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October 19, 2021

VIA E-MAIL AND HAND DELIVERY
Emma.Rodvien@puc.ri.gov

Emma Rodvien, Coordinator
Energy Facility Siting Board
89 Jefferson Boulevard
Warwick, Rhode Island 02888

Re: Docket No. SB-2021-01 – In Re: Revolution Wind, LLC's Application to Construct and Alter Major Energy Facilities in North Kingstown, Rhode Island

Dear Ms. Rodvien:

Enclosed please find an original and four copies of Revolution Wind, LLC's ("Revolution Wind") Responses to the Energy Facility Siting Board's (the "EFSB") Record Requests, issued on October 12, 2021.

This filing includes Revolution Wind's partial responses to the EFSB's Record Requests, specifically Record Requests 3, 4, 5, 8, 9 and 10. On October 19, 2021, the EFSB granted an extension to October 22, 2021, for Record Requests 1, 11, and 12 and to October 26, 2021, for Record Requests 2, 6, and 7, which will be provided on a rolling basis as they are complete.

Thank you for your attention to this matter.

Very truly yours,

Adam M. Ramos

Robin L. Main

AMR:cw
Enclosures

cc: SB-2021-01 Service List (via e-mail)
Meredith Brady (via hand delivery)

SB-2021-01 Revolution Wind, LLC Application for Major Energy Facility
Updated October 19, 2021 (by HA&S)

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Christina Hoefsmit (DEM)	Christina.Hoefsmit@dem.ri.gov;

EFSB Record Request 3

Request:

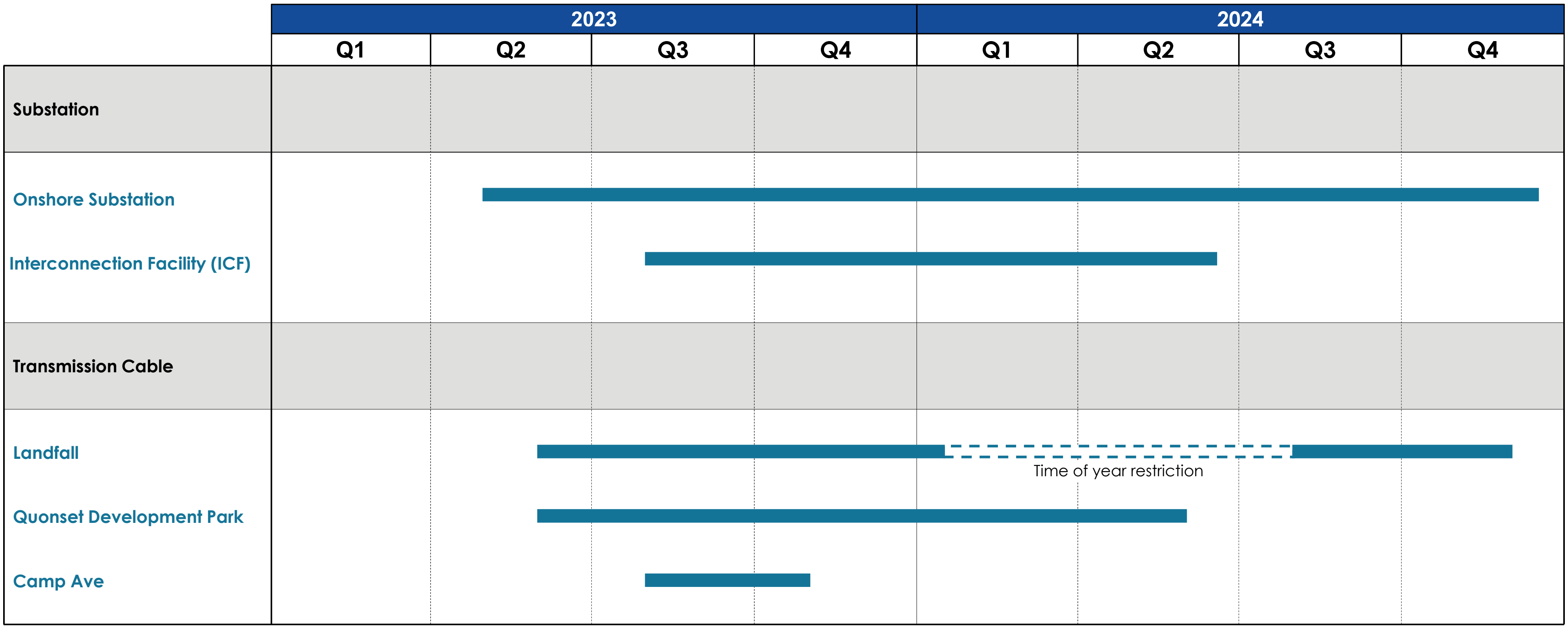
Provide a Gantt chart showing the schedule date of each component of the project.

Response:

Please see Attachment Revolution Wind EFSB RR3-1.

Prepared by or under the supervision of: Ken Bowes and Demetrios Sakellaris

Revolution Wind – Construction Schedule



Notes:
1. Schedule based on expected dates for federal permits.
2. Schedule does not include final restoration activities.

EFSB Record Request 4

Request:

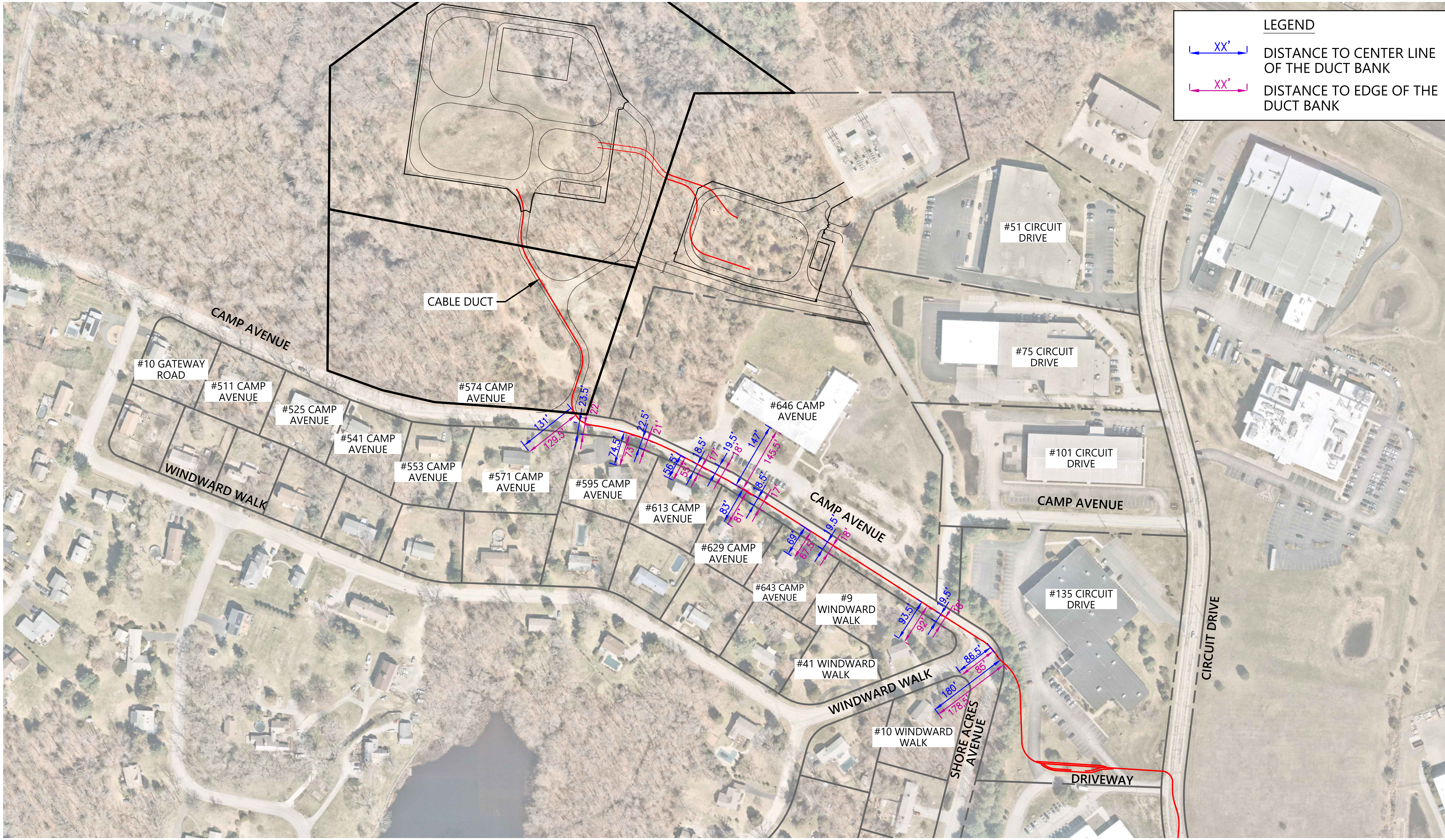
Provide the distance between the center point of the cable/duct bank to each property line and each house along Camp Avenue.

Response:

Please see Attachment Revolution Wind EFSB RR4-1 and response to EFSB Record Request 9.

Prepared by or under the supervision of: Ken Bowes, Demetrios Sakellaris and Sue Moberg

\\vhb\gbl\proj\Providence\73032.01 RWF-Export Cable (2)\Graphics\FIGURES\Camp Ave\Camp Ave Plan.dwg



0
200 Feet

Revolution Wind Powered by Ørsted & Eversource

Setbacks to Residential Properties along Camp Ave
North Kingstown, Rhode Island

EFSB Attachment RR4-1

EFSB Record Request 5

Request:

Provide copies of Mr. Bowes articles – "Effects of Power Line Disturbances on Consumer Electronic Equipment" and "The Effects of Power Line Disturbances on Electronic Products."

Response:

Please see Attachment Revolution Wind EFSB RR5-1 for *Effects of Power Line Disturbances on Consumer Electronic Equipment*, Attachment Revolution Wind EFSB RR5-2 for *The Effects of Power Line Disturbances on Electronic Products*, and Attachment Revolution Wind EFSB RR5-3 for *The Effects of Temporary Overvoltage (TOV) on Consumer Products*.

Prepared by or under the supervision of: Ken Bowes

 IEEE Transactions on Power Delivery, Vol. 5, No. 2, April 1990

THE EFFECTS OF POWER-LINE DISTURBANCES ON CONSUMER ELECTRONIC EQUIPMENT

Lisa M. Anderson

Northeast Utilities
P.O.BOX 270
Hartford, CT
06141-0270

Kenneth B. Bowes

Abstract - This study quantifies the effects of simulated power system transients, voltage fluctuations and momentary interruptions on household electronic equipment. Non-destructive testing was performed to determine the applicability of the CBEMA and IEEE susceptibility curves to consumer electronic equipment. As a result, graphs were developed which illustrate these effects.

INTRODUCTION

Power system disturbances have been present since the inception of the electric utility industry, however, yesterdays loads were more forgiving of disturbances than today's modern equipment. The proliferation of sensitive electronic equipment has made our customers aware of power system disturbances that went unnoticed in the past.

This study was undertaken to provide the electric utility industry with a clearer understanding of the response of consumer electronic equipment to power system disturbances. This study evaluates the susceptibility of the memory functions of consumer electronic products with respect to specific power-line disturbances. The three types of digital equipment tested were:

1) clocks
2) microwave ovens
3) video cassette recorders (VCRs)

The test conditions simulated design goals of computer manufacturers from the IEEE 446-1987[1] and the Computer Business Equipment Manufacturers Association (CBEMA) curves. These curves graphically display the tolerance levels of computer equipment to voltage related disturbances. Defined regions where computer equipment is apt to be effected for both overvoltage and undervoltage conditions are indicated by these curves. Since curves are not available which pertain to household electronic equipment these curves were used to provide a reasonable means of comparison. Figure 1 illustrates the IEEE 446-1987 curve.

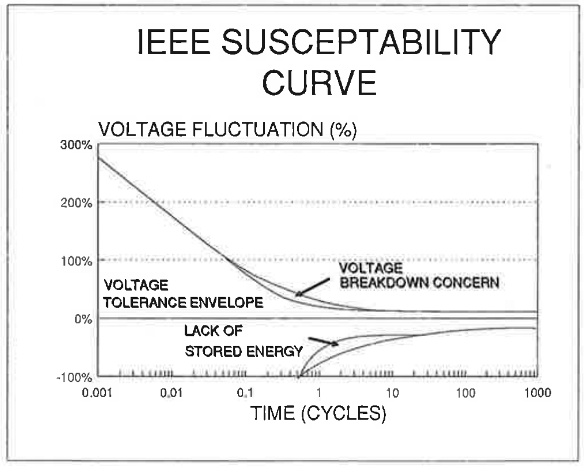


Figure 1

TEST DESCRIPTION

Other studies at NU have identified many of the typical disturbances present on the NU system. One intent of this study was to better quantify the effects of these disturbances. With attention to the disturbances recorded, test equipment was obtained capable of replicating these disturbances and those outlined by the IEEE and CBEMA curve.

Test Parameters - Test parameters chosen for this study were selected to cover a wide range of power-line disturbances. The duration of the test disturbances related directly to the IEEE 446-1987 and CBEMA curves. The magnitudes of the test points were increased for overvoltage and transient tests and decreased for undervoltage tests.

While it was the intent of this study to supply the units under test with more severe disturbances then those indicated on the IEEE and CBEMA curves, the testing was intended to be non-destructive. Test pulses specified in ANSI/IEEE Std. C62.41, Guide for Surge Voltages in Low-Voltage AC Power Circuits (formerly IEEE 587-1980) were not used due to the destructive nature of the pulses. For the purposes of this study, each device was tested for its ability to retain its programmed memory. Each test was repeated a minimum of three times at each test point, for each consumer product.

Equipment Tested - The types of equipment tested were those which often experience the effects of power-line disturbances at the customers residence. Ten of each type; digital clocks, microwave ovens and video cassette recorders were chosen as a sample group. All of the aforementioned equipment was purchased new.

Undervoltage Tests - Undervoltage test points were at 1000 cycles, 120 cycles, 60 cycles, 30 cycles, 6 cycles, 1 cycle and 0.5 cycles. The 1000 cycle point simulated a steady-state undervoltage that would be typical of a voltage reduction or brownout situation. The magnitude of the voltage was lowered until the memory of the unit under test was lost. The remainder of the test points, 120 cycles, 60 cycles, etc. ***simulated voltage sags and/or momentary interruptions*** of varying durations that would be typical of recloser

89 TD 423-5 PWRD A paper recommended and approved by the IEEE Transmission and Distribution Committee of the IEEE Power Engineering Society for presentation at the IEEE/PES 1989 Transmission and Distribution Conference, April 2 - 7, 1989. Manuscript submitted October 13, 1988; made available for printing January 19, 1989.

operations, motor starts, loss of power switchovers and voltage sags caused by faults. All of these tests began at the positive zero crossing of the sinewave.

Overvoltage Test - Overvoltage tests were chosen for the purpose of simulating various surge and high-voltage conditions. The test points were of the same duration as the undervoltages. Limits were established on the magnitude of the overvoltages, keeping with the non-destructive nature of the testing. For the 1000 cycle (steady-state) overvoltage test, a magnitude of 135 volts (+12% of nominal) was applied to each device. For the remaining test points, the voltage limit was increased to 146 volts (+22% of nominal).

Transient Testing - Overvoltage transients were divided into three classifications; low, medium and high power impulses. Three independent single shots were imposed onto the supply to each piece of equipment at each impulse level.

Low-Energy Impulses - The low-energy impulse was a fast interference pulse, characteristic of mechanical switches and small relays. The nominal pulse rise time was 5 nanoseconds. The pulse magnitude was set at a 1000 volt peak with the phase angle fixed at the 90 degree position, thus allowing a 1000 volt peak on the sinewave.

Medium-Energy Impulses - Three different medium-energy pulse forms were applied. Each are characteristic of line power changeovers of fast switches, such as those caused by the switching of inductive loads (motors) and mercury switches. Pulse amplitudes were set to a 1000 volt peak, at the 90 degree phase position for each test. The following describes the type of pulses superimposed onto the positive peak of the sinewave.

* Type I was a 1 microsecond pulse with a 25 nanosecond rise time.
* Type II was a 3 microsecond pulse with a 35 nanosecond rise time.
* Type III was a 10 microsecond pulse with a 100 nanosecond rise time.

High-Energy Impulses - High energy pulses of 100 and 300 microsecond pulse widths, characteristic of utility switching on the power system, as well as lightning were selected to complete the testing. The equipment used was capable of supplying 1000 volt peak impulses on the supply for the equipment tested. Test pulses were randomly applied on the positive half of the voltage sinewave, due to test equipment limitations. The nominal pulse rise time was 1.2 microseconds.

RESULTS

Undervoltage Testing - Since each type of device demonstrated different characteristics to the undervoltage testing, the results are discussed individually below. The test voltages were lowered until memory loss occurred. (Note: Malfunction denotes loss of memory)

Clocks

*Average steady-state malfunction occurred at approximately 40% (48 volts) of nominal(120 volts)
*all clocks malfunctioned at 1000 cycles
*60% of the clocks tested retained their memory for a 120 cycle momentary interruption
*one unit lost memory at 5 volts during the 6 cycle test
*the average disturbance performance curve rose sharply at 30 cycles
*the standard deviation of the test points indicates a large variation between manufacturers

Microwave Ovens

*average steady-state malfunction occurred at approximately 50% (60 volts) of nominal (120 volts)
*all microwave ovens malfunctioned at 120 cycles
*30% of the microwave ovens tested retained their memory for a 60 cycle momentary interruption
*two units lost memory at 5 volts during the 1 cycle test
*the average disturbance performance curve rose sharply at 30 cycles
*the standard deviation of the test points indicates a large variation between manufacturers

VCRs

*average steady-state malfunction occurred at approximately 47% (57 volts) of nominal (120 volts)
*all VCRs without battery back-up lost memory at 1000 cycles
*38% of the VCRs tested retained their memory for a 120 cycle momentary interruption
Note: VCRs with factory installed battery backup were omitted from the above percentages.
*one unit lost memory at 8 volts during the 1 cycle test
*the average disturbance performance curve rose sharply at 6 cycles
*the standard deviation of the test points indicates a large variation between manufacturers

With respect to the steady-state voltage and the duration of the interruption withstood by most units, the best performers were the digital clocks. The majority tested withstood a 120 cycle interruption without loss of memory. In addition, their low voltage withstand levels were superior to both the microwaves and the VCRs.

To gain an understanding of the relationship each type of equipment has with the others, the figure 2 was developed. It illustrates a comparison between the CBEMA and IEEE curve with the malfunction ranges of each type of equipment tested.

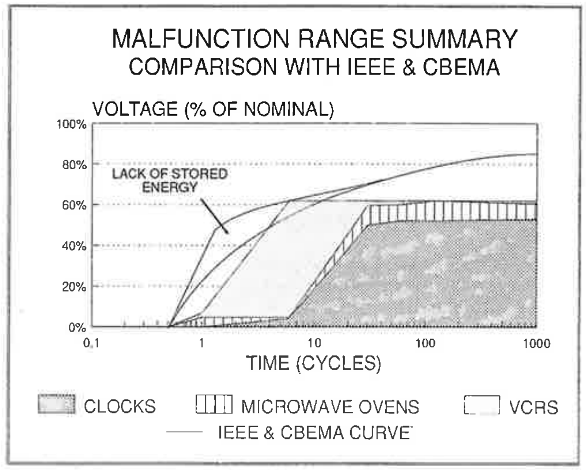


Figure 2

Although it may appear that VCRs failed to perform within the range of the CBEMA curve (@6 cycles), it should be noted that only one VCR tested outside the CBEMA curve. VCRs with factory installed battery back-up were omitted from the system averages. The mean values were collected for each type of device and the averages are shown in figure 3.

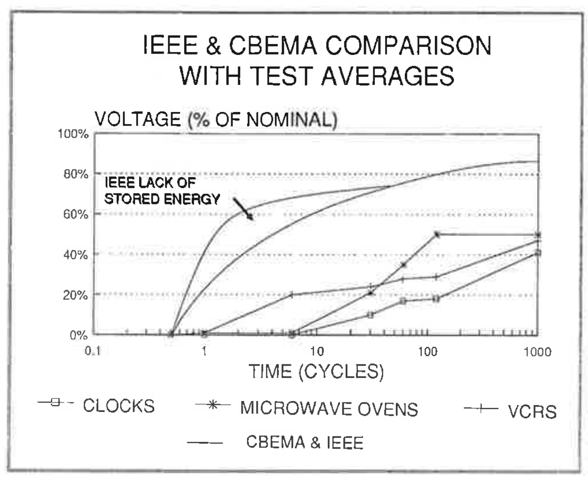


Figure 3

It should be noted that the standard deviations of the test points were large and caution should be exercised when interpreting the average values. Due to the large standard deviation, a more appropriate representation of the equipment performance may be to use the range data as opposed to the average values.

Overvoltage/Transient Testing - Of the devices tested, none illustrated any evident adverse effects or memory loss due to overvoltages. In addition to the overvoltage testing, six different transients were applied to each piece of equipment. The amplitude of the voltage remained constant for each of the impulses. Due to the duration of the spike, the amount of energy seen by the equipment exhibited varying levels of energy as would be typically experienced on a power system. Each device responded satisfactorily to the imposed transients. After repetitive strikes the equipment illustrated no apparent damage or loss of memory due to the high voltage transients.

CONCLUSION

Overvoltage/transient testing performed in this study failed to demonstrate any adverse effect on the equipment tested. However, undervoltage testing did result in loss of memory for each type of device. It is important to note that malfunction of the equipment was determined either by loss of memory or by other noticeable effects. ***Any cumulative effects due to accelerated aging (loss of life) from either undervoltages or overvoltages were not considered in this study.***

The results indicate that most malfunctions of VCRs occurred between 6 and 30 cycles. The malfunction of VCRs occurred at the steady-state voltage of 57 volts (not including units with battery backup). These results were followed by the microwave ovens which typically lost memory between 30 and 60 cycles with a steady-state voltage malfunction at 60 volts. The best performers were the digital clocks. The average digital clock lost memory between 30 and 120 cycles and had a memory loss at a steady-state voltage of 49 volts.

Although the VCRs were the poorest performers, two of the ten had a form of factory installed battery backup. This seems to indicate that some manufacturers are aware of the problems associated with power-line disturbances and have decided to address the matter. Many of the clock manufacturers have made provisions for battery backup capabilities. Once again this shows that there may be a growing interest in the electronic industry to address power disturbance related problems.

This study provides an introduction to the study of consumer electronic products and how they respond to power system disturbances. The information recorded establishes a basis for an increased understanding of the residential customer's power needs. In order to gain a more in-depth understanding of how disturbances effect the customers we serve, further study is required in order to develop a more extensive database. The determination of a curve similar to IEEE Std.446-1987, for household digital electronic devices would prove extremely beneficial to the power industry. By enabling the power industry to gain a better understanding of the power requirements of the customers it serves, the industry will consequently be better equipped to serve them.

It appears from the results of this study that momentary interruptions were the main source of memory loss for digital electronic equipment. The results indicated that although the memory functions of household electronic devices can withstand fairly large voltage fluctuations they have difficulties withstanding momentary interruptions. The results of this study and further studies in this area may be used to determine which causes of power line disturbances (circuit breaker and recloser operations, voltage dips from feeder faults and motor starting, capacitor switching, etc.) create the most problems for sensitive electronic equipment.

ACKNOWLEDGMENT

Special thanks to Dominick M. Lauria of Northeast Utilities for his guidance and assistance.

REFERENCES

[1] IEEE Std. 446-1987, IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications

[2] IEEE Std.587-1980, IEEE Guide for Surge Voltages in Low-Voltage AC Power Circuits

[4] Thompson, B. J., Generating AC Power Disturbances, Test and Measurement World, pp.53-68, March 1988

[5] Transient Voltage Suppression Manual, General Electric, Fifth edition, 1988

Lisa M. Anderson (M-'86) was born in Torrington, CT on October 26, 1965. She received a B.S. degree in Electrical Engineering from Worcester Polytechnic Institute, Worcester, MA in 1987.

She joined Northeast Utilities Service Company, in Meriden, CT working in the Distribution Systems Engineering group in 1987. Miss Anderson is a member of the IEEE Power Engineering Society.

Kenneth B. Bowes (M-'84) was born in Keene, NH on October 12, 1962. He received a B.S. degree in Electrical Engineering from the University of New Hampshire, Durham, NH in 1984.

From 1984 to 1986 and 1987 to present, he worked for Northeast Utilities in Berlin, CT working in the Electronic, Communications and Laboratory Test Department. From 1986 to 1987 he worked for Connecticut Light and Power (a subsidiary of NU) in Simsbury, CT in Distribution Operations. Mr. Bowes is a member of the Instrumentation and Measurement Society and the Acoustics, Speech and Signal Processing Society.

THE EFFECTS OF POWER-LINE DISTURBANCES ON ELECTRONIC PRODUCTS

by

Kenneth B. Bowes
Northeast Utilities
Hartford, CT

Abstract - This study quantifies the effects of simulated power system transients, voltage fluctuations and momentary interruptions on sensitive electronic equipment. The susceptibility of the equipment was compared to the IEEE Std. 446-1987 susceptibility curve to determine the applicability to electronic products. The results are presented in graphical form for each equipment type. This study is an expansion of previous non-destructive consumer electronic testing.[1]

INTRODUCTION

Power system disturbances have been present since the inception of the electric utility industry, however, yesterday's loads were more forgiving of disturbances than today's modern equipment. The proliferation of sensitive electronic equipment has made the consumer more aware of power system disturbances that went unnoticed in the past. The flashing **"12:00"** present on digital clocks, video cassette recorders, and microwave ovens are a continuous annoyance to the consumer and are a concern to the electric utility. The traditional indices of utility reliability do not provide adequate an measure for the tolerance of sensitive electronic equipment to power-line disturbances. New standards for power quality are needed for the electric utility industry which reflect the susceptibility of today's electronic loads.

This study was undertaken to provide the electric utility industry and equipment manufacturers with a clearer understanding of the response of sensitive electronic equipment to power system disturbances. This study evaluates the susceptibility of **memory functions and operation** of electronic products with respect to specific power-line disturbances. The types of equipment tested were:

1) digital clocks
2) microwave ovens
3) video cassette recorders (VCR's)
4) personal computers
5) printers

The test conditions simulated the design goals of computer manufacturers from the IEEE Std. 446-1987 [2] and the Computer Business Equipment Manufacturers Association (CEBMA) curves. These curves are based upon the same operating envelopes or susceptibility limits and are principally the same graph. These curves graphically display the tolerance levels of computer equipment to voltage related disturbances. Defined regions where computer equipment is apt to be affected for both overvoltage and undervoltage conditions are indicated by these curves. Since curves are not available which pertain to sensitive electronic equipment these curves were used to provide a reasonable means of comparison. Figure 1 illustrates the IEEE Std. 446-1987 curve.

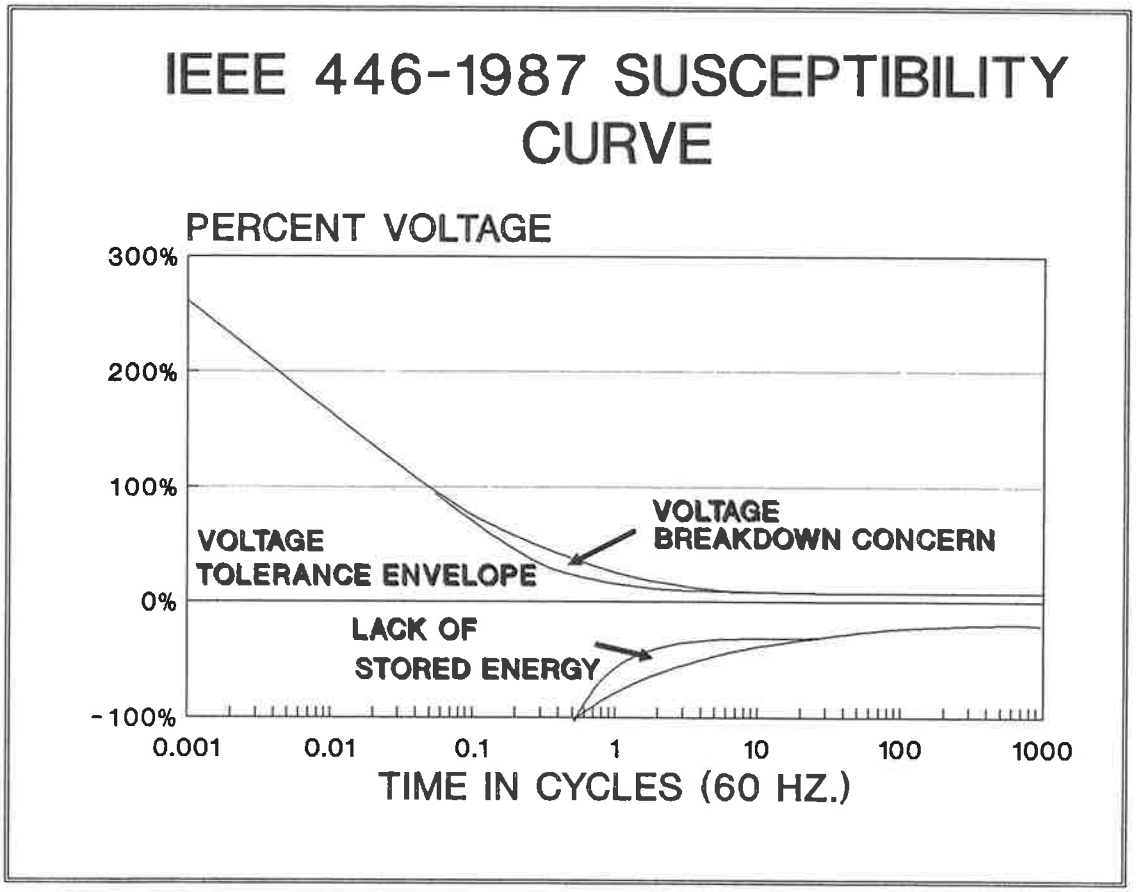


Figure 1

TEST CONDITIONS

An extensive distribution monitoring study conducted by Northeast Utilities for the recording of power-line disturbances has identified many of the typical disturbances present on the power system. Also, as part of the customer service efforts of Northeast Utilities, the disturbance information obtained from power quality investigations performed at customer locations has been compiled for statistical analysis. The disturbance information contained in these databases proved useful in the selection of the types and magnitudes of disturbances to be simulated for this study. With attention to the power-line disturbances recorded and the operating envelope defined by IEEE Std. 446-1987, commercially available test equipment was chosen capable of simulating these disturbances.

The simulation of "real-world" power system disturbances is in practice very difficult if not impossible to do. The complexity and unpredictability of the waveshape and amplitudes of such disturbances makes their generation and repeatability unattainable. However, by simulating a set of standardized and repeatable disturbances based upon measured disturbances and conforming to the IEEE Std. 446-1987 curve, the performance of different models and types of equipment can be evaluated.

Test Description - Test parameters chosen for this study were selected to cover a wide range of power-line disturbances. The types of disturbances were comprised of undervoltage, overvoltage and transient overvoltage disturbances.[3][4] The test frequency remained at 60 hertz for the entire study. The nominal test voltage for all tests was 120 volts rms. The voltage magnitudes of the test points were increased for the overvoltage and transients tests and decreased for the undervoltage tests.

While it was the intent of this study to supply the units under test with more severe disturbances then those indicated on the IEEE 446-1987 curve, the testing was intended to be **non-destructive.** Test pulses specified in ANSI/IEEE Std. C62.41, IEEE Guide for Surge Voltages in Low-Voltage AC Power Circuits (formerly IEEE Std. 587-1980) [5] were not used due to the destructive nature of the pulses. It should be noted that valuable information was obtained from this standard and ANSI/IEEE Std. C62.45 IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits.[6] For the purposes of this study, each device was tested for its ability to retain its programed memory or continue uninterrupted operation. Each test was repeated a minimum of three times at each test point for each electronic product.

<u>**Equipment Tested**</u> - The types of equipment tested were those which often experience the effects of power-line disturbances at the consumer's residence and office. The susceptibility of control instrumentation and associated process computers was not part of this study. Ten of each equipment type; digital clocks, microwave ovens, video cassette recorders, and computer printers were chosen as the sample group. The ten computer printers were comprised of; two laser printers, two ink jet printers and six dot-matrix printers. Six personal computers comprised the remainder of the equipment tested.

<u>**Mode of Operation**</u> - The digital clocks were programed with an alarm time as well as the time of day. A malfunction of the clocks memory was documented if the alarm time or time of day was lost or altered. The microwave ovens were programed with the time of day and also to automatically turn on for unattended cooking. The VCR's were programed to automatically turn on, and record a television show. The date, day of the week and time of day were also programed on the VCR's. A malfunction was noted when any on the memory contents were lost or altered. The personal computers were reading files from their respective disk drives (A drive) into memory during the testing. Computer malfunction consisted of complete system "rebooting" or errors in the files read. The computer printers were receiving data into their print buffers and printing in high quality mode during disturbance simulations. A malfunction occurred when the printer reset or incorrect data was printed.

<u>**Undervoltage Tests**</u> - Undervoltage test points were at 1000 cycles, 120 cycles, 60 cycles, 30 cycles, 6 cycles, 1 cycle and 0.5 cycles. The 1000 cycle point simulated a short term steady-state undervoltage condition that would be typical of a voltage reduction or brownout situation. The magnitude of the voltage was lowered until the memory of the unit under test was lost. The remainder of the test points, 120 cycles, 60 cycles, etc. simulated voltage sags and/or momentary interruptions of varying durations that would be typical of utility recloser operations, motor (inductive load) starts, loss-of-power switchovers, and voltage sags caused by circuit faults. All of these tests began at the positive zero crossing of the sine wave.

<u>**Overvoltage Tests**</u> - Overvoltage tests were chosen for the purpose of simulating various surge and high voltage conditions such as capacitor switching, transformer tap changer operations, and voltage regulator operations. The test points were of the same duration as the undervoltages; 1000 cycles, 120 cycles, 60 cycles, 30 cycles, 6 cycles, 1 cycle and 0.5 cycles. Limits were established on the magnitude of the overvoltages, keeping with the non-destructive nature of the testing. For the 1000 cycle (steady-state) overvoltage test, a magnitude of 135 volts

rms. (+12 % of nominal) was applied to each device. For the remaining test points, the voltage limit was increased to 146 volts rms (+22 % of nominal).

Transient Testing - Overvoltage transients were divided into three classifications; low, medium and high power impulses. A minimum of three independent single shots were applied to each piece of equipment at each impulse level. All of the transients were superimposed onto a 120 volt rms sine wave, supplying the units under test.

Low Energy Impulses - The low energy impulse was a fast interference pulse, characteristic of mechanical switches and small relays. The nominal pulse rise time was 5 nanoseconds. The pulse magnitude was set at 1000 volts peak with the phase angle fixed at the 90 degree phase position, thus allowing a 1000 volt peak on the sine wave.

Medium Energy Impulses - Three different medium energy pulse forms were applied to each piece of equipment. Each was characteristic of line power changeovers of fast switches, such as those caused by the switching of inductive loads and mercury switches. Pulse amplitudes were set to 1000 volts peak at the 90 degree phase position for each test. The following describes the type of pulses superimposed on the positive peak of the sine wave.

* **Type I** was a 1 microsecond pulse with a 25 nanosecond rise time.
* **Type II** was a 3 microsecond pulse with a 35 nanosecond rise time.
* **Type III** was a 10 microsecond pulse with a 100 nanosecond rise time.

High Energy Impulses - High energy pulses of 100 and 300 microsecond pulse widths characteristic of utility switching on the power system, large load switching, as well as lightning were selected to complete the testing. The magnitude of the applied pulses was 1000 volts peak randomly applied on the sine wave. The nominal pulse rise times were 1 and 3 microseconds respectively. High energy impulses were not applied to the personal computers or printers due to equipment availability. The pulse magnitudes of the low and medium energy impulses was increased to 2500 volts peak for the personal computer and printer testing.

RESULTS

Undervoltage Testing - Each type of equipment demonstrated different characteristics to the undervoltage testing and the results are discussed individually below. The bullet items represent the highlights of the testing. The information contained in the bullet items is not found on the graphs that follow unless specifically noted. The magnitude of the voltage for all of the tests was lowered until malfunction occurred. The test data for each electronic product is included in the appendix. (Note: malfunction denotes loss of memory or device reset.)

Digital Clocks

* The average steady-state voltage where malfunction occurred was at approximately 40% (48 volts rms) of nominal (Figure 3)
* All clocks malfunction for an interruption of 1000 cycles
* 60% of the clocks tested retained their memory for a 120 cycle momentary interruption (typical electronic recloser setting)
* The slope of the range data rose sharply at 6 cycles (Figure 2)
* The standard deviation of the test points indicates a large variation between manufacturers

Microwave Ovens

* The average steady-state voltage where malfunction occurred was approximately 50% (60 volts rms) of nominal (Figure 3)
* All the microwave ovens malfunction for a 120 cycle interruption
* Two units lost memory at 5 volts during the 6 cycle test
* The slope of the range data increased sharply at 6 cycles (Figure 2)
* The standard deviation of the test points indicates a large variation between manufacturers

VCR's

* Two of the VCR's contained battery backups for their memory functions
* The average steady-state malfunction occurred at approximately 47% (57 volts rms) of nominal (Figure 3)
* All the VCR's (without battery backup) lost memory for a 1000 cycle interruption
* 38% of the VCR's tested retained memory for a 120 cycle momentary interruption (neglecting battery backed up units)

* The slope of the range data increased sharply at the 1 cycle test duration (Figure 2)
* The standard deviation of the test points indicates a large variation between manufacturers

<u>Personal Computers</u>

* The average steady-state voltage malfunction occurred at 56% (67 volts rms) of nominal (Figure 3)
* All the personal computers reset (malfunctioned) for an interruption of 6 cycles, four malfunctioned at the 1 cycle interruption duration
* The 1000 cycle, 120 cycle, 60 cycle, and 30 cycle test durations exhibited low standard deviations indicating similarity between manufacturers
* Only one personal computer malfunctioned for 0.5 cycle dropout

<u>Printers</u>

* The average steady-state voltage where malfunction occurred was at 63% (75 volts rms) of nominal
* The susceptibility of the laser printers was dependent upon the stage of printing process. The dot matrix and ink jet printers did not exhibit this dependency.
* All of the printers malfunctioned for a 6 cycle dropout (zero volts)
* The slope of the range data rose sharply at the 1 cycles test duration (Figure 2)
* The voltage values for the 1000 cycle, 120 cycle, 60 cycle and 30 cycle test durations exhibited low standard deviations

To summarize the undervoltage testing, a graph of the memory malfunction ranges of the various types of electronic equipment was developed. The term "range" is used to denote the area (worst case) where each type of product malfunctioned. Figure 2 illustrates the relationship each type of equipment has with respect to each other and to the IEEE Std. 446-1987 curve. It is quite obvious that three of five types of equipment (VCR's, personal computers and printers) malfunctioned outside of the IEEE Std 446-1987 operating envelope. It again should be noted that this represents a worst case condition.

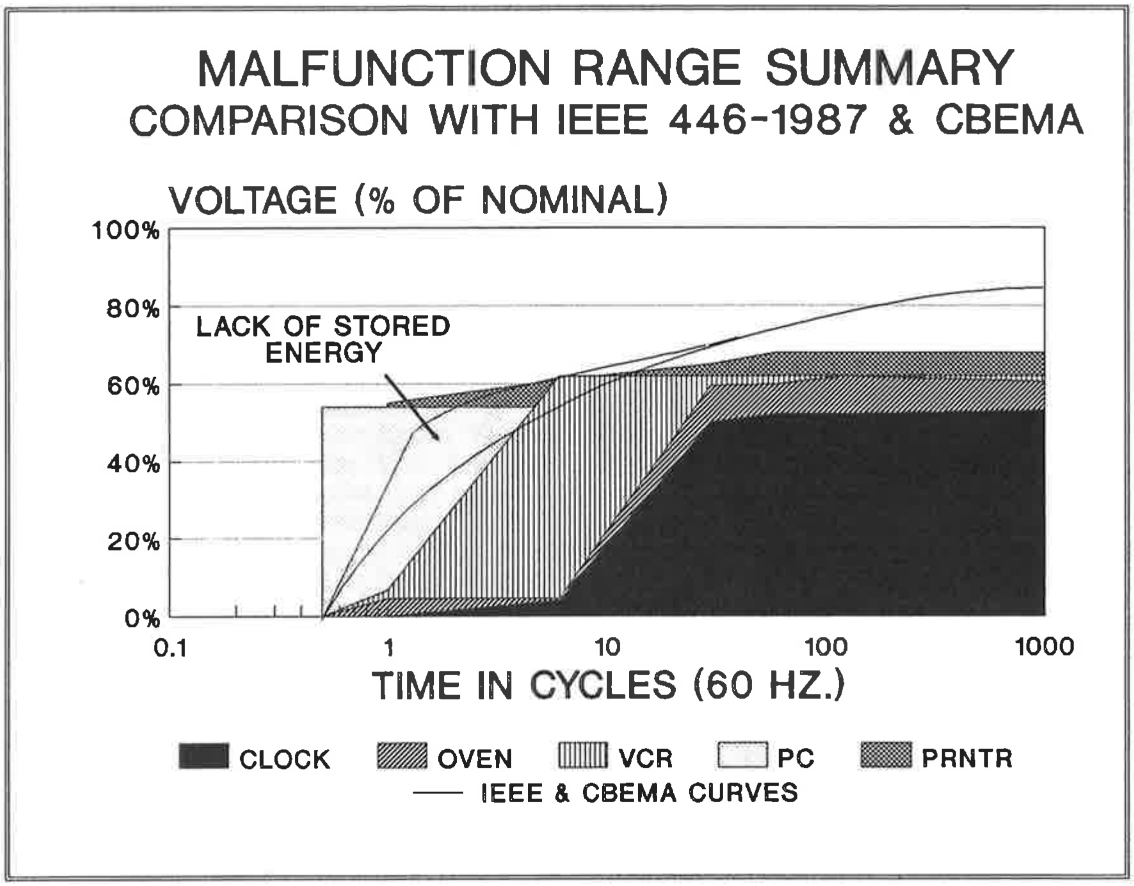


Figure 2

A second graph, (Figure 3), was developed which illustrates the mean values for each type of equipment. The mean value of voltage for memory malfunction at each test duration (0.5 cycles, 1 cycle, etc.) was plotted for each equipment type. The lack of stored energy as depicted in Figure 3 is obvious for the personal computers and printers. The memory malfunction averages for the other types of equipment (digital clocks, microwave ovens, and VCR's) indicate that they will perform under more severe undervoltage conditions then defined by IEEE Std. 446-1987. The standard deviations for the test points for the digital clocks, microwave oven and VCR's were large, indicating a significant variation between different manufacturers. Due to these large standard deviation values, the range data (Figure 2) may be more appropriate for the digital clocks, microwave ovens and VCR's. The standard deviations for the personal computers (0.5, 1, 6 cycles) and printers (1, 6 cycles) indicate that there is also variation between different computer and printer manufacturers.

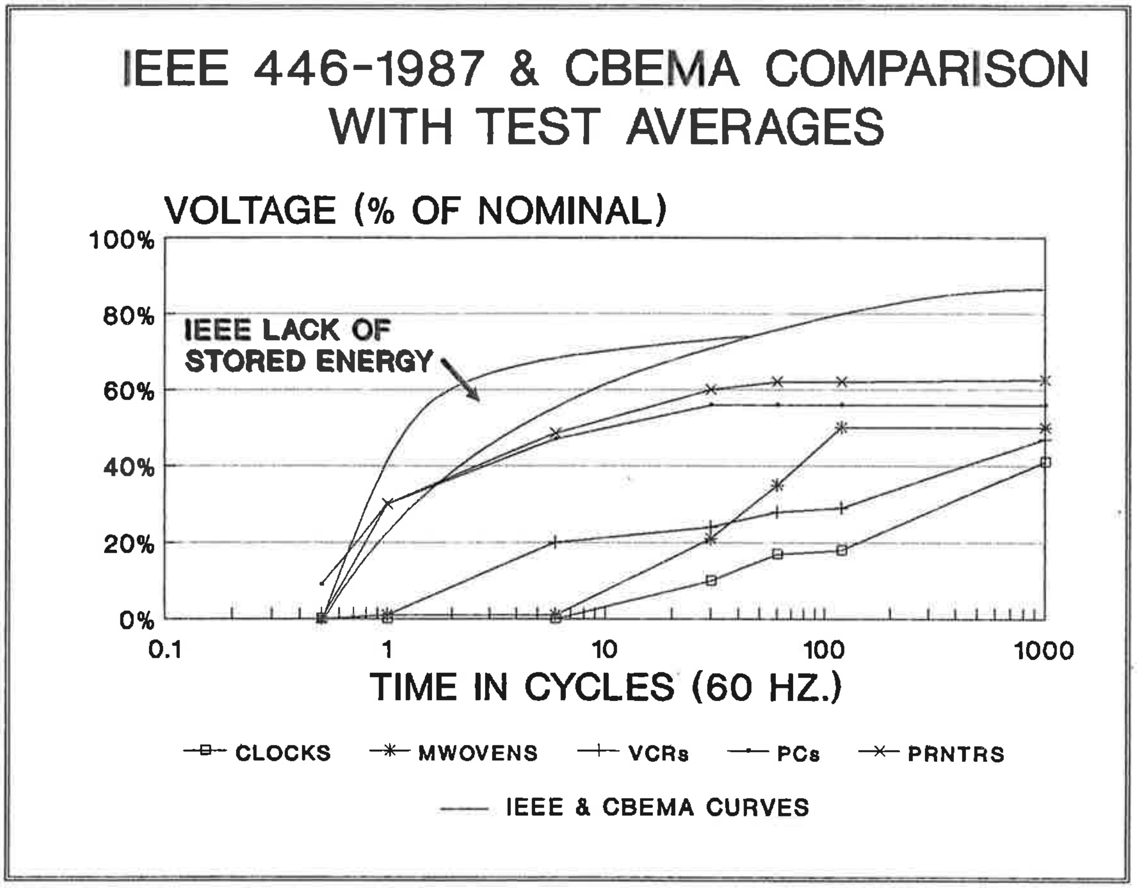


Figure 3

__Overvoltage Testing__ - Of the devices tested, none illustrated any evident adverse effects or memory loss due to overvoltage disturbances. The test durations for the overvoltages were quite short term and no correlation should be made to the damaging effects of prolonged overvoltage conditions.

__Transient Testing__ - Six different pulse types were applied to the digital clocks, microwave ovens and VCR's all with magnitudes of at least 1000 volts peak. Four different pulse types were applied to the personal computers and printers with magnitudes of at least 2500 volts peak. Due to the duration of the impulse, and impedance of the unit under test, the amount of energy seen by the equipment exhibited varying levels as would be typically experienced on a power system. Of the equipment types tested, **only the printers malfunctioned.** One of the laser printers tested would omit characters, change characters and print additional characters when the transients (medium energy) were applied. The second laser printer shutdown when the medium energy impulses were applied. None of the equipment experienced any permanent effects of the testing.

CONCLUSIONS

The results of this study for undervoltage testing were somewhat surprising in that the electronic products tested could operate, for short periods of time, at significantly reduced voltages. All the equipment tested (with the exception of units with battery backup) did malfunction or lose memory during the undervoltage testing. Most of the printers malfunctioned for interruptions of voltage of 0.5 to 1 cycle in duration. The personal computers malfunctioned between 0.5 and 6 cycles for complete loss of voltage. The results indicate that most malfunctions of VCR's occurred for interruptions in the range of 6 to 30 cycles. These results were followed by the microwave ovens which typically lost memory for interruptions of 30 to 60 cycles. The best performers were the digital clocks which malfunctioned at interruption durations of between 30 and 120 cycles. It appears from the results of this study that momentary interruptions were the main source of malfunction for sensitive electronic equipment. The data indicates that although the memory functions of electronic products can withstand large voltage fluctuations, they have difficulties withstanding momentary interruptions of voltage.

Two of the ten VCR's had a form of factory installed battery backup that enabled them to withstand interruptions of greater that 1000 cycles. This seems to indicate that some equipment manufacturers are aware of the problems associated with power-line disturbances and have decided to address the matter. Many of the clock manufacturers have made provisions for battery backup capabilities. Once again this shows a growing awareness in the electronic industry to address power disturbance related effects on their equipment.

The overvoltage testing performed in this study failed to demonstrate any adverse effect on the equipment tested.

The transient testing was intended to be non-destructive and only the laser printers malfunctioned during this portion of the testing. **Any cumulative effects due to accelerated aging (loss of life) from either prolonged undervoltages, overvoltages or transient testing were not considered in this study.**

This paper provides an introduction to the study of sensitive electronic products and how they respond to power system disturbances. The information obtained establishes a basis for an increased understanding of the residential customer's power quality needs. In order to gain a more in-depth understanding of how disturbances effect the customer's we serve, further study is required in this and related areas. The determination of a curve similar to IEEE Std. 446-1987, for sensitive electronic products would prove extremely beneficial to the utility industry and equipment manufacturers. By enabling the utility industry to gain a better understanding of the power quality requirements of the customer's it serves, the industry will consequently be better equipped to serve them. Equipment manufacturers could also benefit by having a standard with which to design their products to for power-line disturbances. Further studies on this topic as well as destructive testing are strongly urged by the author.

Appendix

UNDERVOLTAGE TESTING

DATA VALUES ARE MALFUNCTION VOLTAGES (VAC) FOR EACH PRODUCT.

RESULTS FOR DIGITAL CLOCKS

TEST DURATIONS

DEVICE	0.5 CYC	1 CYC	6 CYC	30 CYC	60 CYC	120 CYC	1000 CYC
CLOCK1	0.0	0.0	0.0	0.0	53.9	53.9	53.8
CLOCK2	0.0	0.0	5.0	20.6	45.9	46.1	47.5
CLOCK3	0.0	0.0	0.0	0.0	0.0	0.0	55.1
CLOCK4	0.0	0.0	0.0	0.0	0.0	0.0	37.1
CLOCK5	0.0	0.0	0.0	0.0	0.0	0.0	49.6
CLOCK6	0.0	0.0	0.0	0.0	0.0	0.0	49.2
CLOCK7	0.0	0.0	0.0	0.0	0.0	0.0	34.8
CLOCK8	0.0	0.0	0.0	45.1	45.1	49.0	60.1
CLOCK9	0.0	0.0	0.0	60.1	62.6	62.6	63.6
CLOCK10	0.0	0.0	0.0	0.0	0.0	0.0	36.0
AVERAGE	0.0	0.0	0.5	12.6	20.8	21.2	48.7
STD. DEV.	0.0	0.0	1.5	21.2	25.8	26.2	9.5

RESULTS FOR MICROWAVE OVENS

TEST DURATIONS

DEVICE	0.5 CYC	1 CYC	6 CYC	30 CYC	60 CYC	120 CYC	1000 CYC
MWOVEN1	0.0	0.0	0.0	69.4	71.9	72.6	72.6
MWOVEN2	0.0	0.0	0.0	0.0	0.0	41.4	41.4
MWOVEN3	0.0	0.0	0.0	0.0	0.0	69.7	69.9
MWOVEN4	0.0	0.0	0.0	67.1	70.0	70.0	70.1
MWOVEN5	0.0	0.0	0.0	0.0	53.5	55.5	55.5
MWOVEN6	0.0	5.5	5.5	71.4	71.4	71.4	71.4
MWOVEN7	0.0	0.0	0.0	0.0	0.0	64.2	64.2
MWOVEN8	0.0	5.1	5.1	46.7	46.7	46.7	46.7
MWOVEN9	0.0	0.0	0.0	0.0	68.5	68.5	68.5
MWOVEN10	0.0	0.0	0.0	0.0	34.5	35.4	35.4
AVERAGE	0.0	1.1	1.1	25.5	41.7	59.5	59.6
STD. DEV.	0.0	2.1	2.1	31.8	29.6	13.1	13.1

RESULTS FOR VIDEO CASSETTE RECORDERS

DEVICE	TEST DURATIONS 0.5 CYC	1 CYC	6 CYC	30 CYC	60 CYC	120 CYC	1000 CY
VCR1	0.0	0.0	0.0	6.2	41.4	46.4	46.7
VCR2	0.0	0.0	0.0	0.0	0.0	0.0	69.6
VCR3	0.0	0.0	0.0	0.0	0.0	0.0	58.0
VCR4	0.0	8.2	50.6	51.5	52.1	52.9	52.9
VCR5	0.0	0.0	0.0	31.8	34.8	35.6	35.7
VCR7	0.0	0.0	74.4	74.4	74.4	74.4	74.4
VCR9	0.0	0.0	0.0	0.0	0.0	0.0	53.1
VCR10	0.0	0.0	65.1	65.1	65.1	65.1	65.1
AVERAGE	0.0	1.0	23.8	28.6	33.5	34.3	56.9
STD. DEV.	0.0	2.7	31.3	29.4	28.4	28.7	11.8

RESULTS FOR PERSONAL COMPUTERS

DEVICE	TEST DURATIONS 0.5 CYC	1 CYC	6 CYC	30 CYC	60 CYC	120 CYC	1000 CY
COMPUTER1	61.3	65.2	65.3	69.3	69.3	69.3	69.3
COMPUTER2	0.0	0.0	66.4	68.8	68.7	68.7	69.3
COMPUTER3	0.0	0.0	57.7	62.0	62.0	62.0	62.0
COMPUTER4	0.0	56.1	59.7	65.0	65.2	65.5	65.8
COMPUTER5	0.0	28.1	28.1	68.6	69.0	69.5	69.5
COMPUTER6	0.0	63.1	63.3	67.7	67.7	67.8	67.8
AVERAGE	10.2	35.4	56.8	66.9	67.0	67.1	67.3
STD. DEV.	22.8	27.8	13.2	2.6	2.6	2.7	2.7

RESULTS FOR PRINTERS

DEVICE	TEST DURATIONS 0.5 CYC	1 CYC	6 CYC	30 CYC	60 CYC	120 CYC	1000 CY
PRINTER1	0.0	35.7	73.6	75.7	76.1	76.1	76.1
PRINTER2	0.0	63.6	65.5	72.9	72.9	72.9	72.9
PRINTER3	0.0	40.5	62.7	77.1	77.1	77.1	77.1
PRINTER4	0.0	59.0	66.1	71.8	71.8	71.8	71.8
PRINTER5	0.0	55.3	61.9	61.9	66.2	66.6	68.4
PRINTER6	0.0	0.0	0.0	68.7	72.9	76.3	76.3
PRINTER7	0.0	0.0	77.7	77.7	82.1	82.1	82.1
PRINTER8	0.0	62.9	62.9	73.6	73.6	73.6	73.6
PRINTER9	0.0	66.1	66.1	72.1	72.3	72.3	72.4
PRINTER10	0.0	7.6	68.0	77.5	77.5	77.5	77.5
AVERAGE	0.0	39.1	60.5	72.9	74.3	74.6	74.8
STD. DEV.	0.0	25.7	20.7	4.6	4.0	4.0	3.6

ACKNOWLEDGMENTS

Special thanks to Lisa M. Anderson who co-authored the paper "The Effects of Power-line Disturbances on Consumer Electronic Equipment" which served as the basis of this paper. Also, special thanks to Anthony Lorusso of Northeast Utilities who provided assistance in this study.

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THE EFFECTS OF TEMPORARY OVERVOLTAGE (TOV) ON CONSUMER PRODUCTS

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ABSTRACT

The failure of sensitive electronic equipment, appliances, and lighting products associated with temporary overvoltage conditions (TOV) have, to date, been documented with little supporting information. The relationship between voltage stress and equipment failure, the modes of failure, and the protection of equipment from overvoltage conditions will be explored in this study. Additional information on the effects of temporary overvoltage on surge suppressor operation also will be presented. The test data displayed in graphic format provides specific information concerning the voltage magnitude verses time necessary for equipment to fail. This study was performed to gain information that could be used for possible utility system changes and for equipment manufacturers to produce a safer and less susceptible product to overvoltage conditions.

INTRODUCTION

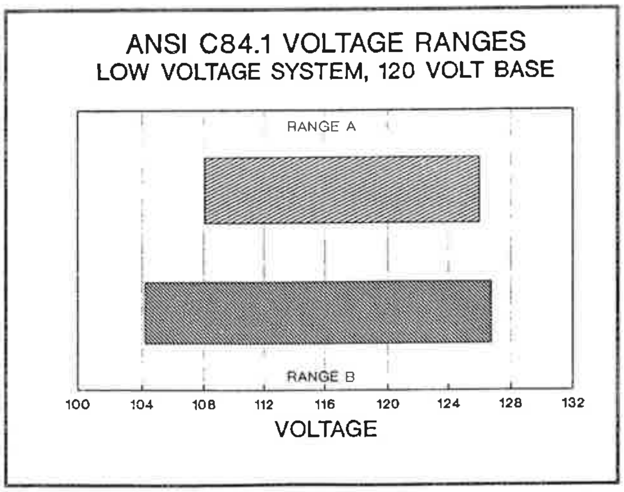
The term "temporary overvoltage" (TOV) is defined, for the purposes of this study, as a sustained increase in the rms value of an entire voltage sinewave for a period of time measured in cycles. This type of disturbance is often referred to as a voltage swell. Although temporary overvoltages or swells account for only a small percentage of the total number of disturbances (based upon surveys on power system mains), their effect on equipment should be considered. The amount of energy in temporary overvoltages can be several magnitudes higher than that of transient disturbances resulting in catastrophic consequences for electronic products and appliances.

Temporary overvoltage should not be confused with a transient, surge, impulse, spike, or any other term used to define a disturbance with a very fast rate of voltage change (dv/dt).

PRESENT VOLTAGE STANDARDS

ANSI C84.1-1982

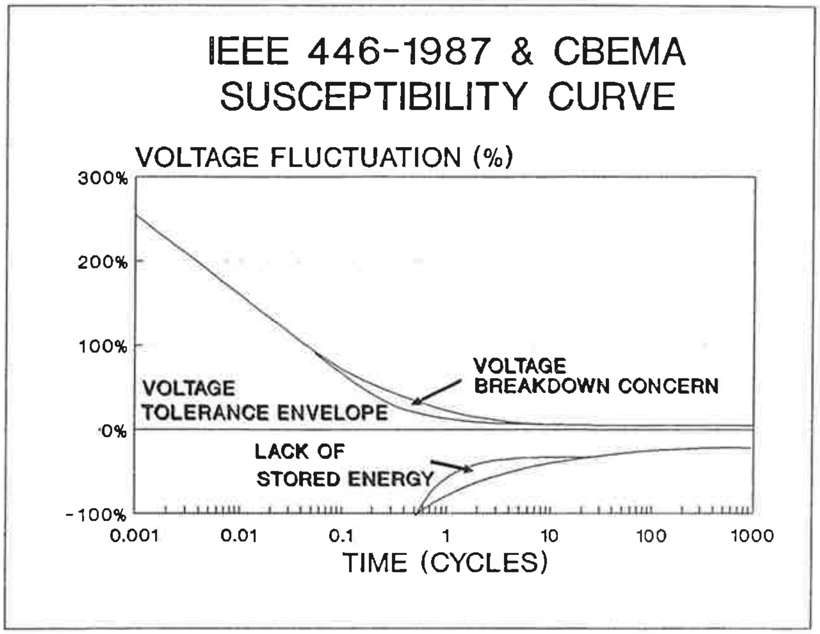
The American National Standards Institute (ANSI) has defined nominal system voltages commonly used throughout the United States in ANSI C84.1-1982. This ANSI standard provides for voltage tolerance limits for two critical points on the distribution system; the point of delivery and the point of connection to utilization equipment. The voltage ranges (see diagram below) define allowable maximum voltages and voltage drops within the distribution system for two different operating conditions at the point of delivery. {1}



The A range specifies normal operating conditions, where the B range is for limited time excursions. The maximum voltages on a 120 volt base are 126 volts (+ 5 %) and 127 volts (+ 5.8 %) for the A and B ranges at the point of delivery. Note Range A limits for 120-600 volt utilization equipment is 125 volts.

IEEE Std. 446-1987/CBEMA CURVE

The IEEE 446-1987 & CBEMA curves specify a + 6 % steady-state overvoltage condition for the design of sensitive computer equipment. The duration of the steady-state voltage limit is defined as 2 seconds or longer, with the permissible voltage level rising to + 30 % at 1/2 cycle (8.33 milliseconds). {2}



The results of the study also will be compared with the IEEE Std. 446-1987 voltage curve with specific emphasis on the "voltage breakdown concern" area of the curve. The IEEE 446-1987 curve is fundamentally the same curve utilized by the Computer Business and Equipment Manufacturers Association (CBEMA) as a guideline for manufacturers to design products. Previous non-destructive testing concerning the susceptibility of consumer electronic equipment and electronic products has provided little information concerning the overvoltage effects (destructive) of powerline disturbances.

ANSI/NEMA MG1-1978

The National Electrical Manufacturers Association (NEMA) specifies a range of +/- 10 % of nominal for the voltage input to motors in ANSI/NEMA MG1-1978. {1}

IBM COMPUTER REQUIREMENTS

International Business Machines (IBM) has a requirement of +/- 10 % of the nominal input voltage for their mainframe computer systems. There is no time limit specified for deviations for this voltage tolerance. {3}

UNDERWRITERS LABORATORIES, UL 991

Underwriters Laboratories, Standard for Safety UL 991, Tests for Safety-Related Controls Employing Solid-State Devices specifies an overvoltage test at 110 % of the operating voltage range for the equipment. {4}

It is evident from the listing of available voltage standards that temporary overvoltage conditions above + 10 % of nominal have received little attention. The IEEE curve specifies design criteria, however it is based upon empirical data. This problem is presently being addressed by two standards groups, the CIGRE Working Group 33.10 and the IEEE Task Force on TOV. The CIGRE has proposed a definition of TOV as an overvoltage higher than the highest system voltage for greater than 2 cycles. {5}

CAUSES OF TEMPORARY OVERVOLTAGE CONDITIONS

There are several ways in which a temporary overvoltage condition can develop on the electric system including the following:

- Ferroresonance and other resonance effects, induction from parallel circuits
- Misoperation of Voltage Regulating Equipment; transformer tap changers, voltage regulators
- Power System Faults

- Loss of Neutral on a normally grounded system
- Accidental contact with conductor of a higher voltage system.

Ferroresonance

Ferroresonance is an overvoltage oscillatory phenomenon caused by the interaction of system capacitance with the nonlinear inductance of a transformer. The capacitive and inductive reactance make a series-resonant circuit that can generate high transient or sustained overvoltage resulting in equipment damage. These conditions are most likely to occur where a considerable length of underground cable is connected to a lightly loaded three-phase transformer bank (especially delta-wye connections). Single-phase switching at a remote location can lead to this condition. {6}

Many new distribution construction techniques make the possibility of ferroresonance affecting equipment more common. Some of these are: the use of underground distribution with its inherent increase in line capacitance verses open wire overhead construction, higher system voltages - resulting in distribution transformers having greater magnetizing reactance, transformer designs with operation of transformer cores at higher saturation, and attempts to suppress zero-sequence harmonic currents with delta-wye transformer connections.

Other overvoltage effects, caused by the change in system impedance with the addition of power factor correction capacitors, and the interaction of harmonic sources also deserves mention. Capacitor bank installations are highly susceptible to overvoltage conditions as a result of a resonance conditions when applied to systems with harmonic generating loads. Induced voltages from transmission lines to distribution circuits, and from distribution circuits to low voltage secondaries and communication circuits are also sources of overvoltage conditions.

Misoperation of Voltage Regulating Equipment

Substation transformer tap changers, although highly reliable devices, do malfunction and can create sustained overvoltage or undervoltage events. Voltage regulators also can produce overvoltage disturbances as a result of malfunction or improper settings. Voltage regulators on utility primary systems can be used on single-phase taps or on all three phases. The regulator settings are most often calculated for balanced load conditions (often not the case) and for a projected load center some distance downstream from the device. As the amount of load changes the output voltage from the regulators is automatically adjusted as necessary, usually in steps of 5/8 % with built-in time delays. Improper settings for the downstream load center can result in steady-state overvoltage conditions of up to 10 % above nominal. Misoperation of a regulator can result in locking in at the maximum boost (+ 10 %) or the minimum buck (- 10 %) tap position.

Customer voltage regulating equipment (whether manual or automatic) is also a source of both overvoltage and undervoltage conditions. Improper transformer tap settings, and power factor correction capacitors locked on during light load periods are some of the common sources of overvoltage conditions. The electronic components in automatic tap switching devices are prone to malfunction, caused by damage from transient disturbances, resulting in device output overvoltage. {7}

The voltage regulation of generators with sudden load changes also deserves mention. With the increase use of on-site generation, (for example: generators used for backup power to homes during power interruptions, by commercial establishments for uninterrupted service to sensitive electronic and computer systems, and by health care facilities), comes the likelihood of temporary overvoltage disturbances. This also is due in part to increased loading of on-site generation.

Power System Faults

During a fault on a distribution system, there will be a significant rise in the current magnitude on the faulted phase (for a single-phase fault). This current also may temporarily have an asymmetrical current component (dc offset) that is a function of the voltage sinewave angular position at the time of the fault and the X/R ratio of the circuit. This can cause an increase in voltage on the unfaulted phases due to a neutral shift that causes transformer saturation and temporary overvoltages until the fault condition is over. {6} The magnitude of these overvoltages has been commonly measured in the field to be greater than 120 % of the nominal voltage.

Loss of Neutral

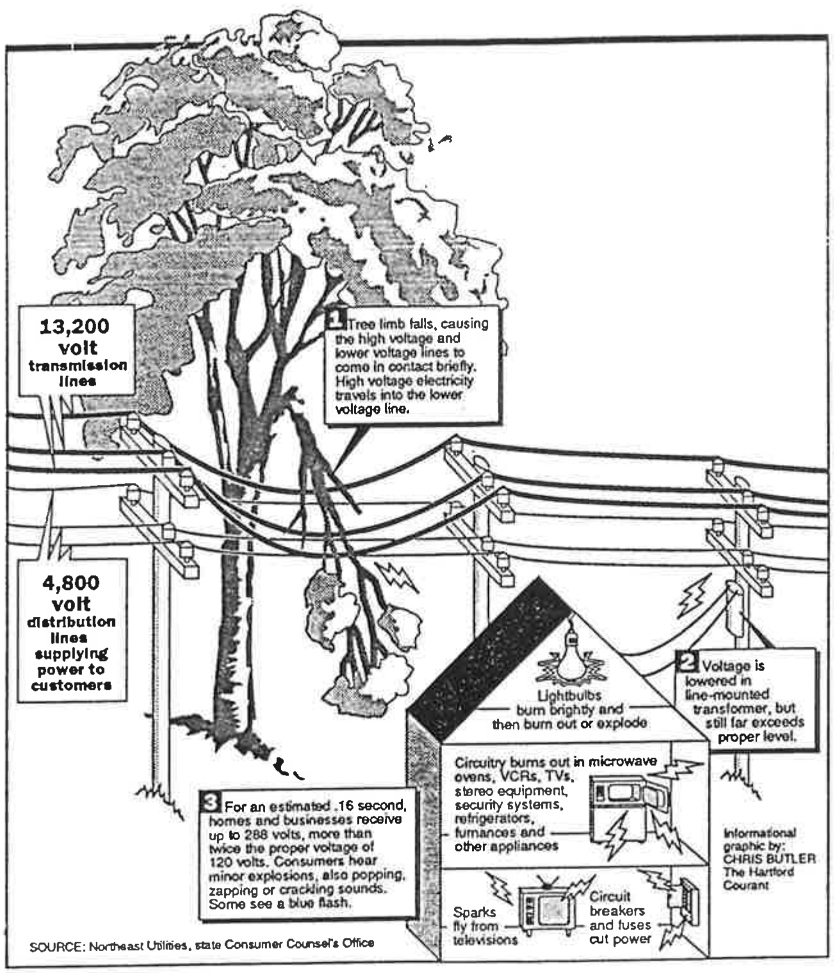
The loss of system neutral (open, loose, or high impedance connection) on a normally grounded system can result in an elevated voltage between the line and neutral. Depending upon the type of system (120/240 volt single-phase, or 208Y/120 volt three-phase) the line-to-neutral voltage on one of the phases will approach the line-to-line voltage as single-phase loads cycle.

The floating of the system neutral can result in equipment failure due to overvoltage, and possible failure of voltage clamping surge protection devices when they attempt to clamp the line voltage. There have been repeated instances documented while investigating power quality complaints where loss of neutrals have been the cause of equipment failures.

Accidental Contact with Higher Voltage System

The overvoltage conditions caused when high-voltage power lines come in contact with lower-voltage systems has become a major concern to both the electric utility industry and the consumer. The reason for concern on the utilities' behalf is the large number of customers that could potentially be affected by this type of disturbance. The resulting overvoltage conditions that can occur prior to the operation of utility system protective devices can cause a great deal of damage to consumer appliances and electronic equipment.

A drawing shown below illustrates one of the possible scenarios leading to an overvoltage condition. It depicts the high-voltage distribution circuit on the top of the pole being forced down into the second distribution circuit by a tree limb. {8} This type of circuit configuration is commonplace across much of the utility industry with circuit crossings and vertical primary construction (circuit conductors spaced over one another rather than horizontally) being the predominant instances.



PRODUCTS TESTED

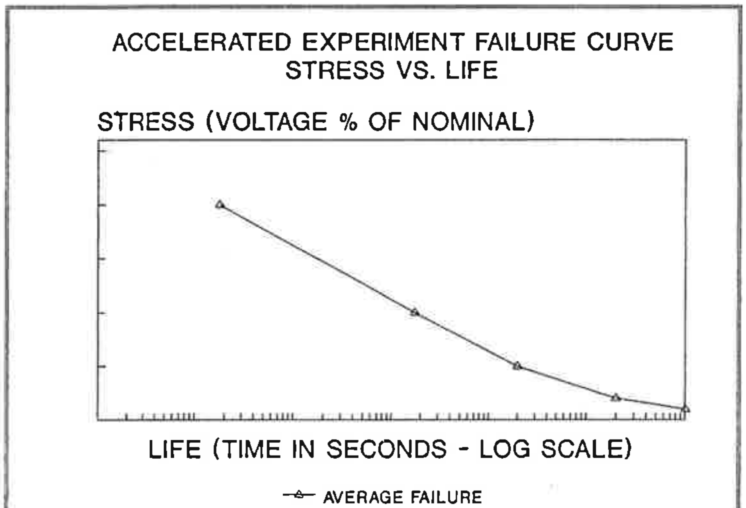
The types of equipment most commonly viewed as "sensitive electronic equipment", as well as a limited number of household appliances and lighting products, were selected for destructive testing. The sample sizes of each type of equipment were limited, with two or three products tested at each test point.

The products tested were: digital clocks, microwave ovens, video cassette recorders, incandescent light bulbs, and surge suppressors. The digital clocks, microwave ovens and video cassette recorders comprised the sample group of sensitive electronic equipment often found within the residential consumer's home. Incandescent light bulbs were tested in an attempt to increase the statistical confidence of the study at a reduced equipment cost, and because of their widespread usage in the home.

The surge suppressors were tested in order to determine their protective ability when subjected to overvoltage conditions as well as possible safety problems. The failure modes of various suppression products such as metal oxide varistors (MOVs) and zener diodes when subjected to elevated line voltage have been recognized as the cause for safety concerns. These semiconductor products often fail as a short circuit across the line and can result in package rupture or intense heating resulting in potential fire.

TEST PROCEDURE

When testing products to failure, a stress verses time curve is often used to present the recorded data. Such a sample curve is presented below with the vertical axis representing the stress levels, (in this case voltage magnitude), and the horizontal axis representing the time in seconds.



SAMPLE FAILURE CURVE

The term failure will be used extensively throughout this paper and deserves clarification. A failure is defined as irreversible, permanent damage to the piece of equipment under test, resulting in destruction of the product or repairs being necessary.

The test points were selected from the following: the IEEE 446-1987 curve, database compilation of measured powerline disturbances, and information provided from computer simulations of the overvoltage conditions on the utility system. The equipment under test was subjected to the specified voltage magnitudes listed below (based on nominal = 120 VAC):

110 % of Nominal	**-**	**132 VAC RMS**
120 % of Nominal	**-**	**144 VAC RMS**
150 % of Nominal	**-**	**180 VAC RMS**
200 % of Nominal	**-**	**240 VAC RMS**
300 % of Nominal	**-**	**360 VAC RMS**

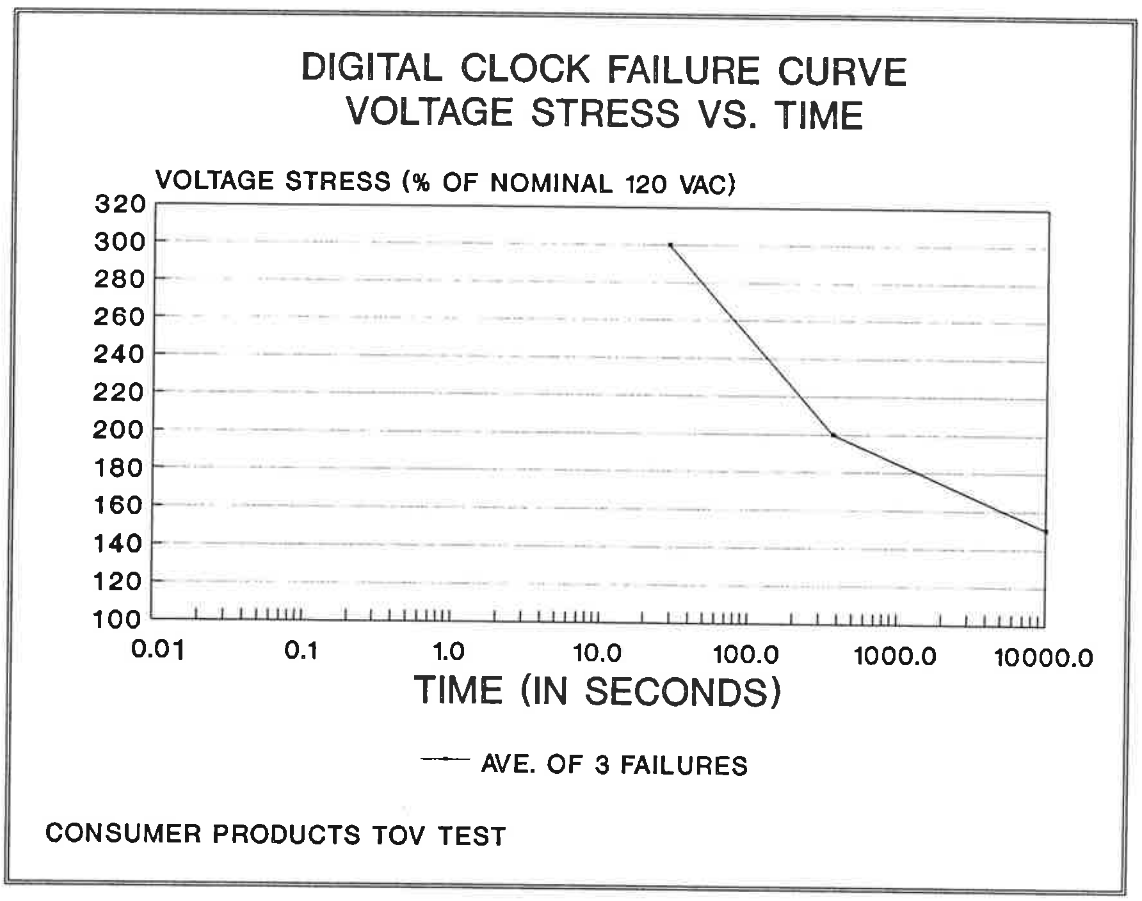
The voltage was supplied from an auto-transformer (Variac) with the equipment under test monitored with a graphic powerline monitor. The voltage was applied to the equipment, and the time until failure was measured and recorded. Some of the tests performed (150 % of nominal and below) did not result in a failure or any noticeable destruction to the equipment. The results for these tests are listed as a time period of greater-than four hours.

The microwave ovens and video cassette recorders were not operating during the testing. These units were turned on but were not cooking or playing a tape during the testing.

Digital Clock Results

The digital clocks exhibited the highest level of tolerance to temporary overvoltage disturbances. At 300 % of nominal voltage it took greater than 28 seconds (1680 cycles) on average before a failure occurred. At 200 % of rated voltage, the failures averaged 367 seconds. Two of the three clocks tested at 150 % of nominal voltage survived a 4 hour test cycle without failure. On the third clock, (150 % of nominal) the test was halted due to melting of its plastic case at 219 minutes. Tests for four hours at 120 % and 110 % of nominal voltage did not produce any clock failures.

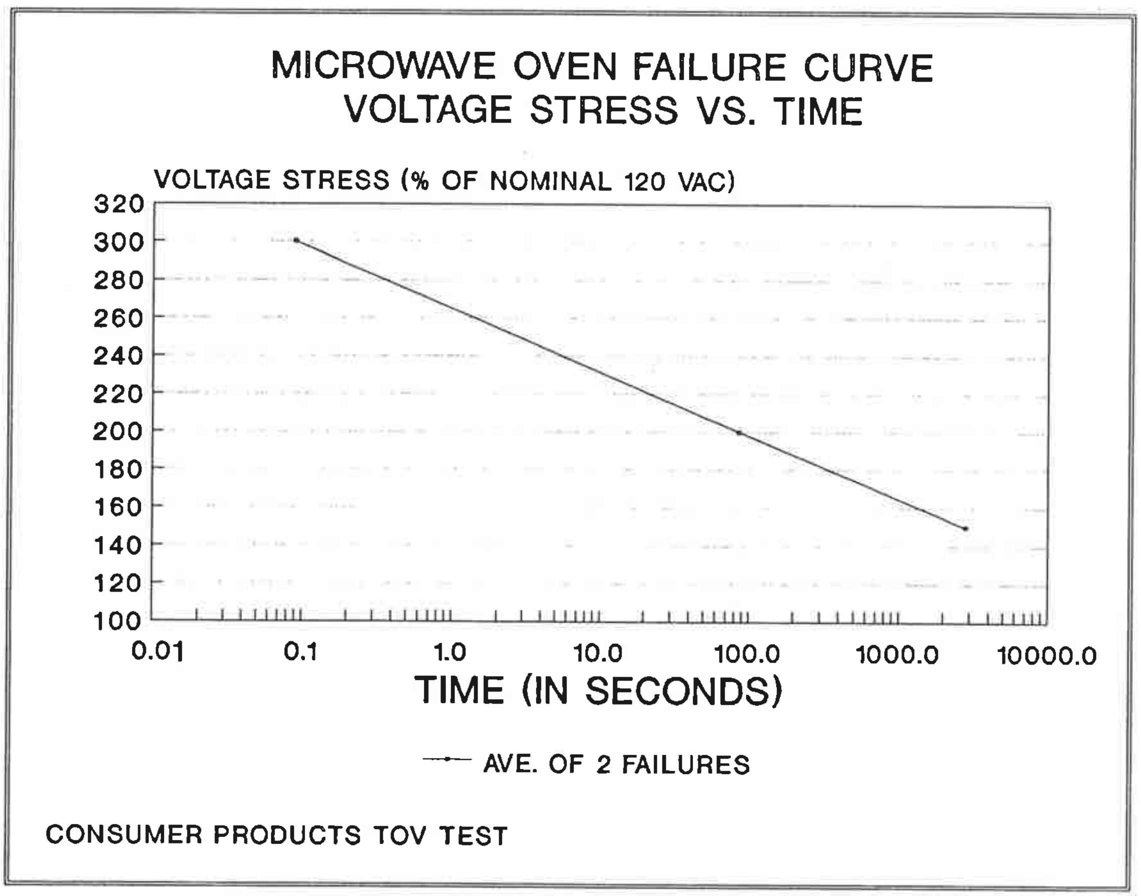
The types of component failures observed were the power transformers in all but one case, where the LED display failed. On the test of the third clock, the power transformer heated the plastic case to the point where it melted through onto the test bench. The test was halted at this time.



Microwave Oven Results

The microwave ovens tested at 300 % of nominal voltage failed within an average of 0.09 seconds. Failure at 200 % of nominal voltage occurred after 86 seconds. At 150 % of nominal voltage microwave oven failure took place after 47 minutes. No failures were recorded for testing at 120 % or 110 % of nominal voltage.

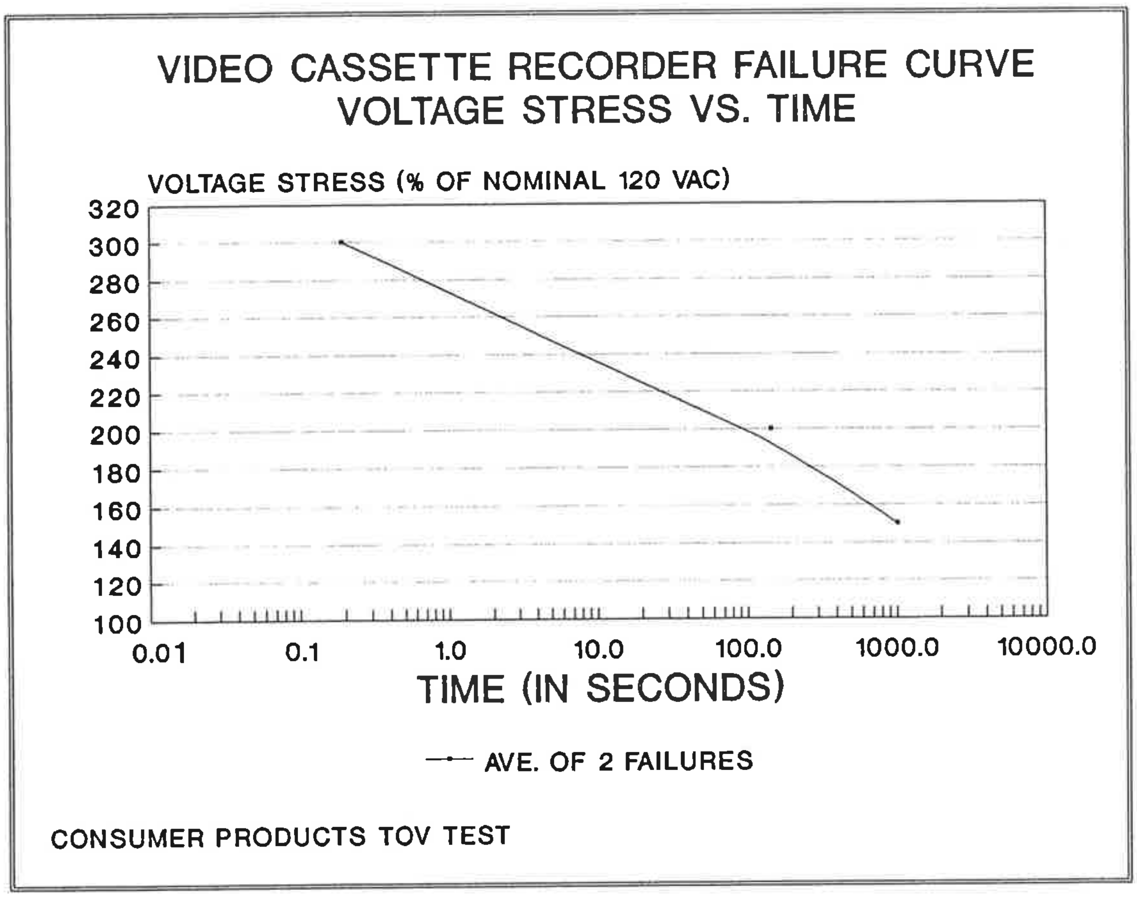
The failures of the devices were due to suppression device failures connected between the line and neutral conductors on the input to the power supply. These failures resulted in package rupture of the suppression devices. Power supply failures also occurred in the microwave ovens for the 200 % and 150 % of nominal voltage tests. The same basic design method of applying a MOV across the power supply input was observed on all the units tested. This practice may warrant review by the manufactures, both for safety and neutral-to-ground suppression performance.



Video Cassette Recorder Results

The results for the testing at 300 % of nominal voltage yielded some interesting findings: both video cassette recorders failed after an average of 0.19 seconds. In both cases, the units were fused and no permanent damage resulted from the testing. At 200 % of nominal voltage the VCR lasted 144 seconds before failure occurred. The power supply transformer shorted and failed in this test. For all the other test points, 150 %, 120 % and 110% of nominal, the VCR's lasted greater than four hours with no failures occurring.

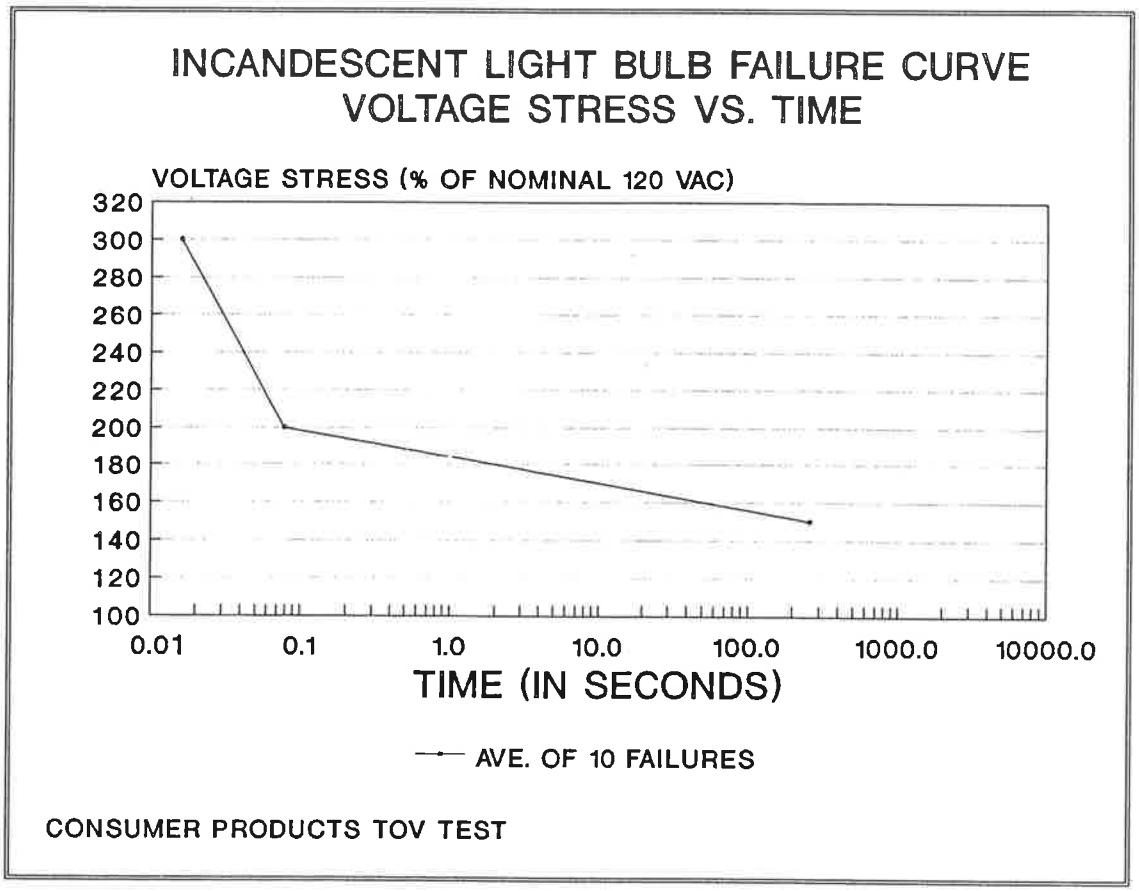
The design of VCRs utilizing fast acting fuses on the input stages appears to be a viable solution in minimizing the effects of some TOV disturbances.



Incandescent Light Bulb Results

The incandescent light bulbs were found to be the most susceptible devices to TOV disturbances. At 300 % of nominal voltage, the light bulbs withstood approximately 1 cycle (0.016 seconds) before failure occurred. At 200 % of nominal, the light bulbs lasted approximately 5 cycles on average before failing. Light bulbs supplied with 150 % of nominal voltage operated an average of 259 minutes before failing. All of the light bulbs tested at 120 % and 110 % of nominal voltage lasted greater than four hours with no failures resulting. Documentation concerning the effects of operating a 120 volt light bulb at higher and lower voltages (+/- 10 volts) is included in the ANSI/IEEE Red and Gray Books.

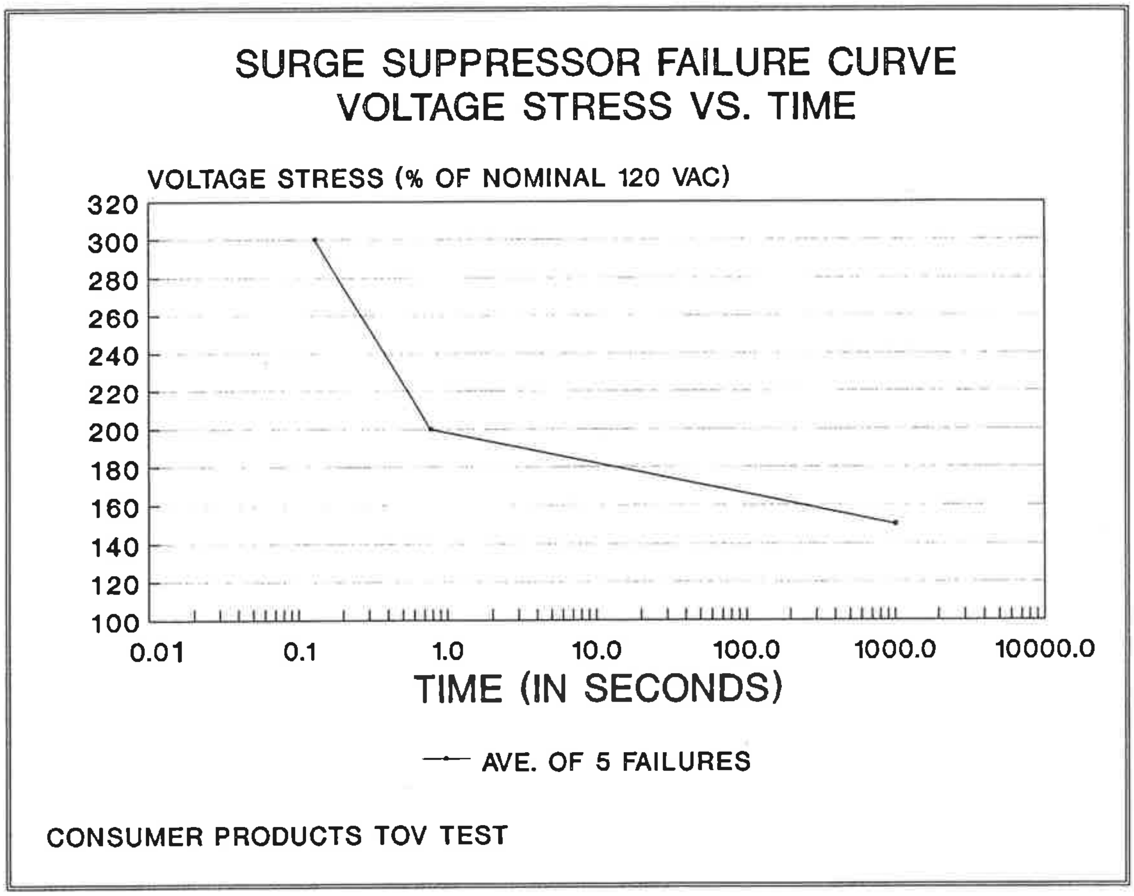
The type of failure for all the bulbs was the filament. There was no damage to the glass bulb for any of the tests.



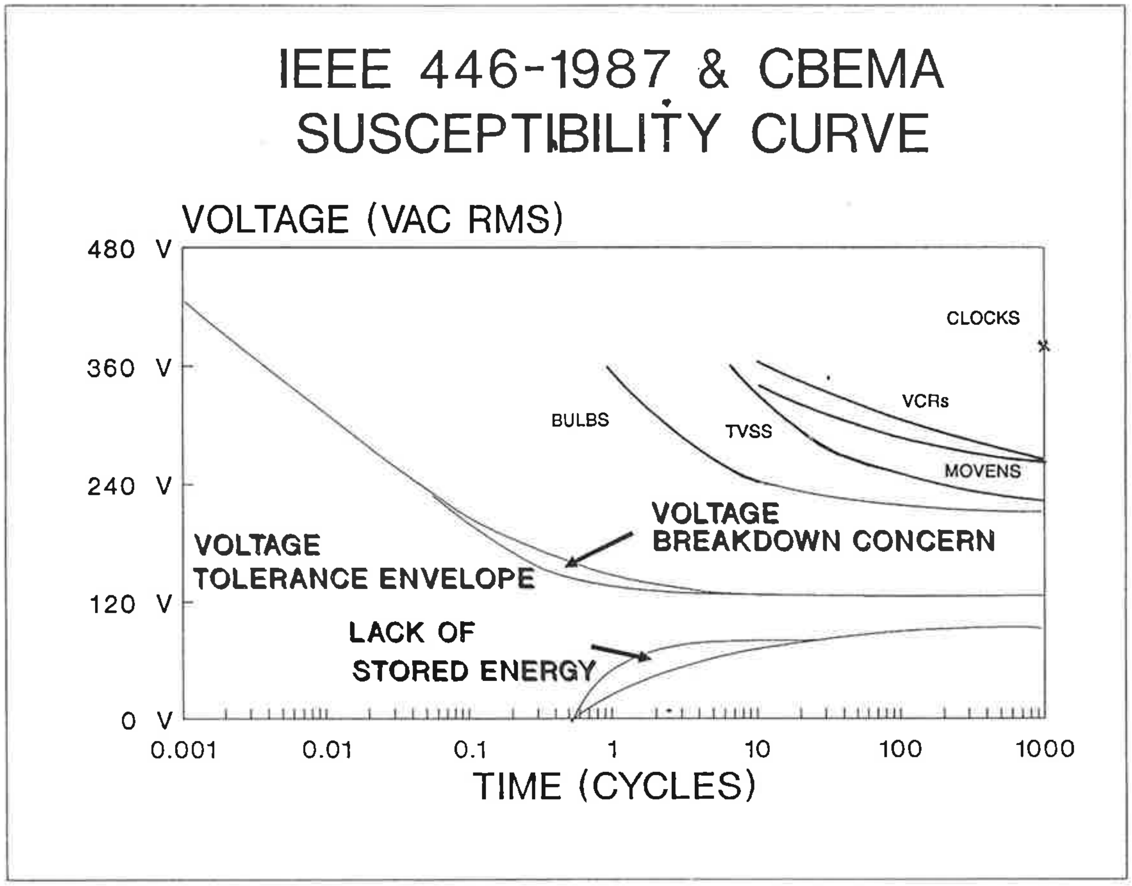
Surge Suppressor Results

The surge suppressors tested covered a broad price range and several clamping voltages. The results at 300 % of nominal indicate that on average the failures occurred at 0.13 seconds (8 cycles). The range of failure times covered from 0.02 seconds to 0.21 seconds. In all cases the suppressors attempted to clamp the line voltage, with clipping of the sinewave until device failure. At 200 % of nominal the failures averaged 0.77 seconds, with a range of 0.14 to 1.59 seconds. The testing performed at 150 % of nominal yielded results ranging from 1.40 seconds to greater than four hours, dependent upon the voltage clamping rating of the suppressor.

The failure mode of the voltage clamping devices is of major concern, as package rupture, mild explosion, melted cases on the plastic housed units, and combustion all occurred during the testing. Temporary overvoltage protection or overcurrent protection capable of disconnecting the device from the line during TOV disturbances appears to be necessary for products with clamping voltages in the range up to 300 % of nominal voltage. The threat of personnel safety or fire from the effects of this type of disturbance on voltage clamping devices should be addressed.



Comparison with IEEE 446-1987 Curve



CONCLUSIONS

The author has addressed the effects of temporary overvoltage on consumer products in three general areas:

1) Review of present voltage standards and activities of the working groups on TOV,

2) Information on some of the conditions that cause TOV disturbances, and,

3) Laboratory test data on the effects of TOV disturbances on consumer products.

REFERENCES

{1} ANSI/IEEE Std. 141-1986, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants

{2} ANSI/IEEE Std. 446-1987, IEEE Recommended Practice for Emergency and Standby Power systems for Industrial and Commercial Applications

{3} Allen, G. W. and Segall, D., "Monitoring of Computer Installations for Power Line Disturbances", IEEE C74 199-6, December 7, 1973

{4} Underwriters Laboratories Inc., UL 991 Standard for Safety, Tests for Safety-Related Controls Employing Solid-State Devices, January 27, 1989

{5} Allina, E., and Dhooge, T., "Beware of Paralleled MOVs", Power Quality Magazine, Premier VI 1990.

{6} Gonen, T., Electric Power Distribution System Engineering, McGraw-Hill, Inc., 1986

{7} Standler, R. B., Protection of Electronic Circuit from Overvoltages, John Wiley & Sons Inc., 1989

{8} Giorgianni, A., "Some take dim view of power surges", The Hartford Courant, November 4, 1989

EFSB Record Request 8

Request:

Indicate the BMPs for noise control to show the efforts that can be taken to mitigate the noise impact of construction in the residential portion of the route on Camp Avenue.

Response:

Best practices to reduce construction noise as safe, reasonable and effective will be included such as:

- Replacing back-up alarms with strobes, as allowed within Occupational Safety and Health Administration (OSHA) regulations, to eliminate the annoying impulsive sound.
- Assuring that equipment is functioning properly and is equipped with mufflers and other noise-reducing features.
- Locating especially noisy equipment as far from sensitive receptors as possible.
- Using quieter construction equipment and methods, as feasible, such as smaller backhoes.
- Using path noise control measures such as portable enclosures for small equipment (e.g., jackhammers and saws).
- Limiting the periods of time when construction may occur is a common approach to minimizing impact.
- Maintaining strong communication and public outreach with adjacent neighbors is an important step in minimizing impact. Often, providing abutters information about the time and nature of construction activities can minimize the effects of construction noise.

Prepared by or under the supervision of: Ken Bowes, Demetrios Sakellaris and Jason Ross

EFSB Record Request 9

Request:

Provide the mG reading at the edge of the road and at each of the residences along Camp Avenue.

Response:

The distances from the centerline of the underground duct bank to the edge of the road and to residences are shown in Attachment Revolution Wind EFSB RR4-1 and listed in the table below. Note that in responses to other data requests EFSB 1-3 and 1-4, distances were specified from the nearest edge of the duct bank and so are 1.5 feet shorter than listed in the table below.

The levels of calculated magnetic fields at average and peak loading of the 275-kilovolt Onshore Transmission Cables are listed in the table below.

Address	Distance to edge of Camp Avenue (feet)	Magnetic field (milligauss) Average Load (Peak Load)	Distance to front of Residence (feet)	Magnetic field (milligauss) Average Load (Peak Load)
9 Windward Walk	19.5	5.1 (6.8)	93.5	0.8 (1.1)
643 Camp Ave	19.5	5.1 (6.8)	93.5	0.8 (1.1)
629 Camp Ave	18.5	5.5 (7.3)	83.0	0.9 (1.2)
613 Camp Ave	18.5	5.5 (7.3)	56.5	1.4 (1.8)
595 Camp Ave	22.5	4.3 (5.7)	74.5	1.0 (1.4)
571 Camp Ave	23.5	4.0 (5.4)	112.5	0.7 (0.9)

Prepared by or under the supervision of: William H. Bailey and Demetrios Sakellaris

EFSB Record Request 10

Request:

In terms of lighting, what is the temperature/color of the light.

Response:

The proposed lighting ranges in temperature from 3000°K to 5000°K and is warm white to cool daylight in color. During emergency situations additional lighting may be required.

Prepared by or under the supervision of: Ken Bowes and Demetrios Sakellaris