Research of distance protection functioning of transmission line with series compensation device

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Abstract. Transmission line is one of the main elements of the power supply system. Line capacity can increase, when series compensation are used. Unfortunately, the use of these devices can lead to a failure of operation or to a false operation of the relay protection of the line itself. To analyse the operation of the relay protection of the compensated line, the RTDS software and hardware complex was selected.

1. Introduction

One of the main factors in the successful development of the electric power industry is to ensure the reliability of power supply to consumers. Reliability largely depends on the functioning of the relay protection. Distance protection is a universal type of protection. The principle of operation is based on measuring of the fault resistance, which in turn is proportional to the distance from the place of damage to the place of relay installation.

Transmission line (TL) is one of the main elements of the power supply system, therefore, devices that can increase the efficiency TL itself and the entire electric power system became more widely used. For example, devices of series compensation, which make it possible to increase the transmission capacity of power lines, are very widespread. These devices belong to the flexible alternative current transmission systems (Flexible AC Transmission Systems - FACTS) [1], which allow to increase the maximum power transmitted through the line by reducing reactance.

When using longitudinal compensation devices, special attention must be paid to the protection algorithms. Capacitors located on the overhead line can affect both the measured resistance, they can also affect the choice of direction, due to the inversion of voltage or current [2].

2. Main part

Voltage inversion or current inversion occurs under the condition of a short circuit near the installation site of the series compensation device (SCD) in case of failure of its protection, that is, in the absence of shunting of the SCD during short circuit. Voltage inversion occurs under the condition when the reactive reactance module of the SCD is greater than the reactive resistance module of the TL from the installation site of the protection to the fault location (except SCD) and less than the module of the sum of the reactance of the system and the reactance of the TL. Current inversion occurs under the condition that the reactance module of the SCD is greater than the sum of the reactance of the system and the reactance of the TL.
Thus, in the event of short circuits occurring on the power line with the installed SCD, it can occur as a false positive $Z_{R33}$ or, even worse, a failure in the $Z_{K32}$ distance protection, as shown in Fig. 2.

3. Simulation results
To study the operation of distance protection of a power line equipped with a SCD based on the Real Time Digital Simulator (RTDS) hardware and software system, a three-stage distance protection model was developed.

The interphase three-phase faults were simulated, as shown in Fig.3. In Fig. 4 the boundaries of the response characteristics of the three-stage distance protection and the value of the measured resistance are displayed.
According to the test results, it was revealed that when installing the SCD at the beginning of the protected line, the capacitor remains in operation and influences on the measured resistance by the protection, since the measured resistance is not only excluded in the response zone of the first protection stage, but is also purely capacitive. To solve this problem, the location of the voltage transformer can be changed to relieve voltage not from the bus side (as usual), but from the side of the line, and remote line protection will work correctly. The test results are presented below in Table 1.

![Figure 4](image1.png)

**Figure 4.** Measurement results.

![Figure 5](image2.png)

**Figure 5.** Power transmission line with a longitudinal compensation device installed at the beginning of the protected line.

![Figure 6](image3.png)

**Figure 6.** Measurement results after changes
Table 1. Test results

| Fault location                                                                 | Fig.3.          | Fig.5.          |
|--------------------------------------------------------------------------------|-----------------|-----------------|
| Interphase three-phase fault at the beginning of the line before the installation of the series compensation (Fault1) | Actuation       | Actuation       |
| Interphase three-phase fault at the beginning of the line after the series compensation (Fault2) | Refusal to operate | Actuation       |
| Interphase three-phase fault at the end of the protected line (Fault3)          | False firing    | Refusal to operate |

4. Conclusions

For the efficient operation of the power supply system, it is necessary that the relay protection is reliable, namely, the protection must operate without fail for all types of fault conditions for which it is intended to be eliminated, and also not to act in case of damage in which the effect of this protection is not provided. According to the test results, it was revealed that the presence of modern multifunctional devices of SCD on the overhead line leads not only to a false response of the protection, but also to a failure of the protection, which significantly reduces the reliability of the transmission of electricity to the consumer.

This work was carried out as part of the international program ERASMUS + project 573879-EPP-1-2016-1-FR-EPPKA2-CBHE-JP “INSPIRE”.

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