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# ANALYSIS OF THE STATCOM DEVICE DURING MAINS VOLTAGE FLUCTUATIONS IN THE MATLAB/SIMULINK ENVIRONMENT

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**ABSTRACT**
*The use of the «Static synchronous compensator (STATCOM)» device in electrical power systems for effective control of their operating modes is considered. An analysis of the STATCOM device with voltage fluctuations from the system is provided. STATCOM simulation was performed in the MATLAB/Simulink environment, and the results of simulations of its operation are presented.*
**KEY WORDS:** *STATCOM, modeling, voltage stabilization, reactive power, voltage regulation*

## I.INTRODUCTION

Over the last few years, power grids in United Power System of Central Asia (UPS CA) have been significantly strengthened and generating capacities have increased up to 18 GW. At the same time, the electrical regime in the association is carried out in conditions not always allowing to provide the necessary regime parameters. There are still problems with the capacity of several cross-sections between power systems, the output of individual power plants, and the provision of the necessary reserve capacity due to the large-scale introduction of Solar and wind power plants. To solve the problems arising in ensuring reliable and quality power supply, the UPS CA carries out works on improvement of methods and means of control of electric modes of the power system based on FACTS technology application. There is a large family of FACTS devices. TCSC, SSSC and UPFC devices are used for voltage maintenance, TCSC, SSSC devices are used for power system stability maintenance. In this article, the FACTS device of STATCOM type is considered for application in UPS CA.

Disturbances in a network with nonlinear characteristics necessitate the use of special devices to ensure the normative values of electricity quality parameters, since reactive power consumed from the network, voltage fluctuations, voltage distortions, voltage imbalance, etc. have a negative impact on the network and the reliability of power supply to consumer equipment. One of the most common devices for solving this problem is a STATCOM – a device based on a static converter capable of statically compensating reactive power, the capacitive or inductive output current of which can vary regardless of the mains voltage. STATCOM regulates reactive power within wide limits (± 100%), is connected via a transformer parallel to the line in the network node, is used to regulate voltage; compensate for reactive power; consume active power from one phase and output it to another, smoothes fluctuations in energy systems at high speed. The physics of the processes occurring in STATCOM is demonstrated using vector diagrams in [1-5]. Advantages of using STATCOM: versatility; when the system is started, there is minimal impact on the network; reactive power compensation occurs in a large range; adjustable in the capacitive and inductive range; high response speed of the control system; minimal dimensions compared with analogues; high efficiency; high reliability with automatic shunting of a damaged serial module. The main disadvantage of the device is the high cost [5-9].

## II.RESEARCH METHODS AND THE RECEIVED RESULTS

The analysis of the operation of the STATCOM device was carried out on a model implemented in the Simulink application of the Simscape library of the MATLAB software package. The main condition is the impact on the network through a power source that simulates the high side of the voltage of the electrical system. The network in question consists of a power supply, power transmission lines, a measuring device, two loads and a STATCOM device (see Fig. 1).
Active elements of the model:

- The "Three-Phase Voltage Source" block, which changes the value of the output voltage amplitude at certain points in time;
- STATCOM unit, voltage regulation, reactive power compensation, smoothing of fluctuations in energy systems at high speed.

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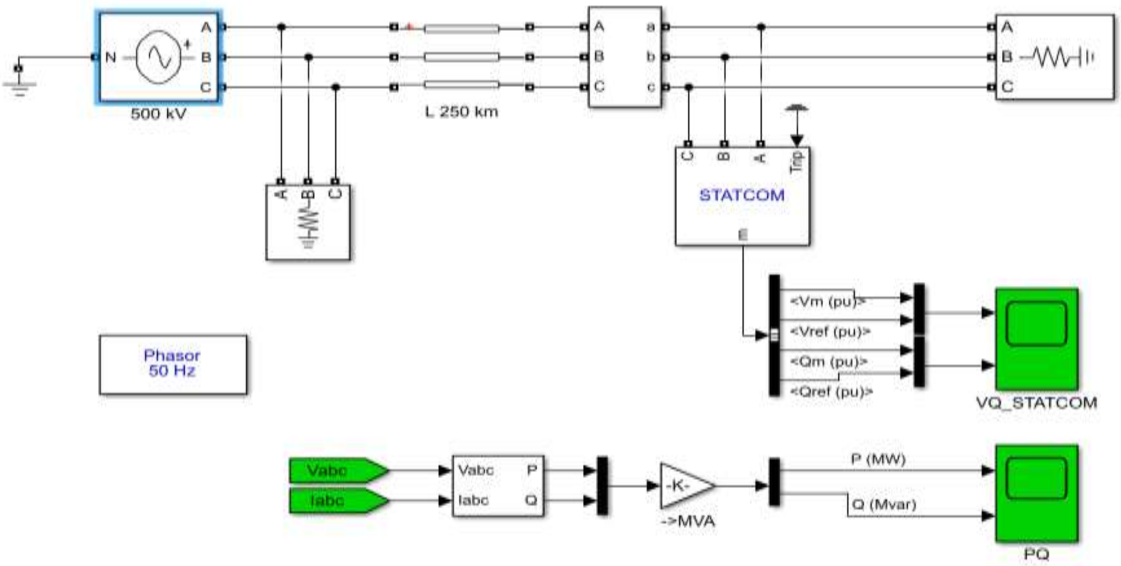


**Fig. 1. Model diagram in MATLAB/Simulink environment**

The main condition of the simulation is the analysis of the reactions of the STATCOM device during voltage fluctuations in the network through reactive power compensation in the interval of 1.5 seconds. The source sets the disturbance in time intervals [0 0.3 0.7 0.9] in seconds, the voltage fluctuation [1 1.1 0.9 1] in relative units of the voltage amplitude of 500 kV. Table 1 shows the main parameters of the blocks.

In case of voltage fluctuations in the network, STATCOM regulates the voltage at the connection point:

- When the mains voltage drops, STATCOM starts generating reactive power to maintain the voltage at the required level;
- If the mains voltage rises, STATCOM starts absorbing reactive power to reduce the voltage.

STATCOM constantly monitors the voltage at the connection point and adjusts the output reactive power to maintain the voltage at a set level. This allows you to smooth out voltage fluctuations in the network. In the settings of the STATCOM block, you can change its parameters, thereby setting reference values for its output signals [9-15].

**Table 1. Main parameters of the source and loads**

| | Block name | Block type | Bus type | Bus ID | $V_{base}$ (kV) | $V_{ref}$ (pu) | $V_{angle}$ (deg) | P(MW) | Q(Mvar) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | Three-Phase Series RLC Load1 | RLC Load | Z | 1 | 500 | 1 | 0 | 150 | 0 |
| **2** | Three-Phase programmable Source (500kV) | | swing | 1 | 500 | 1 | 0 | 0 | 0 |
| **3** | Three-Phase Series RLC Load2 | RLC Load | Z | 3 | 500 | 1 | 0 | 750 | 0 |

The main output signals of the STATCOM model, allowing you to evaluate the effectiveness of STATCOM in regulating voltage and reactive power in the electrical network:

$V_m$ (Output voltage module, the effective value of the phase voltage at the output of the STATCOM inverter). It reflects STATCOM's ability to regulate the voltage at the point of its connection to the network. By changing $V_m$, STATCOM can generate or consume reactive power by affecting the voltage level;

$V_{ref}$ (Reference voltage, the set value of the voltage module that STATCOM must support). The control system uses $V_{ref}$ to generate control actions on the STATCOM inverter. A comparison of $V_m$ and $V_{ref}$ generates a control error used to generate control signals;

$Q_m$ (Measured reactive power, the current value of the reactive power generated or consumed by STATCOM). The $Q_m$signal is used by the control system to regulate the reactive power;

$Q_{ref}$ (Reference reactive power, the set value of the reactive power that STATCOM should generate or consume). The control system compares $Q_m$ and $Q_{ref}$, forming control actions for the inverter.

After running the simulations of the model, the "Scope" block outputs an oscillogram of the main output signals in O.E., in the first window the values of output voltages, in the second the values of output reactive powers (Fig. 2). The values of the basic parameters are set through the "Measurements" block, where $S_b$=1000 MVA, $V_b$=500 kV.

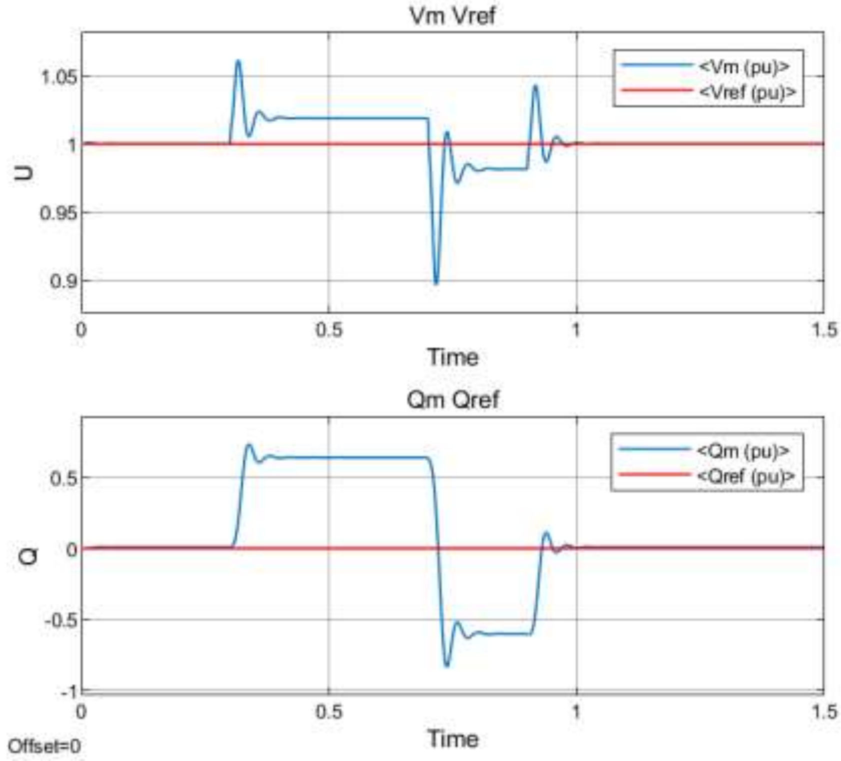


Fig. 2. Oscillogram of STATCOM output signals

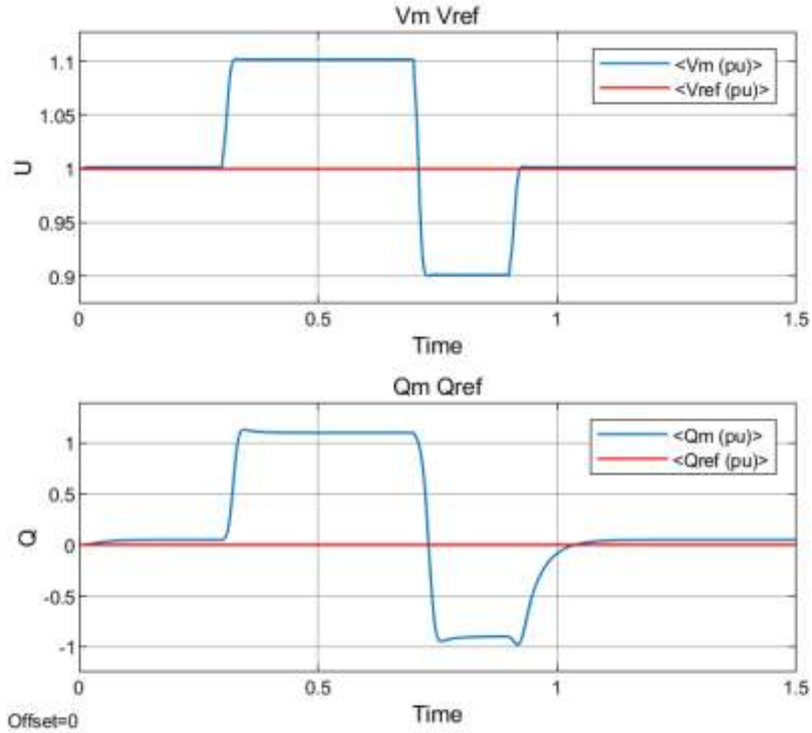


**Fig. 3. Oscillogram of network parameters without a STATCOM device.**

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In the STATCOM block parameters window, you can change the value of the compensated reactive power. When entering a value closer to zero, there is a lack of compensation, which means that the STATCOM block can be neglected in the scheme. (Fig. 3) shows an oscillogram of network parameters without a STATCOM device.
Table 2 shows a comparison of peak values of voltage surges and reactive power.

**Table 2. Peak values of network parameters**

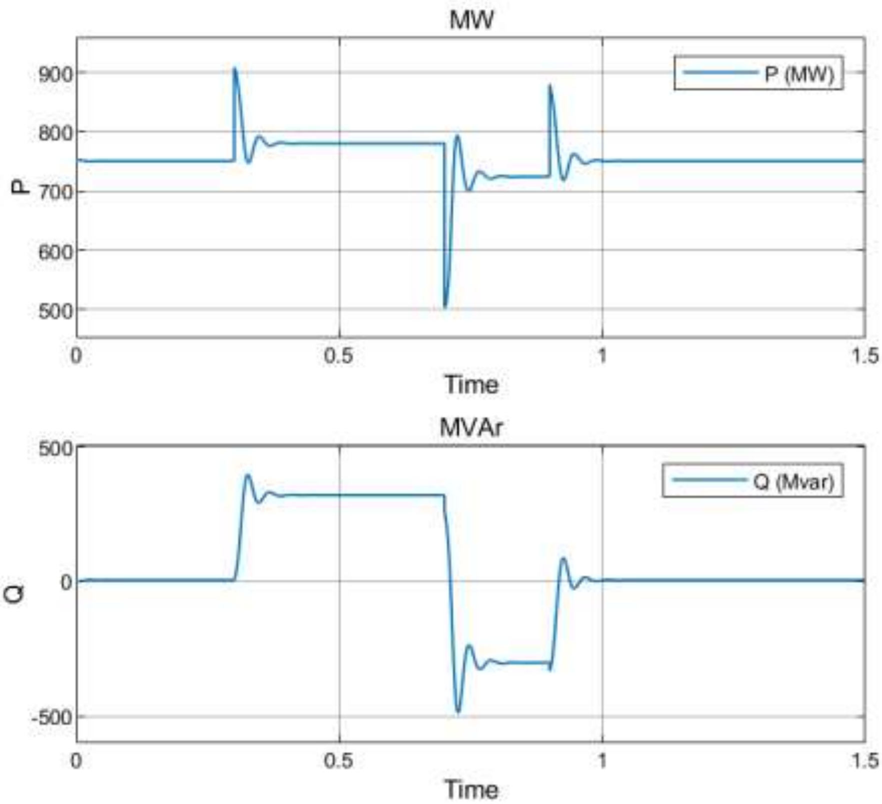
a) with a STATCOM device

| STATCOM | 0-0.3 c. | 0.3-0.7 c. | 0.7-0.9 c. | 0.9-1.5 c. |
|---|---|---|---|---|
| $V_m$ (o.e. / кВ) | 1 / 500kV | 1.061 / 530,5kV | -(0.9 / 450kV) | 1.043 / 521,5kV |
| $V_{ref}$(o.e. / кВ) | 1 / 500kV | 1 / 500kV | 1 / 500kV | 1 / 500kV |
| $Q_m$(o.e. / MBA) | 0 / 0 MVA | 0.736 / 736 MVA | -(0.837 / 837 MVA) | -(0.6 / 600 MVA) |
| $Q_{ref}$(o.e. / MBA) | 0 | 0 | 0 | 0 |

b) without a STATCOM device

| | 0-0.3 м | 0.3-0.7 c. | 0.7-0.9 c. | 0.9-1.5 c. |
|---|---|---|---|---|
| $V_m$ (o.e. / кВ) | 1 / 500kV | 1.093 / 546.5kV | -(0.9 / 450kV) | -( 0.914 / 457kV) |
| $V_{ref}$(o.e. / кВ) | 1 / 500kV | 1 / 500kV | 1 / 500kV | 1 / 500kV |
| $Q_m$(o.e. / MBA) | 0 / 0 MVA | 1.12 / 1120 MVA | -(0.963 / 963 MVA) | -(0.986 / 986 MVA) |
| $Q_{ref}$(o.e. / MBA) | 0 | 0 | 0 | 0 |

The actual values of active and reactive network powers obtained from the "Measurements" block are shown in (Fig. 4). STATCOM contributes to the rapid attenuation of spikes. According to the obtained simulation data:
• the network with STATCOM stabilizes already at 0.93 seconds;
• a network without STATCOM stabilizes at 1.1 seconds (Fig. 3, 4).



a)

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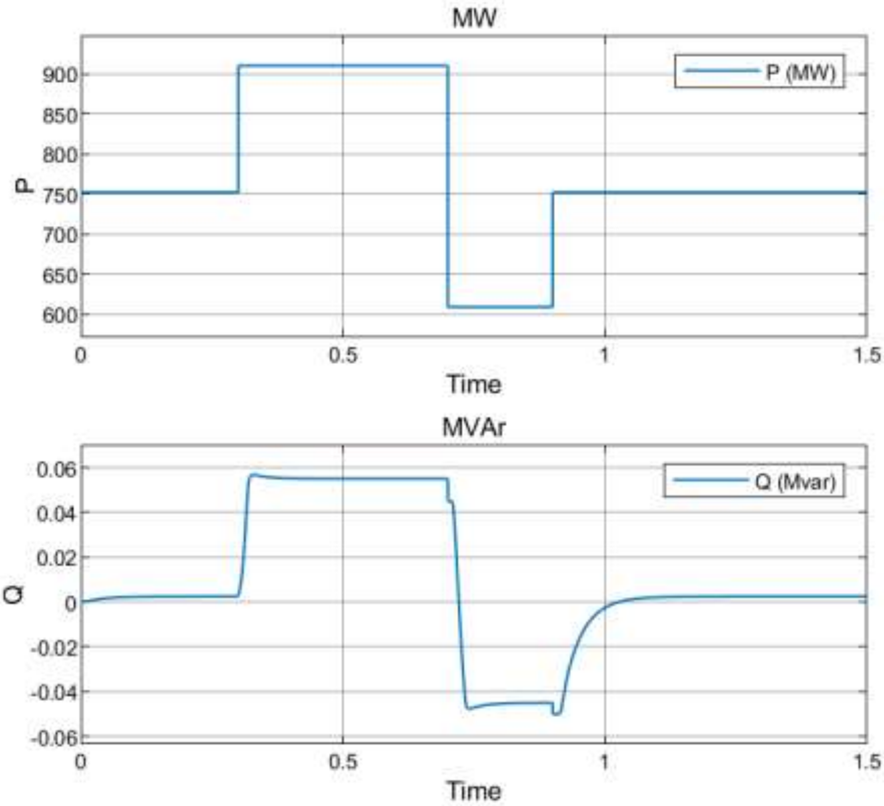


b)

**Fig. 4. Actual values of active and reactive power of the network: (a) - with STATCOM device, (b) - without STATCOM**

## III. CONCLUSION

Modeling of the STATCOM device in the MATLAB/Simulink environment shows its effectiveness in voltage stabilization and reactive power compensation. The results obtained allow us to draw the following conclusions:

1. The STATCOM device successfully compensates for reactive power, ensuring voltage stability in the network and improving the quality of power supply.
2. When external factors change, the STATCOM device reacts quickly and adjusts the power, maintaining the set parameters. Based on the results of the simulation model, the STATCOM device is a reliable tool for maintaining the operating parameters of power systems, increasing energy efficiency and reliability of electrical installations.
3. The model makes it possible to complicate the scheme under consideration based on IEEE schemes [16, 17] and evaluate the possibilities of using STATCOM for the UES of Central Asia.

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