CRITERIA FOR THE INSTALLATION OF SECONDARY SUBSTATION CIRCUIT BREAKERS, PROTECTION SYSTEM SET-UP AND OPERATION OF THE NETWORKS WHEREIN THEY HAVE BEEN INSTALLED

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ABSTRACT

The paper describes the use of circuit breakers along MV feeders to select quickly the part affected by short circuit and improve the continuity of supply on distribution network.

The document is organized in two parts: the first one deals with the HV/MV transformer, MV feeder and secondary substation circuit breakers protection systems coordination.

The second part of the paper considers the first operation data results. We took into account 2008, 2009 and 2010 interruptions data recorded by Enel Distribuzione SCADA system and in particular the number of interruptions on MV feeders before and after secondary substation circuit breakers installation.

The purpose is to make a cost benefit analysis about continuity of supply improvement on those MV feeders where circuit breakers have been installed.

CRITERIA FOR INSTALLATION OF CIRCUIT BREAKERS IN MV/LV SUBSTATIONS

To improve the continuity of supply, ENEL Distribuzione installed circuit breakers, instead of on-load disconnectors, in MV/LV substations in order to enable the quick selection of the portion of the line that is affected by a fault (including short circuit).

Each circuit breaker was installed at the beginning of each MV line's derivation, thereby allowing to preserve the upstream part of line by the opening and closing cycles whenever a fault occurs on the downstream section of network.

In this way is possible to reduce the, so called, "customer moment" for the "duration of long interruptions per LV Customer" (SAIDI) and, specially, for the "number of long and short interruptions per LV Customer" (SAIFI+MAIFI), the continuity of supply indicators foreseen by the Italian Electric Energy Regulator.
Each indicator can be calculated using the following formula:

$$Ind\ QdS = \sum_{k=1}^{N} \frac{N_{Cl\_k} \cdot Val\_ind_k}{N_{Cl\_Line\_i}}$$

where N_{Cl_k} is the number of customers with the same "history" during the event, Val_ind_k is the value of the indicator (minute for the duration and pure number for the number), $N_{Cl\_Line\_i}$ is the total number of customers per the i line 2 and the result $N_{Cl\_k} \cdot Val\_ind_k$ is the "**customer moment**".

In particular, installing the circuit breaker at the starting point of a secondary feeder is possible select rapidly the faults without interruptions of supply for the customers connected to other secondary feeders or main feeder.

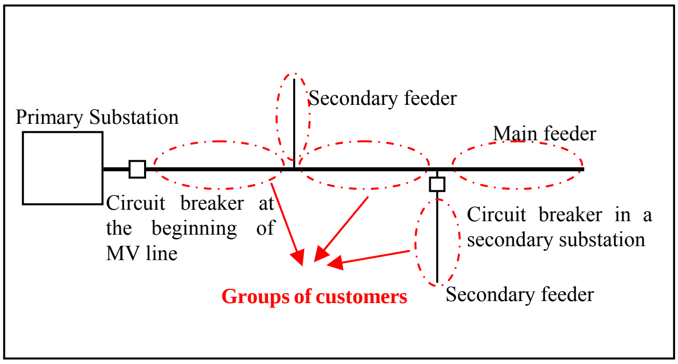

Figure 1 -Groups of customers on a MV line.

COORDINATION PROBLEMS AMONG PROTECTION SYSTEMS

In order to operate correctly the secondary substation circuit breaker, it was necessary to define the settings of protection system of transformers, lines and MV/LV (also called secondary) substation's breakers

I. Coordinating lines and MV/LV substation circuit breakers protection systems

For the coordination of the MV line and secondary substation circuit breakers and identification of short-circuits, it was necessary to set up the protection systems as follows:

Protection Line	current setting – A	Delay time – s (1)
51.S3	2500 A	1 s
51.S2	A) 1300 A (Transformer with nominal power more than 40 MVA) B) 800 A (Transformer with nominal power lower than 25 MVA)	0,25 s
51.S1	$\min(0{,}85 \times Icc\_\min; 1.2 \times In\_line)$ A	1 s
67.S3	$\min(1.4 \times \max(Ic\_line); 150)$ A	0,25 s or 0,1 s
67.S2	Dependant on the length of the network connected to the HV/MV substation	0,4 s
67.S1	Dependant on the grounding system installed into the HV/MV substation	0,4 s or 1 s second without automation. 20 s with automation.

Table 1–MV line protection system settings.

Delocalized protection system	Value of intervention (fault detector's threshold current) – A	Delay time – s (2)
51 (fault detector installed into the MV/LV substation has only one maximum current threshold)	500 A	0 s
67.S2	Dependant on the length of the network connected to the HV/MV substation (circuit breaker at the start of MV line)	0 s
67.S1	Dependant on the grounding system on the network where installed ICS.	Coordinated with network automation system

Table 2 –RTU and fault detector installed into the MV/LV substation settings.

(1) Delay time written on the table does not consider the opening time of circuit breaker, about 0,07 s. All delay times highlighted on the table includes the detection time of protection system, about 0,05 s.

(2) Delay time written on the table is referred to time parameter of RTU. This time does not consider the revelation time proper of fault detector (about 0,08 s), acquisition time of RTU (about 0,02 s) and the opening time of circuit breaker (about 0,07 s).

When circuit breaker are installed along lines connected to a MV bus bar with a large percentage of cable, it is necessary to do a thermal verification of cable shield. In fact, in some cases a current of cross country ground faults can damage seriously the cable shield, so is not possible to set the delay time of line 67.S3 protection equal to 0,25 s obtaining a correct coordination between circuit breakers of secondary substations and upstream of line.

In order to calculate the maximum value of specific energy sustainable by cable shields, total time of cycle of operation of circuit breaker has to be considered. Operative cycle of circuit breaker upstream of cable line is realized by one rapid closure more two slow closure, conventionally 0,96 s.

II. Coordinating transformer and MV line protection systems

In a great number of power stations, ENEL Distribuzione uses standardized HV/MV transformers, with the following rated power: 16, 25, 40 and 63 MVA. In general, when an MV circuit breaker was installed along a MV line, ENEL used the protection settings of a feeder supplying a hub center. On the MV feeders, the maximum current protection on second threshold (51.S2) is set: 1300 A and 1,2 s.

In general, each power transformer has a total of two protection systems installed, one for the HV winding, and another for the MV winding, in order to protect it from overcurrent (overload) and short-circuits.
The protection system on HV winding has the following setting:

- 1st threshold $I = \min\{3{,}5 \cdot I_{1t}; 0{,}45 \cdot I_{cc}\}$ t = 0,8 s for TR $\leq$ 25 MVA
- 2nd threshold $I = \min\{3 \cdot I_{1t}; 0{,}4 \cdot I_{cc}\}$ t = 0,6 s for TR $\geq$ 40 MVA

Into the HV/MV substations, where an HV/MV transformer operates with nominal power lower than 25 MVA during overload, it is possible that the coordination between transformer and line protection systems is not as effective.

In those cases, is necessary to set up the maximum current protection on second threshold to: 800 A and 0,25 s.

$I_{51.S2\text{-line}} = 800$ A < $I_{51.S2\text{-Feeder}} = 1300$ A (0,25 s)

The protection system on MV winding have only one threshold depending by transformer's overloading factor, has the following set up:

- $I = 1{,}4 \cdot I_{2t}$ (per normal over load pair to 130%)
- $I = 1{,}6 \cdot I_{2t}$ (for transformer overloaded to 150% - ONAN/ONAF)

Time of intervention for this protection is 1,5 s. Also in these cases, if the transformer installed in the primary substation has a low nominal power, is possible that there is no coordination between the line and machine maximum current protection systems. In fact, if there are contemporary faults on different lines, it is possible that the MV transformer winding's circuit breaker opens.

IMPROVING CONTINUITY OF SUPPLY

In September 2009, ENEL Distribuzione started an experimental campaign in Sicily, to improve the continuity of supply through the installation of circuit breakers along line. Until December 2010 Enel Distribuzione installed approximately 1100 circuit breakers in 760 MV/LV substation supplied by 365 MV lines.

It is possible to evaluate the benefit of circuit breaker, taking into account the number of faults selected directly by them respect the total amount of faults occurred on MV lines supplying secondary substations where had been installed almost a circuit breaker. The total amount of interruptions relatively of the first nine mouths of 2008, 2009 and 2010, are shown in the bellowing table:

year (1st jan.-30th sept.)	2008	2009	2010
Total amount of events	4756	6877	5838

Table 3 – Total amount of events on MV lines with at least one circuit breaker.

The percentage of interruptions selected directly by MV/LV substation on the MV lines where had been installed a circuit breaker in 2010, is largely increased.

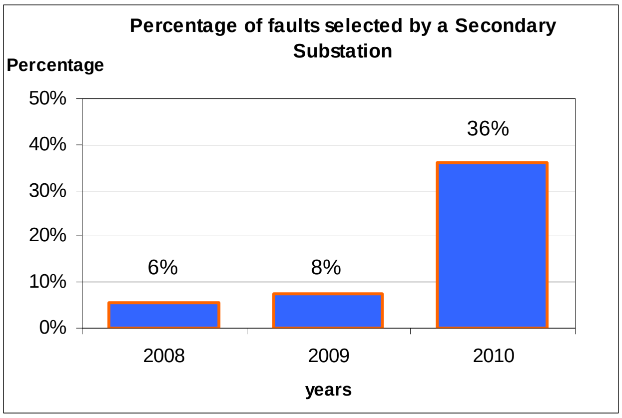

Figure 2 – Percentage of faults selected at MV/LV substation level on the total amount of interruptions occurred on MV line with circuit breaker.

The total amount of interruptions selected directly of these MV/LV is shown in the following table:

year (1st jan.-30th sept.)	2008	2009	2010
Total amount of events	263	521	2097

Table 4 – Total amount of events selected at MV/LV substation level of a MV line with at least one circuit breaker along line.

The percentage of faults selected at MV/LV substation level grew up in 2010.

In particular, it is possible to highlight the effective intervention of circuit breaker, taking into account just secondary substations where had been installed a circuit breaker, it was considered the interruptions selected directly by them relatively to three last years, for nine mouths (January, September). The following table displays the results:

year (1st jan.-30th sept.)	2008	2009	2010
Total amount of events	40	240	1828

Table 5– Total amount of events selected by a circuit breaker installed in a secondary substation.

During the first nine mouths of the operation year 2010, almost the total amount of interruptions selected directly at MV/LV substation level, was selected by a circuit breaker. In fact, the ratio between the intervention of circuit breaker and any kind of switch installed into a secondary substation, is showed on the bellowing table:

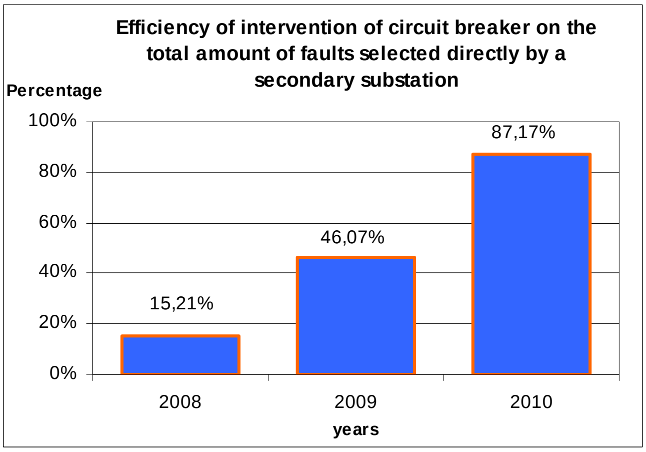

Figure 3 – Efficiency of intervention of circuit breakers installed in MV/LV substations.

The ratio is calculated by number reported respectively on tables 7 and 5.

The increasing of number of selections by secondary substations is due to the circuit breakers installed along line. All multiphase faults that occur on the part of line protected by circuit breaker nearest are selected by it.

This method to operate the network determines the possibility to have no interruptions for customers connected on the first part of MV line. Taking into account all interruptions occurred on the MV lines where circuit breakers had been installed it was calculated contribution to SAIFI+MAIFI about Sicilia Area relatively January – September period. At the same time it was calculated by means simulation, the contribution, to SAIFI+MAIFI, of each interruption selected by secondary substation with circuit breaker, considering this selected by mean breaker of line.

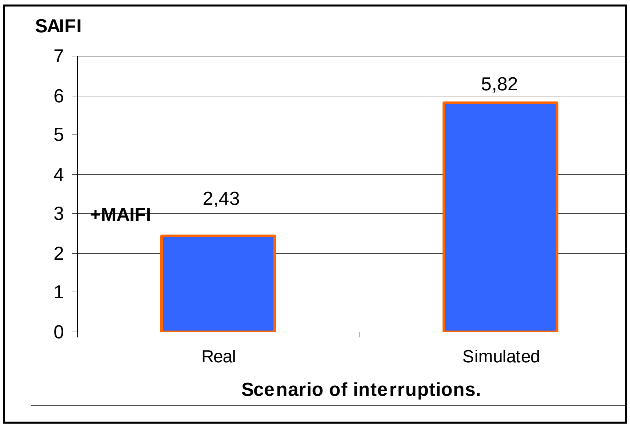

Figure 4 – Real and Simulated value of SAIFI+MAIFI for MV feeder where had been installed a circuit breaker along line.

The benefic effect of a rapid fault selection and reduction of customer moment produces an important improving the continuity of supply, valued by Authority's indicator.

CONCLUSIONS

After one year of experimental campaign with circuit breakers installed along MV feederslines, together with the refinement of protection systems settings to ensure selectivity, it has been possible to assess a substantial improvement of continuity of supply.

REFERENCES

[1] G. Valtorta, L. D'Orazio, R. Calone, V. Salusest, "CONTINUITY OF SUPPLY IMPROVEMENT BY MEANS OF CIRCUIT BREAKERS ALONG MV LINES", *CIRED, 20th International Conference on Electricity Distribution Prague 2009*