THE ORIGIN OF VOLTAGE DIPS MONITORED IN MV NETWORK AND ITS EFFECT ON THE EVALUATION OF MV VOLTAGE DIPS PERFORMANCES INDICES

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ABSTRACT

The subject addressed is the assessment of the origin (High Voltage HV / Medium Voltage MV / Low Voltage LV) of voltage dips monitored on networks and its effect on both voltage dip statistics and indices evaluation at both national and macro area level from the point of view of regulation. The method applied to assess the HV origin of the events refers to both the signal coming from the distance protection of HV lines and to the correlation of the occurrence time of those events which have been monitored on MV bus bars belonging to different HV/MV Primary Substations but underlying a common part of the HV grid. The MV bus bars monitored in this research are those of the Italian MV network monitoring system QuEEN. This method has been partially extended also to the events propagation from the MV to the LV networks thanks to the late installation of a small number of Measurements Units (MU) at specific Secondary Substations in order to realize a sort of "disturbed network tree". The estimation of the percentage of MV events with a probable HV origin at macro area level, for the 2010÷2011 period, has shown a range of variation of about 6%÷15% in comparison with the 37% evaluated at national level. As to the voltage dips performances, indices N_{2a} and N_{3b}, their evaluation at national level for 2011 is affected respectively by the 18,6% and 14,7% by voltage dips with a HV origin. As to the events propagation from the MV to the LV networks a good correspondence between the events monitored at the two voltage levels has been observed.

INTRODUCTION

In the frame of a possible future voltage dips regulation in Medium Voltage (MV) network it is important to be able to assess their origin as the utilities in this case should be responsible only for the events due to faults occurred in their networks. In this contest any preliminary activity focused on the forecasting of the weight that different percentages of voltage dips of different origin could have on voltage dip performance indices becomes a priority. The method applied in this paper to assess the event origin refers to both the signal coming from the distance protection of High Voltage (HV) lines and to the correlation of the occurrence time of those events which have been monitored on MV bus bars belonging to different HV/MV Primary Substations (PS) but underlying a common part of the HV grid. The MV bus bars monitored in this research are those of the Italian MV network monitoring system QuEEN [1]. In this paper the percentage of the MV events with a probable HV origin has been evaluated at first at national level and then at macro area level in order to verify the validity of national results at local level. Besides the statistic of voltage dips of different origin has been compared to the immunity curves normally adopted in the international standard, in order to estimate the weight of the voltage dip percentage with a HV origin on the evaluation of the most common voltage dip performance indices for the MV network. The analysis has been partially extended also to the propagation of these disturbs in the Italian Low Voltage (LV) networks thanks to the late installation of a small number of Measurements Units (MU) at specific Secondary Substations (SS) in order to realize a sort of "disturbed network tree" (Figure 1). The selected substations have been first of all chosen among those which are derived from the PS monitored by the QuEEN system. Besides they belong to 3 different Italian regions (Sicily, Lazio and Piemonte) and are representatives of 3 types of Users (Domestic Users, Tertiary, Tertiary in presence of photovoltaic generation) and of 2 types of line (overhead lines and cables).

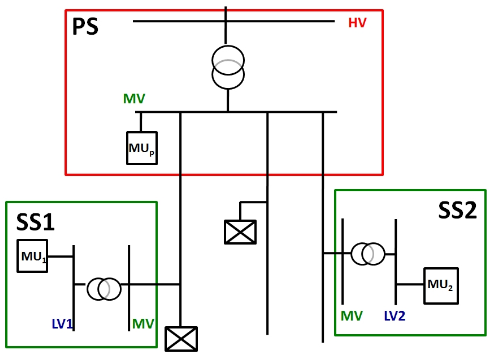

Figure 1: Example of a "disturbed network tree"

VOLTAGE DIPS ORIGIN

Voltage dips monitored on MV distribution networks may have origin in faults occurring in MV networks, HV networks or any Customer' s plants connected to MV networks or, in theory, in LV networks.
A method has been developed to estimate the voltage dip probable origin, which is based exclusively on the analysis of the data monitored by the MV network monitoring system QuEEN.

The method

The method [2] used to estimate, in percentage term, the amount of voltage dips of HV origin, over a one year period, is based on both:

- the detection of events correlated to a signal coming from HV line distance protections, which is provided by the monitoring system;
- the "detailed analysis" of those MV monitored events characterized by correlated occurrence time and relevant to MU belonging to PS underlying a common HV grid ("coincident" instants of voltage dips in the MV network are a proof of the HV origin of the event).

Evaluations at national level

The percentages of voltage dips of probable HV origin, evaluated by applying the above mentioned method to voltage dips data for the monitoring period 2009 ÷ 2011 are summarized in Table 1.

HV/MV voltage dips propagation	2009	2010	2011
N° events of probable HV origin (%) *	28	38	36

* referred to the total number of voltage dips monitored at national level

Table 1: Voltage dips of HV origin monitored in the Italian MV network

On average at national level about the 34% of voltage dips monitored in MV network are coming from the HV network and only the 10% of all the monitored events can be correlated to any starting signal from the HV lines distance protections, confirming the poor reliability of this signal by itself to assess the voltage dip origin[1]. This result is in accordance with the 30% estimation obtained in the past (2008 - 2009 [3]) by applying a method essentially based on a "point by point" comparison among the recordings at the MV and HV bus bars in PS (the last ones supplied by the MONIQUE[2] system of TERNA, the Italian TSO), and in the national transmission network even if on a small number of monitoring sites, surely not representative of the MV Italian distribution network. Referring to the not negligible amount of voltage dips of probable HV origin a first issue to afford is to verify their position against a commonly used immunity curve. Figure 2 and Table 2 show and count the position of HV origin events in relation to Class 2 and Class 3 immunity curves [4][5].

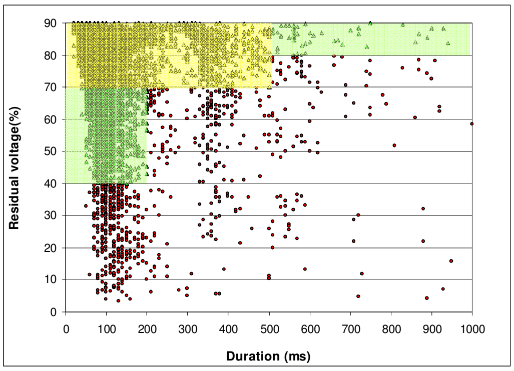

Figure 2: Scatter plot of voltage dips of HV origin monitored in the MV network

Legend:	Events under class 2 curve	Events under class 3 curve	Events in class 2 immunity area
(%) of the HV origin monitored events	20,1	6,6	79,9
(%) of all the events monitored at MV level	7,1	2,3	28,3

Table 2: HV origin voltage dips against the immunity curves

Only the 6,6% of the HV origin events occurs under Class 3 immunity curve that corresponds to the 2,3% of all the events monitored during the year at MV level. Referring to class 2 immunity curve these value increase respectively to 20,1% and 7,1%. The next step has been to verify the distribution along the national territory of this amount of events originated at HV level.

Evaluations at macro area level

Referring to the macro areas shown in Figure 3, the voltage dips of a definite origin do not spread uniformly along the territory as shown in Table 3 and Figure 4.

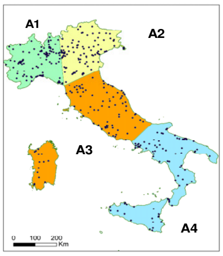

Figure 3: Macro areas

In particular, for 2011, macro area A4 shows (Table 3) the worst performance because of both the highest percentage of dips usually monitored (46,7%) and the prevalent MV origin of these ones (32,8%). As to A2 only the 6,2% of the

[1] In this contest it would be advisable to have more synergies among remote control systems and voltage quality monitoring system, provided that the synchronization problems for the different systems could be resolved.

[2] MONIQUE: System of "MONItoraggio della QUalità della tensione Elettrica" on HV networks.

voltage dips monitored are due to faults in the MV network. The percentages of HV and MV origin voltage dips at macro area level have been evaluated also referring to each macro area total number of voltage dips (Figure 5). In particular for 2011, A1 and A2 are more affected by HV origin events in comparison with the national reference; the majority of events recorded at A3 and A4 have a probable MV origin.

Macro Areas	2010			2011		
	HV (%)*	MV (%)*	HV+MV (%)*	HV (%)*	MV (%)*	HV+MV (%)*
A1	9.3	5.7	15.0	8.1	8.0	16.1
A2	6.6	8.1	14.7	5.6	6.2	11.7
A3	7.4	13.7	21.1	7.9	17.6	25.5
A4	15.2	34.0	49.2	13.9	32.8	46.7
Italia	38.5	61.5	100	35.5	64.5	100

(*)Referred to the total number of events monitored at national level

Table 3: Events origin evaluation at macro area level

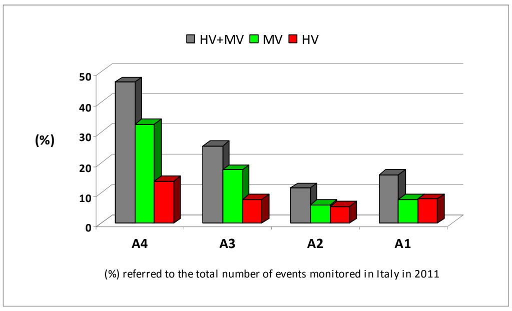

Figure 4: Distribution of voltage dips of different origin along macro areas in 2011

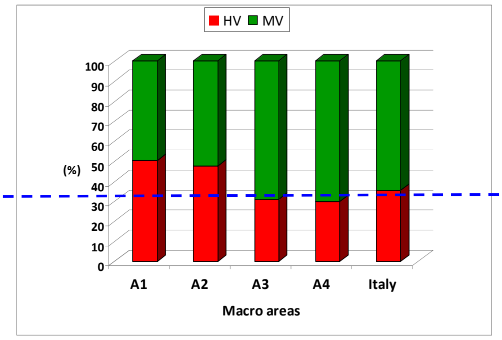

Figure 5: HV and MV dips presence in each macro area in 2011

VOLTAGE DIPS ORIGIN AND INDICES

The "counting" indices N_{2a} and N_{3b}, usually evaluated to assess the Italian network voltage dips performance [6][7], have been computed for the first time taking into account the origin of the events. Referring in particular to 2011 statistics, Figure 6 and Figure 7 show the percentage contribution of voltage dips with a HV and a MV origin respectively to N_{2a} and N_{3b} , at national level (left side).

The N_{2a} index, obtained exclusively on the base of the events with a MV origin, is about the 81,3% of the value computed from the whole statistics. This percentage reaches the 85,3% value for the N_{3b} index. The contribution to N_{2a} and N_{3b} due to voltage dips with a HV origin reaches the 18,6% and 14,7% respectively.

Besides, restricting the analysis to voltage dips with a MV origin, the right side of the figures show the percentage contribution of each macro area to the two indices. In particular the macro areas performances classification do not vary even if HV origin events are neglected (A4 the worst and A2 the best). The N_{3b} index evaluated at macro area A4 is about the 65,8% of the index evaluated at national level exclusively on the base of voltage dips of MV origin.

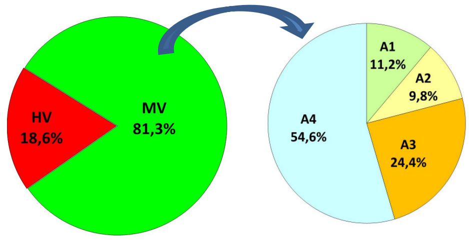

Figure 6: Contributions to N_{2a} of events with respectively a HV and a MV origin at national level (left) and macro area percentage contribution to N_{2a} evaluated exclusively from MV events (right)

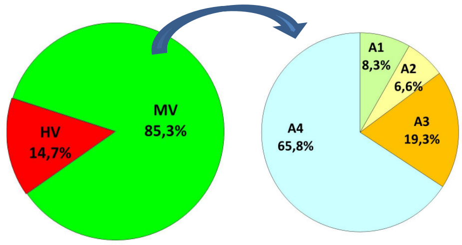

Figure 7: Contributions to N_{3b} of events with respectively a HV and a MV origin at national level (left) and macro area percentage contribution to N_{3b} evaluated exclusively from MV events (right)

EVENTS PROPAGATION FROM MV TO LV

As to the events propagation from MV to LV networks a good correlation has been observed between the measurements performed in CP at MV level and those performed at LV bus bars level in the monitored SS (Figure 8). The differences remarked are mainly due to:

- interruptions involving a MV line that feeds a monitored SS;
- slightly deep voltage dips;
- the alternative feeding of a monitored SS by a MV bar which is not monitored in a primary substation.

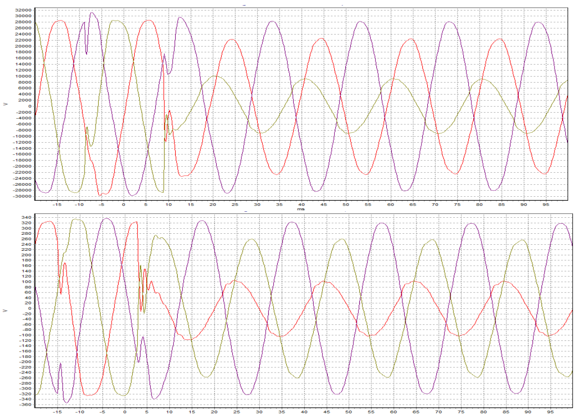

Figure 8: Event monitored at the MV bus bar in PS and at a LV bus bar in a derived SS

As to the interruptions recorded at LV level, it's possible to have two different conditions:

- in case of poly phase faults regarding a MV line, they give origin to events at both MV and LV level;
- in case of a single phase faults no voltage dip occurs.

As an example Table 4 refers to MV/LV events propagation in Sicily and in particular:

- 2 of the 8 interruptions monitored at LV1 are probably due to HV origin events (as all the interruptions monitored in MV);
- the other 6 are probably generated by faults in the MV line which feeds the SS1 where LV1 is installed; these disturbs are recognized as voltage dips at MV level, explaining for the differences between the number of monitored events at MV and at LV1.

Region	Interruptions		Voltage dips	
Sicily	MV	LV1	MV	LV1
	2	8	68	62

Table 4: MV/LV events propagation in Sicily

CONCLUSION

The application of a proposed two steps method for the assessment of the origin of voltage dips monitored in MV networks has led to the following conclusions at national and macro area level:

- about the 34% of voltage dips monitored in MV network are coming from the HV network at national level; only the 10% of all the monitored events can be correlated to any starting signal from the HV lines distance protections;
- the percentages of the events originated at HV level show a significant range of variation at macro area level;
- in particular, for 2011, the South and the Central macro area are characterized by a higher percentage (about 70%), compared to the national average value (about 66%), of voltage dips originated in the MV network;
- the voltage dips performances indices N_{2a} and N_{3b} at national level for 2011 are affected respectively by the 18,6% and 14,7% by voltage dips with a HV origin;
- a good correlation has been observed between the events monitored at MV and LV level even if it would be advisable to have a higher numbers of monitoring sites at LV level to get a more robust statistic.

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