MAGNETIZATION-CONTROLLED SHUNT REACTORS

(G. Evdokunin, M. Dmitriev and others, 280 pages, 2013)

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Introduction

Shunt reactors (SR), as an element of the electric power system, usually appear at substations or power transmission lines of voltage classes 330 kV and higher. In cases of particularly long lines, they can also be used at lower voltages: 110 and 220 kV.

The first and the main purpose of the SR is to reduce the voltage at the open end of the overhead (OHL) or cable line (CL) to an acceptable level when they are switched on one-way to the supply network buses (this may be an electric station or a substation). Such a reactor is installed on a line and is called linear.

The second purpose of the SR installation is to limit the so-called "drain" of excess reactive power from the overhead line or CL (at low loads along the line) into the network adjacent to the line. Such a reactor is installed on the buses of a substation (station) and is called a substation (station). It should be noted that the reactive power drain is dangerous for electric generators of an electric power plant, and manufacturers of generators (usually turbo generators) strictly limit the maximum permissible value of the reactive power consumed by the generator. However, the flow of reactive power to a conventional network, in particular to a lower voltage network, can also pose a danger due to an unacceptable voltage increase.

The third purpose of the SR is to reduce the magnitude of quasistationary (temporary) overvoltages and the energy of switching overvoltages to levels acceptable for the operation of metal-oxide surge arresters installed on the line, which do not always have a sufficient margin for sustained voltage and absorbed energy.

Linear and substation (station) reactors are necessary, first of all, in the modes of low power transmitted through the lines or at no-load regime of these lines. As the active power transmitted through the line increases, the reactive power generated by the capacity of the line is increasingly consumed in its own longitudinal inductance, and, consequently, the need for shunt reactors as additional consumers of reactive power installed at the ends of the line or on the busses of substations (stations) adjacent to the line decreases. The mode of transmission of active power along the line, in which all the reactive power generated by the capacity of the line is consumed in the longitudinal inductance of the line, is called the mode of transmission of natural power. In this mode, there is no need for reactors at all, since the line is balanced in reactive power, i.e. it is neither a source nor a consumer.

If in power transmission modes close to natural, the reactors remain connected to the line (or to the buses) and continue to consume reactive power (although this is no longer necessary), this leads to a decrease in voltage on the line, a decrease in its throughput and an increase in power losses. The negative impact of shunt reactors on throughput is particularly noticeable for long lines, since the total reactive power of the SR for such lines is usually significant.

To exclude the mentioned negative influence, shunt reactors have to be equipped with their own switches and repeatedly switch the reactor with them during the daily schedule of changes in the power transmitted through the lines. At the same time, it is known that reactor switching is undesirable, since it leads to voltage surges in the installation sites of the SR, to the rapid consumption of the circuit breaker resource, to the creation of switching overvoltages affecting the insulation of the reactor windings. In addition, the disconnected state of the reactors is simply unacceptable if it coincides with emergency switching operations on the power transmission, since the high-speed connection of the SR required in this case to limit overvoltages will not be possible.

In addition to reducing the limit of power transmitted along the line, which is mentioned above, shunt reactors, without having smooth regulation of their reactive power, reduce the limit of static stability of the power transmission. So, for example, at the first 1150 kV Ekibastuz–Kokchetav–Kustanai power transmission line, the capacity of the line actually amounted to only about 40% of its natural capacity due to the use of unregulated shunt reactors as reactive power compensation devices.

All the listed disadvantages of SR are overcome by replacing them with controlled shunt reactors (CSR). The creation of the CSR has expanded the scope of the traditional application of shunt reactors. For example, in 35-220 kV networks in Russia and abroad, so-called reactive power compensation devices have already been widely used, which are a parallel connection of a CSR and a capacitor bank, which ensures smooth regulation of reactive power from its consumption mode to its production mode.

The use of controlled shunt reactors makes it possible to increase the limit of transmitted power under the condition of static stability to almost the value of its natural power, which is especially important for extended lines. With the use of CSR, it became possible to create transnational AC power transmission lines with a length of up to 2000-2500 km without using expensive direct current transmission technology.

There is a need for controlled means of reactive power compensation in networks of all voltage classes. However, in networks of 500 kV and above the number and importance of tasks solved with the help of CSR are the most significant.

Firstly, the 500-750 kV lines have a long length, and their phases are made with splitting of wires into several components (to limit losses on the crown). Consequently, such lines are sources of increased reactive power, which, depending on the power transmission mode, varies in a wide range of values, leading to unacceptable voltage fluctuations in the network, to an increase in power losses (when the voltage is lowered), to the risk of damage to equipment (when it is increased). Secondly, 500-750 kV power transmission lines, as a rule, perform a responsible role of magistral and interstate links, and therefore, if necessary, it is important to be able to transmit significant power with a proper margin of stability.

Considering the above, in order to fully illustrate the capabilities of modern controlled reactors, the authors decided to focus in the book on controlled shunt reactors for 500 kV class power transmission. A thorough review, correction and editing of the book was carried out by M. Dmitriev. The general editing of the book was performed by G. Evdokunin.