Development and Research Power-Supply System Model with TCT UCS

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Problem of upgrading the power quality for household consumers electricity has been considered. It was recommended to use the noncontact thyristor controlled transformer with unidirectional current switches. We conducted a set of calculating the power supply system parameters. This allowed to perform of power supply system elements model tests and to create electric power distribution system simulation model in the program Matlab (Simulink). We conducted research of received model and completed the analysis of modeling results.
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Keywords: power-supply system, power distribution system, TCT UCS, simulation model, voltage regulation.

Introduction

Meeting the challenges to improve the power quality in the 0,4 kV network and its economy is closely linked to the regulation of the AC voltage on the side of 10 (6) kV transformer substations (TS). Today Russia is in operation about 500 000 TS voltage 6-10/0,4 kV. At these power transformers TS are not the automatic voltage regulation. Voltage regulation of 0,4 kV on the TP 10/0,4 kV is performed by off-circuit tap changing twice a year (seasonal regulation), provided of the disconnection transformer.

The required level of voltage of 0,4 kV tap devices at the industrial enterprises (IE) is supported on the main step-down substation (MSDS) with the help of load tap changing, as well as with special boosting transformers and other means of voltage regulation. However, most household consumers do not receive electricity at a voltage of 380V required quality, because of voltage deviation exceeds the limits as normally allowed, and the maximum allowable values. The result are:

- low illumination, affecting the deterioration of school children, students, knowledge workers and the population of Russia as a whole;
- failure of expensive electrical equipment, household appliances, etc.

In order for a decision this problem in power-supply system of consumers are encouraged to apply the noncontact thyristor controlled transformers with unidirectional current switches (TCT UCS), through which at times is supported desired voltage level by household consumers.

Materials and methods

Today Nizhny Novgorod State Technical University scientists working on a prototype TCT UCS 10/0,4 kV 400 kV·A [1].

The main functions of the TCT UCS are:

- automatic voltage regulation without turning off the network;
- voltage balancing of 0,4 kV consumers;
- value and power flow direction regulation on the side of 10 kV in the presence of energy sources that are connected to 0,4 kV buses;
- limitation switching current loads and short-circuit current on the side of 0,4 kV.

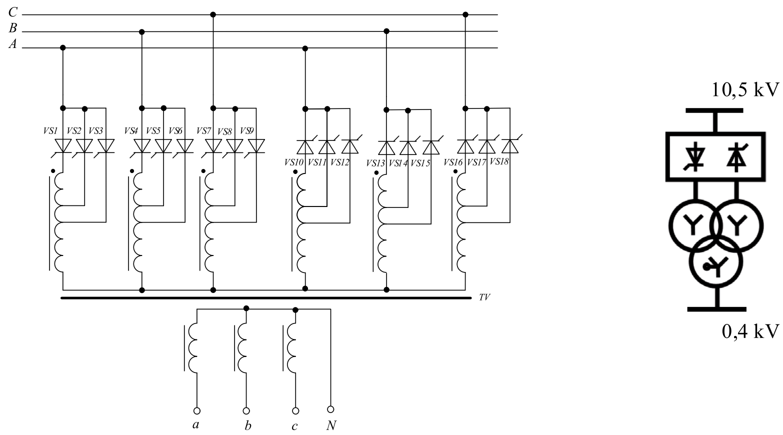
As the TCT UCS dry transformer acts as a closed type with a split primary winding. The main technical parameters of the TCT UCS are: transformer nominal capacity; nominal voltage of high voltage winding ; nominal voltage of low voltage winding; no-load losses; short-circuit losses; no-load current; Y/Yn – connection windings.

To investigate the influence TCT UCS the work of electrical receivers, and vice versa tasked with developing a power-supply system (PSS) simulation model with the power of consumers from the TCT UCS.

The basis adopted a industrial PSS as electric loads, characterized by a variety of electrical receivers with different modes of operation [2].

Modeling environment is an application program Matlab (Simulink). In Simulink it is possible to model a wide range of ready-made electrical devices.

The initial data for modeling industrial PSS are the type, quantity, type of operation, 0,4 and 10 kV receivers nominal



a) b)

Fig. 1. The schematic a) and single-line b) diagram of the TCT UCS

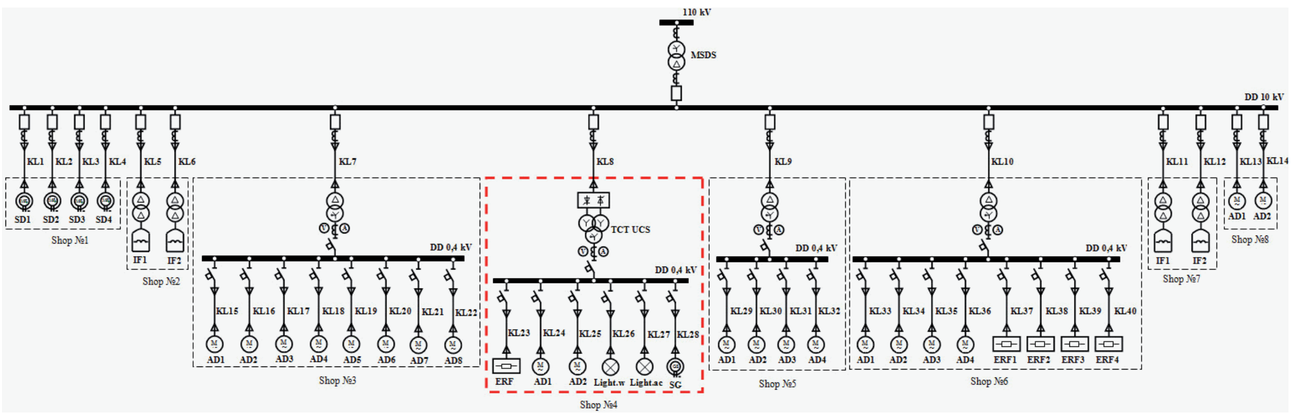


Fig. 2. The single-line diagram industry electricity with TCT UCS

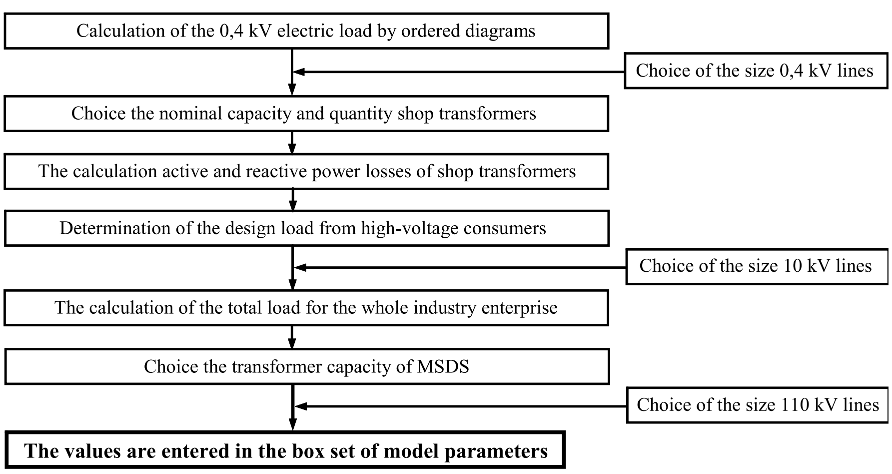


Fig. 3. The procedure for calculating electrical loads and choosing elements of industry PSS

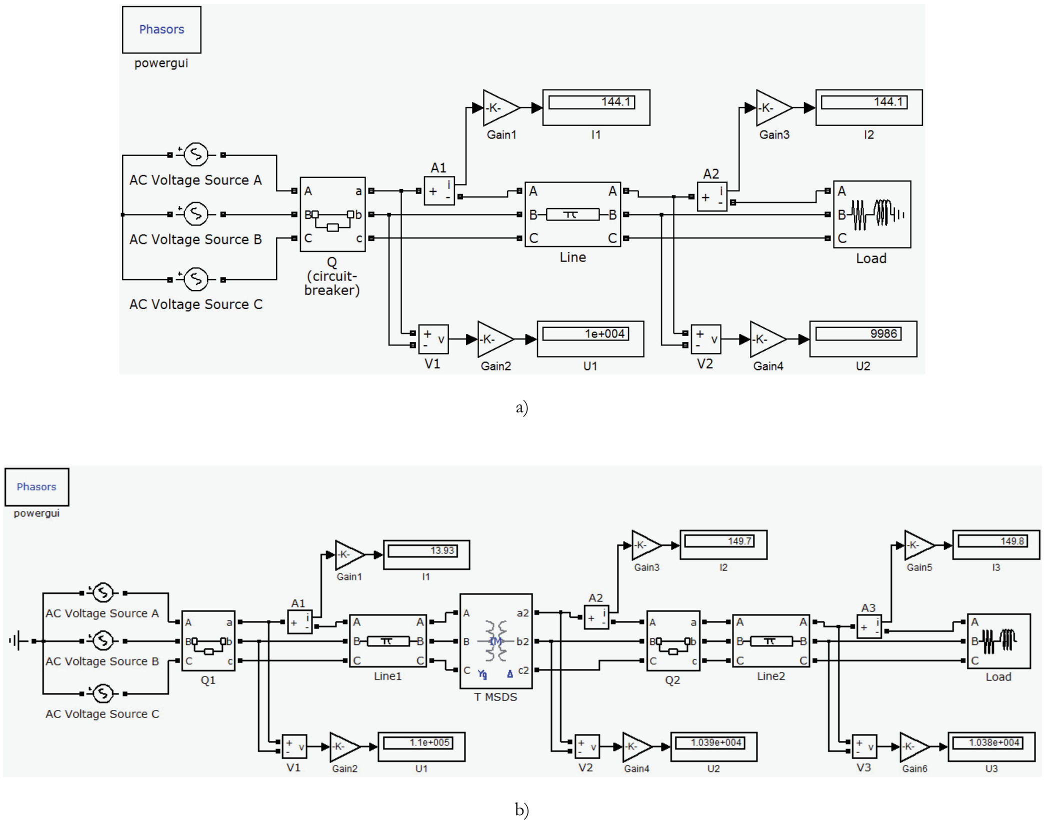


Fig. 4. Modeling of electric power line a) and power transformer b)

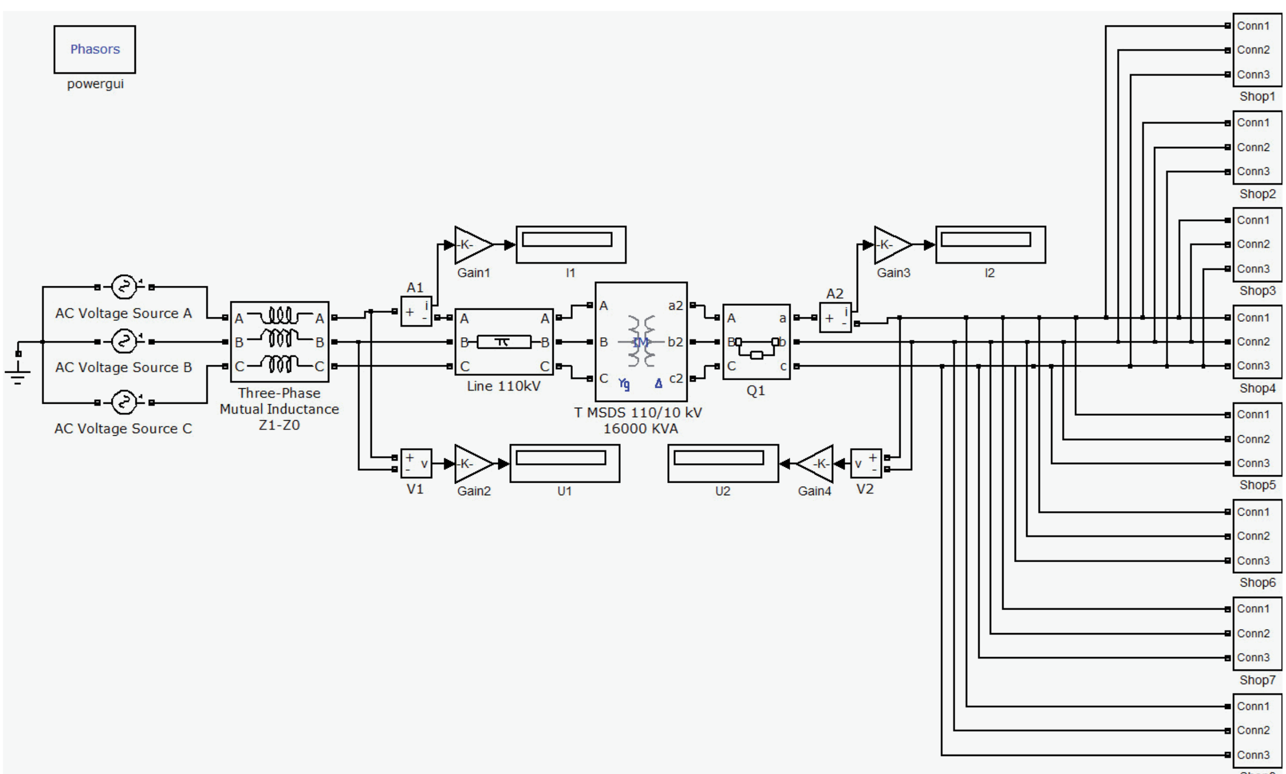


Fig. 5. The industry PSS simulation model

power and electric power line length. On the power-supply diagram the shop with TCT UCS is shown dot line.

On the basis of the calculation of 0,4 and 10 kV electrical loads are selected elements of the PSS: power transformers 10/0,4 kV, distribution network size, transformer MSDS 110/10 kV. Sequence choice of PSS elements is shown on the figure 3.

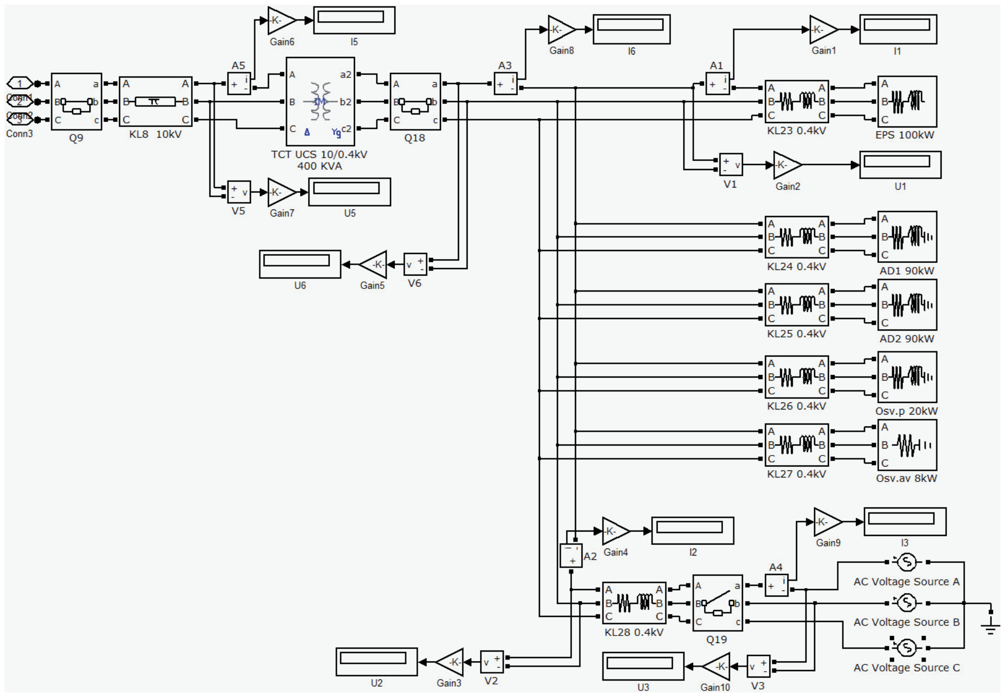


Fig. 6. Masked model shop number 4 of the IE

Tab. 1. The results of research (variant 1)

$К_т = \frac{U_{hv}}{U_{lv}}$	Parameters	Tires of the MSDS 10 kV	The load of 10 kV	Tires of the TS 0,4 kV	The load of 0,4 kV	Source 0,4 кV
28,75=10 %	I, A/U, V	851,9/9647	61,75/9642	393,3/327,3	123,2/327,3	Off
28,5=9%	I, A/U, V	852,2/9647	61,75/9642	396,9/330,3	124,3/330,3	Off
28,25=8%	I, A/U, V	852,4/9646	61,75/9642	400,6/333,4	125,5/333,4	Off
28=7%	I, A/U, V	852,7/9646	61,75/9642	404,4/336,5	126,7/336,5	Off
27,75=6%	I, A/U, V	852,9/9646	61,75/9641	408,2/339,6	127,8/339,6	Off
27,5=5%	I, A/U, V	853,2/9646	61,75/9641	412/342,9	129/342,9	Off
27,25=4%	I, A/U, V	853,5/9646	61,74/9641	416/346,2	130,3/346,2	Off
27=3%	I, A/U, V	853,7/9645	61,74/9641	420/349,4	131,5/349,4	Off
26,75=2%	I, A/U, V	854/9645	61,74/9640	423,9/352,7	132,8/352,7	Off
26,5=1%	I, A/U, V	854,3/9645	61,74/9640	428,2/356,3	134,1/356,3	Off
26,25=0%	I, A/U, V	854,6/9645	61,74/9640	432,6/359,9	135,5/359,9	Off
26=-1%	I, A/U, V	854,9/9644	61,74/9640	436,9/363,6	136,8/363,6	Off
25,75=-2%	I, A/U, V	855,2/9644	61,73/9639	441,3/367,2	138,2/367,2	Off
25,5=-3%	I, A/U, V	855,5/9644	61,73/9639	445,9/370,9	139,6/370,9	Off
25,25=-4%	I, A/U, V	855,9/9644	61,73/9639	450,5/374,8	141,1/374,8	Off
25=-5%	I, A/U, V	856,2/9643	61,73/9638	455,3/378,9	142,6/378,9	Off
24,75=-6%	I, A/U, V	856,6/9643	61,73/9638	460,1/382,9	144,1/382,9	Off
24,5=-7%	I, A/U, V	856,9/9643	61,72/9638	464,9/386,9	145,6/386,9	Off
24,25=-8%	I, A/U, V	857,3/9642	61,72/9638	470/391,1	147,2/391,1	Off
24=-9%	I, A/U, V	857,7/9642	61,72/9637	475,1/395,3	148,8/395,3	Off
23,75=-10%	I, A/U, V	858,1/9642	61,72/9637	480,4/399,8	150,5/399,8	Off

Industry PSS modeling is reduced to construct models of the two main network elements: electric power line and power transformer (figure 4).

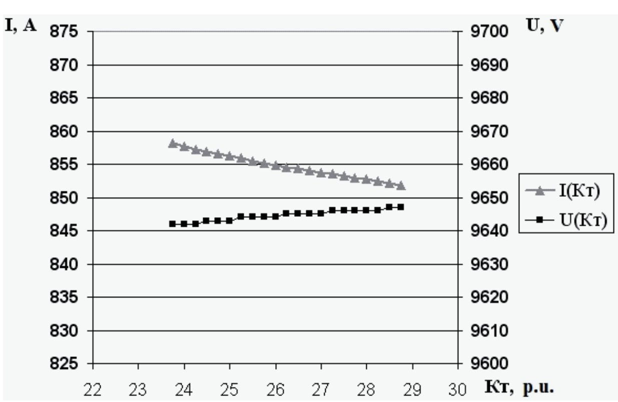
When modeling these elements relative error of current and voltage do not exceed the accuracy of engineering calculations (not more than 5%), indicating that the adequacy of the obtained models the main elements of the PSS.

When building a model of PSS used the principle of structural modeling based on the modeling of individual blocks and the subsequent synthesis of the entire system. The industry PSS simulation model is shown on the figure 5. The model was applied masking function (for blocks allocated by the dashed frame) in order to obtain a more compact circuits.

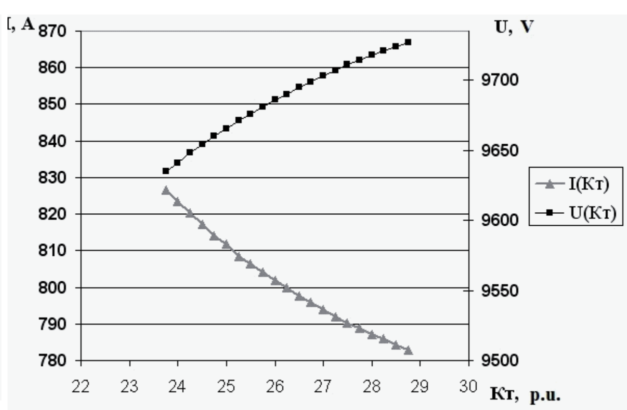
The model of one of the IE shops, which has been used masking function is shown on the figure 6. This shop is set on TCT UCS. This device regulates voltage by means of changing step-down ratio. The regulation takes place in high-voltage windings. In view of the synchronous generator on the tires of 0,4 kV, we can work out voltage regulation range which TCT UCS has. The measurements were made on 10 kV bus sections of the MSDS, on 0.4 kV TS buses as well as on high and low voltage equipment.

Tab. 2. The results of research (variant 2)

$K_T=\frac{U_{hv}}{U_{lv}}$	Parameters	Tires of the MSDS 10 kV	The load of 10 kV	Tires of the TS 0,4 kV	The load of 0,4 kV	Source 0,4 кV
28,75=10 %	I, A/U, V	782,7/9727	62,27/9723	1846/389,8	146,7/389,8	On
28,5=9%	I, A/U, V	784,3/9724	62,25/9720	1774/389,8	146,7/389,8	On
28,25=8%	I, A/U, V	785,9/9721	62,23/9716	1699/390,1	146,8/390,1	On
28=7%	I, A/U, V	787,2/9718	62,21/9714	1626/390,4	146,9/390,4	On
27,75=6%	I, A/U, V	788,8/9714	62,18/9710	1565/390,5	146,9/390,5	On
27,5=5%	I, A/U, V	790,2/9711	62,16/9707	1491/390,6	147/390,6	On
27,25=4%	I, A/U, V	792/9707	62,14/9702	1423/390,8	147/390,8	On
27=3%	I, A/U, V	794/9703	62,11/9698	1343/391,1	147,1/391,1	On
26,75=2%	I, A/U, V	796/9699	62,08/9694	1277/391,2	147,2/391,2	On
26,5=1%	I, A/U, V	797,6/9695	62,06/9690	1214/391,3	147,2/391,3	On
26,25=0%	I, A/U, V	800/9690	62,03/9685	1148/391,4	147,3/391,4	On
26=-1%	I, A/U, V	802/9686	62/9681	1084/391,4	147,4/391,4	On
25,75=-2%	I, A/U, V	804,2/9681	61,97/9676	1032/391,8	147,4/391,8	On
25,5=-3%	I, A/U, V	806,5/9676	61,94/9671	982,5/392,1	147,5/392,1	On
25,25=-4%	I, A/U, V	808,5/9671	61,91/9666	935,6/392,3	147,6/392,3	On
25=-5%	I, A/U, V	811,7/9665	61,87/9661	910,6/392,3	147,6/392,3	On
24,75=-6%	I, A/U, V	814,2/9660	61,84/9656	890,2/392,4	147,7/392,4	On
24,5=-7%	I, A/U, V	817,2/9654	61,8/9649	875,1/392,5	147,8/392,5	On
24,25=-8%	I, A/U, V	820,2/9648	61,76/9643	884,5/392,9	147,9/392,9	On
24=-9%	I, A/U, V	823,5/9641	61,72/9637	899,1/393	148/393	On
23,75=-10%	I, A/U, V	826,6/9635	61,68/9630	931/393,2	148,1/393,2	On



a)

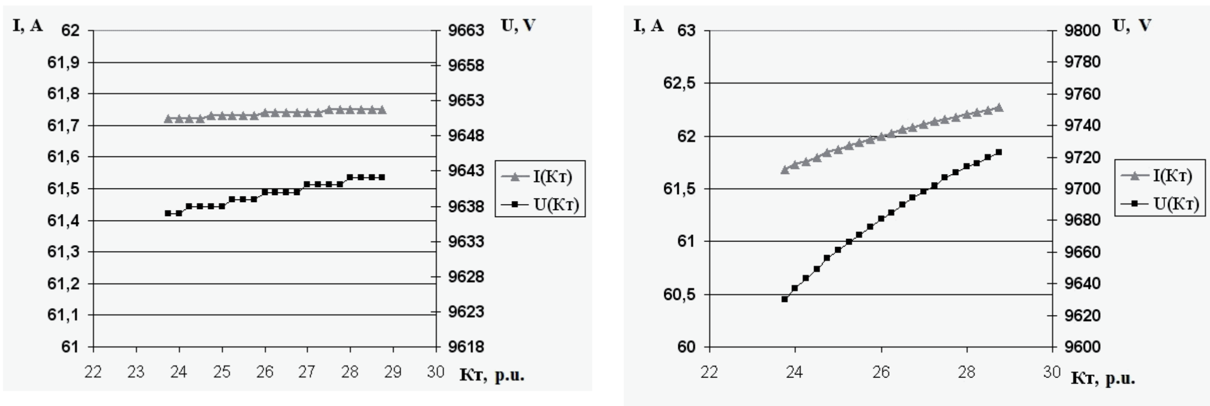


b)

Fig. 7. The current and voltage dependence of: on 10 kV bus sections of the MSDS on step-down ratio if the load supply from the general industrial network a) and parallel operation of sources b)

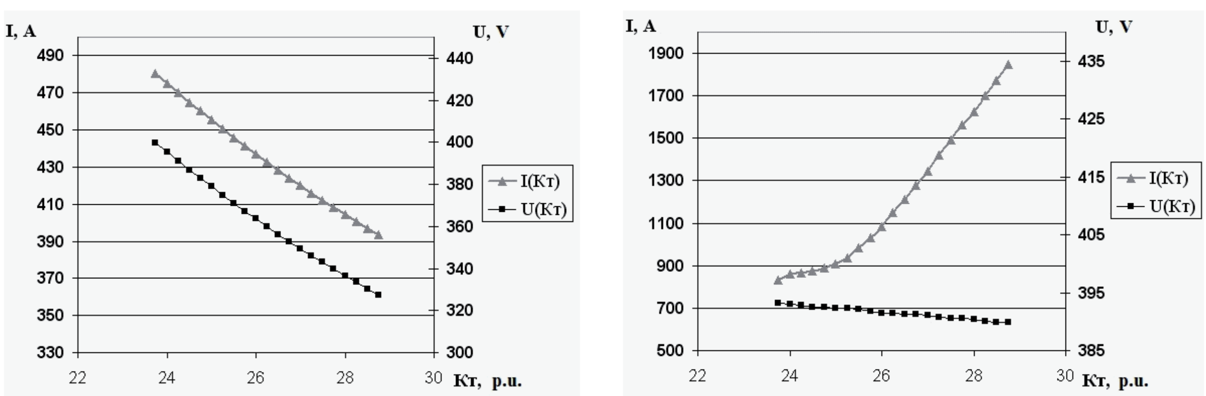
We have chosen voltage regulation range ± 10% of nominal voltage with increments of 1%. We had two types of research: with 0,4 kV generator out of work; with generator in work.

The analysis of the results obtained shows that if the generator is off, 0,4 kV consumers voltage deviation falls outside the permitted values. As a result voltage regulation from -1% to -9% of the nominal voltage is necessary (table 1).



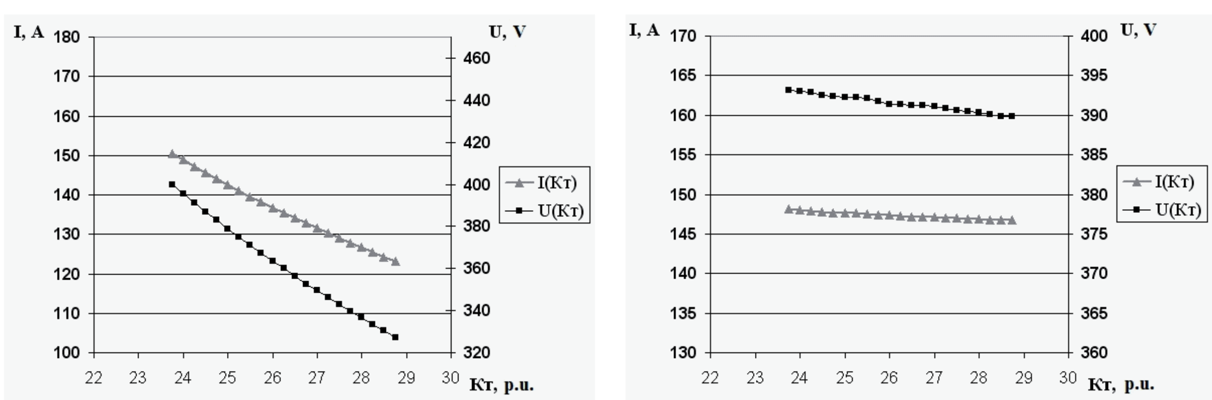
a) b)

Fig. 8. The current and voltage dependence of: on 10 kV consumers on step-down ratio if the load supply from the general industrial network a) and parallel operation of sources b)



a) b)

Fig. 9. The current and voltage dependence of: on 0,4 kV TS buses on step-down ratio if the load supply from the general industrial network a) and parallel operation of sources b)



a) b)

Fig. 10. The current and voltage dependence of: on 0,4 kV consumers on step-down if the load supply from the general industrial network a) and parallel operation of sources b)

If generator operation is parallel, voltage deviation both of low and high voltage receivers falls within the permitted range. In this case the range for voltage regulation is ±10% of the nominal voltage (table 2). Therefore in case of operation in parallel wide voltage regulation is provided both for low and high voltage consumers.

Thus it is clear that the voltage regulation to within ± 10% of the nominal voltage, consumers voltage deviation falls outside the permitted values if the load supply from two sources. If the load supply from the general industrial network, the allowable voltage regulation range is decrease significantly.

Results and Discussion

It was developed electric power distribution system simulation model with the power of consumers and conducted investigations of this model, namely we work out the allowable voltage regulation range by means of TCT UCS. The analysis of the results obtained shows that in case of the general industrial network and 0,4 kV generator working simultaneously wide voltage regulation is provided both for low and high voltage consumers.

The simulation results showed, that the experimental and theoretical current and voltage values of PSS elements do not exceed the accuracy of engineering calculations (5%), indicating that the adequacy of the developed model.

Conclusion

The industry PSS simulation model allows you to:

1) investigate the operating modes of TCT UCS in the PSS;
2) investigate the influence of TCT UCS the work of electrical receivers and PSS as a whole;
3) investigate the influence of electrical receivers to work of TCT UCS;
4) investigate the normal and emergency operating modes of electric networks, as well as conduct a number of other studies.

References

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