APPLIANCES IMMUNITY TO REAL-WORLD VOLTAGE DIPS AND SHORT INTERRUPTIONS IN PUBLIC SUPPLY NETWORKS

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ABSTRACT

This paper is focused on the short voltage events in the supply networks. In the first part there is a description of immunity curves and theirs testing process. The next part is devoted to voltage dips and short interruptions in public supply system. There is a description of fundamental dip-parameters and classification method of them on the second part of paper. The paper describes a confrontation of immunity curves of some tested appliance with voltage events in real public supply network and calls attention to deficiencies at statistical classification of voltage dips and short interruptions in supply systems.

1. INTRODUCTION

Electric appliances immunity is generally defined as the ability to work in the presence of an electromagnetic disturbance without characteristic degradation. The testing of electric devices immunity against voltage dips and short interruptions is given by the standard EN 61000-4-11 [2] that specifies testing techniques and sets testing levels. The testing voltage behaviour is based on nominal RMS voltage of concrete tested appliance. The changes of voltage have to be very quick and can start and finish in any phase angle of voltage. Pre-dip and post-dip voltage magnitude is equal to nominal voltage. The shape of the testing voltage dip is very close to rectangular one.

2. IMUNITY CURVES AND ITS TESTING

Immunity curves appear from well known IEEE curve (shown on Fig. 1) and they represent the appliances immunity to short voltage events. The lines enclose the area in which the equipment is able to work without function changing and data lost (in the case of computer sources). Immunity level to voltage dips and short interruptions is given by bottom curves.

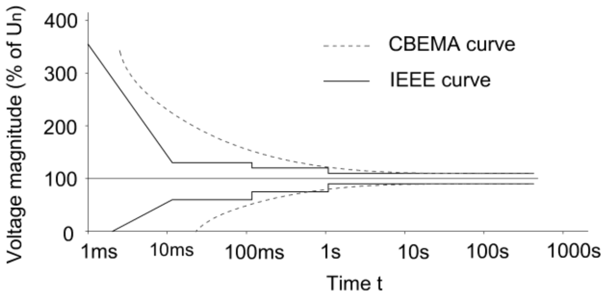

Figure 1: CBEMA and IEEE curve [7]

The testing of immunity curves is complicated process, it is necessary to have a special programmable power source and special analysing devices to attainment of exact results. The testing process is described in detail in [5]. For example the immunity curves of computer source shown on Fig. 2 are the result of the testing process.

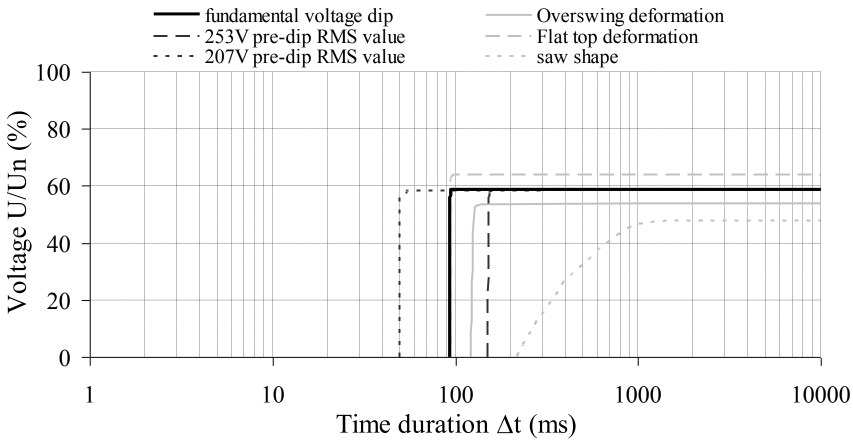

Figure 2: Immunity curves of tested computer source CWT 235 ATX for some of chosen dip-parameters modifications [6]. Function criterion: interruption of output supply voltage and computer system was rebooted.

3. VOLTAGE DIPS AND SHORT INTERRUPTIONS IN PUBLIC SUPPLY NETWORKS

The short voltage dip is a short duration sudden reduction of RMS voltage, which is caused by short-circuits, overloads, starting of large motors, etc. And as the two-dimensional electromagnetic disturbance the short voltage dip is described by dip magnitude and time duration. Although the voltage dip has in accordance with [2] only two parameters to its description, voltage dip can have a lot of variations [5], such as variable pre-dip and post-dip RMS voltage value, variable shape (rectangular, saw, triangle and others) with different voltage falling and rising time, wave distortion by harmonics, variable initial dip phase angle and others. These dip variations very influence correct functions of all connected appliances, especially computer sources, light sources and other appliances containing switch-mode power supplies (SMPS). Influence of voltage dip variations on immunity curves of computer source is shown on Fig. 2.

Short voltage interruption is short duration voltage dip to zero voltage. In the three-phase supply systems the problem of the short voltage interruptions is more complicated. The short voltage interruption can occur in one phase or in two phases or in the all three phases of supply system. It is not exactly defined if it is possible to use term “short voltage interruption” for single phase voltage dip to zero value or only for three-phase voltage dip to zero value.

The statistical classification of voltage dips and short interruptions in public supply networks is done for understanding of power system stability and its reliability. In accordance with [1] all voltage events are divided into several following subcategories (Table 1, Table 2).

Residual voltage [%] / Time duration t [s]	10ms≤t <100ms	100ms≤t <200ms	200ms≤t <500ms	500ms≤t <1s	1s≤t<3s	3s≤t <20s	20s≤t <1m	1m≤t <3m
85 ≤ d < 90	N_{11}	N_{21}	N_{31}	N_{41}	N_{51}	N_{61}	N_{71}	N_{81}
70 ≤ d < 85	N_{12}	N_{22}	N_{32}	N_{42}	N_{52}	N_{62}	N_{72}	N_{82}
40 ≤ d < 70	N_{13}	N_{23}	N_{33}	N_{43}	N_{53}	N_{63}	N_{73}	N_{83}
5 ≤ d < 40	N_{14}	N_{24}	N_{34}	N_{44}	N_{54}	N_{64}	N_{74}	N_{84}
d < 5	N_{15}	N_{25}	N_{35}	N_{45}	N_{55}	N_{65}	N_{75}	N_{85}

Table 1: Statistical classification of voltage dips in public supply networks [1]

Time duration t [s]	t < 1s	3min ≥ t ≥ 1s	t > 3min
Number of interruptions	N_1	N_2	N_3

Table 2: Statistical classification of voltage interruptions in public supply networks [1]

4. MEASURING OF SHORT VOLTAGE EVENTS IN REAL PUBLIC SUPPLY NETWORK

Short voltage events in real public supply networks have to be measured by special measuring analysers, which are mainly located in important substations, shunt transformers in rural networks etc. Voltage events analysers have to have a sufficient value of memory to recording many hundreds of events because analysers monitor and record voltage events without person control for a long period of time, such as with a year period of data downloading. As it can be seen on Table 1, many voltage dips and interruptions (events) were registered in the tested public network. Total number of registered events was 265. Table 1 contains all recorded voltage dips and interruptions in tested supply network because for intention of this article it was not necessary to separate voltage dips from short interruptions. Voltage interruptions are included at the last column (signed as 5% >U ≥ 0%).

Residual voltage level / Time duration level	90% > U ≥ 85%	85% > U ≥ 70%	70% > U ≥ 40%	40% > U ≥ 5%	5% > U ≥ 0%
10ms ≤ Δt < 100ms	13	10	3	1	0
100ms ≤ Δt < 200ms	28	24	11	42	19
200ms ≤ Δt < 500ms	1	1	4	11	4
500ms ≤ Δt < 1s	4	2	4	0	0
1s ≤ Δt < 3s	7	1	1	0	34
3s ≤ Δt < 20s	0	0	0	0	6
20s ≤ Δt < 60s	0	0	0	0	5
60s ≤ Δt < 180s	0	0	0	0	8
180s ≤ Δt	0	0	0	0	21

Table 3: Number of voltage dips and interruptions in the first phase of tested three phase supply network

As it can be seen in Table 1, the most frequent voltage dips are dips with dip-duration at intervals from 100ms until 200ms. In this interval the most frequent dips are dips with residual voltage at intervals from 40% until 5% of nominal voltage (42 times); then from 90% until 85% (28 times) and then from 85% until 70% of nominal voltage (24 times). The most frequent voltage interruptions have duration at intervals from 1s until 3s (34 times). Voltage interruptions with durations at intervals longer than 180 seconds are also very frequent but these voltage interruptions cannot be called as short; these are called as long-time voltage interruptions. No electric device can work continuously along the long-time voltage interruption.

All recorded voltage dips and interruptions are also shown on Fig. 3.

As it was mentioned above all electric devices need the power supply for theirs correct working. It was determined by several tests [6] that voltage interruptions with time-duration about 10 second and longer can be considered as long-time interruptions, they have the same influences on tested devices as a voltage interruption with never-ending duration.

5. CONFRONTATION OF VOLTAGE DIPS AND SHORT INTERRUPTIONS IN REAL SUPPLY NETWORK WITH IMMUNITY CURVES OF COMPUTER SOURCES

Fig. 3 shows immunity curves of different types of computer sources together with symbols designating measured voltage dips and short interruptions. The Fig. 3 has not the exact predicative avocation because immunity curves were measured for fundamental voltage dip (sin wave without distortion by harmonic, nominal pre-dip and post-dip RMS voltage vale, rectangular shape of voltage dip with exactly defined durations of voltage falling and rising time, zero value of pre-dip phase angle, etc.) defined by [2] and described in detail in [6], while voltage dips and interruptions recorded in supply network include all possible voltage dips variations and modifications without specification of them.

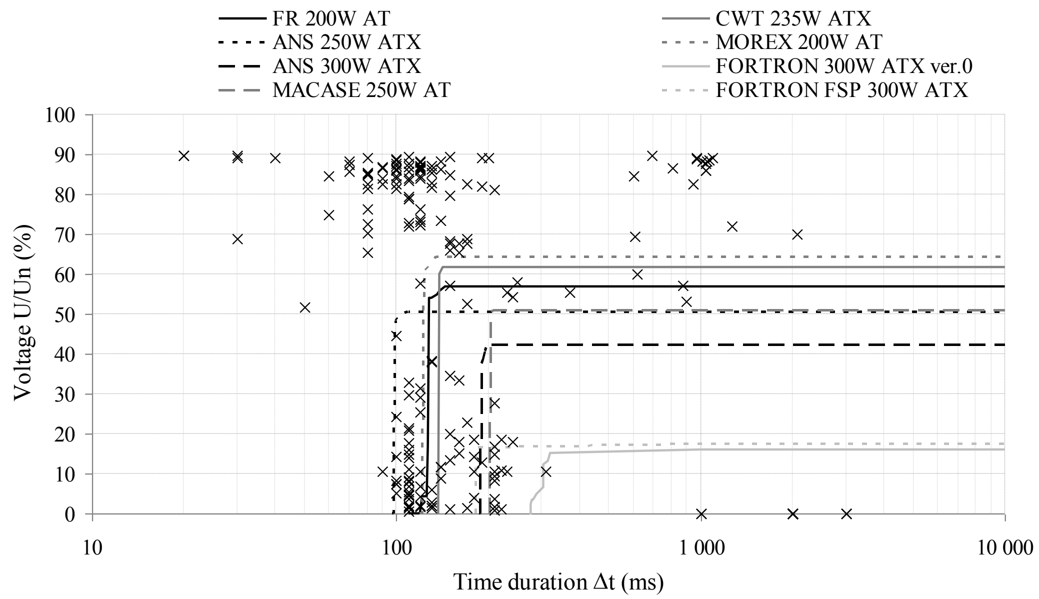

Figure 3: Immunity curves of tested computer sources along with mapping of short voltage dips and interruptions

As it can be seen in Fig. 3 the computer source FORTRON 300W ATW version 0 has best immunity to voltage dips and short interruptions. It is immune to nearly all voltage dips in supply network – only one voltage dip caused its reboot. It is immune to short interruptions whose time durations are not longer than about 270ms. With respect to voltage dips and short interruptions recorded in tested supply network the computer source ANS 250W ATX has the worst ability to immunity to them.

6. CONCLUSION

In laboratory conditions there is a tendency to parameterize the influence of each voltage dip parameters on the immunity curves of tested appliances. All real-world voltage dips in public supply networks are dips with more than one dip-parameters modification. Although we are able to simulate all possible modifications of voltage dips and test theirs influence on connected electric appliances; because the voltage events analysers mainly save only two fundamental parameters of voltage events (residual voltage and time-duration) we are not able to exactly reconstruct real world voltage dips. The results obtained in laboratories will never have the same predicative values as the results obtained in supply networks till the analyzers do not save other important data about voltage events.

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