DETERMINATION OF BOUNDARY MODES OF POWER FLOW REGULATORS

Sapaev Khushnud Babajanovich - prof.
Sharipov Muslimjon Salimjon ugli - master.
Eraliev Abbosbek Solohiddin ugli - master.
Tashkent State Technical University

Abstract: In the article, with the help of vector diagrams, “special” points of the power flow regulators, which are impossible to exchange energy between the load and the source, are determined, and also the vector parameters of the currents and voltages of the converters are determined, in accordance with which the programs of controllers are compiled.

Key words: STATCOM, transistor, shift angle regulator, inverter

The most efficient way of power transmission is the use of flexible power transmission systems (FPTS), created on the basis of converting equipment of a few generations. Currently, a group of converting devices are known that are used to create a GEP [1]. This is primarily:

- converters for power transmissions and direct current links (CPT, DCL);
- static thyristor compensator. This device consists of an antiparallel thyristor, reactors or compensators connected in parallel or in series in the power lines;
- Devices based on voltage inverter circuits operating in the mode of a reactive power source (STATCOM or STATKON);
- longitudinal compensation thyristor devices (LCTD), allowing to regulate the longitudinal reactance of power transmission lines;
- electric energy storage devices (EESD) are devices designed for partial or complete separation in time of the processes of generation and consumption of electricity.

Of the listed, consider devices based on a voltage inverter circuit (STATCOM). A schematic diagram of a three-phase STATCOM is shown in Fig. 1.

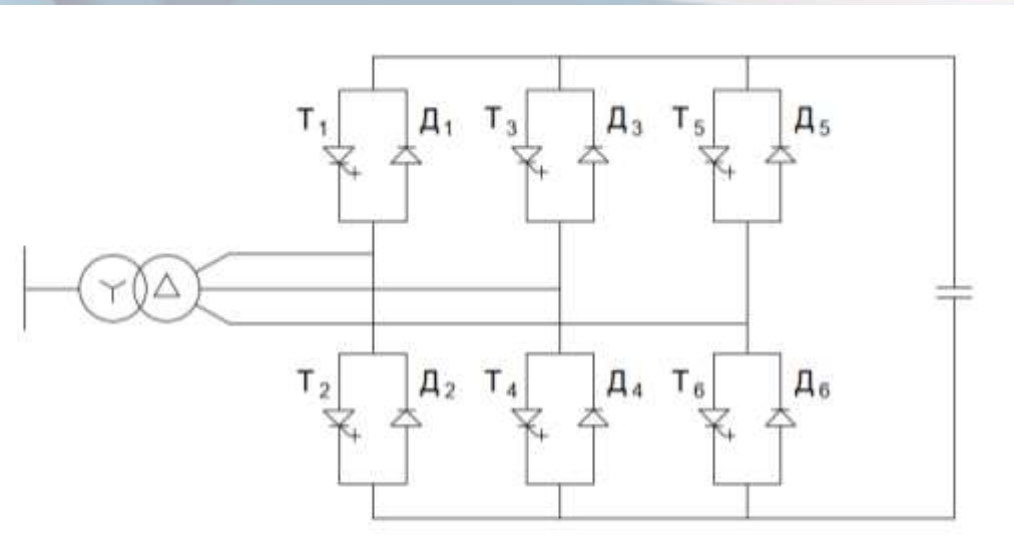

Fig. 1 Schematic diagram of a three-phase STATCOM

These standard thyristor and transistor switch circuits are available from nearly all leading electrical engineering firms in America, Europe and Asia.

With the help of STATCOM, the following devices for regulating reactive power flows in power transmission lines are being developed worldwide:

a) parallel power regulator - STATCOM, connected in parallel to the line buses;
b) sequential power regulator (PRM) - STATCOM, the primary winding of the transformer of which is connected to the line in series;
c) combined (double) power flux regulator (ORPM) - two STATCOM devices, one of which is connected to the line bus in parallel, and the other in series, like the PRM, with capacitors common to both inverters on the DC side;
d) displacement angle regulator (DAR) - a device consisting of a separate rectifier connected in parallel on the line and an inverter connected in series in series for both converters of capacitors on the DC side.
Of the listed, the subject of attention of this work is the study of the possibility of ORPM in single-phase AC networks. In particular, we will consider the principle of voltage stabilization at the load connection node using a circular vector diagram we built for a single-phase AC transmission line.
The scheme for connecting the ORPM to the buses of a single-phase line with a Z-load node is shown in Fig. 2.

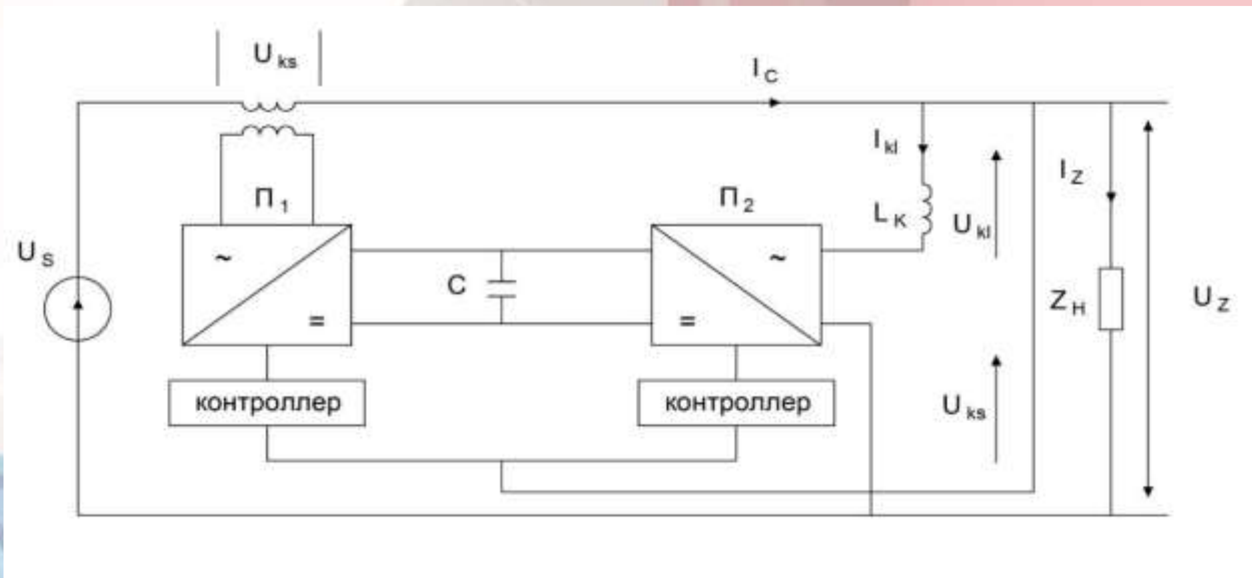

Fig. 2 Scheme of connecting the ORPM to the busbars of a single-phase line

In this circuit, converters P_1 and P_2 are single-phase STATKOM, working with alternating rectifiers; and inverter modes. In practice, standard STATCOM modules based on powerful MOSFTN and IGBT transistors are widely used. Firms Siemens, Toshiba, Hitachi and others, in addition to standard modules, also produce intelligent modules, which also include drivers - control circuits (microcircuits) - protection devices against various modes of overload and short circuit. Drivers included in the sets of intelligent modules, with an appropriate feedback system, have the ability to implement any mode of operation P, and P_2, including WIR and PWM modes when they work autonomously or together.
In Fig. 3. Without specifying controllers and feedback, a schematic diagram of an ORPM in a single-phase line, operating from an alternating current network with a voltage $U_s(t)$, are shown. This circuit, with appropriate combinations and the correct choice of elements L, C_d and parameters of a serial transformer, can realize all four modes specified in points a, b, c, d. In this case.
- mode "a" corresponds to the autonomous operation of the converter P_2;
- mode "b" corresponds to the autonomous operation of the converter P_1,
- modes "c" and "g" correspond to the joint work of P_1 and P_2;

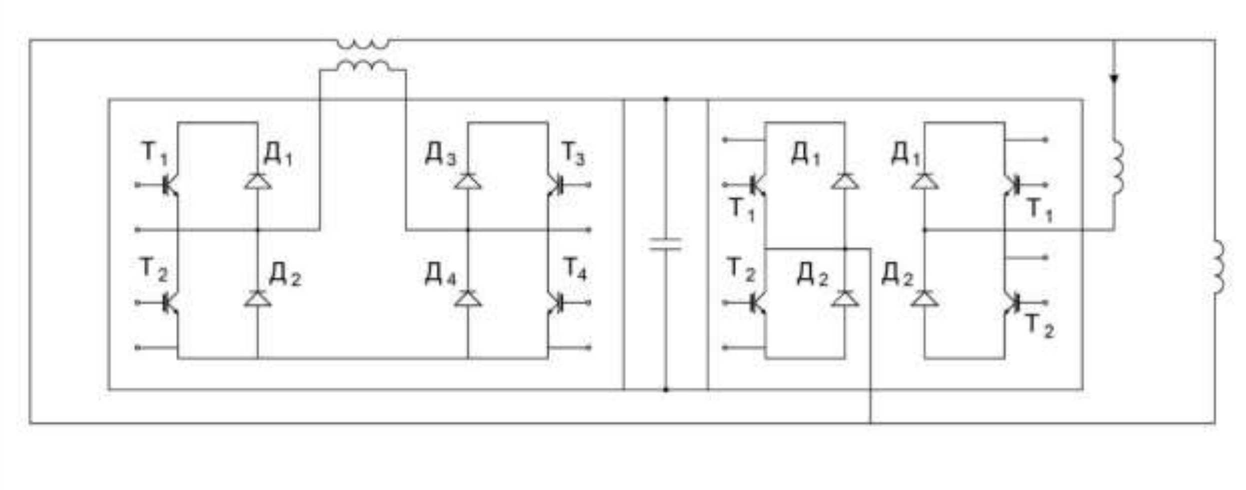

Fig. 3 Schematic diagram of a transistor ORPM of a single-phase power line

If in the generalized ORPM scheme (Fig. 3) P $_1$ and P $_2$ are represented as instantaneous power regulators [2], then a vector diagram shown in Fig. 1 can be constructed for them which reflects on the complex plane the position of the vectors of currents and voltages of the circuit in terms of the first harmonic. In the resulting diagram, the vectors U $_{si}$, U $_{zi}$, U k si reflect the voltages of the converter P $_1$ connected in series to the line at the values U $_{zi}$ <U (t) $_s$, and the vectors U $_{s2}$ U, U $_{k\,S2}$ - the voltage P $_1$ at the values U $_{zi}$ > U $_s$ (t).
Such an arrangement of voltage vectors P $_1$ can be considered as the mode of energy transfer from the source U $_s$ (t) to the storage capacity C, with possible values of U $_{21}$ <U $_s$ (t). Converter P $_1$ works in this case in the voltage inverter mode. With increasing U $_z$, starting from the value U $_z$ = U $_s$ (t) (point A), the source receives energy from the storage device C, which corresponds to the rectifier mode P $_1$.
Similarly, for the converter P $_2$ connected in parallel to the line, operating in the load current regulation mode, the vectors I $_{z1}$, I $_{s1}$, I $_{to}$ and reflect currents at U $_c$ > <J $_s$ (t). In this case, P $_2$ operates in the inverter mode, feeding the load with energy accumulated in C. Vectors U $_{K22}$, U $_{K52}$, U $_{KZ2}$ (Fig. 4) - reflect currents P $_2$ at values U $_c$ <U $_s$ (t), which corresponds to work converter P $_2$ in rectifier mode. Point "B", in which U $_c$ $^=$ U $_s$ (t) corresponds to the mode of transition P $_2$ from the inverter mode to the rectifier mode and vice versa.

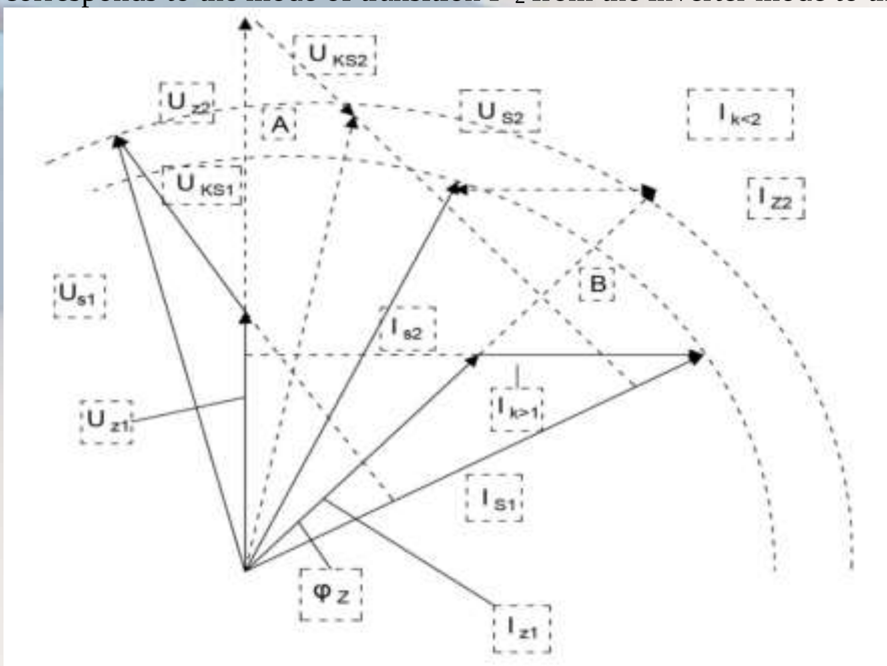

Fig.4 Vector diagram of a single-phase ORPM at the first harmonic.
Thus, for the implementation of the above mode "in" the ORPM using the constructed vector diagram, the boundaries of the two possible modes of the ORPM are clearly defined:

- the mode of transferring additional energy from the source to the load;
- the mode of energy release from the load to the source;

In the first case, P_1 works in the rectifier mode, and P_2 - in the inverter mode, and in the second, on the contrary, P_1 works in the inverter mode, and P_2 - in the rectifier mode.

The very idea of exchanging energy between a source and a load for different purposes using ORPM is not an innovation, however, as a result of this work, the following should be noted:

- by constructing vector diagrams, it was possible to determine the singular points "A" and "B" (transient modes corresponding to equivalent active loads) P_1 and P_2, in which none of points a, b, c, d for ORPM are performed;
- it was possible, with the help of vector diagrams, to determine the values of vector parameters for both modes of ORPM, in accordance with which it is necessary to set programs and control modes of controllers.

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