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Design of AC Electronics Load Surge Protection

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***Abstract*—**This study examines the design and construction of AC Electronics load surge protection in order to carry electric surge load arisen from faults in low voltage electricity system (single phase/220V) by using the principle of electronics load clamping voltage during induction period so that electric voltage could go through to safe load and continue to work. The qualification of the designed device could prevent both transient over voltage and voltage swell. Both will work in cooperation, resulting in the ability to improve and modify the quality of electrical power in Thailand electricity distribution system more effective than the past and help increase the lifetime of electric appliances, electric devices, and electricity protection equipments.

***Keywords*—**Electronics Load, Transient Over Voltage, Voltage Swell.

I. Introduction

AT present, production process in the industry requires higher technology electric appliances with higher sensitivity to the changes in quality of electrical power than in the past. Still, electrical system lacks stability and quality due to natural phenomena [1-7], electricity faults, switching devices, using non linear devices, and improper grounding [8-9]. The above-mentioned causes of problem in electrical power quality are from electricity usage and electricity user. The right approaches in solving electrical power quality problem must receive helping hands from all sectors.

Surge protection devices are mostly imported and expensive [10]. Those devices could solve temporary electrical surge such as lightning. However, they could not solve problem of voltage swell. Moreover, every country runs different electricity system. An analysis to solve electrical power quality problem must be based on real situations.

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The solution by adding electronics load inside surge protection device could prevent voltage swell and electrical voltage will not exceed the specified range [4]. Therefore, that improves electrical power stability and quality and increases the lifetime of electric appliances, electric devices, and electricity protection equipments.

II. Principles and Theories

According to international standards, IEEE defines electrical power quality as the attribute of current, voltage, and frequency of electricity distributor in normal state which will not make electric equipments malfunction or damage. The main reason for considering electrical power quality is that higher technology electric appliances have higher sensitivity to the changes in electrical power quality than in the past. The increase in using higher technology electric appliances and the electricity system which connects every section together will break down the whole system if one part is affected by electrical power quality problems.

A. Electrical Power Quality Problems are Caused by 5 Main Reasons

1. Natural phenomena such as lightning
2. Electrical faults
3. Switching in devices
4. Using non linear devices in industrial system
5 Improper grounding

B. Transient over Voltage [8]

1**.** Impulsive transients which has high pitch current and voltage takes place immediately without changes in frequency. It is set to have one direction terminal. The duration of higher voltage is 5 ns – 0.1ms. The cause is lightning which might take place directly or nearby, damaging equipments in the system due to over voltage.

2. Oscillatory transient which has high voltage or current without changes in frequency. Still, anode and cathode change rapidly in the form of waves. The duration is around 0.3 ms – 5ms. The cause is switching in system devices, damaging electric appliances and insulator will become impaired quickly.

3. Voltage Swell occurs when the AC voltage RMS value rises between 1.1 to 1.8 pu. during 10 ms – 1 min. Most causes are due to phase, not from direct electrical faults. Other causes are large load is removed from the system or large capacitor installed in the system, damaging electric appliances or making devices with high sensitivity to changes in power distributor quality malfunction or stop working.

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III. Experimental Design

As for circuit design, there were 2 sets of protection mode in order to prevent surge according to the specific capability of designed material to work effectively with the system as follows:

Set 1 is mode for transient over voltage protection.
Set 2 is mode for voltage swell protection.

A. *Mode for Transient Over Voltage*

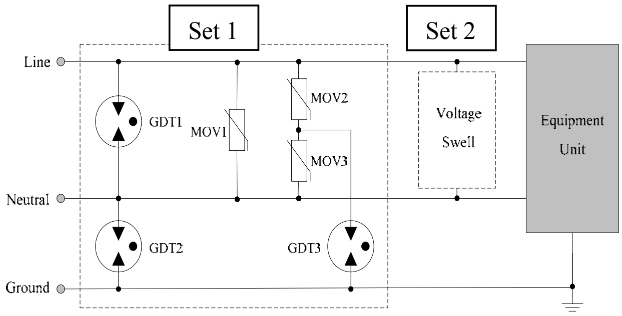

Fig. 1 Set 1 or mode for transient over voltage.

This mode comprises of the following components:

1. Gas Discharge Tube (GDT) material
2. Metal Oxide Varistor)MOV) material

As shown in Fig. 1, this is mode for surge protection in parallel with electricity system. It has GDT in front in order to reduce the power going through to next protectors without damaging. MOV material will reduce over voltage left from forefront material in order to let voltage go through Set 2 and equipment unit will not damage.

B. *Mode for Voltage Swell*

This mode would reduce voltage swell of RMS value which was higher than the specified range (or 220 V ± 10%). Design of this mode is in parallel with electricity system without considering how much load consumes current. This device will examine and compare voltage. When voltage reaches the specified point, the signal will be sent to drive gate to control FET to conduct and control the level of let through electrical voltage to clamp equipment unit in a proper time so that nothing damages as shown in Fig. 2.

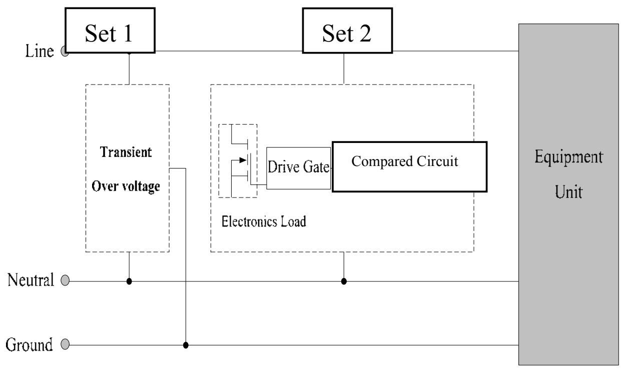

Fig. 2 Set 2 or mode for voltage swell.

This mode comprises of the following components:

1. Electronics load functions as load to receive power from over voltage.
2. Drive gate controls voltage and current.
3. Voltage comparer compares voltage during the time of electrical faults.

C. *Block Diagram of All AC Surge Protection Equipments*

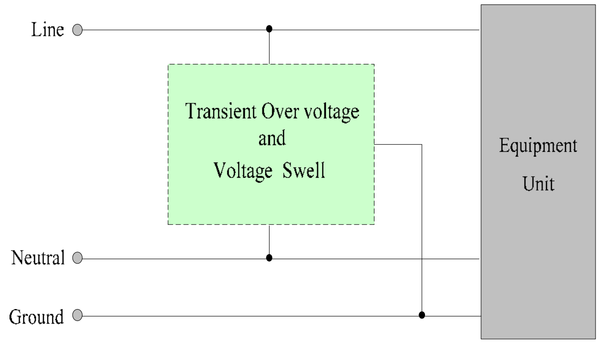

Fig. 3 Block diagram of all AC surge protection equipments

IV. Research Results and Evaluation

A. *Capability Experiment for Transient Over Voltage*

Fig. 4 shows the circuit to test the device in order to get the value of voltage going to the designed load in AC electronics load surge protection device. It is in parallel with the system in order to know whether it complies with the design or how much it is different from the design. The experiment was done by shooting surge power with 6000 voltage range. Fig. 4-5 show the waveform of standard voltage surge at 1.2/50 μs [11-13]

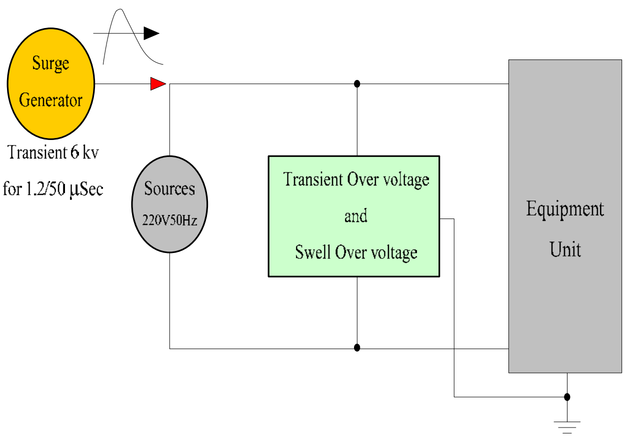

Fig. 4 Circuit to test the device for transient over voltage

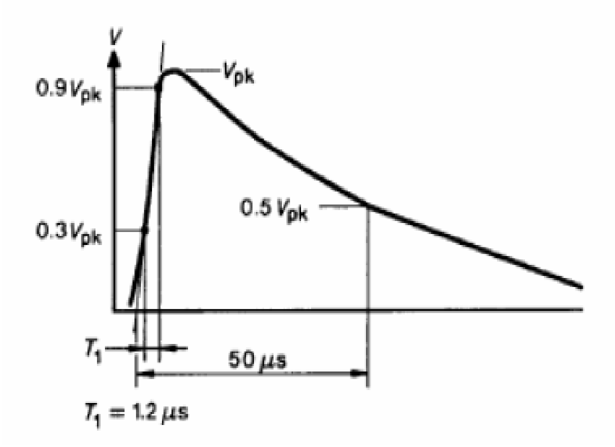

Fig. 5 Waveform of standard voltage surge at 1.2/50 µs

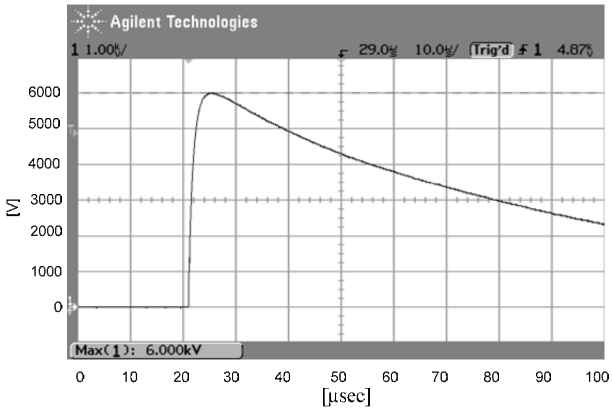

Fig. 6 Waveform of test signal with 6000 voltage range (1.2/50 µs)

TABLE. 1 RESULTS FROM THE DEVICES FOR TRANSIENT OVER VOLTAGE

SEQUENCE TEST	VOLTAGE TEST VT[V]	LET THROUGH VOLTAGE VLT[V]
1	6000	562.5
2	6000	563.7
3	6000	564.5
4	6000	565.2
5	6000	566.4
6	6000	567.1
7	6000	567.9
8	6000	568.7
9	6000	569.3
10	6000	570.3

Results from the experiment in Table 1 shows the value of let through voltage was satisfactory, in other words, let through voltage did not exceed 600 V peak as shown in Fig. 8, 9 and 10, respectively. Fig. 7 shows comparison graph of voltage test and let through voltage in a linear manner.

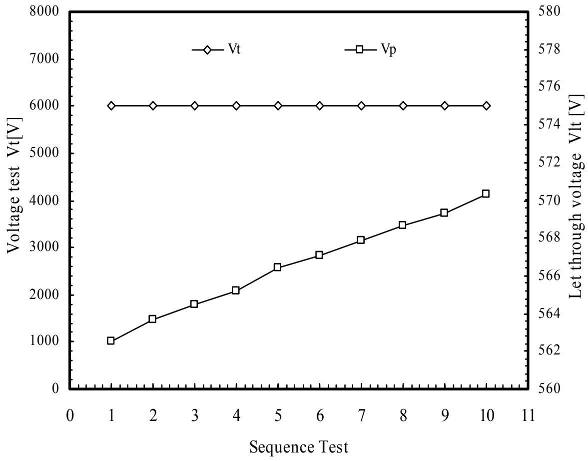

Fig. 7 Comparison graph of voltage test and let through voltage

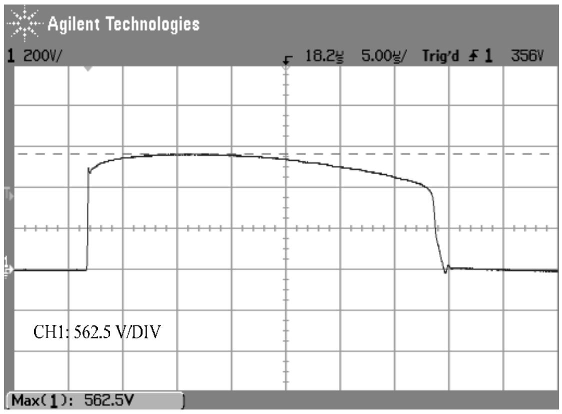

Fig. 8 Signal of let through voltage at output, sequence 1

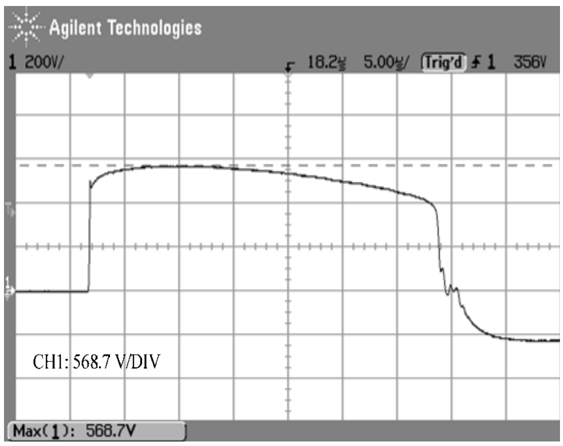

Fig. 9 Signal of let through voltage at output, sequence 5

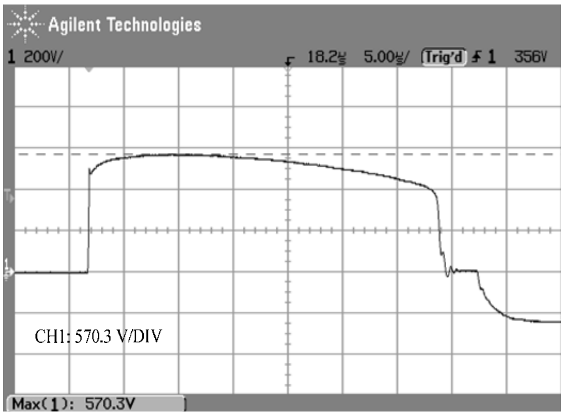

Fig. 10 Signal of let through voltage at output, sequence 10

B. Capability Experiment for Voltage Swell

Fig. 11shows the circuit to test the device for voltage swell in order to test electronics load clamping voltage. Electrical power is let through with AC 50 Hz voltage with voltage range at 260, 280, 300, 320, 340, 360, 380 and 400 V RMS respectively. Results of clamping voltage test must not exceed 220 V ± 10%. Fig. 12 – 15 show the waveform of voltage swell within the specified voltage range.

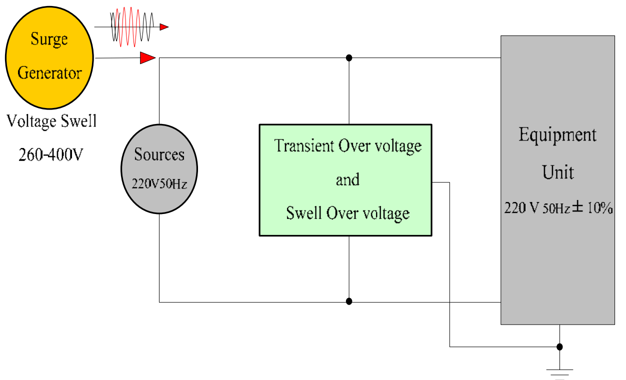

Fig. 11Circuit to test the device for voltage swell

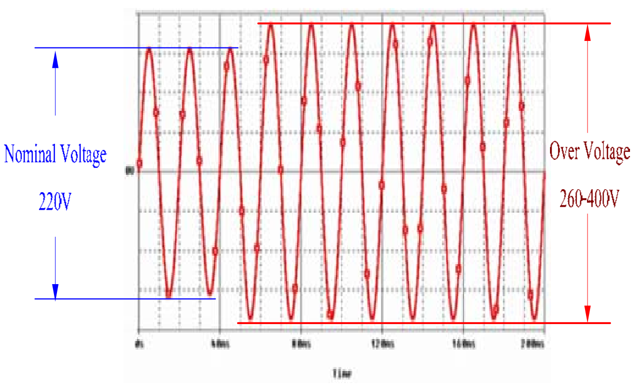

Fig. 12 Waveform of voltage swell

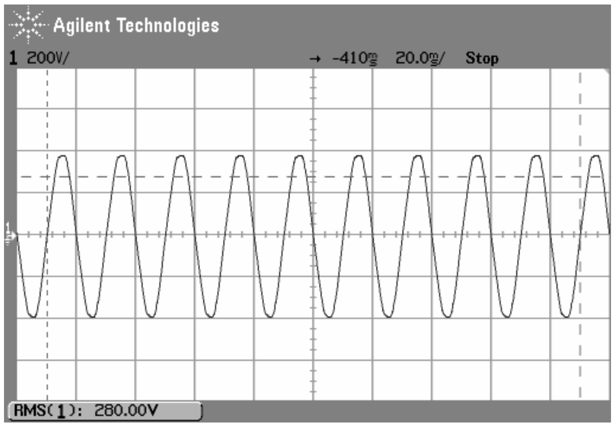

Fig. 13 Waveform of test signal with 280 V voltage range

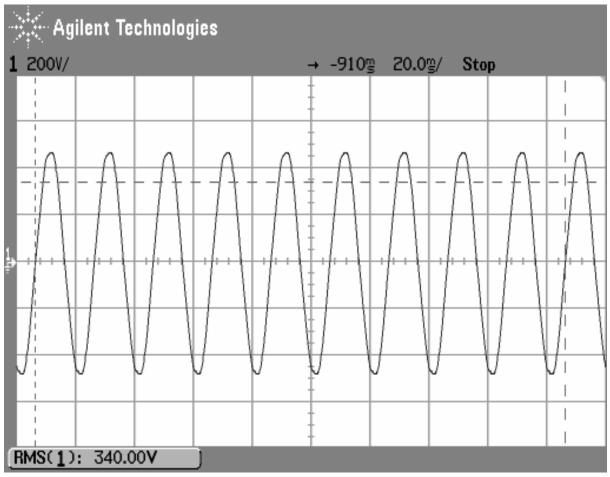

Fig. 14 Waveform of test signal with 340 V voltage range

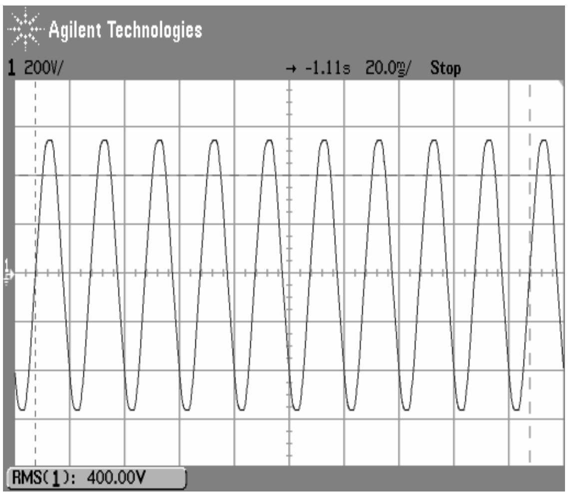

Fig. 15 Waveform of test signal with 400 V voltage range

TABLE 2 RESULTS FROM THE DEVICE FOR VOLTAGE SWELL

Sequence Test	Voltage test Vt[V]	Clamping Voltage Vc[V]	Leakage current Cl[A]
1	260	202.81	2.750
2	280	206.99	3.350
3	300	213.44	4.075
4	320	218.30	4.694
5	340	222.33	5.146
6	360	227.56	5.984
7	380	230.07	6.546
8	400	234.50	7.227

Results from the experiment in Table 2 shows that electronics load clamping voltage did not exceed the specified voltage range or between 198 – 242 V. Fig. 16-17 show comparison graphs of voltage test and clamping voltage and leakage current in a linear manner. Fig. 18 – 20 show samples of measured oscilloscope signal of voltage (CH1) and current (CH2) which clamp electronics load during the operation when over voltage occurs in the system.

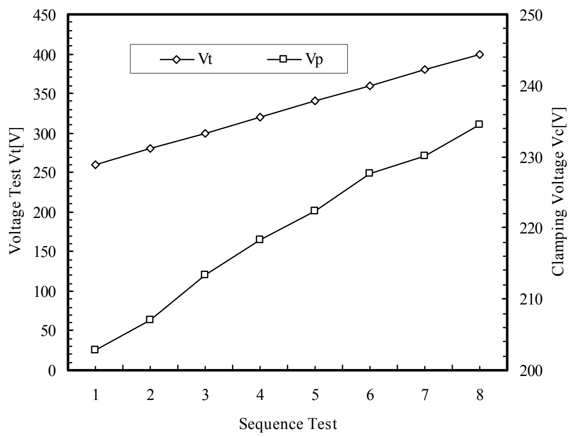

Fig. 16 Comparison graph of voltage test and clamping voltage

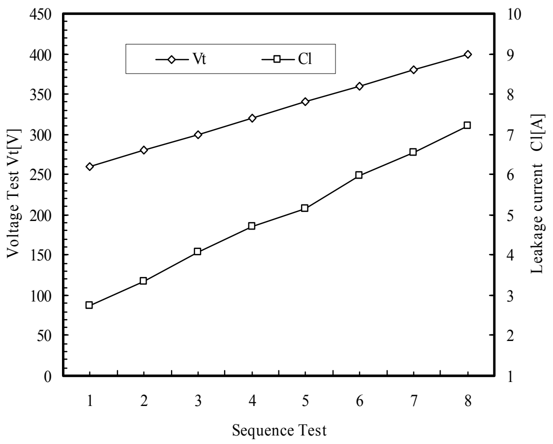

Fig. 17 Comparison graph of voltage test and leakage current

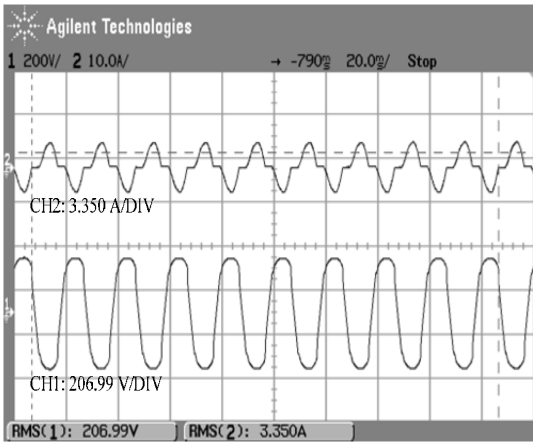

Fig. 18 Output signal of current and voltage test at 280V

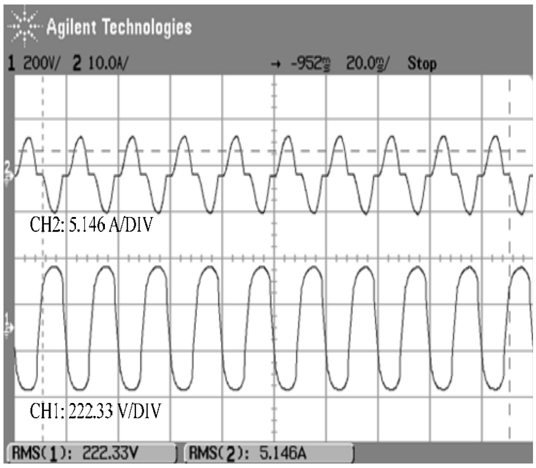

Fig. 19 Output signal of current and voltage test at 340 V

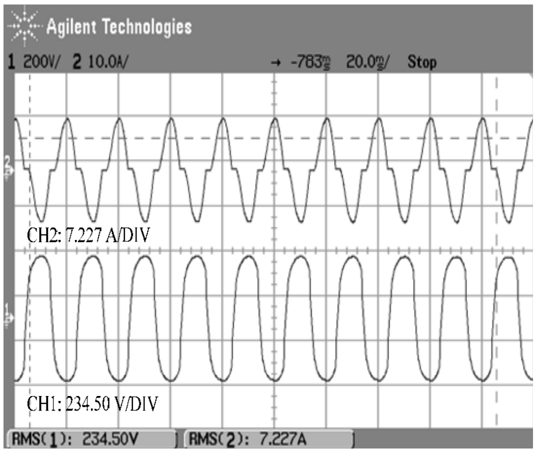

Fig. 20 Output signal of current and voltage test at 400V

V. CONCLUSION

Experiment of AC electronics load surge protection in low voltage electricity system (220V, 50Hz, and current less than 20 amp) shows that the designed device could carry electrical surge load which agree with IEEE and IEC standard [11-13]. Let through voltage was still low and clamping voltage was within the specified standards. This device could be used to prevent voltage surge arisen from electrical faults with effectiveness.

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