in reference to the load phase.

1. Mode "Norm"

The winding of high voltage (HV) W_1 of the transformer is short-circuited by normally closed contacts $K_{1.1}$ and $K_{2.1}$ of contactors K1 and K2 accordingly.

The voltage of the grid is equal to the voltage of the load. 1

2. Mode "Bounded above".

The control system which is not shown in the picture contains contactor K1, with that its normally closed contact $K_{1.1}$ uncloses, and normally open contact $K_{1.2}$ closes. The circuital current goes from the grid phase through automatic protection switch A_{PS}, L, normally closed contact $K_{2.1}$ of contactor K2, the winding of high voltage (HV) W_1 of the transformer, through the closed normally open contact $K_{1.2}$ of contactor K1, the limiting resistor R, connected to a zero point of the grid N.

As a result of the closure of the normally open contact $K_{1.3}$, the phase thorough automatic protection switch A_{PS}, is applied to the coils of the time relay TR2 and TR1, which begin counting the time delay of shunting L and R.

The polarity of the windings of the regulating transformer is shown in the diagram. With the given polarity the load voltage will be equal to the difference of the phase voltage of the grid and EMF, induced by the winding of high voltage (HV) W_1 in the winding of low voltage (LV) W_2 of the transformer.

3. Mode "Base limiting".

The control diagram includes contactor K2, further the scheme works similarly to what is described in Item 2 *"Bounded above"* with the only exception that to TR2 and TR 1 the phase is applied through automatic protection switch A_{PS} and closed normally open contact $K_{2.3}$, and the polarity of the winding of high voltage (HV) W_1 is reversed, and the load voltage will be equal to the sum of the phase voltage of the grid and EMF, induced by the winding of high voltage (HV) W1 in the winding of low voltage (LV) W_2 of the transformer.

To do away with commutation overloads there were used varistors V1, V3 and V2, V4, switched accordingly, parallel to contacts $K_{1.1}$, $K_{1.2}$, belonging to contactors K1 and $K_{2.1}$, $K_{2.2}$, belonging to contactor K2 commuting the winding of high voltage (HV) W_1 of the transformer.

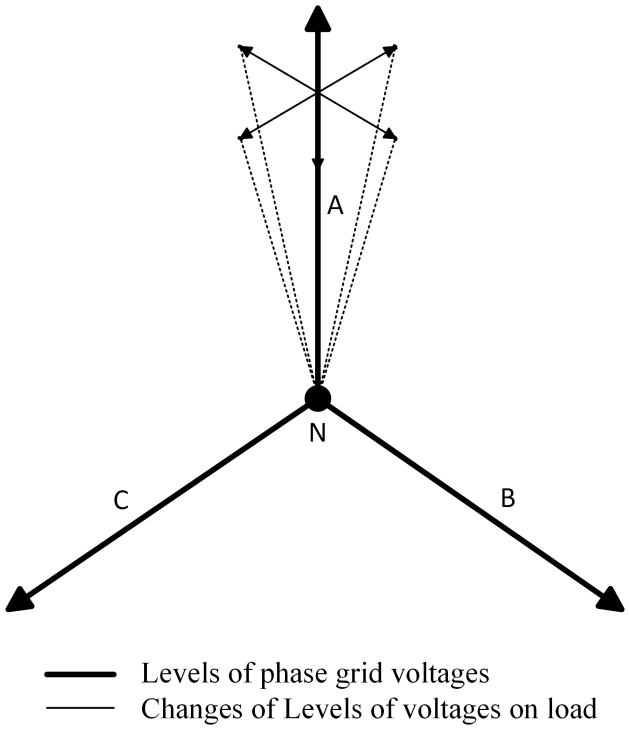
The work of power part.

Automatic switch A_G, automatic switch A_L perform protection and commutation functions for the device and the load accordingly. Automatic switch A_B serves for putting the device in the state "bypass".

Thus, the essence of the use of the device for regulating consumers' voltage is as follows: the winding of low voltage W_2 of the transformer is switched in series with the load into one of the grid phases. The winding of high voltage W_1 of the same transformer is switched with different polarity between the point N and one of the phases A, B, C of this grid or short-circuited with switching off the grid. Due to angle shift on phases of voltage vectors on the windings of high voltage and low voltage we get the points, shown on the vector diagram, corresponding to voltage on the load (Fig. 2).

Fig. 2. Vector diagram of grid voltages and regulation of output voltages on load with the use of the device of DSM for regulating customers' voltage

Thus, we have n steps of the regulator of voltage, using one transformer in the phase and one set of regulating and commutation facilities.



With the corresponding switch of diagram elements and the choice of parameters of components there can be used both phase and linear voltage of three-phase grid of 0,4 kV.

III. TECHNICAL ESSENCE OF THE PROCESS OF REGULATING CUSTOMERS' VOLTAGE WITH THE USE OF INNOVATIVE METHOD AND DEVICE OF DSM

Let's consider an example of regulating customers' voltage with the use of the innovative method and device of DSM, developed and produced by the scientific industrial enterprise LLC "AVEC" (Novosibirsk, RF) under the trademark NORMEL™®© [11].

As it is known, the capacitance of the transformer is equal to the product of load current and winding voltage of low voltage (LV) of the transformer. Due to the use of the patented electrical circuit solution [3, 4, 5, 6], the capacitance of the transformer is K times less than the load capacitance, where K is the coefficient of transformation. In serial production of the given device of DSM with the nominal capacitance of 55 kWA, there are used single-phase dry transformers with nominal capacitance 1 kWA, voltage

230/13 V, which coefficient of transformation (K) is equal accordingly to:

$$K = 230 /13 = 17.7 \quad (1)$$

Therefore, the capacitance of the load connected through this transformer, can reach 17.7 kWA.

According to data in the technical specification of the produced innovative device of DSM, the efficiency coefficient of transformers is 97.8%. Thus, 2.2% of the transformer capacitance is "lost" inside itself at its nominal load.

Because in the considered case load capacitance is 17.7 kWA, then, accordingly, 2.2 % from 17.7 kWA make 39 VA.

Then, relating to the load in per cent the losses in the device will make (39 · 100) / 17 700 = 0.22 %.

Thus, the efficiency coefficient of the presented innovative device of DSM will make: 100% – 0.22% = 99.78 %

We do not know any other devices for regulating customers' voltage with such an efficiency coefficient.

We should highlight the two main distinctions of the presented method and device o**f** DSM for regulating (normalizing) customers' voltage from other commonly known methods and devices of stabilization.

The first distinction from stabilizing devices, that maintain voltage level within the bounds of pre-set values, lies in the fact that the innovative device of DSM, called by us "normalizer", keeps output voltages, in the framework of the operational range, according to the Standard, 230 V ± 5-10%.

The second distinctive peculiarity of the normalization scheme is the regulation of output parameters of the grid by using differently directed moving forces in thick windings of low voltage (LV) of transformers, integrated into phase chains, from the side of thin windings of high voltage (HV), through changing their polarity.

The implemented method and device of DSM for regulating customers' voltage give a number of advantages.

1) Regulation of customers' voltage occurs without disconnection of supply network, which removes problems connected with power commutations and corresponding transient processes as well as power interruption.
2) Due to the use of the patented scheme solution 95% of the capacitance is transferred by electric way and only 5% by electromagnetic. As a result, transformers are used which capacitance does not exceed 5% from the nominal capacitance of the normalizer. All this is done in a single phase way and automatically. It has a positive effect on cost, mass and size parameters of the equipment.
3) The absence of power commutation elements in the scheme of the innovative device of DSM (normalizer) creates conditions for its lasting and reliable work.

From the above said it is clear that the use of the patented method and device for regulating customers' voltage within the range of the standard requirements provides not only a normal work of customers' equipment, but also leads to the reduction of consumed capacitance and losses in the network, as the effect from the use of the method can be seen both on the low and high sides of the network, including the source, that is the power station.

IV. Conclusions

The experience of introducing innovative technology for regulating customers' voltage showed that it is possible to solve several global technical problems at once, namely:

1) the mass use of the method and device of DSM allows in practice to come closer to meeting the standard for quality of consumed electric energy, as the pre-set voltage level is maintained automatically;

2) at the heightened level of voltage there is achieved the reduction of electrical capacitance on average by 10-15% with normal work of equipment;

3) the service life of equipment, including household and lighting equipment increases due to the favorable mode of their electric supply;

4) with mass use of the method and device of DSM the stability of work of synchronous generators at power stations increases, that is their stability against short circuits, variations of voltages, other transient states, and thus stability and reliability of energy system on the whole due to the reduction of consumed capacitance;

5) losses in the network are reduced not less than by 10 %, if the voltage reduces by 12 V, due to which they increase a possibility to switch additional capacitances to electric power system up to 10%, or the period of reconstruction works in electric chains considerably increases;

6) the use of the device gives the possibility to control the consumption of electric energy at the level of 0.4 kV from the control centre.

The mass use of the device in perspective allows to consider a question of reasonability of changing the conception of customers' power supply, namely:

- to produce and transfer electric energy at the highest voltage, permitted by the Standard;
- to consume electric power at the lowest possible voltage, permitted by the Standard.

It will exclude systems with SWE (switch without excitement) on supply transformers of distribution sub-stations of 10\0.4 kV or 6\0,4 kV.

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