



Protection Technology

Attractiveness of line differential protection promotes wider use

The differential protection principle is based on Kirchhoff's current law. Based on its advantages, it is now used not only in the transmission grid but also more frequently in distribution networks. Thomas Liebach and Andreas Jahr describe the wide application ranges of this protection principle and highlight the advantages of the Siprotec 5 series for modernization measures, among others.

Transmission lines and cables in the medium- and high-voltage network form the transportation routes for electrical energy and are thus the backbone – the basic structure – for the electrical transmission and distribution network. The safe, fast and selective protection of these connections – in case of faults – has tremendous significance for supply security and also substantial economic relevance,

above all with respect to failure costs during shutdown of key industries.

The main protection principle for protecting lines in German-speaking countries is distance protection. Due to the high integration of networks for historical reasons, overcurrent time protection and even directional overcurrent time protection are frequently not sufficient to solve the protection task in case of a fault.

Differential protection principle for a wide range of applications

In addition to distance protection, the differential protection principle is used for short lines, for lines with high supply relevance, as well as in conditions that involve ensuring very short tripping times. 100% selectivity along the entire protected line segment as well as high sensitivity and

fast tripping support the use of this protection principle, which is based on Kirchhoff's current law. Line differential protection can be used in a variety of ways, for radial, circular or any meshed network configurations with cables and overhead lines.

In the transmission grid, digital line differential protection has been established as a main protection principle for over 20 years. A special characteristic in (extra-) highvoltage grids are the relatively long lines, the higher share of capacitive leakage currents, as well as the significance of these lines for energy transport and network stability.

But even in distribution networks, this protection principle is used more and more frequently, among other reasons due to the ever more frequently available optical communication paths between the substations of the network providers.

Over the past 10 years, new challenges have risen for the selectivity of distance protection with the increasing decentralization of energy production and the expansion of renewable energy systems. This means the following:

- Fewer rotating generator masses in the power plants
- More electricity infeeds into the network via current-limiting inverters – lower short-circuit performance
- An increasing volatility of energy production and thus modified load flows and infeed performance in the case of power failure
- Increased use of networks and selected network regions respectively.

Based on enhancements that led not only to the increase in performance of the protection devices but also to the improvement of the protection algorithms, modern differential protection devices offer an ideal solution for various applications.

Line differential protection with the Siprotec 5 device platform

Line differential protection on the basis of the standardized Siprotec 5 offers a level

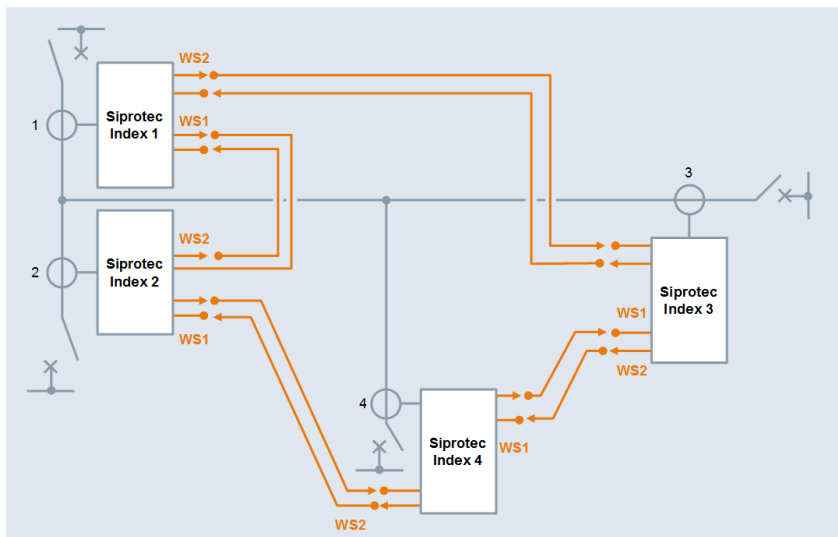


Figure 1. Line differential protection in a ring topology using the sample of a line with four ends

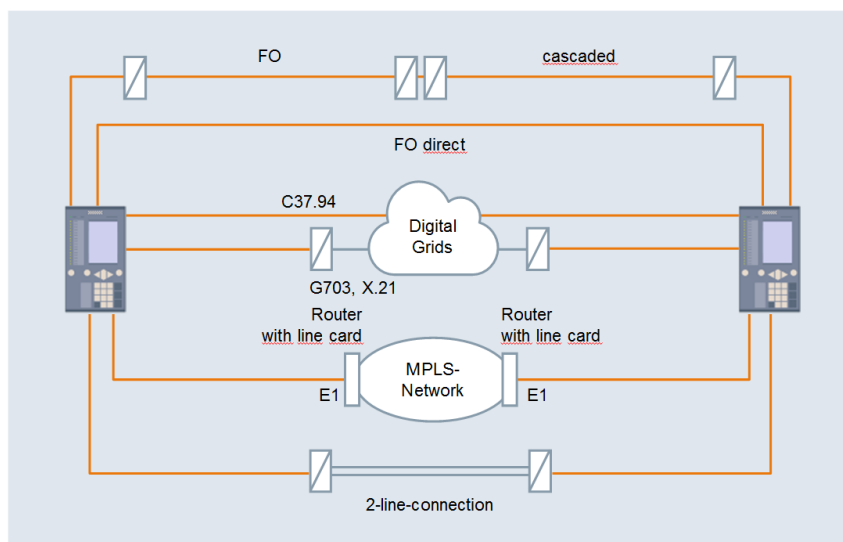


Figure 2. Communication versions for differential protection devices of the Siprotec 5

of differential protection for very high fault sensitivity and an additional level for extremely quick clearing of high-current faults.

The second level was supplemented with an additional, special algorithm for the detection of possible current transformer saturations. This leads to a substantial improvement in stability in case of external faults with current transformer saturation. The measurement principle of the quick differential offers the instantaneous values of the current.

With the 7SD8x and 7SL8x differential

protection types of the Siprotec 5 series, short command times of 8 to 11 ms are achieved as a result.

Possible evolving faults, i.e. the transition from external – high-current faults – to internal faults – even with small differential currents – are also detected by means of special algorithms, such that tripping is possible in the shortest possible time.

High-capacitive charging currents can occur in long cables and high-voltage lines.

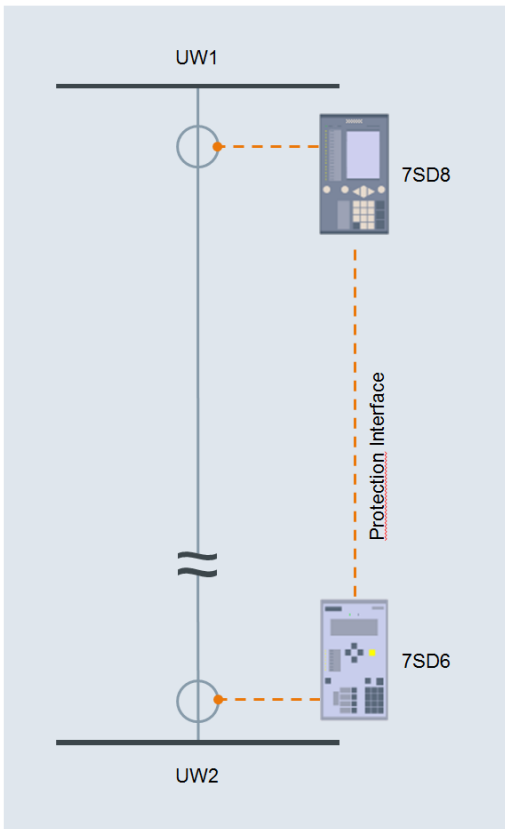


Figure 3. Example of a two-end line with different device platforms

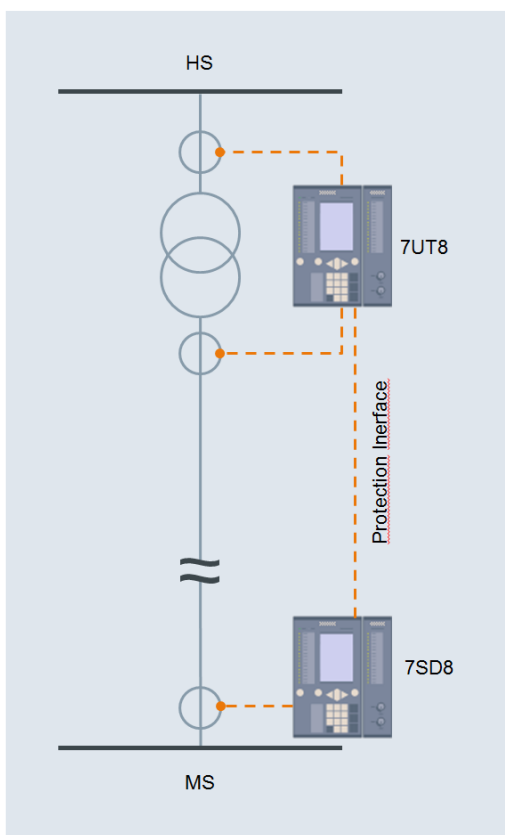


Figure 4. Communication between transformer and line differential protection with monitored communication protection interface

The load current compensation used in line differential protection determines the voltage- and current-dependent load currents and makes them available for the differential current calculation. As a result, the protection sensitivity of the classical differential protection characteristic curve can be increased. As a consequence, a high level of sensitivity can be achieved even by means of lower start values, despite high load currents.

In addition to lines with two ends, there are also line structures with multiple ends in transmission grids (Figure 1). The configuration of a ring communication has the advantage of redundancy, such that in the event of interruption of the communication rating, a fully-functional protection scheme can be maintained. If a definitive interruption of the protection interface communication occurs between more than two devices of the system, the system automatically switches over to emergency protection operation.

Modern digital protection devices are characterized by flexibility in their application possibilities. This particularly applies to line differential protection for the various signal transmission versions. The general rule applies that

- the protection of existing infrastructure can be implemented without expansion investments
- the protection device can be easily adapted with little time and effort when there are changes in the communication, e.g. by means of later investments
- the protection can utilize redundant and, where applicable, different communication systems
- the protection system delivers reliable protection and short tripping times in case of faults, even over very long distances.

For line structures with several ends, even different transmission procedures can be used between the participants (Figure 2). The communication algorithms implemented in the protection conform to the current state-of-the-art and provide a high level of reliability. Among other things, connection to digital networks is supported, e.g. using older transmission technologies such as SDH (synchronous digital hierarchy) or state-of-the-art technology such as IP-MPLS (multiprotocol label switching).

The use of communication plug-in modules, which the user can replace without opening the protection device, creates flexibility and saves time, as well as overhead in retrofitting or in case of a change in communication technology.

Flexibility in modernization

Like other technical equipment, protection devices also have higher recommended use and service life limit. For digital protection devices of high quality, this is around 20 to 25 years.

In case the secondary technology is replaced, above all the principle of modernization applies to a complete system (substation). By contrast, line differential protection is a protection principle that extends across several substations. This means that in the modernization of a protection device at one end of the line, a decision also needs to be made as to what should happen with the device on the other end. In practice, the owners of substations with the corresponding line ends – both in the distribution and transmission grid – may sometimes even be different companies.

The modernization of the line differential protection principle is facilitated if the replacement of the devices at the line ends can be carried out independently from one another in terms of time. From firmware version 7.90, the protection devices from the Siprotec 5 series with the 7SD8x and 7SL8x offer this option with respect to the installed predecessor device types 7SD61x and 7SD52x. This means that protection device modernization at the end of the line is possible without additional overhead on the other end of the protection system. For the Siprotec 4 series, the hardware version must be 7SD610/DD (or higher), 7SD52/EE (or higher). In terms of firmware, all versions are supported from V4.70. A parameter change is not necessary on the Siprotec 4 devices. Thus, the overhead in commissioning is limited to the new system. All existing two- and multi-end configurations can be converted. This facilitates the conversion and new installation of switchboards, reduces the planning overhead and shortens the time of interruption (Figure 3).

With the protection algorithms of modern protection devices, it is possible to not only monitor lines and protect them reliably in case of faults, but with a minor expenditure in devices, this can also include the integrated transformers (Figure 4). Inrush current stabilization is the logical choice especially in cases where a transformer is located in the protection zone of the line differential protection. On the 7SD8x and 7SL8x respectively, when switching on, there is an increase in the stabilization current if the inrush current detection has responded. This prevents undesirable hyper functions of the sensitive protection system.

In addition to inrush current detection, line differential protection also has supplementary control mechanisms. In case there is a disruption in the communication connection, the protection device automatically switches over to a reserve protection function. This can be a definite time-delay overcurrent protection or distance protection principle. Among other things, the measured value monitoring functions include wire break detection, measurement voltage failure monitoring, which is relevant for charge current compensation, sum current monitoring and analog/digital conversion monitoring.

The commissioning of the line differential protection poses special challenges to the protection system test due to the spatial separation of the line ends. In order to support commissioning and any periodic testing of the protection system, the line differential protection devices enable a periodic exchange of the measured values. These values can be displayed in the devices on all ends of the protection system and facilitate testing for the test engineer.

The devices of the Siprotec 5 series also have an integrated web browser. The settings and measured values of the removed devices are also displayed there (Figure 5 and 6).

Outlook

Protection systems and communication systems in energy supply today are subject to IT security requirements. State-of-the-art device platforms offer users the security



Figure 5. Web browser of Siprotec 5 - display of device data

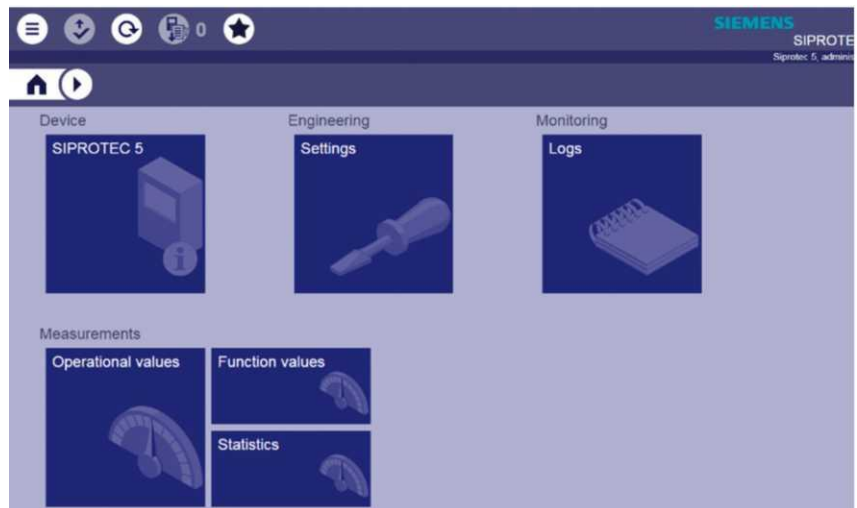


Figure 6. Web browser of Siprotec 5 - display of the main functions

mechanisms currently required – e.g. according to the BDEW/OE white paper on IT security.

The expansion of the scope and depth of data exchange currently being observed does not stop at protection and station control technology. The new opportunities, for example, with the introduction of the process bus, lead to numerous advantages – including improvements in reserve protection. That is why it is worthwhile to further harden the information structure against external threats. That is also why line differential protection will continue to expand its position in the field of network protection devices, above all where difficult

network conditions prevail, and based on its advantages, it will be used in more and more diverse applications.



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