NEWS IN FAULT PASSAGE INDICATORS IN OVERHEAD AND UNDERGROUND MV LINES

Manuel JÁRREGA DOMÍNGUEZ
Schneider Electric España - Spain
Manuel_jarrega@schneiderelectric.es
José Chaves
Schneider Electric Industry
Jose_chaves@mail.schneider.fr

INTRODUCTION

Fault Passage Indicators (FPIs) are used by Electricity Distribution Utilities around the world. As a matter of fact, and while these have been around for decades, electrical engineers have not found a more cost-effective way to locate faulty network sections. True, FPIs necessitate the patrolling of the faulted feeder, but, since fully automatized networks are still some years down the road, linemen have to manually operate the sectionalizer anyway, so that FPIs don't bring an added burden. In other words FPIs are key in reducing the outage time, in essence they do not reduce the number of outages but only their impact on the network. They will save the costly half-and-recloses which:

- are dangerous
- stress the network equipment
- very often create multiple faults. When performing several half and reclose cycles, the weak isolation points in the network are stressed and after a while can lead to an additional isolation fault, creating a very difficult fault location case to the linemen.

Some utilities have been more too often disappointed utilizing FPIs. This was due to various factors:

a/ wrong settings, poor supplier's advice and technical support
b/ wrong installation
c/ poor product quality

The purpose of this paper is to examine the impact of the above for Fault Passage Indicators and explain the solutions proposed by Schneider Electric in this matter.

Operation

Firstly, we need to remind the Principle of Operation of Fault Indicators. Using FPIs for fault tracing is straightforward as shown in Figure 1. Patrolling from the tripped main feeder CB or the tripped CB downstream on the faulted line, the fault is always located between the last flashing FPI/substation and the first non-flashing FPI/substation.

Provided the FPI trips when, and only when, it is supposed to this is indeed an easy way to perform the fault localization routine. There are two types of faults in a cable network, the earth fault and the phase-to-phase faults. 80% of the faults found on a cable networks are indeed earth faults. This is the reason why most of FPIs include in fact EFi (Earth Fault Indicators), detecting phase faults with 3 CTS, and earth fault by summing the 3 current values.

Flashing reset
The FPI will start flashing when a fault is detected. It will reset:
- automatically when the MV voltage comes back
- After a required time set by user (1 to 16h)
- Manually with a local reset button

Limits of operation

Case of the backfeed capacitive current

By construction, with its shield, an MV cable acts as a capacitor. This shield acts as a barrier to the electrical field but not to the electromagnetic field. This is the reason why CTs can be used around XLPE or PILC cables.

At the fault location, not only an active Ia fault current is flowing, but also the whole capacitance of the feeder.

If the current passing to earth is very low and the capacitance of each feeder is high it will very quickly become impossible to make ammeter measurements, the trip value has to be set very low for this (5 to 20A) and this means that the trip-value is below the capacitance on each non faulted feeder. The other Faulted Current Indicators on the non faulted feeders will therefore trip as soon as a fault appears, when the capacitance current/backfeed current flows. This so-called "sympathetic" tripping means that all the Faulted Current Indicators flash, and the faulted section cannot be located.

For example, for underground Fault Indicators, backfeed current can be from 3 to 5 A/km of cable.

Directional Fault Passage Indicators

Until recently there was no satisfactory solution allowing the quick localization of earth-faults on compensated MV networks (Networks, the neutral point of which are equipped with an arc-suppression coil or Petersen coil).

On a compensated network, the Petersen coil, connected between the HV/MV transformer neutral and the ground, generates a zero-sequence inductive current that will compensate the capacitive current, so that the resulting fault current on the faulted feeder is very low, whereas it still is important on the non faulted feeders (where the capacitive backfeed current is not compensated). See figure 2.

The Faulted Current Indicator must detect the earth fault before the feeder protection trips, and it must not "confuse" the capacitive current and the active fault current.
In order to distinguish the reactive current from the active current, the direction of the current must be established. Bardin elected the transient method in which the indicator analyzes a well-known transient phenomenon of a sudden capacitive discharge at the moment of the fault appearance.

**Detection Principle**

**Flite 3xx** detection principle is based on the analysis of transient states of residual voltage $V_0$ and residual current $I_0$, in the next ms following he fault. At the time when the phase-to-earth fault occurs, the fault direction can be determined according to phase comparison of residual voltage and current.

![Flite 3xx Diagram](image)

The detection sequence is as follows:
- Open a few ms measurement window as soon as a $V_0$ or $I_0$ threshold are crossed
- Measure the phase difference between transient $V_0$ and $I_0$ during this measurement window and deduct the fault direction
- Distinguish the fault type: Single phase-to-earth or other
- Store the fault if $V_0$ is still present after a 50ms time-out and increment the fault counter.

Wait for permanent fault confirmation (protection tripping or power under fault conditions) after the possible reclosing cycles (10, 40 or 70s configurable) before starting the light indication.

**Different types of FPIs**

**OVERHEAD FPIs**

The MV overhead network is very sensitive to harsh environments (storms, salt environment,...etc) and this is the most important part in MV networks. The consequence is a lack of efficiency and poor quality of service. There is very much cases with repetitive faults which nobody knows which is the reason. The recloser automation runs and the fault disappear, but nobody knows which is the reason. Clip-on FPI detect homopolar (current increment in phase with fault; only valid with impedant and solidly earthed neutral networks) and phase-to-phase faults.

**Clip on FPI**

This type of devices will be installed one by phase. FPIs detects intensity fault with built-in electromagnetic field sensor. If the value is bigger than FPI setting, that one will light on, both for phase and earth faults.

Other interesting possibility is to use other powerful detection algorithm: $di/dt$. In this case Clip-On FPI is reading intensity increment in definite time increment. If this one is bigger than the setting (by example, 25 A), FPI will light on.

![Clip-on mounted Flite 110](image)

To assure fault is real, FPIs validate the fault only if the main breaker trips (loss of voltage)g electric field generated by Medium Voltage line.

During first seconds overhead line is energized, FPI detects inrush current, avoiding false fault detection.

**Pole mounted FPI**

Other overhead line FPI type it’s pole mounted equipment. This device it’s mounted in the pole. This equipment can detect homopolar (in impedant and solidly earthed neutral networks) and phase-to-phase faults. In this type of equipment it’s very important some installation conditions to reach correct performance.

![Pole mounted Flite 210](image)

Pole mounted FPI have the same performance that we commented in Clip-on case:

- Powerful detection algorithm $di/dt$.
- Absolute value detection.
- Fault confirmation with zero voltage.
- Inrush current filter.
- Timer reset and voltage presence reset.
- ...etc

This type of devices could include like option dry contact to give fault detection information to RTU.
Clip-on and pole mounted FPIs are normally equipped with batteries (lithium battery), but in second case it’s possible to use solar cells and Cd-Ni rechargeable battery.

**DIRECTIONAL OVERHEAD FPIs**

When we are working in isolated neutral network we could need overhead directional FPI if capacitive currents are high. In this case we need to distinguish which it’s fault current direction. FPI needs to see which it’s residual voltage in homopolar fault to be able to see which it’s homopolar current sense. This characteristic demands this type of device will be pole-mounted.

Directional overhead FPIs have three sensors:
- Residual voltage sensor.
- Electromagnetic field sensor in horizontal position for phase-earth faults.
- Electromagnetic field sensor in vertical position for phase-to-phase faults.

**UNDERGROUND NETWORK FPIs**

Fault current indicators in underground networks are dedicated to direct, resistive earthing or in some cases on isolated neutral systems. These devices are ammeter detectors and they are reading with sensors in each phase and (if it’s necessary depending on neutral system) an homopolar CT.

Underground network FPIs can detect phase-to-phase and phase-to-earth faults. They are fully programmable on site with mini-switches.

It’s possible to set:
- Fault current settings (earth fault and phase fault).
- Fault current time duration (by example 50 ms).

FPIs include a led in box to indicate fault. These type of equipments can light on external lamp too.

Other performance it’s the possibility to give dry contact to substation RTU. Very much underground network FPIs are connected to RTUs in Spain because they are used in urban underground networks where an outage could have very bad consequences for costumers.

Current sensors (single core, split core, waterproof) allow to read the phase and earth fault current.

**NEW PERFORMANCES IN OVERHEAD FPIs:**

**REMOTE INDICATING DEVICES**

To know the status of FPIs, Utilities perform a «line patrol» as soon as feeder protection device (CB or Recloser) trips. This patrol is time-consuming and some network sections
may be hard to access: traffic jams in urban areas, difficult terrain in rural areas, long outgoing feeders or personnel security problems.
A solution is to use remote indicating FPIs. Although investment is higher than conventional FPIs, payback is quick because the outage time decreases: gain in Non Distributed Energy (hence non-billed) is substantial and quality of supply increases.

Normally this type of FPIs provides the following functions:
- Detecting all types of faults (phase-to-phase and phase-to-earth). The most advanced devices include di/dt algorithm.
- Continuously recording the current measurements (average, minimum and maximum currents).
- Checking every minute the MV status (absence/presence).
- Battery level.
- Average information every hour.

Telesetting from local device interface. Using a PC connected to the interface it’s possible read and change the FPIs settings (it isn’t necessary remove FPIs from overhead line).

Local device interface integrate and memorize all informations. This equipment has events recorded with date & time stamping and clock. These events will be reported to Control Center using the standard communication protocol of the SCADA (DNP3, IEC 870, Modbus, etc.).

Remote indicating FPIs could to be used in critical points that for the Utility it’s necessary to know quickly if appear some fault.

**Overhead FPIs with remote indication**
Remote indicating devices are Clip-on mounted (one by phase). These equipments include a short-range radio it’s communicating continuously to local device interface. This one will send the informations by standard protocol (DNP3 or IEC 870-5-101) to Utility Control Center using a long range radio or telephone line or GSM.

Overhead network supervision will be complemented with normal FPIs (Clip-on or pole mounted).

![Clip-on communicating FPIs Flite 116 and G200](image)

**Underground FPIs with remote indication**
Once again, these FPIs can transmit fault indication, but also usefull line information (load, max load, min load, battery status, equipment status, etc..) using the standard SCADA protocol and a long range radio, telephone line or GSM.

**SCHNEIDER FPI SOLUTIONS**
FPI Schneider solution is Easergy Flite and Flair range. Overhead solution is Flite range and underground solution correspond to Flair range.

In overhead networks FPIs it’s possible to use Clip-on mounted Flite 110 even 36 kV. From 20 kV to 66 kV it’s possible to use Flite 117. Both equipments have characteristics commented before.

Other Clip-on mounted are Flite 116. These devices are used with device interface G200 like remote indicating FPIs. Flite 116 include short-range radio to communicate with G200 device. This one can communicate with Utility Control Center in IEC 870-5-101 or DNP3 protocols.

In pole-mounted FPI range it’s possible to use Flite 210 or Flite 230. Main difference between these devices is Flite 230 is using solar cell and Flite 210 is using only battery.

In directional overhead network FPIs exits Flite 3xx offer. These ones are pole mounted equipments and include electromagnetic and residual voltage sensors to read phase-earth fault sense.

In underground network FPIs it’s possible to use Flair range. Flair 279 is used when it’s possible to use external supply power in the substation (220 Vac). Flair 219 is used when doesn’t exists external power supply or the costumer prefers this solution.

Flair range include directional earth-phase fault FPIs in his devices Flair 3xx.
OTHER SCHNEIDER DEVICES INCLUDING FPIs.

Easergy T200 is a RTU range offer for substations and our overhead switch PM6. These equipments include:

- Cubicle.
- Battery and power supply module.
- Local control module.
- Communication board with the most standard protocols (IEC 870-5-101 or DNP3).
- Current acquisition kit (electronic board and sensors). It’s possible to read current value.

There are two device types: Easergy T200I in substation control and Easergy T200P in overhead switch PM6. Both type of equipments could include FPI phase-to-phase and phase-to-earth detection.

Finally, Easergy T200 range it’s an integrated solution in cases that we need telecontrol and FPI in the same substation or overhead switch.

REFERENCES