PROJECTOR MODELING AND PERFORMANCE ANALYSIS WITH NON IDEAL SUPPLY CONDITIONS USING ATP SIMULATOR

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***Abstract* – This paper is aimed at proposing a computational model to represent projector devices and to perform studies involving non-ideal voltage supply conditions. In order to validate the model, experimental and computational analyses are carried out to highlight the equipment behavior and the model accuracy under normal and abnormal conditions. The equipment is represented throughout a switched source with a boost converter. Although the results are related to this specific product it should be emphasized the approach could be extended to other products having similar principles. Both theoretical and experimental investigations take into account: voltage distortion, fluctuation, sag, swell and interruption.**

***Keywords* – Boost converter, computational modeling, equipment performance, power quality, projector and switched source.**

I. INTRODUCTION

In recent years, the electrical supply may show no ideal characteristics that can compromise the normal operation of consumer devices [1]. This situation may jeopardise the physical appliance integrity and refunding request are greatly increasing. This is especially true for new technology devices which are, generally, more sensitive to the power quality.

In order to have means to analyze the relationship between a claimed damage and a given voltage disturbance, the use of computational tools arises as a promising approach. In general, this strategy comprises the following steps: equipment model and experimental validation, device and system time domain computational implementation, facilities to simulated voltage disturbances, and finally, the comparison between the equipment withstand capability and disturbed voltage impacts upon the investigated product.

Within this context emerge the modern devices named as projectors. These have been intensively used for a variety of application comprising residential leisure to professional use. According to information of specific utilities, this device is becoming a matter of great concern due its high cost and the growing number of request for refunding due to abnormal voltage conditions at the mains.

Thus, this paper focuses the subject of modeling, validation and performance investigation of projectors with abnormal supply conditions such as: harmonic distortions, variations of voltage of short duration (sag, swell and interruption) and voltage fluctuations.

II. APPROACH

To carry out the above proposal, the following steps were followed:

A. Equipment Model

The equipment considered in this paper is shown in Figure 1. The product input voltage can vary from 100 to 240 V, 50/60 Hz, and the selected supply voltage for this paper studies are associated to 220 V, 60 Hz supply. This voltage is hereby on denominated as the reference voltage.

Fig. 1. The projector equipment used for the studies.

Throughout manufacturer datasheet information and laboratory investigation, it was possible to derive the simplified equivalent circuit given in Figure 2. According to representative offices the units considered in the circuit are the main components which will often be the reason for the damage occurrence in such type of device. For this paper purposes only the switched source and the boost converter are fully considered, the other components are included in a simplified way. Further details of the simplified model can be found in [2].

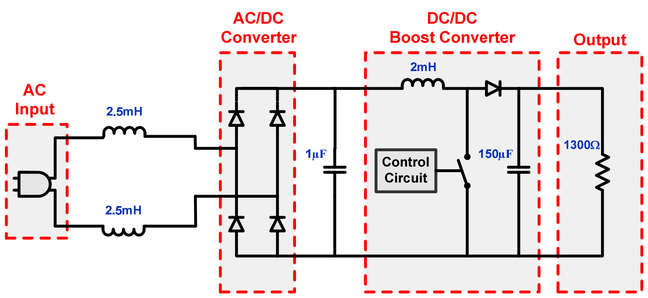


Fig. 2. The proposed projector simplified electric circuit.

B. Computational Implementation

The program used for the computational studies is the ATP (Alternative Transients Program). This software is a very well accepted tool to deal with time domain representation of electrical power systems. In order to insert the above projector model in this program, the ATPDraw facilities have been used. To perform typical distribution or other electrical system, the program uses internal libraries which are not described in this paper. Additional information in relation to this can be found in [3].

C. Model Validation and Studies

Once the model has been included into the ATP simulator, the next step goes in the direction of validating the proposed projector representation. To achieve this goal, a set of studies involving ideal and non-ideal voltage supply conditions were utilized to reproduce both theoretical and laboratory performance behavior. By comparing corresponding results it is possible to establish qualitative and quantitative comparative terms in order to conclude the proposed model accuracy. The laboratory arrangement is given in Figure 3. It comprises a programmable HP6834A source, three-phase, 4.5 kVA and other equipment to register the voltage and current waveforms.

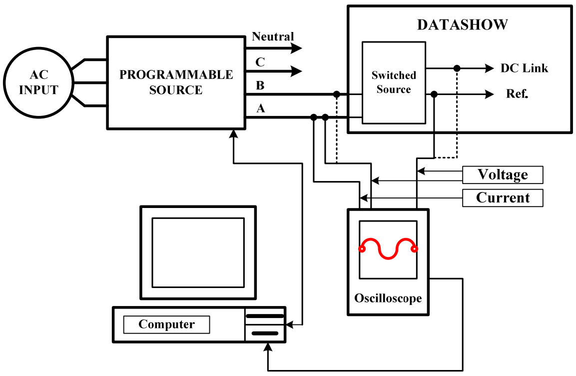


Fig. 3. Experimental arrangement for the studies.

III. STUDIED CASES

Table I shows the cases investigated in this paper. It can be seen that, in addition to the ideal condition, named as Case 1, a few non-ideal voltage situations were also considered. The last ones aimed at accomplish the validation process with distinct power quality indicators, as defined by the national and international standards.

TABLE I
Studied Cases

Case	Characteristics
1 – Ideal and Rated Condition	Fundamental voltage - 220 V, 60 Hz;
2 – Voltage Swell	Fundamental voltage - 220 V, 60 Hz, containing swell of 20% lasting for 10 cycles.
3 – Voltage Sag	Fundamental voltage - 220 V, 60 Hz, containing sag of 40% over 10 cycles.
4 – Voltage Interruption	Fundamental voltage - 220 V, 60 Hz with a interruption during 3 cycles.
5 – Harmonic Distortion	Fundamental voltage - 220 V, 60 Hz, with a total harmonic distortion of 20%.
6 – Voltage Fluctuation	Fundamental voltage - 220 V, 60 Hz, showing a flicker defined by a Pst (Probability short-term) level of 5 pu.

IV. RESULTS

By performing the above studies it will be possible to obtain a comprehensive overview of the projector behavior with normal and abnormal voltage conditions. For each situation, the following variables are focused for both simulation and experimental investigation:

- Input AC voltage;
- Input AC current;
- DC link regulated voltage.

A. Ideal Condition: Case 1

This first situation considers the projector is operating with ideal and rated conditions. Thus, this situation aims at reproducing the reference case to be used for comparison purposes with other studies. In addition to this application, the results are first used to validate the model as their expected values are previously known from the manufacturer data.

Figures 4 and 5 illustrate the voltage and current waveforms at the equipment input. As already stated, both experimental and computational results are given.

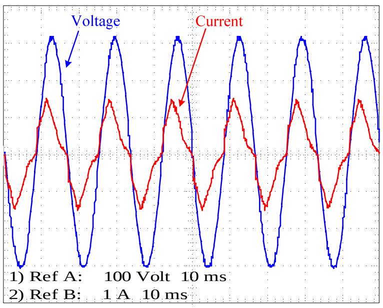


Fig. 4. Supplied voltage and input current - Case 1 - Ideal condition – Experimental.

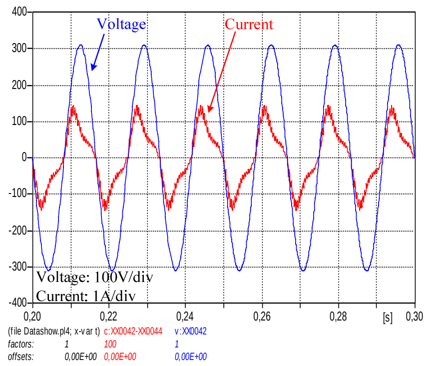


Fig. 5. Supplied voltage and input current - Case 1 - Ideal condition – Computational.

Figures 6 and 7 illustrate the experimental and computational regulated DC voltage waveforms. These are taken at the boost converter output.

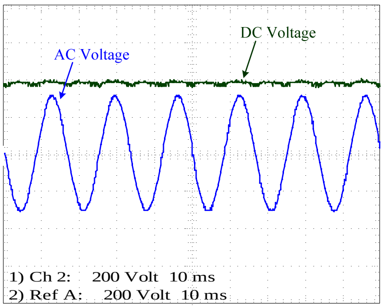


Fig. 6. Supplied voltage and regulated DC voltage - Case 1 - Ideal condition – Experimental.

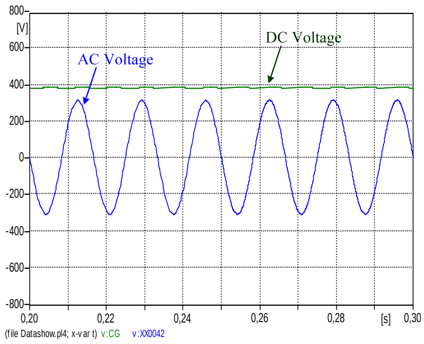


Fig. 7. Supplied voltage and regulated DC voltage - Case 1 - Ideal condition – Computational.

It can be seen that the results derived from the laboratory experiments and those obtained from the ATP are in very close agreement. Both waveforms and values are quite similar. The only appreciable distinction is found on the high frequency oscillation upon the current waveform. Although they appear in both experimental and computational results, the latter shows higher level. This effect is introduced by the high switching frequency associated to the boost converter. The difference between the waveforms can be attributed to the integration period used for the theoretical studies. The input current RMS values and the harmonic spectrum (THD) are given in Table II. Therefore, concerning ideal and rated conditions, the model has been fully validated.

TABLE II
Computational and Experimental Values

Input Current	Computational	Experimental
RMS (A)	0.86	0.87
THD (%)	24.11	21.44

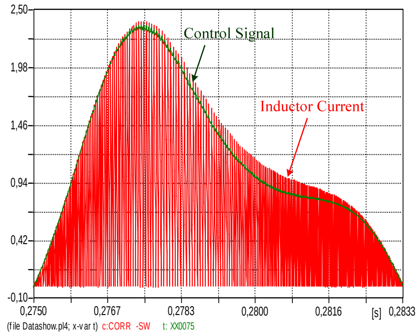
In order to provide means for a better understanding about the equipment functioning in terms of internal characteristics, further details related to the boost converter operation are presented in the sequence.

The electric circuit that provides the switching control of the boost converter is given by a proportional and integral function. The output signal of this function is obtained by comparing a 380 Volts reference level with the regulated DC voltage.

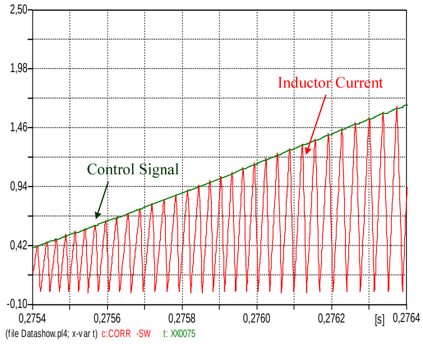
The boost converter operation comprises the following steps:

- When the switch is closed, the input source supplies energy to the inductor and the current that flows arises linearly;
- When the switch is opened, the inductor supplies the stored energy to a RC load and the current is linearly reduced [4].

Figure 8 (a) shows the inductor current and the switch control signal during a time interval of ½ cycle of the fundamental frequency. Complementarily, Figure 8 (b) provides the corresponding zoom during the rising control period. The result is obtained from the ATP model and emphasizes the boost converter performance under Case 1 conditions.



(a) ½ cycle.



(b) Zoom for the rising control period.

Fig. 8. Inductor current and switch control signal - Case 1 - Ideal condition – Computational.

B. Voltage Swell: Case 2

The voltage and current waveforms at the equipment input are shown in Figures 9 and 10.

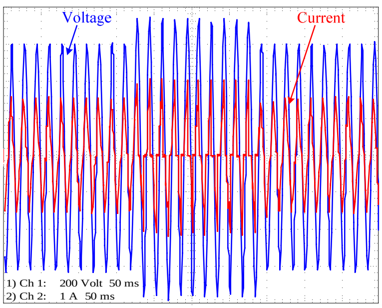


Fig. 9. Supplied voltage and input current - Case 2 - Voltage Swell – Experimental.

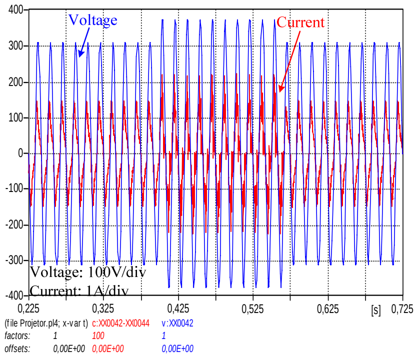


Fig. 10. Supplied voltage and input current - Case 2 - Voltage Swell – Computational.

Figures 11 and 12 illustrate the experimental and computational regulated DC voltage waveforms.

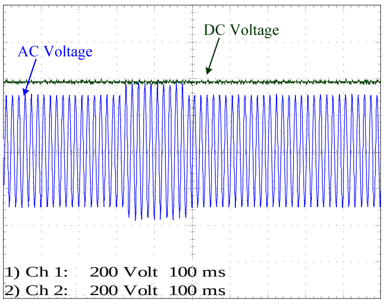


Fig. 11. Supplied voltage and regulated DC voltage - Case 2 - Voltage Swell – Experimental.

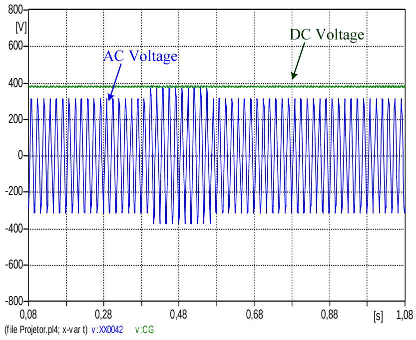


Fig. 12. Supplied voltage and regulated DC voltage - Case 2 - Voltage Swell – Computational.

Once again the results derived from the experiments and those obtained from the ATP are in good accordance. The input current peak values are given in Table III. Therefore, concerning both rated and swell voltage conditions, the model has been validated.

TABLE III
Computational and Experimental Values

Input Current	Computational	Experimental
Peak value (A)	2.23	2.08

C. Voltage Sag: Case 3

Following the previous cases, Figures 13 and 14 show the voltage and current waveforms at the equipment input.

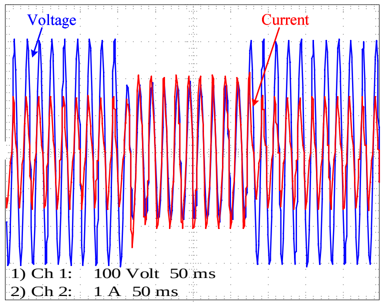


Fig. 13. Supplied voltage and input current - Case 3 - Voltage Sag – Experimental.

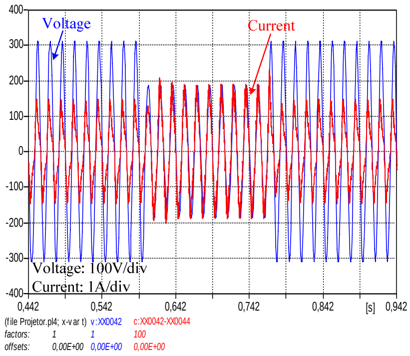


Fig. 14. Supplied voltage and input current - Case 3 - Voltage Sag – Computational.

Figures 15 and 16 illustrate the experimental and computational regulated DC voltage waveforms.

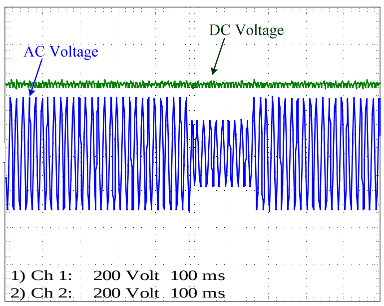


Fig. 15. Supplied voltage and regulated DC voltage - Case 3 - Voltage Sag – Experimental.

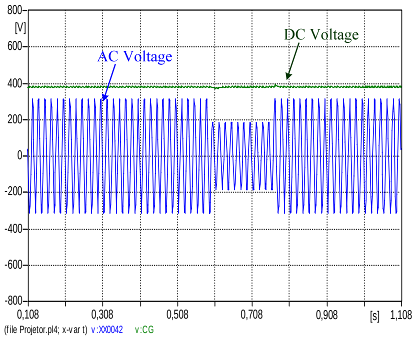


Fig. 16. Supplied voltage and regulated DC voltage - Case 3 - Voltage Sag – Computational.

The input current peak values are given in Table IV.

TABLE IV
Computational and Experimental Values

Input Current	Computational	Experimental
Peak value (A)	2.30	2.60

D. Voltage Interruption: Case 4

With the above non ideal situation, Figures 17 and 18 illustrate the voltage and current waveforms at the equipment input.

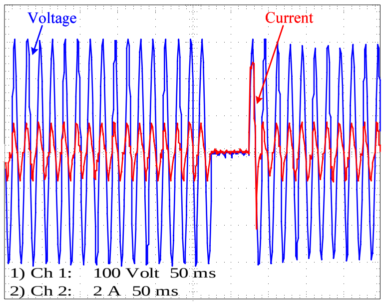


Fig. 17. Supplied voltage and input current - Case 4 - Voltage Interruption – Experimental.

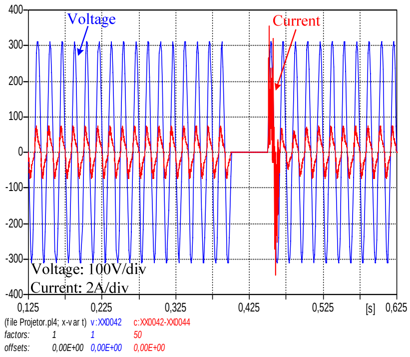


Fig. 18. Supplied voltage and input current - Case 4 - Voltage Interruption – Computational.

Figures 19 and 20 illustrate the experimental and computational regulated DC voltage waveforms.

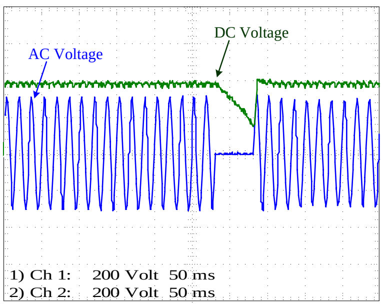


Fig. 19. Supplied voltage and regulated DC voltage - Case 4 - Voltage Interruption – Experimental.

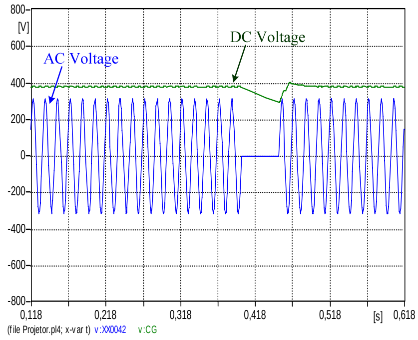


Fig. 20. Supplied voltage and regulated DC voltage - Case 4 - Voltage Interruption – Computational.

Again the results derived from the experiments and those obtained from the ATP are within acceptable agreement. The input current peak values are given in Table V.

TABLE V
Computational and Experimental Values

Input Current	Computational	Experimental
Peak value (A)	6.68	5.03

E. Harmonic Distortion: Case 5

Concerning the operation with distorted voltage conditions, Figures 21 and 22 illustrate the voltage and current waveforms at the equipment input.

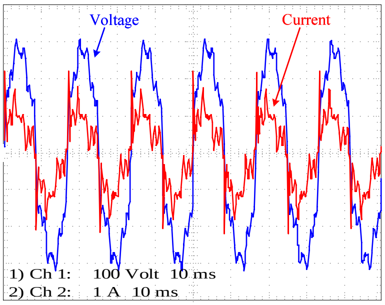


Fig. 21. Supplied voltage and input current - Case 5 – Harmonic Distortion – Experimental.

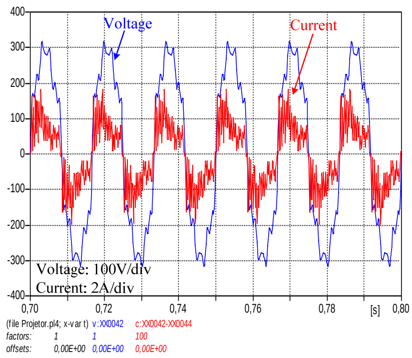


Fig. 22. Supplied voltage and input current - Case 5 – Harmonic Distortion – Computational.

The DC link has shown a similar behavior to Case 1 and it will not be repeated at this point. The input current RMS and peak values are given in Table VI.

TABLE VI
Computational and Experimental Values

Input Current	Computational	Experimental
RMS value (A)	0.91	0.92
Peak value (A)	1.83	2.20

F. Voltage Fluctuation: Case 6

The effect of a supply voltage containing low frequency fluctuation is highlighted by Figures 23 and 24, which illustrate the voltage and current waveforms at the input.

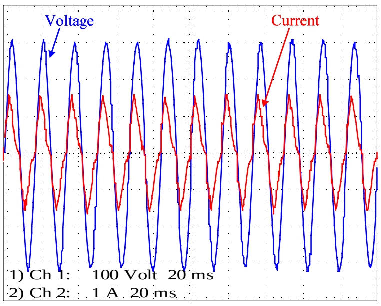


Fig. 23. Supplied voltage and input current - Case 6 – Voltage Fluctuation – Experimental.

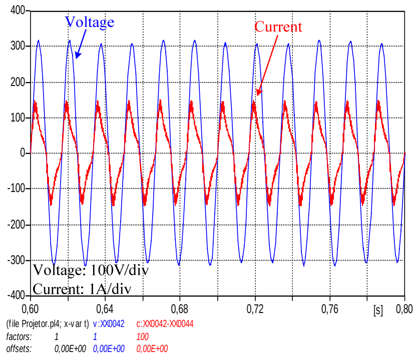


Fig. 24. Supplied voltage and input current - Case 6 – Voltage Fluctuation – Computational.

As previously, the results derived from the experiments and those obtained from the ATP are in accordance. The input current RMS and peak values are given in Table VII.

TABLE VII
Computational and Experimental Values

Input Current	Computational	Experimental
RMS value (A)	0.91	0.92
Peak value (A)	1.48	1.64

V. CONCLUSION

This paper proposal has focused the subject of electro-electronic appliances concerning time domain computational modeling and operation with ideal and non-ideal supply conditions. A specific device, namely, the projector, was chosen to be described and investigated. The reason for that was given by the necessity of accurate models towards the analysis of consumers refunding due to distribution system disturbances. The high cost of this product allied to its sensibility to voltage deviation from ideal conditions has emerged the investigation here described. As already mentioned, some utilities are been requested to repayment processes involving this appliance.

The paper contribution at providing a time domain projector modeling has been shown to be achieved. The validation process involving corresponding theoretical and experimental investigation has proved the model adequacy for both transient and steady state investigations. By implementing this product into the well acceptable ATP software it was possible to obtain a computational platform which allows the focused equipment studies with both ideal and non ideal supply voltage conditions. Thus, an important step has been given in the subject of aching a computational procedure to support final decisions concerning equipment refunding requests.

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