Greater Safety for Existing Technology

Potential savings through new concepts in protective relaying

The company

EVI – the power supply company in Hildesheim – is a regional utility company for electricity, gas, water, and local heat. It provides services to the approximately 110,000 residents of the city of Hildesheim. For power supply in the medium-voltage range, EVI operates a 20 kV power system as an all-cable system with about 500 stations, including main switching stations, power system protection stations, and transformer stations. Upstream supplier Avacon supplies the energy for this medium-voltage power system using three transformer substations. EVI operates its medium-voltage power system with impedance grounding at the star point.

The starting situation

A standard power system protection station from EVI is built as a three-feeder system equipped with two cable feeder and one transformer. Until now in these stations, a Siemens 7SA500 numerical distance protection relay has protected each of the outgoing cable feeders. A remote terminal unit records the information from the distance protection relay and the power system protection station using single-fiber wiring. The unit forwards the information to the power system control center through other gateways. EVI operates an extensive telecontrol network for transmitting the information.

In the monitoring direction, the scope of information of the standard power system protection station consists of the following messages: supply and protective voltage missing, DC voltage system malfunction, system control on site and device malfunction, distance protection relay, and fault locator.

The distance protection pickup and distance protection tripping are transmitted as measured values from each of the two existing distance protection relays. If protection trips, the fault location measured by the protection relay is also transmitted in this manner. Furthermore, each outgoing cable feeder transmits the present measured value of the outgoing current. In the control direction, information transmitted also includes CLOSE/TRIP commands for each of the two circuit-breakers and a reset command for transmitting the fault location of the distance protection. As a result, the total volume of information includes about 14 messages, 4 measured values, and 5 commands for each power system protection station.

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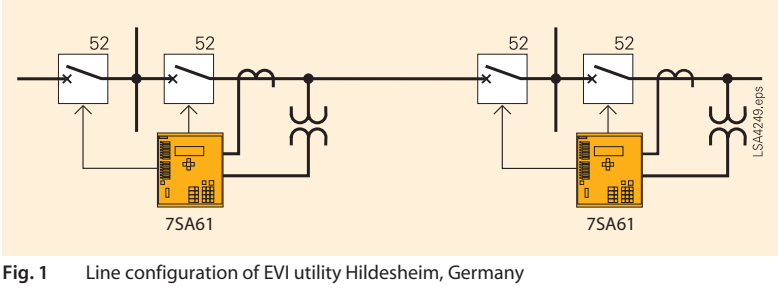

Fig. 1 Line configuration of EVI utility Hildesheim, Germany

The telecontrol systems is over 20 years old, and the protection relay system about 15 years. As a result, there has been an increased incidence of equipment failure in the past two years. The ongoing costs for repairs, spare parts, service and handling have continued to climb. The switch to modern engineering became economically necessary.

In switching to new equipment, the company looked for cost-effective standard solutions. Rather than replace the existing technology one-for-one with modern equipment, EVI established the following criteria for the modernization:

- Modernize 10 substations initially, using the same technology.
- Choose an optimal cost-to-performance ratio for the new technology.
- Use the same hardware for distance protection and telecontrol in these systems.
- Maintain at least the same functionality of the power system protection station while reducing the number of primary components in the substation.
- Replace the two existing distance protection relays with a single relay that ensures at least the same functionality.
- Avoid using single-conductor wiring between the distance protection and telecontrol.
- Use the standardized IEC 60870-5-103 interface to transmit the protection relay's information and measured operational values to a higher-level telecontrol unit.
- Specify a telecontrol unit that can record information from the protection relay via the standardized IEC 60870-5-103 interface and transmit this information and other data to a gateway via the standardized IEC 60870-5-101 interface.
- Connect the telecontrol units on a polling mode demand basis. This method will ensure optimal use of the communications line network resources and a low interface demand to the higher-level gateway.
- Specific new devices with easy, intuitive operation and parameterization, requiring a minimal training period.

The concept

A new concept was developed according to these criteria that calls for one distance protection relay for two outgoing cables. EVI selected the Siemens SIPROTEC4 7SA61 distance protection relay and a suitable telecontrol unit for transmitting.

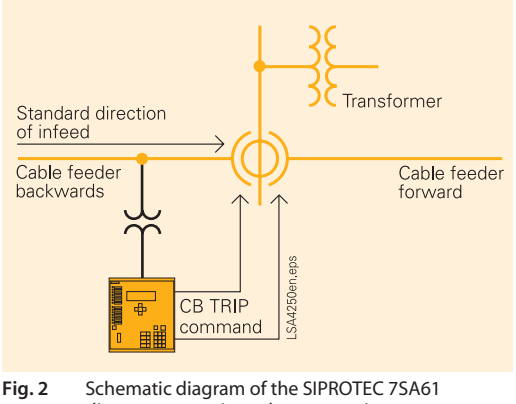

Fig. 2 Schematic diagram of the SIPROTEC 7SA61 distance protection relay connection

The new 7SA61 distance relay was to take over the tasks of the two old existing distance relays. As a result, the 7SA61 connects to one current-transformer assembly and only one outgoing feeder. The second current-transformer assembly in the other outgoing cable is no longer needed and is available for other systems. This configuration can be implemented in the EVI network because of the ring structure of the cable network, with the option of redundant feed-in from both ends.

Our experience with numerical protection relays has shown that the risk of an uncontrolled failure is low. Self-monitoring in the numerical protection relay is expected to lead to high availability. The low failure rate and the associated rapid delivery service from PTD PA strengthens the system.

If a fault current occurs, the new Siemens 7SA61 distance relay selectively trips the faulty line in the system for the forward or backward direction via the corresponding circuit-breaker.

For this purpose, the following parameters are set in the 7SA61 distance protection relay (see Fig. 3 and 4): The settings of the parameters of zones Z1 and Z2 indicate the forward direction, while the parameters of zones Z3 and Z4 indicate the reverse direction. In zone Z5 there is an X-value each for the forward and reverse directions. The R-value of zone 5 is always set to the larger R-value of the two cable runs regardless of the direction. This solution is acceptable, since this value deals with the grading in the second backup stage (grading: "Z1–Z2–Z5 (forward)") and "Z3–Z4–Z5 (reverse)"). In addition, the 7SA61 distance protection provides a directional and a non-directional time zone as the end time for grading.

If a fault occurs, the result is processed directionally in the distance protection. This directional information about the pickup and the tripping is generated in the 7SA61 protection relay for the first zone ("trip forward" = Z1, Z2, Z5 (forw)) and the second zone ("trip reverse" = Z3–Z4–Z5 (rev.)") using a CFC function, output to the appropriate circuit-breaker. The information is also forwarded to the telecontrol unit (RTU) over the IEC 60870-5-103 interface.

Circuit-breaker failure protection

When a fault occurs, if the associated circuit-breaker of the system does not trip after a set time of 100 ms in spite of the TRIP-command from the 7SA61 protection relay, and if at least 1.2 times the rated through-current is still flowing via the system's current transformer, the protection relay detects the situation and a logic function shuts off the adjacent circuit-breaker. This function serves as circuit-breaker failure and busbar protection.

Telecontrol connection of the power system protection station

Vital boundary conditions for the new telecontrol unit include the serial interfaces for unit connections in accordance with IEC 60870-5-101 and IEC 60870-5-103 protocols. The telecontrol connection is implemented on a polling mode basis on a line with up to five stations (see Fig. 5). This line connects to an interface of the higher-level gateway by means of the IEC 60870-5-101 protocol. The gateway's task is to concentrate information from telecontrol lines and telecontrol units and forward it to the control system.

The telecontrol system in the respective power system protection station transmits the information from the local input/output modules and the information from the Siemens distance protection relay connected via the IEC 60870-5-103 protocol to the gateway.

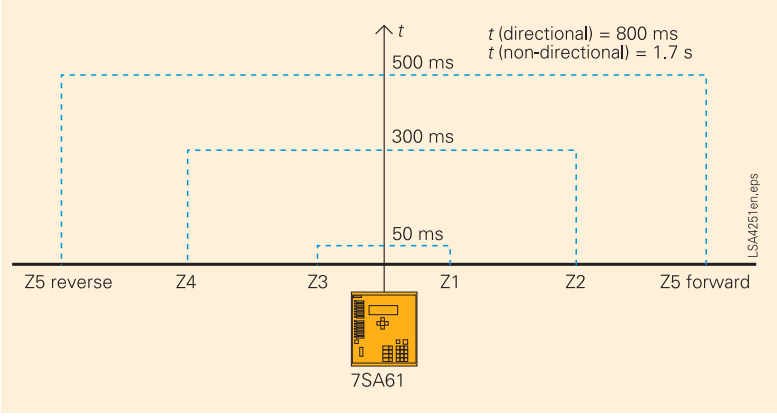

Fig. 3 Zone grading of the distance relay

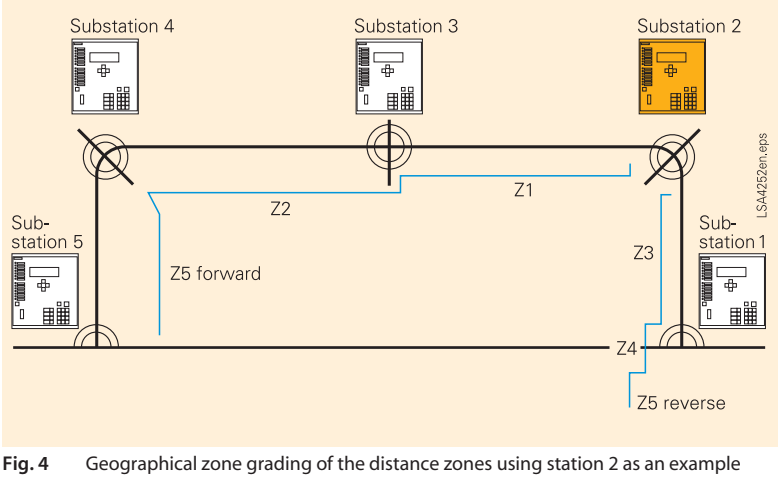

Fig. 4 Geographical zone grading of the distance zones using station 2 as an example

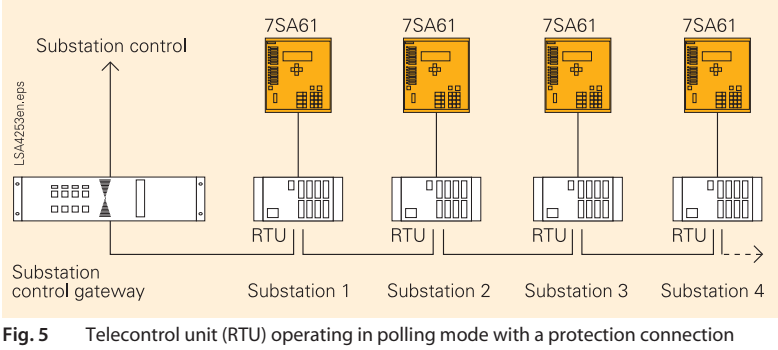

Fig. 5 Telecontrol unit (RTU) operating in polling mode with a protection connection

The special advantages

The tested, flexible technology allowed a power system protection station to be modernized in only three days. Little time was needed for wiring – especially when connecting the distance protection – since all information is transmitted by standard data cable via a serial RS485 interface.

When an event occurs, all information from the protection relay – such as pickup and tripping information, operational and fault signals, and the measured value of the identified fault location – is transferred to the telecontrol unit over the IEC-103 interface. The R- and X-values of fault locator are transmitted to the control center over the serial interface. All information is available quickly, so users can analyze the fault location quickly and correctly regarding the direction according to the mathematical sign of the transmitted value.

The standardized measured-value message with the values for *I*, *U*, *P*, *Q*, as well as the frequency, is transmitted cyclically from the protection relay. Due to the very high accuracy of the 16 bits for digital transmission of the measured values, these values are now – for the first time – also conveyed from each of the modernized power system protection stations to the control center. The control center integrates these values in load management.

After the power system protection station was modernized, primary and secondary tests ensured proper functioning for protection and precise telecontrol system and transmission of the information for all sorts of faults.

From practical experience

A fault in EVI's 20-kV medium-voltage system provided real-world confirmation for the solution. Two days after one power system protection station was modernized, a phase-to-earth fault in an outgoing transformer station in the 20 kV network "tested" all functions of the telecontrol and protection relaying system. The protection correctly detected and processed the fault in the network and trip the faulty the station. The system properly recorded, processed, and transmitted all fault-related information to the control center, and so it was possible to remedy the fault quickly.

Conclusion

Conversion to the new SIPROTEC protection system has paid off for EVI in many respects. The safety of the network increased significantly without requiring replacement of a large part of the existing systems, and without exceeding the budget. The solution also clearly improved the system's transparency in cases of fault. EVI can now analyze, trace, and clear faults more quickly.