International Conference on Renewable Energies and Power Quality (ICREPQ'14)
Cordoba (Spain), 8th to 10th April, 2014
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, No.12, April 2014

The Power Quality of the distribution networks and its impact on the Telecommunication Next Generation Access Network

R. Chiumeo[1], F. Cucchietti[2], G. Griffa[2], L. Tenti[1]

[1] RSE Ricerca sul Sistema Energetico SpA
Via Rubattino 54, 20133 Milan (Italy)
Phone /Fax number:+0039 02.3992.5126, e-mail: Riccardo.Chiumeo@rse-web.it, Liliana.Tenti@rse-web.it

[2] TELECOM ITALIA – Technology-Innovation& Engineering
Via Guglielmo Reiss Romoli 274, 10142 Turin, (Italy)
Phone/ Fax number:+0039 011.228.8143, e-mail: flavio.cucchietti@telecomitalia.it, gianluca.griffa@telecomitalia.it

Abstract. The paper deals with the Power Quality of the electrical distribution network and its impact on the new telecommunication networks. In particular, in the frame of the deployment of the Next Generation Access Network (NGAN) in the Fiber To The Cabinet (FTTCab) architecture, the impact of severe voltage dips and micro interruptions on the most important Information and Communications Technology (ICT) devices has been evaluated experimentally by Telecom Italia, defining in particular a sort of customized voltage dips immunity area for its telecommunications network equipment (TLC). On the base of these experimental results RSE has performed statistical analyses on voltage dips occurring outside this area which could be responsible in theory for the telecommunication devices reboot. The analyses are based on the data provided by the MV distribution network monitoring system QuEEN in the assumption that MV dips could be totally transferred to the LV network where the telecommunication cabinets are connected. A short analysis of voltage dips propagation from the medium voltage MV to the low voltage LV networks has been performed, on a few measurements sites at disposal in order to confirm this assumption.

Key words

Next Generation Access Network, FTTCab, FTTH, Cabinets, Power Quality, Voltage dips.

1. Introduction

Telecom Italia, like many telecom service providers worldwide has been extending its Ultra Broad Band (UBB) services mainly based on the Fiber To The Cabinet (FTTCab) architecture to the main Italian towns. More precisely, currently more than 25 Italian Cities are covered by FTTCab BB services, while 100 Megabit access is now available in Milan through Fiber To The Home (FTTH). The goal is to cover hundred and twenty-five cities by the end of 2015, corresponding to coverage of close to eight million properties (roughly 35% of the landline population) [1]. The deployment of these fixed access architectures for the Next Generation Access Network (NGAN) imply the installation of cabinets by the telecommunications operators which include sensitive active broadband equipment [2],[3],[4].

The cabinets can be either remotely powered from the central office through the telecom copper pairs or be connected to the local supply. In the latter the Power Quality of the network plays an important role as very short interruptions or severe voltage dips could cause the reboot of any UBB equipment, requiring long time for the restoration of UBB services. On the other hand in case of both an assessed good quality of the electrical network and a sufficient immunity to voltage dips of the Cabinets' equipment the option of avoiding any backup (battery or super-capacitor) could become viable (at least in certain areas). Telecom Italia Lab (TILab) have performed experimental tests on typical ICT equipment to identify the immunity area to voltage dips of its TLC network equipment to be compared with that of typical home equipment (TV, modems …). Referring to the immunity curve identified by these test, RSE have performed proper statistical analysis of the voltage dips monitored by the Italian MV distribution network monitoring system QuEEN [5] in order to provide a raw idea concerning the expected impact of BB equipment directly connected to the electrical grid without batteries. The statistical analysis have been then locally extended to the LV network to evaluate the events propagation from the MV to the LV level.

2. TILab test results

A certain number of tests on the electrical immunity of home equipment (access gateway, LCD TV, Set Top Box, …) together with UBB equipment for FTTCab and FTTH have been performed in TILab's Laboratories in Turin in 2009.

As an example, Fig.1, reports the immunity area related to a Plasma TV 42". As it can be seen, such device can operate with voltage dips with a duration up to 550ms. On the other hand, Fig. 2 illustrates the immunity area of a VDSL2 modem. In this case, it can be recognized its immunity towards voltage dips of up to 180ms. Finally,

Fig. 3 reports the immunity area of a small Optical Network Unit (ONU) capable to provide up to 96 VDSL2 ports. These types of ONUs are currently used for the NGAN project by Telecom Italia, which is based on a FTTCab architecture. As reported in such Figure 3, the BB equipment can operate with voltage dips up to “only” 42ms. To this end, it must be highlighted that the reboot time, once the provisioning of the electrical energy is restored, typically lasts several minutes.

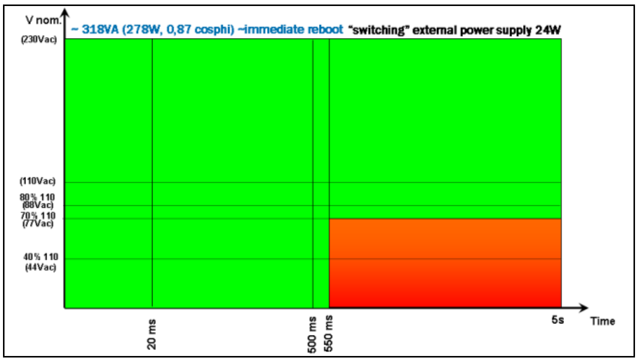

Fig.1.Immunity area of a plasma TV 42”

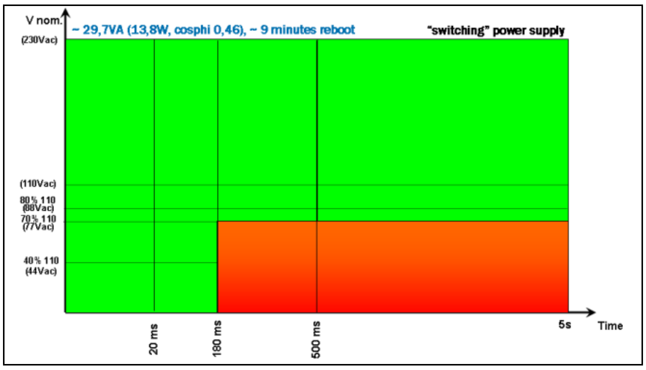

Fig. 2.Immunity area of a VDSL2 modem

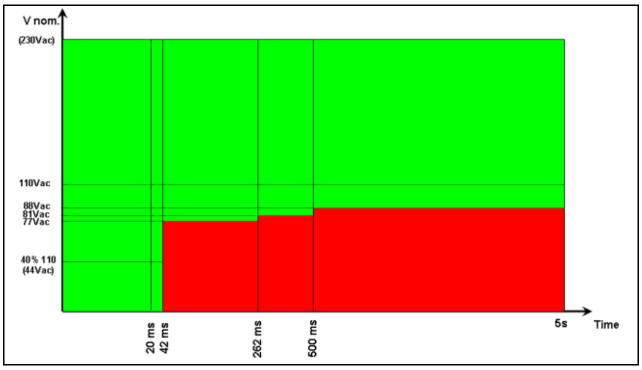

Fig. 3.Immunity area of a ONU VDSL2 for FTTCab

In general, the comparative analysis highlighted that home equipment have much greater immunity to dips than required by current international standards and typically significantly higher than the current TLC devices(Optical Network Units - ONUs and xDSL modems). This leads to significant probability of voltage dips affecting TLC devices and not home equipment; such condition could be misinterpreted by UBB customers making them attribute the inefficiency of the service to the telecommunication operator rather then to the distribution network power quality.

In this frame test results on the quality of the electrical network should help with the sizing of the problem and in finding appropriate backup solution.

B. TILab Zone of interest

Referring to the voltage dips main characteristics (residual voltage U and duration D) two principal zones can be identified on the base of the above mentioned test results (Fig.4):

1) *Zone R.* $U > 30\%$ $\quad 20ms \le D \le 60s$
which is a no-reboot area for the equipment under analysis (immunity area). This excellent immunity against voltage reduction is due to the inherent features of the switching power supply designed to work with all voltage ranges used Worldwide, thus accepting seamless operating conditions down to less than 100V (to comply with the 110V nominal voltage).
2) *Zone A.* $U \le 30\%$ $\quad 20ms \le D \le 60s$
which is a possible reboot area for UBB equipment and therefore an area of interest for PQ statistical analysis (zone of interest).

Zone A, in its turn, can be split in the following areas on the base of voltage dip duration:

Zone B. $U \le 30\%$ $\quad 20ms \le D \le 100ms$
Zone C. $U \le 30\%$ $\quad 100ms \le D \le 500ms$
Zone D. $U \le 30\%$ $\quad 500ms \le D \le 60s$

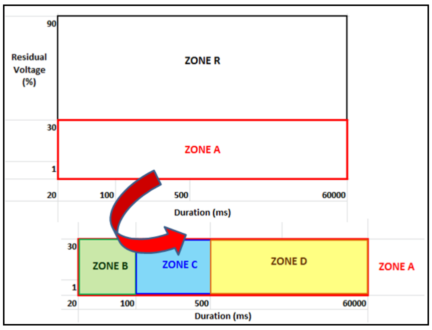

Fig.4.Zone of interest for UBB equipment

3. RSE voltage dips statistic at MV level

Statistical analysis of voltage dips monitored on 400 MV busbars of primary substations of the Italian distribution network have been performed at different levels (national, macro area, regional, rural and urban area) on the base of the data provided by the QuEEN monitoring system through the years 2009÷2012, in the assumption that MV dips could be totally transferred to the LV network where the telecommunication cabinets are connected.

The multilevel approach has been chosen in order to evaluate the performance to severe events of areas comparable to a urban conglomeration, of interest to

UBB deployment, without losing statistical representativeness too much by crossed checks of the result at the different levels.
First of all the numerousness of voltage dips, for the whole monitoring period, in the TILab Zones of Interest have been assessed. Besides the duration distribution of voltage dips in *Zone A* have been evaluated in order to get useful indications for establishing the possible need of a backup compensating strategy.

A. *Voltage dips statistics at national, macro area and regional level*

The events monitored in *Zone A* represents about the 5,3% of the total number of voltage dips in the examined period (Fig. 5).
The majority of "Type A" events concentrates in the *Zone C* (83,5%) where long duration deep voltage dips (D > 500 ms) represent only the 2.8% of the total number of "Type A" events.

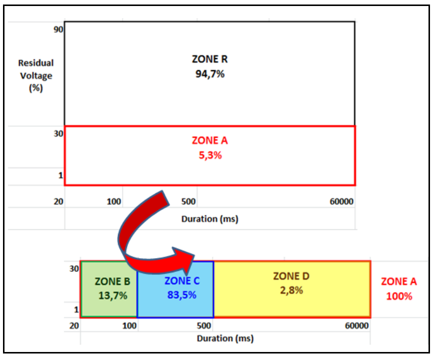

Fig. 5.The distribution of events in the zone of interest

Table I summarizes the result of the statistical evaluations at the different levels of analysis.

Table I. – Statistic for voltage dips in *Zone A* 2009÷2012

Type of statistic		Zone of Interest			
		A	B	C	D
		N° voltage dips in a year per point of measurement			
National Level	Italy	5,4	0,7	4,5	0,1
Level A	Zone with a high density of inhabitants	5,9	0,7	5,0	0,2
Level B	Zone with a low density of inhabitants	5,2	1,0	4,0	0,2
Macro Area Level	A1 North West	3,4	0,6	2,8	0,1
	A2 North East	2,6	0,6	2,0	0,1
	A3 Center and Sardinia	4,5	0,9	3,5	0,1
	A4 South	11,3	0,9	10,0	0,4
Regional Level	Sicilia	21,7	1,6	19,4	0,7
	Campania	7,9	0,6	6,9	0,4
	Puglia	6,2	0,7	5,3	0,1
	Lazio	6,1	0,7	5,3	0,1
	Toscana	3,7	1,2	2,5	0,1
	Veneto	3,6	0,4	3,2	0,1
	Piemonte	3,3	0,7	2,6	0,0
	Lombardia	2,0	0,3	1,6	0,0
	Emilia Romagna	1,3	0,4	0,9	0,0

At national level *Zone A* is characterized by the occurrence of 5,4 event per year per point of measurement (PME), of which 4,5 events show typical *Zone C* duration.
These results do not vary significantly when we refer only to measurements sites (89) belonging to areas characterized by more than 50000 inhabitants (about 6 events per year per measurement point should be expected in comparison with the 5 events monitored at sites characterized by a low density of inhabitants, <5000).

Taking into account the four macro areas in which the national territory can be subdivided, the number of events occurring in *Zone C* is around 2,5-3 events per year per point of measurements for three macro areas in comparison with the 10 events monitored in the South.
Limiting the analysis to a group of regions whose biggest towns are going to be interested by the first UBB deployment phase and which have at least 20 QuEEN sites it is possible to verify a great difference in the performances of Sicily (19,4 event /y*PME in C) and Emilia Romagna result (0,9 event /y*PME in C). The other regions, on the average, show performances which are aligned to the corresponding macro area ones as has been already assessed on national scale in previous work [6][7][8][9].

As to the distribution of duration of voltage dips in the *Zone A* at national level (Fig. 6) it is possible to make the following remarks:

- a first peaks of events is centred within the duration range 120-140 ms (P1);
- a secondary peak correspond to the duration of 320 ms (P2);
- P2/P1 = 9,2%;
- ≈ 80% of *Zone A* events are characterized by duration D ≤ 180ms;
- ≈ 8% of *Zone A* events has duration D > 320ms;

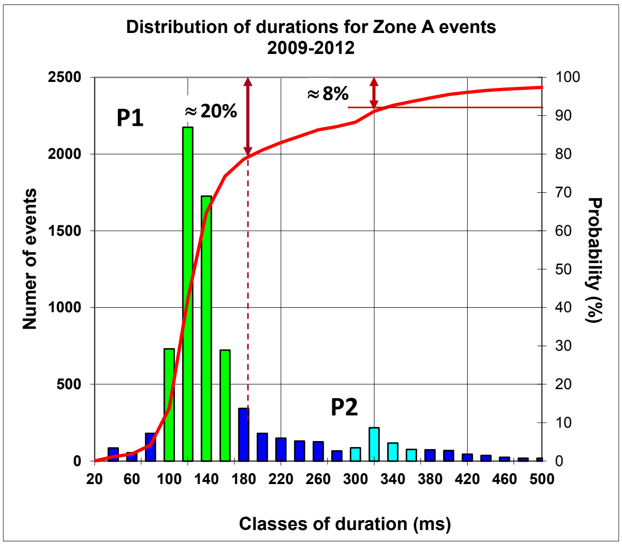

Fig. 6.The distribution of durations for Zone A events

B. *Voltage dips statistics at rural/urban level*

In order to get more significant information for the faced problem a group of 23 provinces has been selected among those interested by the NGAN deployment. This aggregate, named Group of Urban Provinces (GUP), includes both urban and rural area and consists of 167 QuEEN measurement sites, being still a representative aggregate.
The results of the analysis are shown in Table II and Fig. 7.

Table II

GUP	N° events per year per point of measurement			
Year	A	B	C	D
2009	4.7	0.6	4.0	0.1
2010	5.0	0.6	4.4	0.1
2011	3.9	0.4	3.4	0.1
2012	4.6	0.6	3.9	0.1
mean value	4.6	0.5	3.9	0.1

The number of events monitored in *Zone C*, 3,9 events per year per measurements point, is more similar to Level B (less populated areas) performance, than Level A. This confirms that a group of provinces cannot be considered representative of a urban behavior from the point of view of the QuEEN system monitoring sites. The distribution of duration for the events in *Zone A* confirms the presence of two peaks centered respectively at 120-140 ms and at 320 ms, probably due to the typical line faults clearing time. The mean ratio of the two peaks in the period 2009-2012 is P2/P1=8,2% and a yearly growing trend is evident (≈18% in 2012).
The percentage of events with duration respectively D≤180 ms (20%) and D > 320 ms (8%) are the same evaluated at national level.

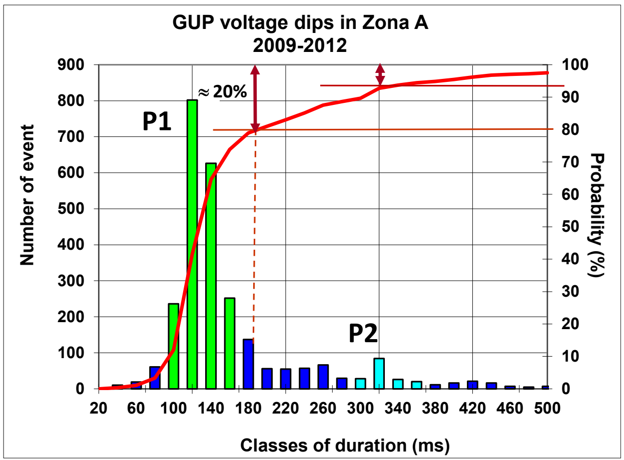

Fig. 7.The distribution of durations for Zone A events in the 23 monitored provinces (GUP)

C. Voltage dips statistics at urban level

A second aggregate of measurement sites has been selected taking into account only the QuEEN sites (40 sites) installed in 7 big Italian towns (Reduced Urban Group Urban or RUG) having each more than 250000 inhabitants. The associated statistic is shown below.

Table III

RUG	N° events per year per point of measurement			
Year	A	B	C	D
2009	3.4	0.6	2.6	0.1
2010	2.9	0.5	2.4	0.1
2011	2.3	0.4	1.9	0.0
2012	2.8	0.4	2.2	0.2
mean value	2.9	0.5	2.3	0.1

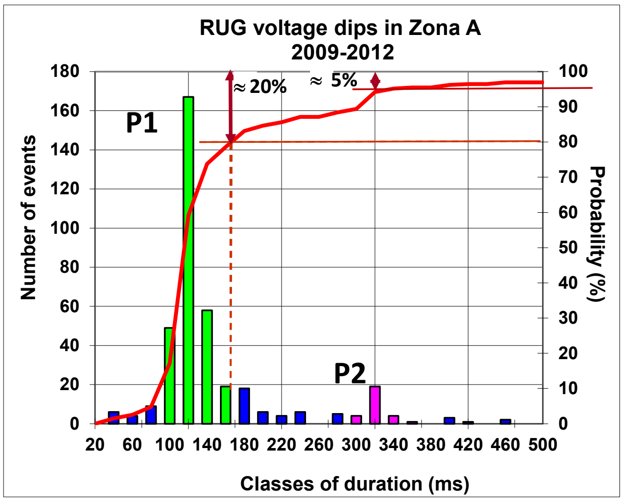

Fig. 8.The distribution of durations for Zone A events in 7 big towns (RUG)

The number of events monitored in C (about 2 events per year per point of measurement) is comparable to those of the macro area North West and North East. As to the distribution of duration:

- the first peaks is centred at 120 ms (P1);
- the secondary peak still appears at 320 ms (P2);
- P2/P1 = 9,6%;
- ≈ 80% of Zone A events are characterized by duration D ≤ **160ms**;
- ≈ **5%** of Zone A events has duration D > 320ms;

The distribution of durations for the RUG aggregation appears slightly shifted towards shorter values. This could be an advantage in view of a possible strategy of voltage dips compensating with proper backup solution that could be differentiated according to specific geographical power quality.

Referring to the statistical analysis performed at MV level, it is possible to draw the following conclusions:

- "*Type A*" events represent only the 5,3% of the voltage dips monitored in the examined period;
- the majority of "*Type A*" events occurs in *Zone C* (100 ms…500 ms);
- "*Type A*" events numerousness vary both with the macro area (the South shows the worst performance) and with the region, even if the performance at regional level are aligned with those of the associated macro area;
- a selected group of provinces or towns monitor less "*Type A*" events than an urban area which have more than 50000 inhabitants (Level A);
- the distribution of duration of the events points out at every level of analysis (national, regional, macro area, group of provinces or towns) that ≈ 80% of "*Type A*" voltage dips has a duration D ≤ 180 ms .

4. RSE voltage dips statistic at LV level

The PQ disturbs that usually affect UBB equipment at the Cabinets' level could be caused also by faults originated at LV level by other users. These disturbs cannot be taken into account by the statistical analysis previously shown which are based on data monitored at MV level. However in order to get a first raw estimate of the ratio of events propagated from the MV network with those monitored at LV level a brief statistical analysis has been performed at local level. The LV analysis is referred to data acquired at secondary substation level. The ratio above mentioned has been estimated as near to 1.

The detailed analysis of these data proves that:

- the MV events move to the LV network where they are monitored;
- any possible differences is due to the interruptions of the MV line from which the secondary substation has been derived. In particular:
  - polyphase faults involve both an interruption for the faulted line and a voltage dip at the MV busbar, at all the MV lines and at their associated derivations which are supplied by the above mentioned busbar;
  - single phase faults are responsible for the interruptions of the faulted line but do not generate any voltage dips.

5. Conclusion

This work is a first step in the settlement of the impact of voltage dips occurring in the electrical networks on the ICT equipments involved by Telecom Italia plans of development, the so called NEXT Generation Access Network. The step has been fulfilled by the evaluation of the voltage dips numerousness outside the immunity area for these equipment and of the distribution of their durations, where the immunity area has been defined by experimental tests. The performed analysis has been based on the QuEEN MV PQ data, taking into account a MV/LV propagation coefficient of voltage dips near to 1. In the future it will be useful to perform more investigations on low voltage faults impact on LV voltage dips statistic.
The results of the analysis will be useful to the Telco to implement proper backup solutions optimizing the tradeoff between immunity and investments.

Acknowledgement

The RSE research activities in this work have been financed by the Research Fund for the Italian Electrical System under the Contract Agreement between RSE S.p.A. and the Ministry of Economic Development - General Directorate for Nuclear Energy, Renewable Energy and Energy Efficiency in compliance with the Decree of March 8, 2006.

The TELECOM Italia research activities have been developed in the frame of a research collaboration with RSE.

References

[1] http://www.telecomitalia.com/tit/en/archivio/media/comunicati-stampa/telecom-italia/mercato/consumer/2013/06-20.html
[2] http://www.telecomitalia.com/content/dam/telecomitalia/it/archivio/documenti/Innovazione/NotiziarioTecnico/2011/n1-2011/capitolo2_bassa.pdf (in Italian)
[3] http://www.telecomitalia.com/content/dam/telecomitalia/it/archivio/documenti/Innovazione/NotiziarioTecnico/2012/n2-2012/capitolo6.pdf (in Italian).
[4] http://www.telecomitalia.com/content/dam/telecomitalia/it/archivio/documenti/Innovazione/NotiziarioTecnico/2012/n2-2012/capitolo10.pdf (in Italian).
[5] R. Chiumeo, M. de Nigris, L. Garbero, L. Tenti, A. Porrino, “The Italian Power Quality Monitoring System of the MV Network: Results of the Measurements of Voltage Dips After 3 Years Campaign”, CIRED 2009, Prague 8÷11 June 2009.
[6] R. Chiumeo, L. Garbero, L. Tenti, C. Gandolfi, M. de Nigris, “The voltage dip performance assessment of the Italian MV network through global indices”, 21st International Conference on Electricity Distribution, CIRED 2011, Frankfurt, paper 0886.
[7] R. Chiumeo, L. Garbero, L. Tenti, “Le prestazioni della rete in MT in relazione ai buchi di tensione”, Official Journal of AEIT, Milan (2011), pp.14-25 (in Italian).
[8] R. Chiumeo, C. Gandolfi, L. Garbero, F. Malegori, M. Volta, L. Tenti, “The origin of voltage dips monitored in MV network and its effect on the evaluation of MV voltage dips performance indices”, 22nd International Conference & Exhibition on Electricity Distribution, Stockholm (2013), paper 0655
[9] R. Chiumeo, M. de Nigris, C. Gandolfi, L. Garbero, L. Tenti, 2010, "Voltage dips performance characterization by PQ indices at national and macro area level", 14th International Conference on Harmonics and Quality of Power, ICHQP, Bergamo, paper 93