A NEW INTEGRATED PROTECTION SYSTEM FOR THE MV SECTION OF PRIMARY SUBSTATIONS

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ABSTRACT

The paper describes a new integrated system that provides all the functions to protect up to 10 MV feeders and to control a variable Petersen coil connected to the same MV bar using a single compact device.
System features, performances, direct and indirect savings and first prototype applications are included.

INTRODUCTION

Performance and cost of protection devices currently used by ENEL Distribution Division its Primary Substations cannot be improved further without changing the structure of the system.
Even the introduction of a substation optical LAN, according to the last commercial solutions, actually gives small advantages, taking into accounts the correspondent installation costs.
Therefore a completely new approach is necessary in order to change the architecture of protection and control system so as to add new functions and reduce costs.
The origin of this idea comes from the structure of the controller used in ENEL Petersen variable coil systems in stalled in correspondence of each MV bar in Primary substations (HV/MV).
In fact, the ENEL automatic tuned coil adopts an electronic device to operate the coil tuning and a special controller to continuously monitor the insulation status of each MV feeder line; this controller has the capability of performing earth fault protection for all the MV lines on the controlled bar.
Therefore, to fully protect a MV feeder, an over current protection and a reclosing function have to be added only.

After a quick feasibility study to verify the compliance of the controller with the performance requirements of the system, these two functions have been integrated in the device by means of light HW/SW upgrades.

GENERAL DESCRIPTION

The “Integrated protection System” is a single electronic device installed in correspondence of each MV bar in a HV/MV Substation, capable to perform the following functions for each MV line feeder supplied by the bar:

- directional earth fault protection;
- special protection against re-striking/evolving earth faults;
- over-current protection;
- programmable recloser;

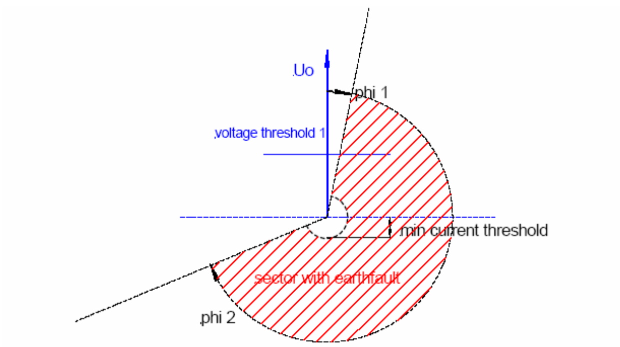
Moreover the device provides:

- Petersen coil automatic tuning and insulation condition monitoring;
- coil efficiency monitoring;
- transmission of information to the RTU (Remote Terminal Unit) for the remote control of the system.

Directional earth fault protection

Three different intervention sectors, using 50Hz components, have been implemented for compensated and isolated network situations:

- sector 1 (67.S1), compensated network/ grounded neutral through resistors;
- sector 2 (67.S2), isolated network;
- sector 3 (67.S3), cross country fault (double single phase earth fault).



The adjustable parameters per each sector are:

- voltage threshold;
- phi1 = (alpha);
- phi2 = (beta);

The adjustable parameters per each MV line are:

- current threshold;
- delay time 1(=T67.S*);
- delay time 2(=T67.S*c) for fast tripping if external closure / reclosure or input function CIF_FAST_PIG_TRIP is set (delay time contraction);

Special protection to avoid improper transformer protection tripping

These additional features avoid the tripping of the transformer earth fault backup protection (max Vo) when re-striking or progressive faults occur on a MV feeder line.

Re-striking faults

Two methods are implemented to detect earth faults with intermittent characteristic: if the MV network is operated with insulated neutral a particular logic combination based on the analysis of 50 Hz component is adopted; on the contrary, if the network is operated with compensated neutral, the algorithms for directional ground fault protection using 50 Hz components are temporarily deactivated and a different method adopting a time domain approach is turned on for the detection of the feeder under fault.

Progressive faults

When the homopolar voltage (Vo) threshold is exceeded for longer than an adjustable delay time, a fast trip observation time window is opened. If this observation time window is active, earth faults which are already existing or starting inside the window produce the immediate tripping of the feeder.

If Vo goes below the adjusted threshold for longer than the resetting time the fast trip window is deactivated.

Of course timing must be chosen so as to be shorter then the delay time set for Transformer protection.

Over-current protection

The 3 phase maximum current protection has been implemented adopting 3 independent intervention thresholds.

- 51.S1: overload protection
- 51.S2: short circuit protection
- 51.S3: short circuit protection

Current threshold and delay time can be set for each threshold.

The maximum allowed internal intervention time (without any additional delay time) must not exceed 50 ms.

In fact, 51.S3 is usually set to 0 delay time (that means 50ms) and very high value of current.

At the moment the device is equipped with simple maximum current protection; a version with directional maximum current protection function is under development.

Programmable recloser

The auto reclosing function can be triggered by earth faults or three phase maximum current protection.

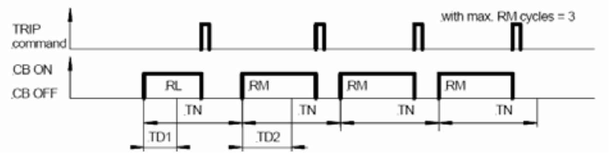
Reclosing cycle starts only if CB is closed before tripping.

The trigger function of each tripping sector (earth fault or 3 phase maximum current protection) can be disabled per parameter settings.

Three different modes are available:

- E ... reclosure excluded;
- R ... fast reclosure;
- R+L ... fast + slow reclosure;

A typical R+L cycle adoteped an MV feeder is shown in the figure below.



Petersen coil automatic tuning and insulation condition monitoring;

The device activity includes all the necessary measures, calculations and actuations necessary to :

- tune the coil in case of network extension variations;
- detect slow variation in the insulation level of each feeder line belonging to the controlled MV bar.

The methods used to perform these functions can be different according to the algorithms used by the different brand of Petersen coil systems but the final result must be the same and in any case compliant with ENEL specification.

Monitoring of Petersen coil efficiency

In ENEL compensated neutral substations, Petersen coil efficiency is usually monitored by a special panel (called MOIM) and by an over current device (called DV926) to detect the fault current flowing into the coil.

When an earth fault occurs on a MV feeder line:

1. a current is detected into the coil;
2. one of the feeder protections activates in Sector 1.

If this two conditions go down in 2 seconds without any tripping of the MV line breaker, the coil has successfully cleared the fault otherwise the coil intervention is not positive.

In both cases, some pieces of information are sent to the RTU and then to the control Centre, signalling for each earth fault positive and negative coil intervention and the code of the involved MV line.

This function, necessary for network maintenance, has been fully integrated in the Centralized device, without any need of MOIM and DV926.

Transmission of information to the RTU

For the transmission of information to the RTU and then to the Telecontrol Central System, the wires are limited to the minimum using a serial type of data exchange.

The physical interface is a standard RS486; the protocol is a simple MODBUS in RTU mode.

By means of this interface information regarding the sector activated in case of trips, Petersen coil efficiency messages and insulation degradation alarms are sent to the RTU.

Measures are still sent in analog format (±5mA or 4-20mA) but, in future developments, a serial data format can be implemented.

Fig.1: Integrated protection System

System Reliability

Using a single device to protect up to 10 MV lines, may produce a decrease in the reliability of the system if a careful design is not pursued.
In fact, a fatal fault in the central device causes the loss of protection for all the MV lines on the bar and consequently the trip of the transformer back up protection, in case of a fault occurring on the controlled lines.
With the traditional solution consisting of one protection panel for each MV line, the probability of the transformer tripping due to one malfunctioning MV panel is 1/10 less.
Therefore, from one hand, it is important to be careful in the design of the device as far as reliability is concerned, adopting the proper derating in the choice of electronic components, duplicating the weak units (such as the power supply unit), etc.
From the other hand, spare parts must ever be available for a quick repair and their installation must be easy.

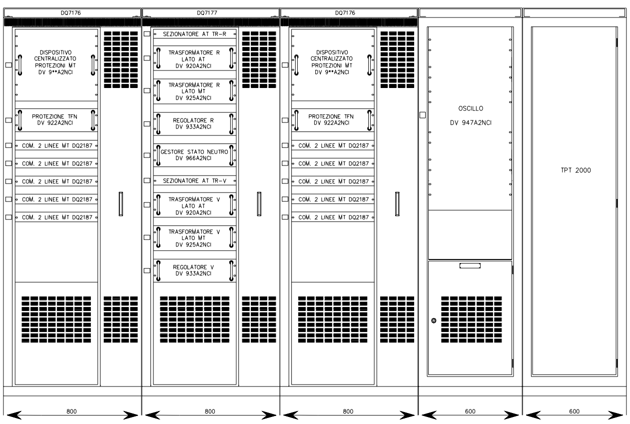


Fig.2: Complete MV protection and control system of a standard Primary Substation (including RTU, and RCE)

Direct and indirect savings

This device can be surely successfully adopted in the project of new HV/MV substations more then in existing ones but if the upgrade towards compensated MV neutral point requires the change of MV line protections, the use of the centralized device for each MV bar could be viable.
The direct savings coming from the use of the centralized device are very evident:

- One device to protect up to 10 MV feeder instead of 10 single protection panels;
- Petersen coil functions all included;
- No need of a device for Petersen coil efficiency monitoring;
- no need of a rack mount system to install 10 protection panels;
- Simplified wiring system towards the field and towards RTU.

There are also indirect savings from the reduction of room and components:

- reduction of the average indoor temperature;
- reduction of DC power supply and battery capacity;
- reduction of maintenance costs.

PROJECT DEVELOPMENT

The project development has been undertaken in cooperation with a firm having a proved know how in the matter; three main phases are selected:

- Phase 1: preparation of technical specifications in teamwork with the builder: October 2005-April 2006;
- Phase 2: preliminary test of the equipment in a simulated environment (laboratory test, both by the manufacturer and in CESI, also with the application of real faults records) and delivery of 6 prototypes to be installed in 3 standard ENEL HV/MV substations: from April 2006 to November 2006;
- Phase 3: Installation of prototypes and field tests: December 2006 in the HV/MV substations of Bagheria (Sicily), Rieti La Foresta (near Rome) and Pieve di Soligo (nord east of Italy).

After this period, on the basis of the results obtained, the definitive technical specifications will be defined, as well as the application guide.

MONITORING OF THE SYSTEMS AND FIRST OPERATION RESULTS

Test in real environment has been arranged installing the equipment in parallel with traditional protections and connecting it to remote control system as if there was a different substation. In this way it is possible to compare the operation results of these two substations during all the test period round. In a first phase traditional protection devices

will be active on the circuit breakers, while the Integrated protection System will be in parallel, connected only to the fault recorder. Afterwards, in a second phase, the Integrated protection System will be connected to the Circuit Breakers.
To allow remote actions on the new equipment, an ISDN connection is provided in each substation using a special Modem to avoid non unauthorized intrusions.
The test should last a period going from 6 months to one year.
As shown in the following small examples from the Event log regarding the Substation "Rieti - La Foresta", the new equipment seems to work exactly the same as the traditional one.

data evento	ora evento	Eercizio	nome cabina	nome montante	descrizione
01/01/2007	8.24.49	Viterbo	FORESTA	PIANA REAT	SCATTO D.TERRA 2 SOGLIA
01/01/2007	8.24.50	Viterbo	FORES_SPERIM	PIANA REAT	SCATTO D.TERRA 2 SOGLIA
25/12/2006	3.03.13	Viterbo	FORES_SPERIM	SELLECCHIA	SCATTO MAX I 2 SOGLIA
25/12/2006	3.03.13	Viterbo	FORESTA	SELLECCHIA	SCATTO MAX I 2 SOGLIA
03/01/2007	12.10.31	Viterbo	FORESTA	PISTIGNANO	SCATTO MAX I 3 SOGLIA
03/01/2007	12.10.32	Viterbo	FORES_SPERM	PISTIGNANO	SCATTO MAX I 3 SOGLIA
25/12/2006	3.04.23	Viterbo	FORES_SPERIM	SELLECCHIA	RICH LENTA POSITIVA
25/12/2006	3.05.12	Viterbo	FORESTA	SELLECCHIA	RICH LENTA POSITIVA
04/01/2006	23.30.06	Viterbo	FORES_SPERIM	CONTIGLIAN	RICH RAPIDA POSITIVA
04/01/2006	23.30.57	Viterbo	FORESTA	CONTIGLIAN	RICH RAPIDA POSITIVA

CONCLUSIONS

The solution is extremely innovative and seems to offer many advantages.
Combined with the Compact MV switchgear housed in a container, fully equipped and factory assembled, it will allow to build (or rebuild in the same site) a sophisticated HV/MV substation (tunable Petersen coils, MV network automation, etc.) with very low cost and in very short time, also reducing maintenance costs.
Therefore it can be the optimum solution for substation renewals, both in Italy and abroad.

In the future, the implementation of directional over-current protection and IEC 61850 protocol will be considered.
In fact, this device can be a fundamental component of the new ENEL protection, automation and control system able to deal with dispersed generation (SMART GRIDs) and to assure, in the meantime, a higher service quality levels to MV and LV customers (**S**mart **D**istribution **N**etwork **O**peration project).

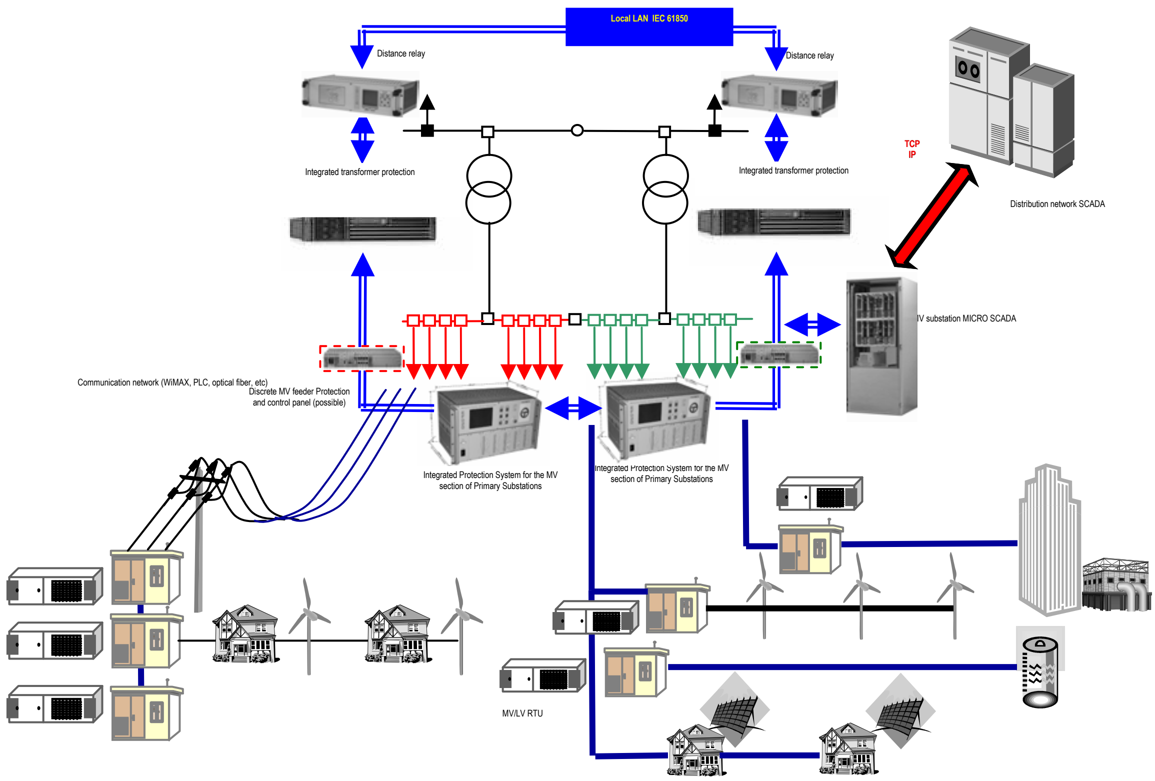


Fig.3: Architecture of ENEL Future Smart Distribution Network