2010

The 230 V CBEMA curve - Preliminary studies

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Publication Details
S. T. Elphick & V. W. Smith, "The 230 V CBEMA curve - Preliminary studies," in 20th Australasian Universities Power Engineering Conference: Power Quality for the 21st Century", 2010, pp. 1-6.

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Abstract
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Keywords
230, CBEMA, curve, Preliminary, studies

Disciplines
Physical Sciences and Mathematics

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The 230 V CBEMA Curve – Preliminary Studies

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Keywords-CBEMA; 230 V; sag; immunity; susceptibility; ITI

I. INTRODUCTION

The ITI, formerly CBEMA, curve as defined in [1] and shown in Figure 1, is widely used throughout Australia as an indication of the sag immunity of equipment connected to electricity distribution networks. This is in spite of the fact that the curve was specifically developed to apply only to Information Technology (IT) equipment connected to 120 V 60 Hz electricity networks. The percent of retained voltage levels represented on the curve are intended to be based on a 120 V base, however, they are often directly transferred to a 230 V base. The limitation of the curve with regard to applicable equipment and system voltage/frequency render the relevance of the curve to the Australian 230 V 50 Hz system and its applicability to equipment other than IT equipment a matter of conjecture.

The study presented in [2] indicates that the CBEMA Curve provided a general indication of the voltage sag tolerance that could be expected of an entire plant. However, the tolerance of individual pieces of equipment was not assessed. There is very little other literature which discusses the applicability of the ITI Curve to 230 V electricity distribution systems.

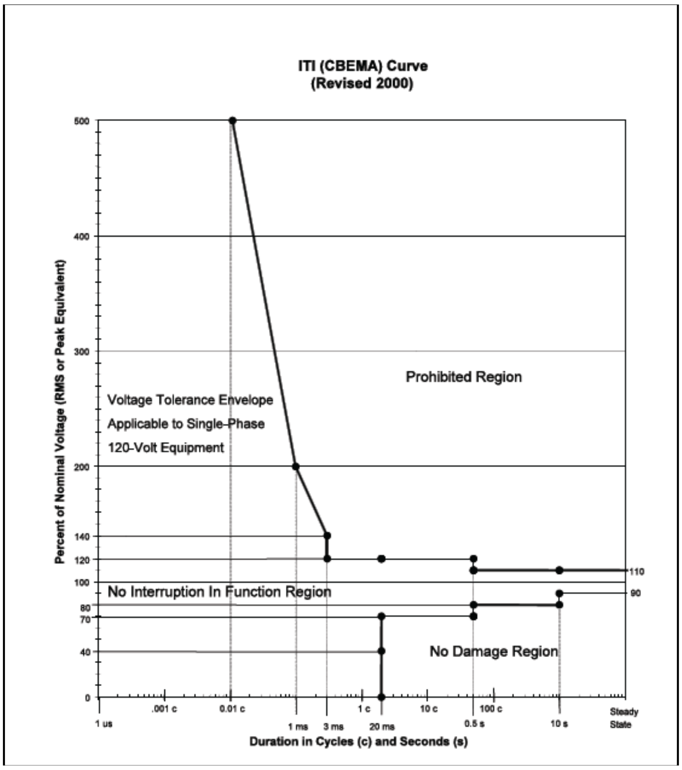

Figure 1. ITI Curve [1]

This paper describes preliminary studies aimed at development of an ITI or CBEMA type curve(s) applicable to the Australian 230 V 50 Hz electricity distribution system. In the first instance, the curve(s) are developed to describe AC input voltage tolerances for a range of the most common domestic equipment. In this stage of the study only sensitivity of equipment to voltage sags is investigated. Behaviour for swells, which are included in the ITI Curve, is beyond the scope of the study. Sags are deemed to be of more importance than swells in this instance due to the fact that they occur far more frequently than swells and an argument can be made that sags are the most costly of all power quality disturbances due to lost production. For example, data in [3] provides some

Acknowledgement: The authors would like to thank the Australian Strategic Technology Program (ASTP) of the Energy Networks Association for their generous funding of this project.

details of the potential costs of voltage sags to manufacturing plants.

II. Sag Susceptibility Assessment Methodology

A. Application of Sags

The arbitrary waveform generator at the University of Wollongong is capable of generating voltage sags with durations down to 0.1 cycles. This device is used to apply voltage sags to the equipment under test (EUT). A methodology has been developed to assess whether or not the EUT is operating normally during the applied voltage sag and to determine if the equipment under test is functioning as expected after the application of the voltage sag. This methodology is tailored to suit each specific EUT and is used to assess the susceptibility of the EUT to the applied voltage sag. It is not feasible to apply every potential sag duration and depth to each EUT. As such, a range of sag depths and durations has been developed to assess the EUT. The sag depths and durations which have been applied to each EUT are shown in Table 1. Sags which have been applied are marked with an "X". More emphasis is placed on deeper short duration sags as it is believed that most resolution is required in this area as opposed to shallower sags due to the fact that impact on equipment will be greatest for deeper sags.

TABLE I. Sag Depths and Durations Applied to each EUT

Retained Voltage (%)	**Duration (Cycles)**																		
	1	**3**	**5**	**7**	**9**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**200**	**300**	**400**	**500**
80										X					X	X	X	X	X
60						X	X	X	X	X	X	X	X	X	X				
40				X	X	X	X	X	X	X									
20	X	X	X	X	X	X	X	X	X	X									
10	X	X	X	X	X	X	X	X	X	X									
0	X	X	X	X	X	X	X	X	X	X									

B. Equipment Tested

The domestic equipment tested is of two main types; electronic and refrigerator. The electronic equipment tested was the following: -

- Televisions (TVs). Three technologies, CRT, Plasma and LCD have been assessed. These 3 technologies represent the most common television types found in domestic homes. The CRT TV was a 51 cm model, the plasma TV was a 32 inch model and the LCD TV was a 32 inch model.
- Personal Computer (PC). A Pentium 4 PC has been assessed. A brand new 500W power supply was installed in this PC immediately prior to testing.
- LCD PC Monitor. A 17 inch monitor from a well-known manufacturer has been assessed.
- DVD players. Two DVD players have been assessed. These 2 DVD players represent different manufacturers and price points. The first DVD player priced at approximately $60. The second is priced at approximately $110.
- Clock radios. Two clock radios were assessed. These two devices represent 2 different price points. The first clock has a price of approximately $60. The second has a price of approximately $30.
- Microwave oven. The microwave tested was a modern inverter type from a well-known manufacturer with a 1.1 kW rating.
- Home Printers; a laser and an inkjet all-in-one type have been tested
- Portable hard disk drive. A 1 GB model from a well-known manufacturer has been assessed.
- CFL lighting. A 14W model from a well-known manufacturer has been assessed.

For the refrigerator type equipment the following equipment has been tested: -

- Air Conditioners; a portable type and an inverter split system type have been tested. The inverter air conditioner is a 3.3 kW model while the portable air conditioner is a 1.33 kW model
- A modern refrigerator has been tested. The refrigerator was a 600 L side-by-side fridge/freezer model. This device was specially selected as it contains electronics which enable the user to set target temperatures for the fridge and freezer.

C. Equipment Assessment Procedures

Assessment of equipment performance was undertaken using a number of methods depending on the EUT. These methods include audio and visual observation, specialised test circuits and data monitoring. Regardless of the assessment method, monitoring of equipment behaviour was performed for all tests using a Hioki 3196 power quality analyser. This is a modern instrument compliant with IEC61000.4.30 Class A [4].

The exact method of assessment of the susceptibility of the EUT to each sag level was dependant on the specific EUT. In all cases, the EUT was considered to be susceptible to the sag if it did not continue to function in what was considered to be a normal fashion for the duration of the sag. Normal behaviour varies for each EUT. What constituted normal behaviour as far as these tests were concerned as well as the methods used to assess the immunity/susceptibility of each EUT are detailed below:

1) Televisions

Each television was tested connected to a DVD player which was playing a DVD. The DVD player was supplied from an external source and as such did not experience the sag applied to the televisions. Normal operation was considered to be the television displaying the DVD with correct picture and audio. The television was judged to be susceptible to the sag if the picture was lost or if the television turned off and had to be manually reset. Assessment of the TV performance was primarily made by visual observation.

2) DVD Players

Each DVD player was tested connected to a television and playing a DVD. The television was connected to an external source and as such was not susceptible to the sag applied to the DVD players. Normal operation was considered to be correct output of DVD picture and audio. The DVD player was considered to be susceptible to the voltage sag if picture output was lost of if the DVD player turned off and required manual intervention to restart. Assessment of the DVD player performance was primarily made by visual observation.

3) Printers

Printers were tested while printing a document. This mode of operation was considered to be the most onerous with respect to the printer power supply. Normal operation was considered to be the continuation of printing throughout the duration of the applied sag. The printer was considered to be susceptible to the sag if printing failed or was interrupted. Assessment was made by visual observation.

4) Computer Monitor

Assessment of the computer monitor was similar to the methods used for televisions. The monitor was tested connected to a computer supplied from an external source. Normal operation was considered to be correct display of the computer output. Susceptibility was based on visual observation and the device was considered susceptible if output was lost.

5) Portable Hard Disk Drive

The device was tested while connected to a computer. Assessment of this device was made through visual observation of the indication lights on the front of the device as well as the connection status to the computer. The device was considered susceptible if the indication lights extinguished or if the computer indicated that connection to the drive had been lost.

6) Clock Radios

The clock radios were tested simply displaying the time. Normal operation was considered to be uninterrupted operation throughout the duration of the sag. Assessment was made visually and the clock radio was considered to be susceptible to the sag if the time was lost or reset (started blinking).

7) CFL Lighting

CFL lighting was tested mounted base down in a test board. Normal operation was considered to be light output regardless of intensity. The device was considered to be susceptible to the applied sag if light output was lost, that is the tube extinguished. Assessment was made through visual observation.

8) Personal Computer

Normal operation of the computer was defined to be display of output and correct processing of requests. A small recursive program was written in order to assess if the computer was able to continue processing programmatic instructions. This program caused hard drive activity. The PC was considered susceptible to the applied sag if the power supply reset or if the running program was interrupted or failed.

9) Microwave

The microwave was tested by heating a large bowl of water on the maximum power setting. Normal operation was considered to be continued heating operation for the duration of the sag. Assessment of susceptibility was made through visual observation.

10) Air Conditioners and Refrigerators

Unlike the above equipment, the air conditioners and refrigerators are not exclusively electronic. Instead, these devices have a motor component and a control electronics component. The sag susceptibility of these components is highly unlikely to be identical. As such, assessment of the performance of these devices was somewhat more complicated than for the preceding devices.

For the air conditioners, testing was performed in cooling mode with the compressor running. Compressor operation was assessed through audible noise observation and observation of the input current. For the inverter air conditioner the target temperature was set to 18 °C while for the portable air conditioner the target temperature was set to 17 °C. Normal operation was assessed to be continued operation of all electronics and the compressor throughout the duration of the voltage sag.

For the refrigerator, the model tested has electronics which allows the user to specify fridge and freezer temperatures. For the test, the fridge target temperature was set to 10 °C while the freezer target temperature was set to 3 °C. As was the case for the air conditioners, normal operation was assessed to be continued operation of all electronics and the compressor throughout the duration of the voltage sag. Assessment of normal performance was made through a combination of visual and audio observation as well as observation of input currents.

III. Results

A. Electronic Appliances

Figure 2 shows the sag susceptibility curve for selected electronic devices. These devices were selected as they represent the most susceptible of all the appliances tested. All other appliances had performance which was similar to or better than that for the appliances shown. It can be seen that the sag susceptibility of the electronic appliances is dominated by the susceptibility of the microwave. However, even the performance of the microwave is considerably better than that defined by the ITI Curve which is also shown on the graph.

The ITI Curve was originally formulated to apply to information technology (IT). Figure 3 shows the sag susceptibility of the IT equipment which has been tested. The performance of the PC dominates the performance of the IT equipment. It can be seen that the IT equipment has performance significantly better than that defined by the ITI Curve.

As stated, the sag susceptibility of the electronic appliances is dominated by the microwave and the PC. These two devices are also the highest power devices tested and it is likely no coincidence that these appliances had the highest sag susceptibility. For the remainder of the smaller power rated equipment sag immunity performance was better than that defined by the curve for the laser printer in Figure 3.

The fact that the majority of the electronic equipment has sag immunity considerably better than that defined by the ITI curve is due to the fact that most modern electronic equipment is supplied by switch mode power supplies with a large input range, typically 100 – 240 V. This means that even if the voltage falls to 50% or 115 V for a 230 V nominal system, the voltage is still within the normal operating range of the switch mode power supply. In fact the voltage must drop to 43% of a nominal 230 V before the input voltage is below the switch mode power supply rating. As such, it is clear that the retained voltage values defined by the ITI Curve do not transfer well to equipment connected to the Australian power system.

B. Refrigeration Appliances

Figure 4 shows the sag susceptibility curve for the refrigerator type equipment that was tested. It can immediately be seen that the refrigerator type equipment is considerably more susceptible to sags than the electronic equipment (with the exception of the microwave). All of the refrigerator type equipment contained compressors and it was these compressors which were found to be sensitive to sags. It should be noted that the inverter air conditioner has been included in the refrigerator type appliance category. Although it is debatable as to whether or not this appliance should be classed as electronic due to the inverter front end, the fact that it had performance similar to that of the other refrigerator type appliances is the reason that it is included here. In fact, the curve for the inverter air conditioner cannot be seen in Figure 4 due to the fact that it has the same shape as the curve for the portable air conditioner.

For the refrigerator type equipment, even relatively shallow sags often lead to stalling of the compressor units even though the device electronics appeared to be operating normally. In fact, the control electronics of each device displayed similar sag susceptibility to that seen for the low power electronic equipment detailed in the previous section. Due either to built-in appliance protection systems, or simple appliance operating characteristics, once the compressor was stopped it was often several minutes before it came back on line.

C. All Domestic Appliances

Given the data shown in Figures 2, 3 and 4, Figure 5 shows the sag susceptibility curve for all domestic appliances. For the appliances tested, this curve defines the sag immunity of electronic equipment connected to the Australian 230 V nominal power system.

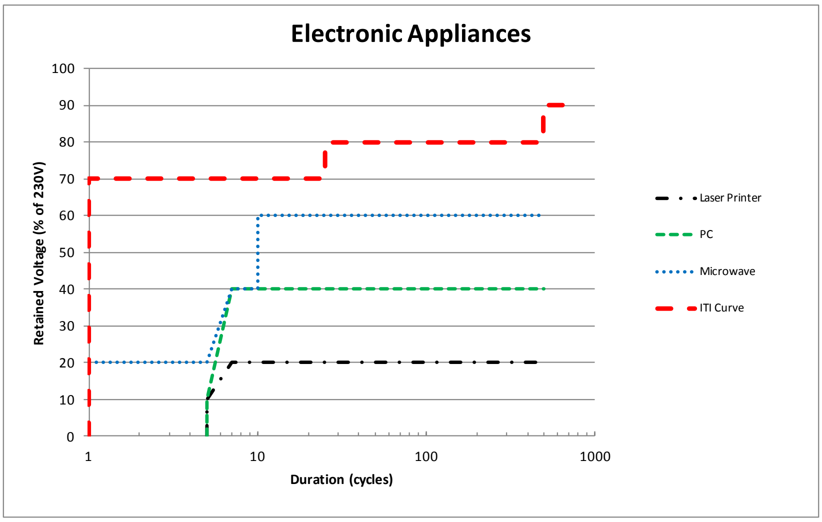

Figure 2. Sag Susceptibility Curves for Selected Electronic Equipment

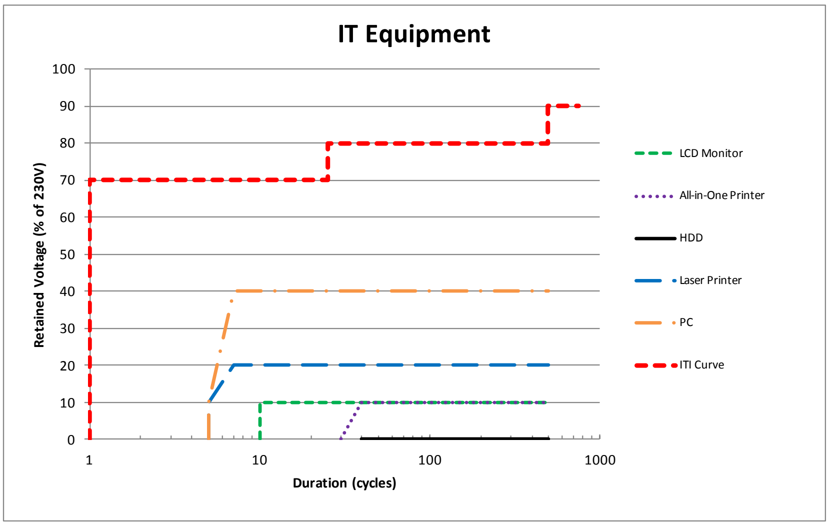

Figure 3. Sag Susceptibility Curves for IT Equipment

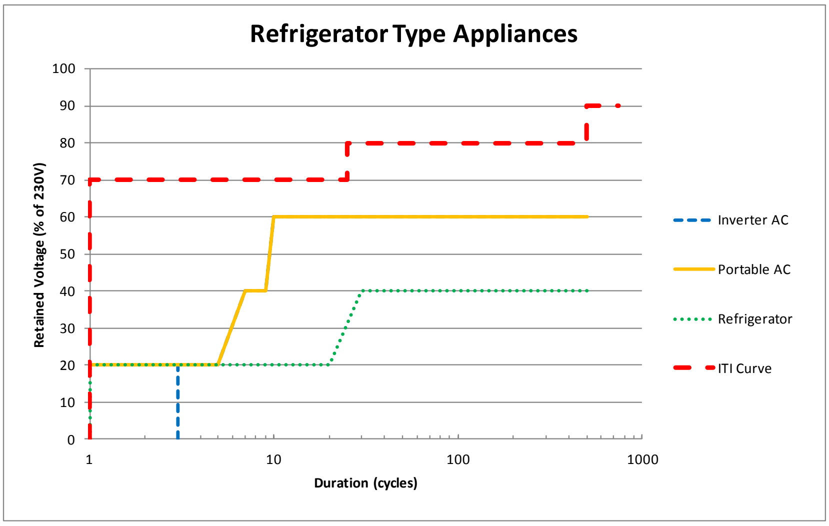

Figure 4. Sag Susceptibility Curves for Refrigerator Type Equipment

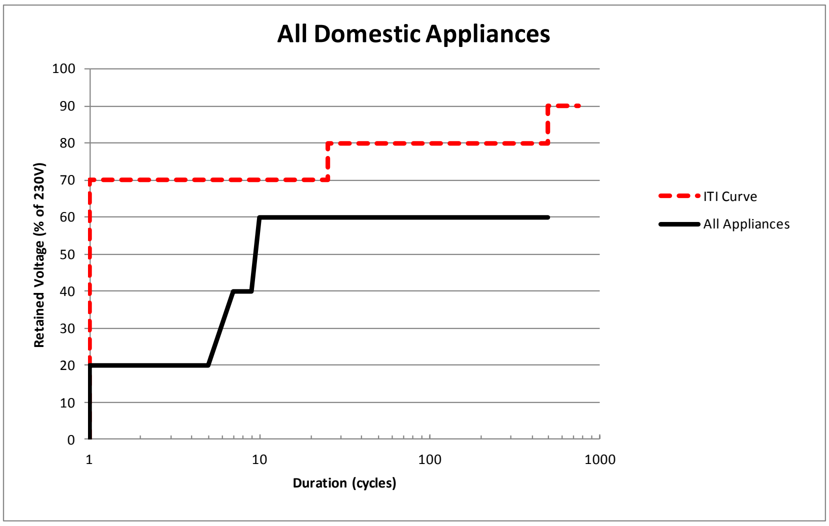

Figure 5. Sag Susceptibility Curve for All Domestic Appliances

IV. CONCLUSIONS

The purpose of this study was to begin development of an ITI or CBEMA type curve(s) applicable to the Australian 230 V 50 Hz electricity distribution system. In this first instance, curves have been developed to describe AC input voltage tolerances for a range of the most common domestic appliances. The study has not been limited to IT equipment which is what the original ITI Curve was developed for.

The domestic equipment tested can be roughly divided into 2 categories; electronic equipment and equipment with compressors. It has been found that the sag susceptibility of the electronic appliances is dominated by the susceptibility of the microwave oven. However, even the performance of the microwave oven is considerably better than that defined by the ITI Curve. The ITI Curve ostensibly applies to IT equipment. The result for the IT equipment tested in this study has sag immunity performance considerably better than that defined by the ITI Curve. For the equipment with a compressor, it was found that these devices are much more susceptible to voltage sags due to the behaviour of the compressor units. These units stalled or ceased to operate even for relatively shallow sags.

Overall, results for domestic appliances show that equipment connected to the Australian 230 V network has sag immunity considerably greater than that defined by the ITI Curve. As such, the applicability of the curve for individual pieces of equipment connected to Australian 230 V electricity networks is questionable and the need for further work in this area is apparent.

REFERENCES

[1] "*ITI (CBEMA) Curve Application Note*", Information Technology Industry Council, http://www.itic.org, last accessed 12 August 2009.

[2] Ian McMichael, Robert Barr, "*Network Voltage Disturbances and Manufacturing Plant Performance*", Electricity Engineers Association of New Zealand Annual Conference, Auckland, 16 - 17 June, 2006.

[3] David Chapman, *"The Cost of Poor Power Quality"*, Power Quality Application Guide, Copper Development Association, March 2001.

[4] IEC Standard for Electromagnetic Compatibility (EMC) – Part 4-30: Testing and Measurement Techniques – Power Quality Measurement Methods, IEC61000-4-30, 2000.