Limitation of internal overvoltages in power static converters with fully controlled thyristors

Mykhailo Korchak, Yevhen Fediv, Olha Sivakova
Department of Electric Power Engineering and Control Systems,
Lviv Polytechnic National University

INTRODUCTION

In the Smart Grid concept, the problem of regulating the flow of electrical power is intended to be solved by means of power electronics and, above all, by converters based on fully controlled power thyristors and transistors.

Switching semiconductors causes complex transients in power static converters, which is accompanied by a redistribution of energy reserves in the RLC elements and, as a consequence, overvoltages may occur in them. The most characteristic cause of internal overvoltages is the mode of closing the control voltage of fully controlled semiconductor devices in the composition of converters for systems of flexible forwarding of alternating current (FACTS), compensation of reactive power or rectifiers of technological installations with improved coefficient of power, inductance.

Due to the high energy efficiency of using fully controlled thyristors in power converters for their operation in modes of forced thyristor closure at industrial frequency, the study of ways to limit switching surges is especially relevant.

Known methods for limiting overvoltages

The main ways to avoid the impact of this phenomenon on electrical equipment are:

1. Application of reverse diodes, which translate the current of the closing valve into a reverse diode, which is switched on with reverse polarity with respect to the main working semiconductor element; reverse diodes effectively prevent the occurrence of internal overvoltages in voltage converters made according to the schemes of autonomous voltage inverters.

2. Application of sniper (damping) units, in which the surge energy is stored in the form of a charge of the capacitor with its subsequent scattering in the resistor: RC - resistor-capacitor snapper, or RCD - resistor, capacitor, diode.

3. Application of surge arresters with nonlinear current rating:

a) varistors (nonlinear resistors) are not suitable to limit switching overvoltages due to their lack of speed.

Limiting Diodes

Among all methods, the most effective use of TRANSIL or TVS diodes.

TVS diodes were created in 1968 in the United States to protect industrial equipment from discharges of atmospheric electricity. In the conditions of use of electronic devices both industrial and household purpose it is of great importance to protect these devices from natural electrical impulses.

Unlike varistors, which are also used to limit surges, TRANSIL diodes are more fast-acting. The TRANSIL diode has a response time of several picoseconds. TRANSIL bi-directional diodes always switch on in parallel with the equipment.

Typical value of varistor actuation time when exposed to overvoltage is 25 ns. This may not be sufficient for some equipment. The theoretical pulse rate of the TRANSIL diodes per pulse is in the picosecond region. The manufacturer states that in the laboratory it is difficult to create a transient pulse, which the TRANSIL diode would operate with a delay, that is, at its peak. The simulated rise time of the front was always within 5 ns - in practice, this time could be several picoseconds.

Creation of mathematical model of TRANSIL diode in MatLab Simulink environment

The SimPowerSystems block library is quite extensive, however, sometimes the user-required device model may be missing. This applies, for example, to non-linear resistors, saturated reactors, new types of electric motors, etc. In this case, the user can create the model himself based on the Simulink blocks and the SPS blocks.

The current-voltage characteristic of the diode is given by the formula:

where i,u - instantaneous values of current and voltage;

U_0 is the voltage threshold;

I_0 is the value of the current of the device at the threshold voltage;

α - the degree of determining the nonlinearity of the device is usually in the range from 0 to 50.

On the basis of the current-voltage characteristic (3) we have created a custom electrical block with parameters repeats the parameters of the power supply system of the enterprise, in the Simulink environment, the block diagram is shown in Fig.1.

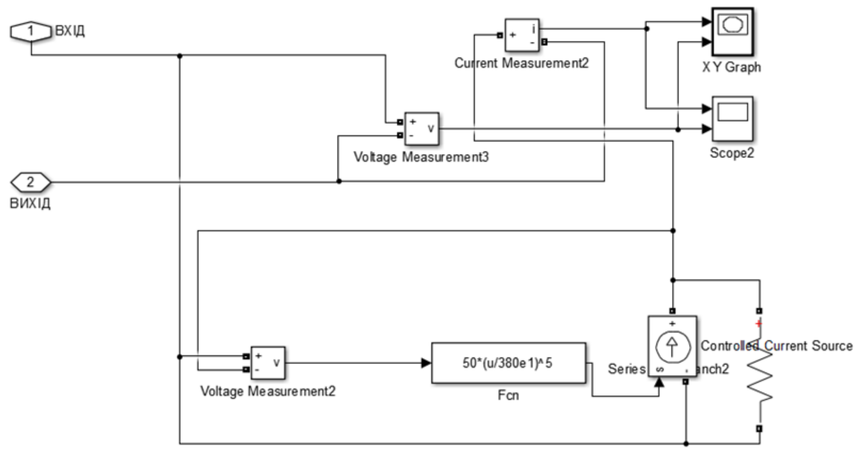

Fig.1. Model of electrical unit that replicates the parameters of the TVS diode

The current-voltage characteristic of the diode is given by the formula:

$$i = I_0 \left(\frac{u}{U_0} \right)^{\alpha}$$

where i,u - instantaneous values of current and voltage;

U_0 is the voltage threshold;

I_0 is the value of the current of the device at the threshold voltage;

α - the degree of determining the nonlinearity of the device is usually in the range from 0 to 50.

Modeling of the selected model of the reactive power compensation system and implementation of the created surge arrester

To limit the switching voltages, I apply the previously created block of the surge suppressor, which simulates the parameters of the TVS diode, we connected Schematic diagram for simulating the operation of a single-phase bridge converter in the mode of generating reactive power compensation with the implemented TRANSIL diode unit. it in parallel to the model of the capacitor battery. The obtained scheme is shown in Fig.2

After the simulation of this scheme was obtained graphs of voltage. (Fig.3).

As we can see, from fig. the switching overvoltages in the system go beyond what is inadmissible to the converter system, since such overvoltages are capable of damaging the equipment.

After the simulation of the model in which the TRANSIL diode unit was implemented, the graphs of current voltage (Fig.4) were obtained.

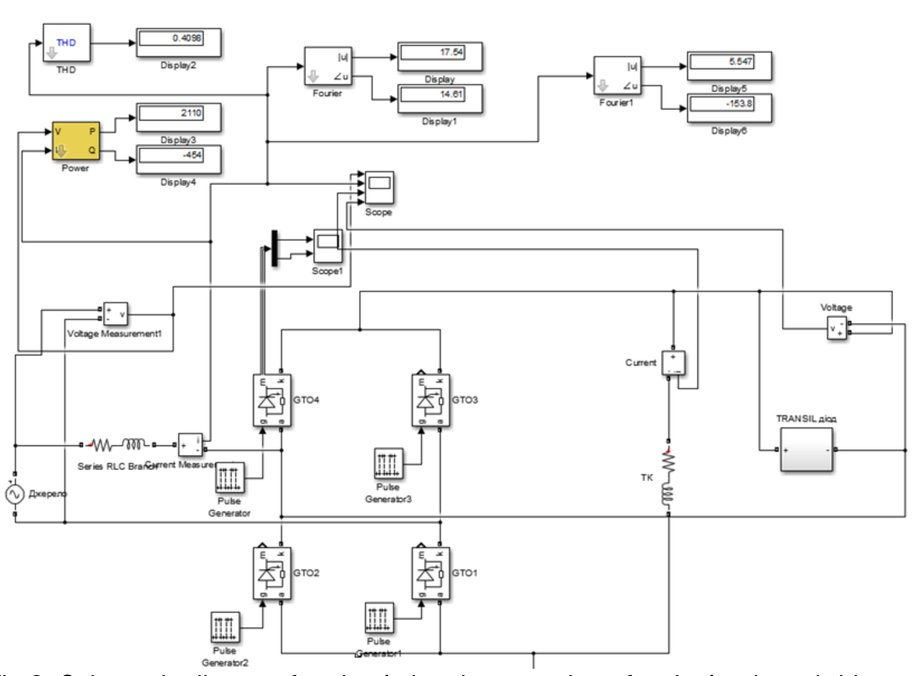

Fig.3. Schematic diagram for simulating the operation of a single-phase bridge converter in the mode of generating reactive power compensation with the implemented TRANSIL diode unit.

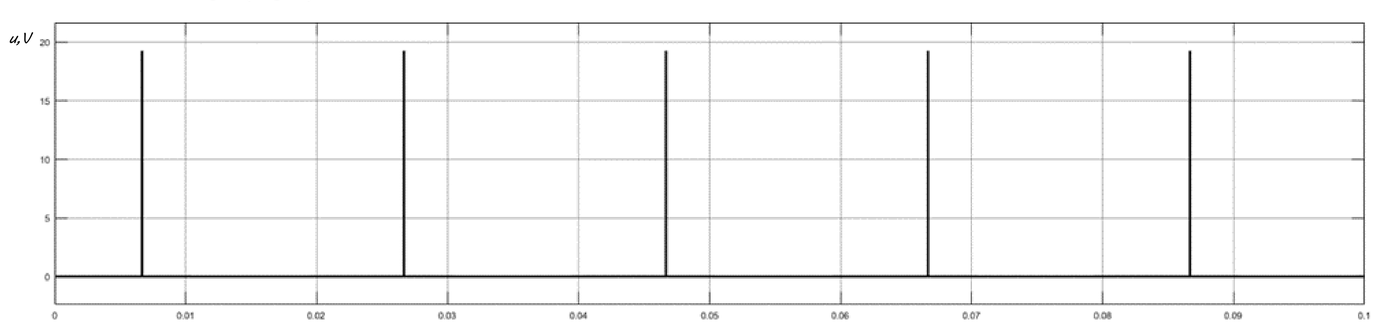

Fig.3. Graph of voltage versus simulation time without diode unit

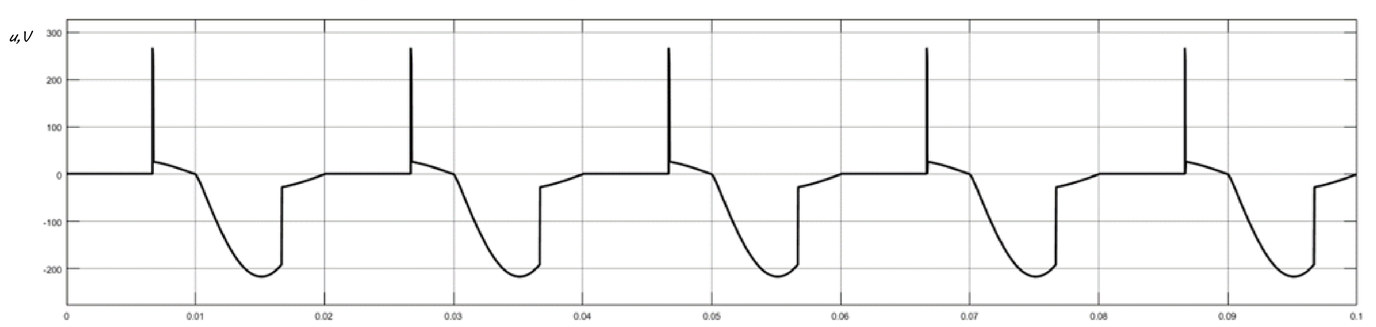

Fig.4. Graph of voltage versus simulation time with a TVS unit implemented.