IDENTIFICATION AND LOCATION OPEN PHASE FAULT IN THE MV NETWORK WITH WIRELESS DATA ACQUISITION

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ABSTRACT

Medium voltage networks commonly spread over large rural areas. Typical structure contains overhead lines in majority. Due to construction issue lines are treated by many damages. In this paper the methods of fault detection and localization system is described for open phase fault in line wires. The method of applying the distributed measurement system in existing MV network with minimum effort is shown.

INTRODUCTION

Medium voltage distribution networks covering large areas, especially rural and forest areas. Most common construction of the power line used in those networks is a three phase overhead line. By location and construction the overhead line is threaten for many damages caused by environmental and weather phenomena, i.e.: temperature, winds, lighting and other. The ground fault is most often occurred type of fault in such networks, it usually takes about 70-80% of all recorded faults. Typical protection schema of MV lines is based on power protection units located in substation. For all of these protections most important signals that indicates fault occurrence are zero sequence voltage and current. There are a few types of faults that indicates insufficient levels of zero sequence voltage or current signals, i.e.:

- high resistance fault (R_F>>0),
- intermittent fault,
- simultaneous occurrence open phase and phase-to-ground fault.

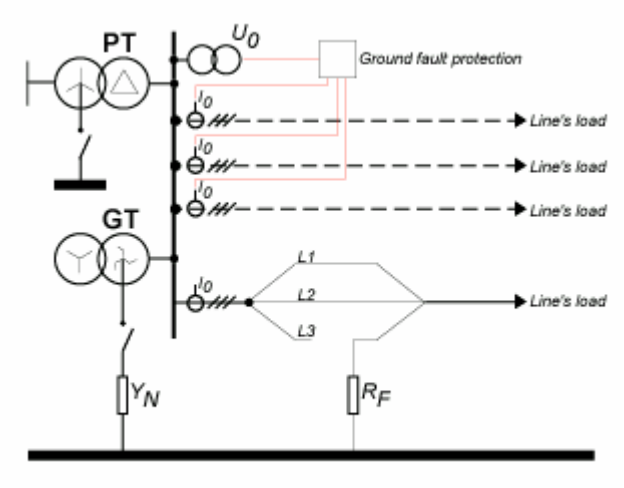

Figure 1. Scheme of the MV network with the fault.

These faults will stay undetectable for substation protection systems operating with zero sequence signals.

Very interesting case is an open phase fault with simultaneous phase-to-ground fault occurrence (open phase fault may be consider as particular case, where $R_F = \infty$). This type of fault is shown in Fig.1.

Substation protection units cannot identify such kind of fault. The solution is measurement placed in-deep network where faults occur. Proceeded research showed that measurement of the negative sequence voltage (NSV) in lines far away from the substation gives an opportunity to proper identification of that fault.

OPEN PHASE DETECTION

Open phase fault cannot be properly identified by substation protection devices due to low zero sequence signal levels [1,4]. This type of fault causes in a strong asymmetry in each node of MV line located behind the fault point. During research carried over these case within last years the best way for proper fault's detection method based on negative sequence voltage measurement was chosen. The measurement points can be located in line's core and lateral extensions.

In this method all measurements are taken on secondary windings of consumer transformer. Results of the measurement are sending to supervising system by telemetry unit via GPRS transmission. The MV/LV consumer transformer in polish distribution networks uses a typical windings connection. A measurement connection in the low voltage circuit is given in Fig.2 (dashed line is optional connection).

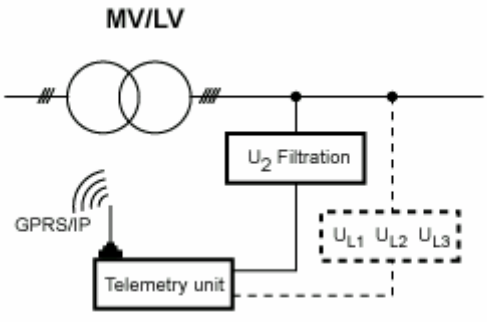

Figure 2. Measurements on the secondary winding in the consumer transformer.

Results of the measurements on the secondary side of the consumer transformer are given in Fig. 3. The RMS values of the phase voltages and the negative sequence voltage observed on secondary side of the transformer shows different behaviour during a fault without ("B") and with

phase-to-ground ("C"). Normal state is described with letter "A" on figure. The difference between voltages behaviour "B" and "C" is used to identify type of fault. Identification of the damaged phase wire in the MV line based on phase voltages can be provided too.

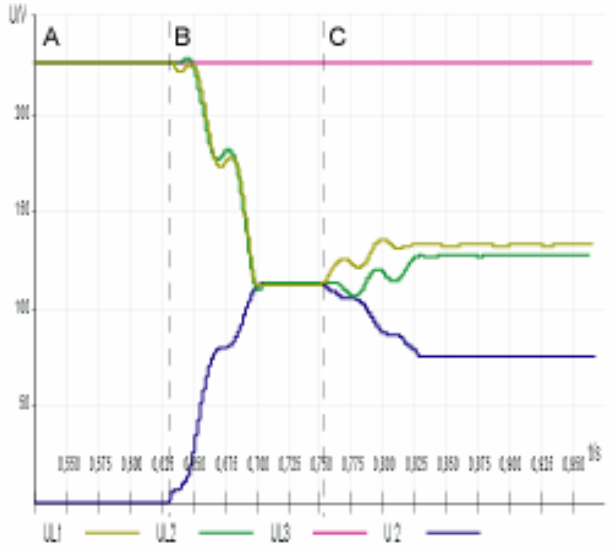

Figure 3. Phase voltages and negative sequence voltage on secondary side of the transformer (UL1,UL2,UL3 - phase voltages, U2- negative sequence voltage).

Start-up threshold for negative sequence voltage is given by equation:

$$U_2 > k_2 \cdot U_{fn},$$

where:
U_2 - negative sequence voltage,
U_{fn} - nominal voltage,
k_2 - start-up coefficient.
Choosing start-up coefficient value can change sensibility of relay operating, and can be also used for determination of voltage asymmetry level in the network nodes. Detailed description of developed algorithms is available in authors' recent publications related to open phase detection [3].

TELEMETRY DEVICE

Presented methods of open phase identification are based on measurement of the voltages on the secondary side of the consumer transformer. In that case VT are not necessary, so it makes construction of protection unit easy and low cost. The key element of the distributed measurement system is communication. For years it was a weak point of any remote control system, because it required a wire connection between devices. At present time communication is still the most important thing, but the wireless communication is available. Many manufacturers offer ready to use telemetry equipment that can be applied for any purpose. Developed system use one of such telemetry unit available in Poland, it is a family of telemetry units MT made by AB-MICRO.
Basic detection of the fault is based on negative sequence voltage, for advanced algorithm [3] with fault type detection and damaged MV line's wire identification the phase voltages are needed. Negative sequence voltage is taken from output of the analogue filter (NSF). The voltages are directly connected from low voltage phase wires and negative sequence filter to analogue input of MT unit. Analogue input of MT unit typically operates with four threshold start-up values of input signal. This feature can be used for voltage asymmetry level monitoring too. Telemetry unit can be programmed by user with internal commands language carried with additional software by unit manufacturer.

FAULT LOCALIZATION SYSTEM

Developed system is based on distributed measurements of negative sequence located at MV line end nodes. Measurement is taken at low voltage side of the consumer transformer as described above. The asymmetry of voltage powering the consumer transformer is examined. After critical asymmetry occurrence signal indicating fault is sent to supervising centre by GSM/GPRS network. The main rule in localization of the fault is knowledge of line's nodes with high asymmetry level (HAS). The line's end node means the node where consumer transformer is mounted. It has individual ID code and is assigned to powering line section.
The information about transformer ID's and powering line configuration are stored in the database. Fault is indicated by measurement of the NSV. Fault localization consist on determination of all line marked HAS and allocation of the first line section in the series that have a mark FS. Line sections operating with normal voltage level are described as CS (it means - "clear" section). The idea of the system for open phase localization is shown in Fig. 4. On this figure the result of the system localization appoint on faulted section marked with thick red line.
Under normal conditions of voltages in network the telemetry units located in end nodes does not send any information or send it rarely. The information about damage of the phase wire in MV line is sent only when the fault occurred.
Of course telemetry unit can be configured to send much more data to central unit when i.e. continuous monitoring of the asymmetry level is needed. GSM network that support GPRS transmission is best solution for data acquisition from telemetry devices located in distributed measurement system. The channel throughput offered for data transmission from a single telemetry unit is used in few percent. For monitoring a small MV network localization system can work even with communication based on SMS services, but large structure of MV networks needs GPRS transmission mode.
System for open phase localization has small requirements with devices and communications. Building a distributed system for open phase determination and faulted section localization is extremely easy. With many products offered on the market everyone can build such system with minimum effort and at low cost.
The basic elements needed to build the system:

- GSM communication channel,
- telemetry unit with analogue inputs and programming capabilities,
- OPC server/client software,
- HMI/SCADA system.

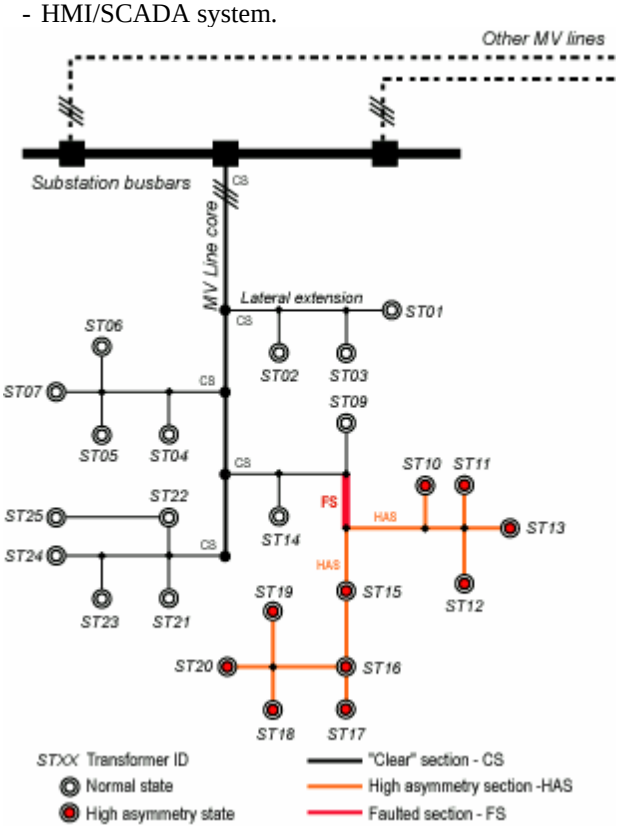

Figure 4. The idea of the open phase fault localization.

For good operation of wireless communication the isolated APN (Access Point Name) is needed. It means that all telemetry units operate in selected, isolated subnetwork of the GSM network. Access to devices in APN for other users located outside of APN is deny. Devices working within APN have private addresses in GSM and IP network.
Telemetry unit such as described above have to work with OPC drivers. Industrial standard OPC (OLE for Process Control). was designed for support easy connectivity PLC units (Programmed Logic Controller) with Windows operating systems. OPC server/client drivers are working together with many HMI/SCADA software (i.e,: iFix, PlantView). It makes connectivity from Windows based application to remote device's resources with easy configuration capabilities. System structure with described elements is shown in Fig. 5.

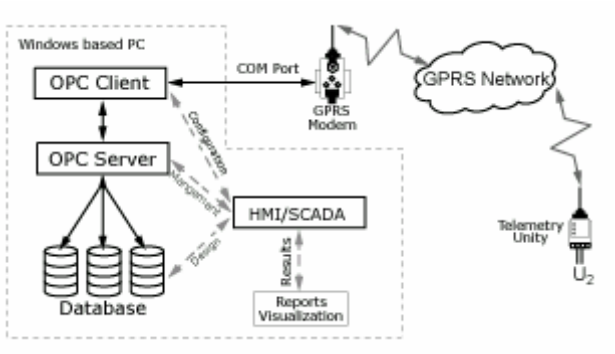

Figure 5. Distributed measurement system structure.

CONCLUSION

Presented distributed system for open phase identification and localization based on wireless communication is good solution to make such kind of fault detectable. It expands capabilities of the substation protections with ability to protect whole MV network. This solution can be applied for low voltage network in area power quality, protection, load control and more. Wide range of accessible on the market software and hardware units makes opportunity of building the distributed measurement system in fast and easy way.

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