AN INNOVATIVE INTEGRATED CURRENT/VOLTAGE SENSOR FOR OUTDOOR FAULT DETECTORS

Roberto CALONE  
Enel Distribuzione – Italy  
roberto.calone@enel.com

Alberto CERRETTI  
Enel International – Italy  
alberto.cerretti@enel.com

Giorgio DI LEMBO  
Enel Distribuzione – Italy  
giorgio.dilembo@enel.com

Luca GIANSANTE  
Enel Distribuzione – Italy  
luca.giansante@enel.com

ABSTRACT
To improve the quality of supply, many European and foreign Utilities use motor-driven switches along the MV lines, both simply remote-controlled and able to operate autonomously (for example thanks to protections). Enel, in Italy, installed about 90,000 motor-driven switches in protected boards and nearly 20,000 remote-controlled pole-installed switch disconnectors. About 1/3 of switchboard installed switches are equipped with fault detectors (to be installed on MV underground cables) and, by means of an Remote Terminal Unit signals from fault detectors, it is operated an automatic fault clearing and supply restore. Recently ENEL purchased some thousands of an outdoor fault detector equipped with an innovative integrated current/voltage sensor, suitable both for networks with compensated neutral, isolated neutral or resistor earthed. The current signals are detected by means of non ferromagnetic transducers. The overall performance of this outdoor fault detector is absolutely in line with that of the traditional cable fault detectors, allowing it to be totally coordinated with the MV feeder protections (its sensitivity allows to select phase to earth faults up to 6 kΩ on networks with compensated neutral). These outdoor fault detectors, able to detect overcurrents and cross country faults besides the directional detection of phase to earth faults, are perfectly suitable to equip pole-installed switch disconnectors and reclosers, making possible the automatic selection of faults with low costs.

MAIN CONCEPTS OF ENEL MV NETWORK OPERATION
To improve the quality of service, many European and foreign Utilities use motor-driven switches on MV feeders, on-load switch disconnectors or circuit breakers, fitted either in metallic boards or on poles. Moreover, these switches may be simply remote-controlled or may be also able to operate autonomously (for example thanks to protections). In Italy, more than 80,000 MV/LV substations (equipped with motor driven switch disconnectors in metal boxes) are remote controlled by means of suitable RTUs which perform also MV network automation (faulty branch selection and supply restore on healthy branches) operating the switches on the basis of signals received from a fault detector called RGDAT.

This RGDAT, designed for MV underground cables, is able to discriminate short circuits as well as similar faults and single-phase earth faults as follows:
- Non directional overcurrent (polyphase) detection;
- Non directional cross country faults detection;
- Directional phase to earth fault detection (varmetric for insulated neutral networks, wattmetric for compensated ones). Directional detection of phase to earth faults also works in MV networks with resistor earthed neutral point.

The directional detection is absolutely necessary on compensated MV networks; by means of neutral grounding and MV network automation it is possible to obtain the best performances of MV networks concerning quality of supply [1], [2], [7], [8], [10].

The architecture of the ENEL higher performances neutral impedance is shown in Figure 1; with this grounding solution, actual fault detectors (RGDAT/C, for MV underground cables) is able to select earth faults in the range 6 ÷ 4 kΩ (Figure 2, for MV networks with capacitive phase to earth currents in the range 100 A=300 A, 1,5+2,2 times the value obtainable on insulated MV networks. In Italy there are about 100,000 RGDAT/C installed and operating with excellent results. Almost all MV feeders are operated with automation rules active FNC automation technique [3], [4], [5], [6], [9], [11].

THE OUTDOOR FAULT DETECTOR

The main limitation of RGDAT/C is that it is not possible to install it on overhead feeders. As a consequence, remote controlled pole mounted switch disconnectors (SF6 insulated, more than 18,500) are not automatized.

The adoption, on overhead feeders or non-protected air-insulated MV/LV substations, of 3 traditional iron core phase CTs absolutely does not allow acceptable error levels to be reached on current regulations to be set on the RGDAT for the directional selection of earth faults (1-2 A homopolar current on primary side, to obtain proper sensitivity). In addition voltage signals have to be derived in some way, for instance installing capacitive dividers on air insulated MV busbar of the substations.

Some manufactures have developed or are developing an innovative integrated current/voltage sensor, for outdoor installation on every phase, suitable both for networks with compensated neutral, with isolated neutral and resistor
earthed.

Figure 1: Scheme of Petersen coils according to ENEL specs. Contactors CRp and CCRs are used only for thermal protection of resistors, contactor CRs exclude part of series resistor according to coil position to limit active current

Figure 2: 20 kV - C=95 % - Standard settings of 67 protection relays/fault detectors with compensated network: 6 V homopolar voltage - 2 A homopolar current, primary values. Standard settings of back up maximum homopolar voltage protection on MV busbar: 15 V homopolar voltage

The current signals are detected by means of non ferromagnetic transducers, based on Rogowsky principle. Voltage are derived by means of capacitive dividers.

At the moment one system is completely developed and has been purchased in many thousands pieces. Some hundreds pieces have been already installed in Italy, and about 20 are also operating in Enel rumenian distribution networks, on pole mounted switch disconnectors (Figure 3).

The overall performance of these outdoor fault detectors is absolutely in line with that of the RGDAT/C, so it is totally coordinated with the MV line protections. Actual field tests have demonstrated the correct selection of single-phase earth faults up to 4,1 kΩ (due to limits of the test resistor, not of the device), while laboratory tests have shown a correct behaviour in line with theoretical evaluations.

These outdoor fault detectors are perfectly suitable to equip pole installed motor operated switch disconnectors. This makes possible the automatic selection of faults by these switches and can be installed with a cost increase lower than 20% with respect to the total cost of a pole mounted switch disconnector, including its RTU.

Outdoor fault detectors consists in three integrated current-voltage sensors (one on each phase) a control unit for conditioning and elaborating the signals (the same as for RGDAT/C), has a nominal current of 500 A and has the same features as RGDAT/C. It can be installed on compensated, insulated and earthed through a resistor MV networks with 8kV ÷ 24kV voltage, has a short time withstand current ≤ 25 kA, t ≤ 1 sec and an operating temperature in the range - 25 °C ÷ + 55 °C for sensors, -10° ÷ + 55° for control unit.

In addition to very heavy functional tests (Figure 4, Figure 5) and protection relays standard environmental tests (climatic, EMC, insulation, mechanical), many other tests have been required and positively passed on the sensors, as ageing tests (5.000 hours, according to Annex C of IEC 1109 Standard), and tests according to point 7.4, Amendment 1 of IEC 1109 Standard, to EN 60507, to EN 60383-2, to EN 60383-2, to IEC 60695- 11-10 (former IEC 60707) etc.

In the fault detector available at the moment all the errors associated to the output signal of the sensors are compensated by means of the control unit (both HW and SW). Hence the fault detector was functionally tested as a single integrated component; so no definite sensor accuracy class has been required. Anyway, first test showed an accuracy class not far from 0,5 according to EN 60044-7 and EN 60044-8, and this result can be easily increased by modifying the HW and acting on production process.

A different sensor prototype (Figure 6, Figure 7), which will be used in another outdoor fault detector whose definitive prototype will be, probably, available by June 2008 (end of tests in the first months of 2010), has higher accuracy class, better than 0,1 class (for the current a ratio error of 70 ppm, a phase error of 0.07 centiradians and a relative accuracy among sensors: <50 ppm); nominal current is 650 A, nominal voltage 8-24 kV and temperature range for sensors -30 ÷ +80.
OUTDOOR FAULT DETECTOR INSTALLATION

This new outdoor fault detector can be easily installed on MV/LV substations directly fed by overhead feeders, (Figure 8). The installation of outdoor fault detector on pole installed switch disconnectors is shown in Figure 9.

ACTUAL FIELD TESTS

The state of art of ENEL solutions for MV network operation, neutral grounding with automatic tunable Petersen coils, centralized protection for MV busbar of HV/MV substation [10], MV network automation with FRG and FNC rules, both on MV/LV substations equipped with switchboards installed switches (RGDAT/C), wall mounted switches (non included in metallic boards) and pole mounted switch disconnectors (both with outdoor fault detectors) was shown, through actual filed tests, during a meeting held in Italy, October 21st-24th, with the partecipation of NTE from Norway, DONG from Denmark, Vattenfall from Sweden, EDF from France, Groupe E from Switzerland, SSE from Slovakia, Endesa from Spain and, of course, ENEL Infrastructures and Networks from Italy, ENEL Distributie Muntenia, Banat and Dobrogea from Rumenia (Figure 10, Figure 11).

POTENTIAL USAGE OF OUTDOOR FAULT DETECTOR IN ENEL

ENEL MV network, in Italy, consists in 25,598 MV feeder with a total length of about 338,000 km. A potential installation of 60,000 - 70,000 outdoor fault detectors has been estimated. At the moment more than 4,000 detector have been purchased and are being installed.

In ENEL rumenian MV networks (Enel Distributie Muntenia, Enel Distributie Banat and Enel Distributie Dobrogea), instead, (37,400 km, mainly overhead, with exceptions of urban areas), pole installed motor operated switches have to be widely introduced on MV network (about 500 are already in operation, twice this number will
be installed in 2009) and potential number of outdoor fault
detectors to be installed could reach 10,000 pieces.

Figure 8: installation of cable fault detector on MV/LV
substations directly connected to MV overhead feeders

Figure 9: installation of outdoor fault detector on pole
installed switch disconnectors (rumenian MV network)

CONCLUSIONS
New outdoor fault detectors with integrated voltage and
current sensors, have high performances and low costs.
They have maximum current and cross country faults
detection functions (50), besides directional phase to earth
faults detection (67), for insulated MV networks,
compensated ones or earthed by means of a resistor.
Many thousands have been purchased by ENEL and are
being installed at the moment, both in Italy and in Rumenia.
Starting from the new integrated voltage & current sensors
many developments are possible, thus rendering this new
innovative device extremely interesting.

REFERENCES
[1] B. Ceresoli, A. Cerretti, E. De Berardinis, A.
Gallerani, P. Perna, G. Valtorta: “Neutral connection
to earth in medium voltage networks: operation
experience”, CIRED 2001, Amsterdam, 18-21 giugno
2001
tramite impedenza nelle reti MT di Enel Distribuzione
”, L’Energia Elettrica, Volume 78 (2001)
direzionale per l’automazione della rete di media
tensione ”, L’Energia Elettrica, Volume 78 (2001)
G. Valtorta: “Automatic fault clearing on MV
networks with neutral point connected to ground
through impedance”, CIRED 2003, Barcellona, 12-15
maggio 2003
Veglio: “Telecontrol and automation on Enel
Distribuzione’s network: strategy and results” CIRED
2003, Barcellona, 12-15 maggio 2003
Signorelli: “Nuove soluzioni per il telecontrollo, la
supervisione e l’automazione della rette elettrica AT ed
MT”, Forum “Telecontrollo Reti Gas Acqua
Elettriche”, Firenze, 2-3 ottobre 2003
in the continuity of supply due to a large introduction
of Petersen coils in HV/MV substations”, CIRED
2005, Turin, 6-9 giugno 2005

