CHARACTERIZATION OF SEQUENCE OF EVENTS POTENTIALLY RESPONSIBLE FOR THE REBOOT OF ULTRA-BROADBAND TELECOMMUNICATION DEVICES

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ABSTRACT

The paper deals with the impact of the quality of service of the electric distribution networks on the new generation telecommunication network, which provide the main Italian towns with ultra-broadband services. Telecom Italia has adopted the fibre to the cabinet architecture for its ultra-broadband services, involving tens of thousands of active nodes installed in street cabinets, initially powered through remote DC feeding from Telecom central stations. The increased push towards ultra-broadband coverage requires more energy hungry equipment so feeding from local electrical distribution network has been adopted.

The paper addresses in particular the evaluation and characterization of sequence of voltage dips, which could disrupt the service to clients through the reboot of the ultra-broadband devices installed in the street cabinets, in order to acquire useful input to set a suitable compensation strategy for them (short term storage devices, including super-capacitors), to compensate the most frequent voltage disturbances. The engineering solution adopted by Telecom Italia is based on both the results of RSE statistical analysis and the supply requirements/capabilities of telecom devices to be powered.

INTRODUCTION

Telecom Italia (TI) has been providing the main Italian towns with Ultra Broad Band (UBB) services mainly based on the Fiber To The Cabinet (FTTCab) architecture [1]÷[4]. That architecture enables a smooth and cost-effective evolution of the services to the client, being capable to deliver data speed in the 100Mbit/s region and constitutes a step towards the long-term Fiber To The Home (FTTH) architecture. In FTTCab, the optical distribution network (ODN) is deployed from the TI's Central Office to the outdoor street cabinet. Such cabinet includes active broadband equipment, connected to the local power supply from public mains (FIGURE 1).

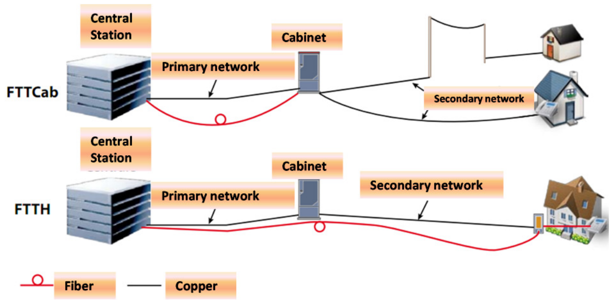

Figure 1. FTTCab and FTTH architectures

The customers are connected to the cabinets through the existing copper pairs through Very high speed Digital Subscriber Line (VDSL2) transmission technology. The Power Quality (PQ) of the distribution electrical network therefore plays an important role at cabinet level. From Telecom perspective, severe voltage dips are those which can cause the reboot of the ultra-broadband (UBB) equipment in the cabinet and the subsequent loss of service. This service disruption could last several minutes due to the restoration time needed by the telecom equipment and the authentication procedures of other service providers. From a Telecommunication Company (TelCo) perspective, there is the need to identify the best economically viable solutions, that minimize such disruptions. One more aspect to be taken into account is that today many home ICT devices are able to withstand voltage dips much longer than those required by the Standard (10ms), and survive up to some hundreds of milliseconds. This translates into a requirement to the telecom network equipment to be able to cope to same or longer voltage dips.

The power supply elements used in telecom equipment are commonly compatible with both 230Vac and 110Vac and thus can operate below 100Vac. So, in Europe, the voltage dips that are critical to the events are typically those characterized by residual voltage lower than the 30% of the nominal supply voltage. On the base of statistical analysis carried out at national level, RSE has estimated the frequency of occurrence of such events which could potentially have a negative impact on the UBB devices. To set a suitable compensation strategy, the telecommunication operator has also to take into account the possibility of occurrence of sequences of severe voltage dips, to avoid the reboot of a device which has just “overcome” a severe event, thanks to a compensating device. Such device, typically a capacitor, will need relatively long times to recharge, after compensating the first event. So statistical analysis have been performed to identify sequences of events characterized by “lap time” ranging from 200 ms to 10 seconds. On the base of these first results, TI has made its deployment plans taking into account local powering solutions, where no battery is adopted but rather a super-capacitor able to guarantee an immunity of roughly 1.7s @ 250W, to be installed in the cabinet. A first engineering solution is presented in the present paper.

THE PQ PROBLEM SIZING

Severe events

Referring to the results of the experimental activity performed at TI Lab’s Laboratories [5], the voltage dips responsible for the reboot of UBB devices are those occurring in Zone A (Figure 2). These events are therefore characterized by residual voltages lower than 30%. On the base of statistical analysis carried out at national level in the period 2009-2012, based on data collected at MV level by the QuEEN[1] monitoring system, RSE have estimated the voltage dips numerousness[2] outside the immunity area (Zone R) defined by experimental tests for these equipment and the distribution of their durations[3].

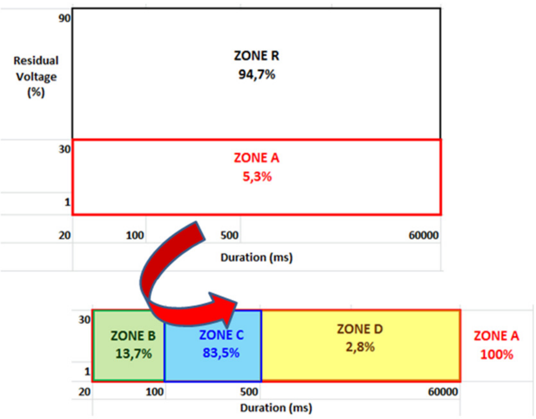

Figure 2. Reboot zone (A) for UBB devices

The most important results of the analysis are summarized hereafter:

- the “severe events” occurring in Zone A represents about the 5.3% of the total number of voltage dips monitored in the period;
- the majority of “Type A” events concentrates in Zone C (83.5%) with duration ranging in the interval: 100 ms < Duration ≤ 500 ms;
- the **97.2%** of these “severe” voltage dips have duration lower than **500 ms**;
- long duration voltage dips (D > 500 ms) represent only the 2.8% of “Type A” events.

Sequence of events

To set a suitable compensation strategy the telecommunication operator has also to consider the possibility of occurrence of “sequences of severe voltage dips” to avoid the possible reboot of a device which has just “overcome” a severe single event thank to a compensating device. Therefore statistical analysis have been performed to identify sequences of Type A events characterized by lap time (time between the start point of two subsequent events as shown in Figure 3) ranging from 200 ms to 10 s.

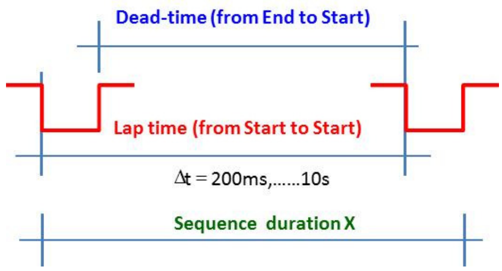

Figure 3. Characterization of sequences of severe events

The results are shown in Figure 4:

- the sequences of events with a lap time ≤ 1s (red curve) correspond only to the 4.2 % of the total number of severe events (Type A);
- this percentage corresponds at the same time to:
  - the 29.3 % of sequences of severe event with a lap time ≤ 1min (blue curve);
  - more than a half (52,1%) of sequences of events with Δt ≤ 10 s.

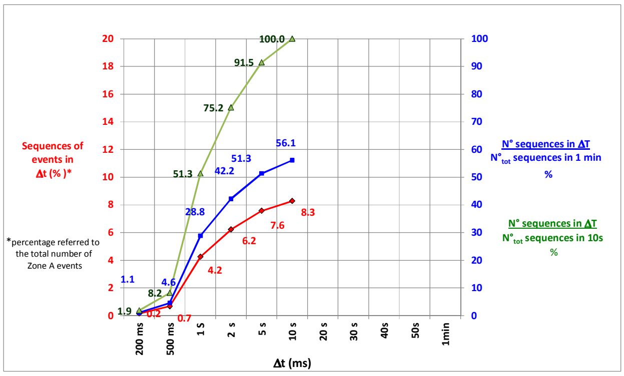

Figure 4.Numerousness of sequences of Type A events occurring in Δt from 200 ms to 10 s

[1]QuEEN: the Italian MV networks voltage quality monitoring system collecting PQ data by 400 instruments installed on HV/MV substations MV bus-bars and statistical representative of the network (http://queen.rse-web.it).

[2] Micro-interruptions occurring in MV lines cannot be monitored by the QuEEN monitoring system used by RSE as monitoring units are installed at MV bas bars in primary substations.

[3] The analysis are based on the QuEEN MV PQ data, assuming a MV/LV voltage dips propagation coefficient near to 1.

A prevalence of sequences of very close events is so observed. In order to analyse in details the sequences occurring within 10 sec the frequency histogram of their dead times has been evaluated (Figure 5) together with the histogram of the duration of the first event of the sequences analysed (Figure 6 and Table I).

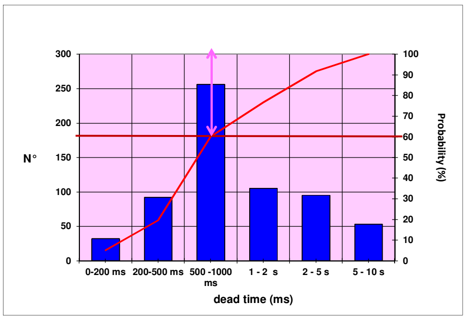

Figure 5. Dead time histogram for sequences of events with Δt within 10 sec

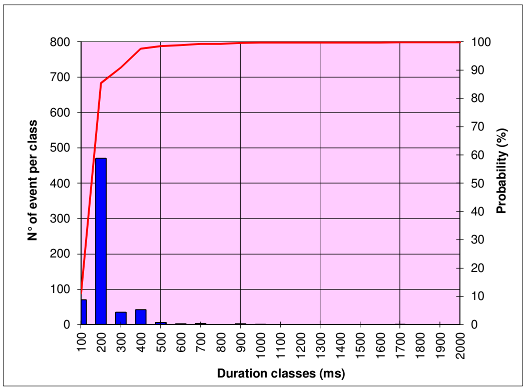

Figure 6. Histogram of first event durations for sequences of events occurring within 10 sec

The following observations can be made:

- the 40% of sequences within 10sec have got dead time in the range 500÷1000 ms;
- about the 85% of sequences within 10s are characterized by a first event duration ≤ 200 ms;
- the mean duration of the first events (164.3 ms) represents a small percentage of the lap-time (10 s) of these sequences;
- the probability of a first event duration > 1s is about 0.3%.

Table I

1° Event duration in sequences with Δt within 10 s		
Average	**Max value**	**Min valus**
164.3	2910	30
95%	**50%**	**25%**
344	130	120

THE TELECON ITALIA COMPENSATION STRATEGY

For the deployment of its UBB access network in FTTCab architecture, characterized by active remote street cabinets supplied by the DSO public power network, Telecom Italia is going to make use of back-up solutions for micro-interruptions, by the adoption of continuity modules as "SuperCAP" (based on ultra-capacitor technology).

At the moment, a back-up unit has been realized to be installed between the 230Vac/48Vdc supply and the UBB devices of the FTTCab plan, at 48 Vdc level, to compensate micro-interruptions generated by the public network at 230Vac, making no use of continuity batteries. This module works in direct current at 48 Vdc, storing energy in ELDC (Electric Double Layer Capacitor) cells and giving it back in case of a supply voltage shortage.

Principle diagram and technical characteristics

The module consists of three main blocks:

- input section, for disconnecting cells from the input when DC power is affected by an AC voltage event (voltage dip or micro-interruption), avoiding current (and energy) flow backwards to the input;
- charge control unit, for the control of charging (at constant current) and discharging phases of the compensating unit;
- energy storage unit, made up of 20 SuperCAP cells (25 F each), connected in a serial way and each of them working at 2.4 V.

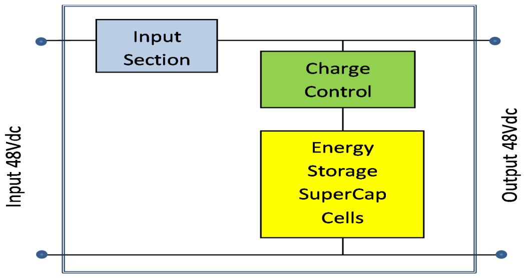

Figure 7. Block diagram of TI's backup module (SuperCAP)

Figure 8. TI's compact backup module for micro-interruptions

Here below the main technical data of this first backup solution (see Figure 8) that Telecom Italia has identified and that will be adopted in the new FTTCab deployments:

Capacity	1.25 F
Base SuperCAP cell	25 F
Cells number	20
Nominal/Max Voltage	48 / 54 Vdc
Nominal backup time	1.7 s @ 250W
Recharge current	< 1A
Extended temperature range:	-40°C / +70°C
Cooling technique	natural convection
Extended lifetime	> 10 years
Life cycles (@ 25°C)	500000
Dimensions (WxHxD)	50x100x120 mm

This backup module is mounted in a metallic box, that can be installed on DIN rails, for quick and easy operation in the UBB outdoor street cabinet of FTTCab access networks.

Telecom Italia application

UBB equipment, the so called ONU (Optical Network Unit) or MSAN (Multi Service Access Node) are designed to operate, on their power 48 Vdc nominal feeding input, in the range from 40.5 to 57 Vdc (ref. standard ETSI EN 300 132-2).

In order to assure UBB service's continuity, the power feeding system (with back-up unit for micro-interruptions compensation) must be able to assure that the operating input voltage to UBB equipment is kept in this range, as long as possible.

In the current TI's solution for voltage disturbances compensation, the ONU equipment (with 192 VDSL2 ports) is powered at 48 Vdc nominal voltage. When a severe voltage dip or a micro-interruptions occurs on DSO public power network, the load of the ONU (250W as a maximum, with all the 192 costumer with VDSL2 service active) is powered by the back-up unit, with its voltage lowering down from 48 to 40.5 Vdc (minimal operating voltage of UBB equipment). With the current implementation of TI's back-up unit, this phase has a duration of about 1.7 s, with a rate of voltage decreasing of (48 - 40.5) / 1.7 = 4.412 V/s.

The same back-up unit has, instead, a complete recharge phase duration of about 90 seconds (with current control and limitation, to avoid overload on ac/dc power supply unit), this meaning that the rate of voltage increasing, during recharging phase, is of 48 / 90 = 0.534 V/s.

The choice of a 1.7 s for the nominal backup time has been suggested by the results of the statistical analyses previously presented. In fact even if most of the severe events (97.2 %) have durations within 500 ms we have to take into account the probability of occurrence of "longer" sequences of these events. As the 4.2% of the "severe" events (Type A) could appear in sequence characterized by a lap time of 1 sec and taking into account the typical duration of the first event of the sequence (164.3 ms) and its typical dead-time (200ms) a backup time of 1 s should cover most of the sequences. Considering the environmental conditions at which the UBB devices normally operate (T > 25C°), and the consequent possibility of a worsening of their performances during the time due also to their ageing, the nominal backup time has been fixed at 1.7 s to have a margin of operation.

TI will still explore, with help of the research bodies and industry players, further ideas or solutions for the compensation of micro-interruptions from public mains, possibly affecting UBB services. It must be also taken into account that similar approach and solutions, with regard to the one presented in this paper, are already available on the market and have been adopted by other TelCo. In this context it would be useful to have a joint action (TelCos/Vendors/Research) on this issue, also at the standardization level.

CONCLUSIONS

Most of the severe voltage dips which could be responsible, in FTTCab access networks, of the UBB devices reboot have a duration less than 500 ms (97.2%). Sequence of severe events have been analysed: referring to those sequences occurring within 10s, in fact the 52% of them are concentrated in 1s. Moreover, the first event of these sequences has a mean duration of about 160 ms and dead-time of 200 ms.

Taking into account these results, together with the environmental condition at which the UBB devices operate, TI has identified a first back-up solution for voltage dips disturbances based on SuperCAP technology. This solution can be considered a starting point for future developments, that will look also at possible alternatives to be reached through a joint action TelCos/Vendors/Research on the issue.

Acknowledgments

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