

Protection of Load Surge by Designing Alternating Current Electronics

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Abstract

The purpose of this research is to investigate the design and construction of AC Electronics load surge protection in order to carry electric surge load caused by faults in low voltage electricity systems (single phase/220V). This is accomplished through the application of the principle of electronics load clamping voltage during the induction period, which allows electric voltage to pass through to safe loads and ensures that the system continues to function. The testing of the finished product has the potential to protect against both transiently high voltages and steadily rising voltages. Together, they will work to improve and modify the quality of the electrical power in Thailand's electricity distribution system, making it more efficient than it was in the past and contributing to an increase in the lifetime of electric appliances, electric devices, and electricity protection equipments.

Keywords: *Electronics Load, Transient over Voltage, Voltage Swell.*

INTRODUCTION

The manufacturing process in the industry necessitates the use of electric appliances with higher levels of technological sophistication and more sensitivity to variations in the quality of the electrical power than in the past. However, the lack

of stability and quality in the electrical system can be attributed to natural occurrences [1-7], electricity faults, switching devices, the use of non-linear devices, and poor grounding [8-9]. The utilisation of energy and the actions of those who utilise electricity are the root

causes of the issues with the quality of the electrical power.

All facets of society have a responsibility to collaborate on developing effective strategies for improving the quality of electrical power.

The majority of surge protection devices are imported, making them prohibitively expensive [10]. These devices have the potential to alleviate brief electrical surges, such as those caused by lightning. However, they were unable to find a solution to the problem of voltage surge. In addition, each nation's electrical infrastructure is completely unique. An investigation into how to improve the quality of electrical power must be founded on actual circumstances.

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.

PRINCIPLES AND THEORIES

Electrical power quality is defined by the IEEE as the attribute of current, voltage,

and frequency of an electricity distributor in normal condition that will not cause electric equipment to malfunction or be damaged. These worldwide standards are based on the definitions provided by the IEEE.

The most important reason to take into account the quality of the electrical power is the fact that electric appliances with more advanced technology are more sensitive to variations in the quality of the electrical power than they were in the past. The rise in the use of electric appliances with more advanced technology, along with the fact that the electricity system ties every sector together, can cause the system as a whole to fail if just one portion is disrupted by issues with the electrical power quality.

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. 5 Improper grounding

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.

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.

Mode for Transient over Voltage

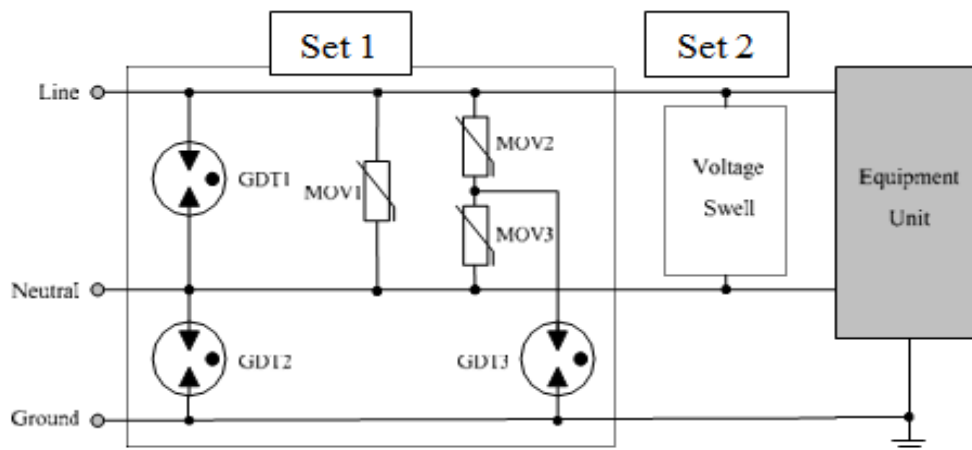


Fig. 1 Set 1 or mode for transient over voltage

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.

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.

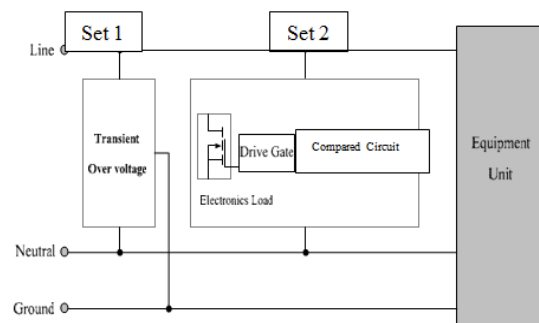


Fig. 2 Set 2 or modes for voltage swell

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.

Block Diagram of All AC Surge Protection Equipments

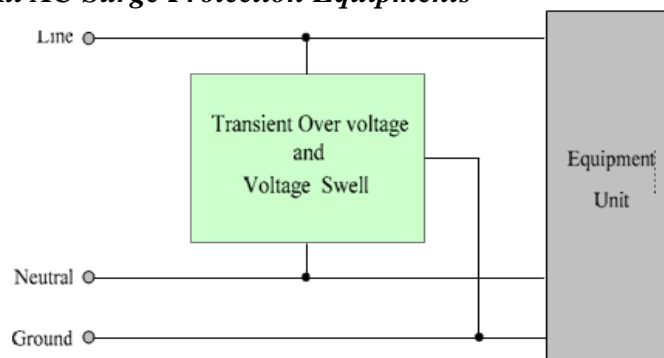


Fig. 3 Block diagram of all AC surge protection equipments

RESEARCH RESULTS AND EVALUATION

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 μ s [11-13]

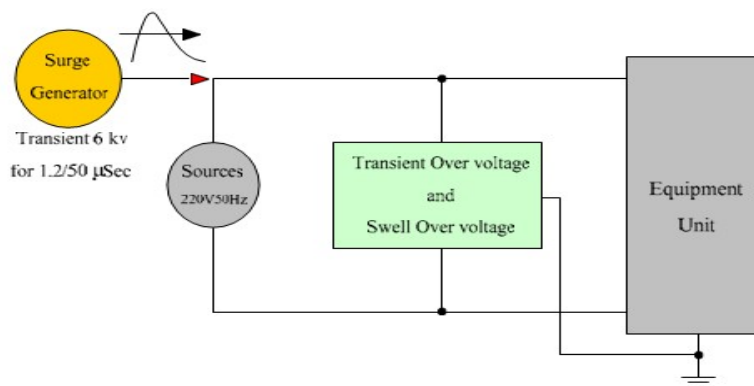


Fig. 4 Circuit to test the device for transient over voltage

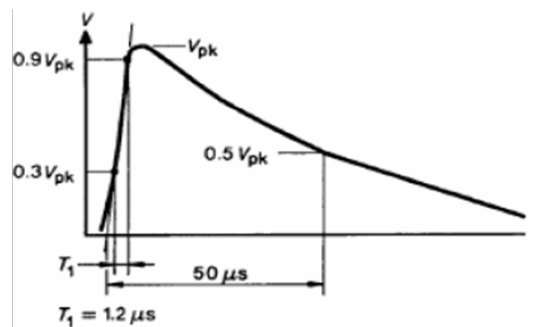


Fig. 5 Waveform of standard voltage surge at 1.2/50 μ s

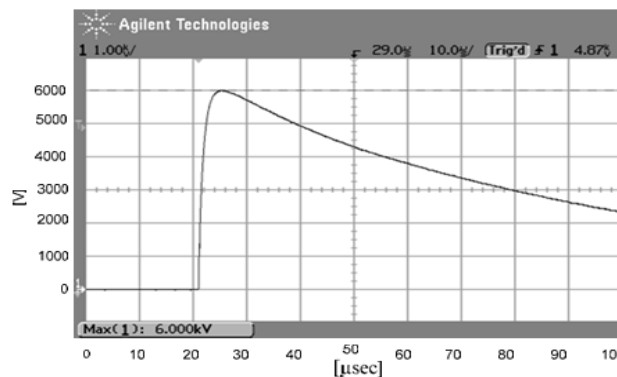


Fig. 6 Waveform of test signal with 6000 voltage range (1.2/50 μ s)

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.

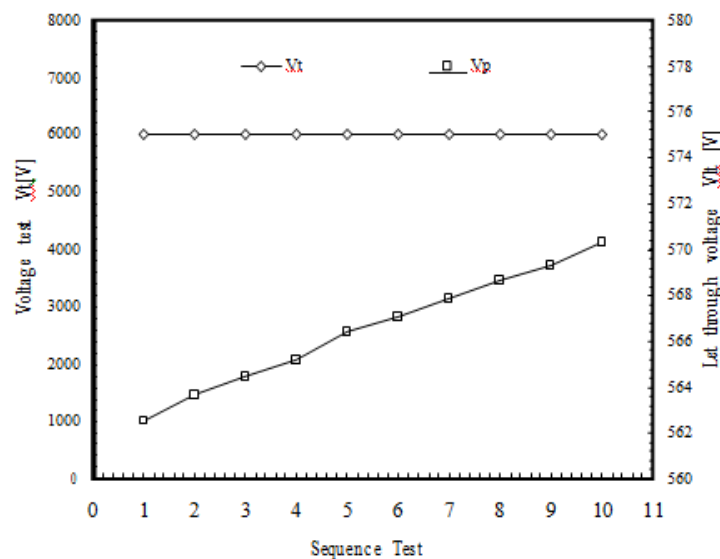


Fig. 7 Comparison graph of voltage test and let through voltage

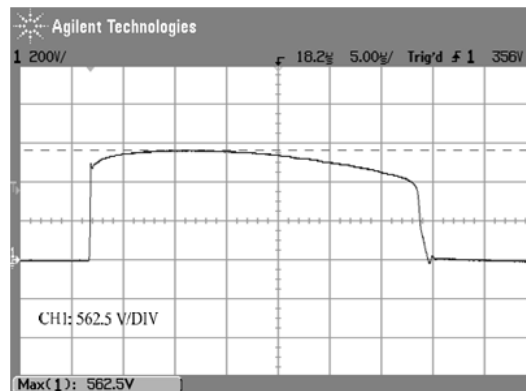


Fig. 8 Signal of let through voltage at output, sequence 1

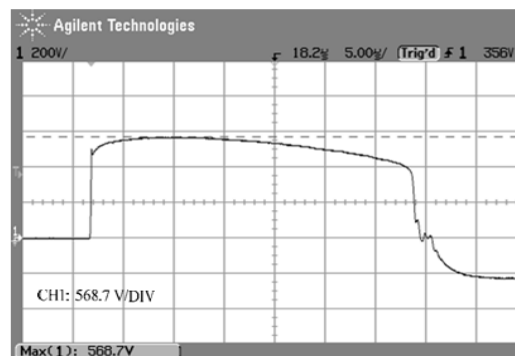


Fig. 9 Signal of let through voltage at output, sequence 5

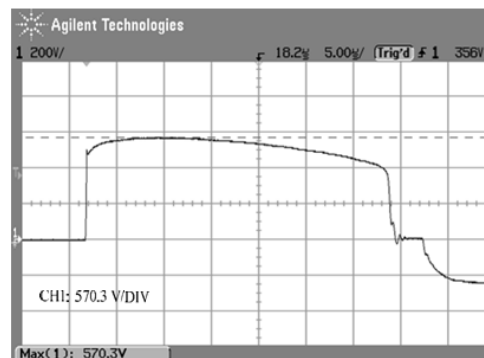


Fig. 10 Signal of let through voltage at output, sequence 10

Capability Experiment for Voltage Swell

Fig. 11 shows 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 $220\text{ V} \pm 10\%$. Fig. 12 – 15 show the waveform of voltage swell within the specified voltage range.

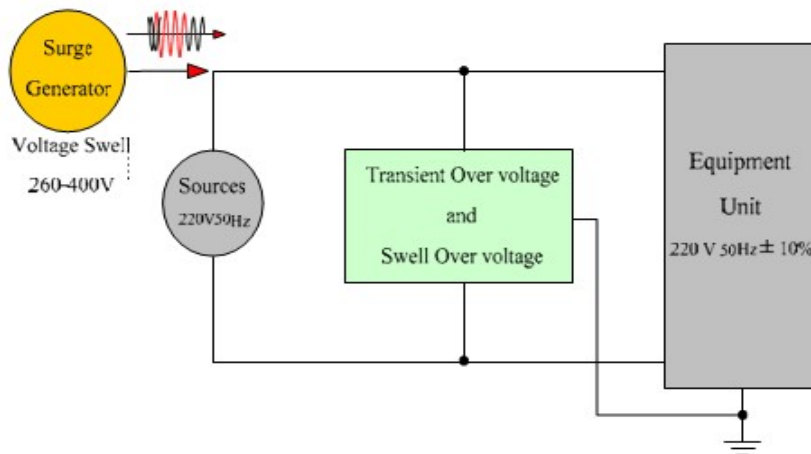


Fig. 11 Circuit to test the device for voltage swell

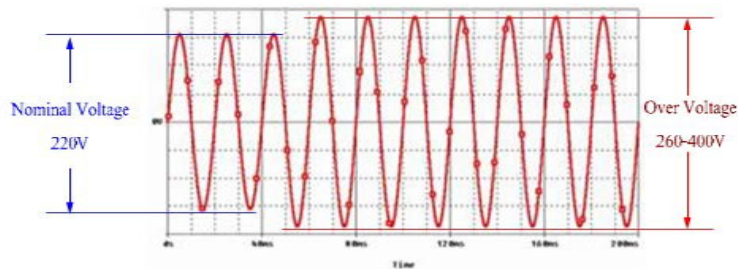


Fig. 12 Waveform of voltage swell

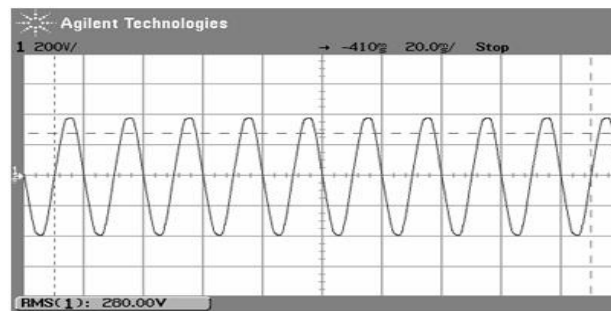


Fig. 13 Waveform of test signal with 280 V voltage range

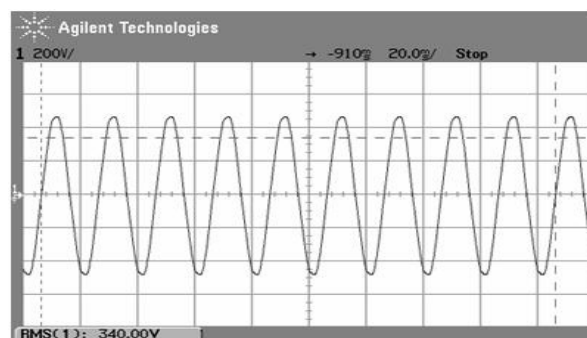


Fig. 14 Waveform of test signal with 340 V voltage range

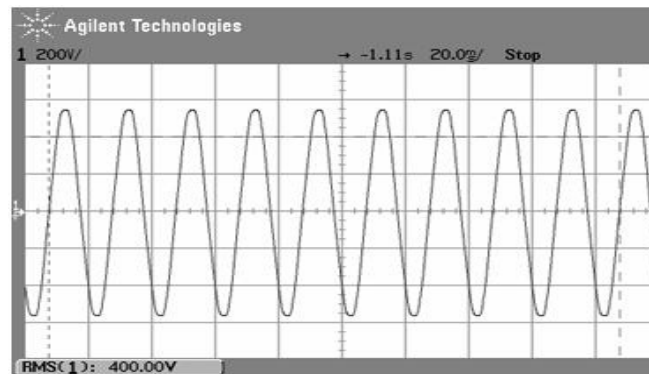


Fig. 15 Waveform of test signal with 400 V voltage range

TABLE 2: Results from The Device For Voltage Swell

Sequence	Voltage test	Clamping Voltage	Leakage Current
Test	V _t [V]	V _c [V]	I _l [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

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.

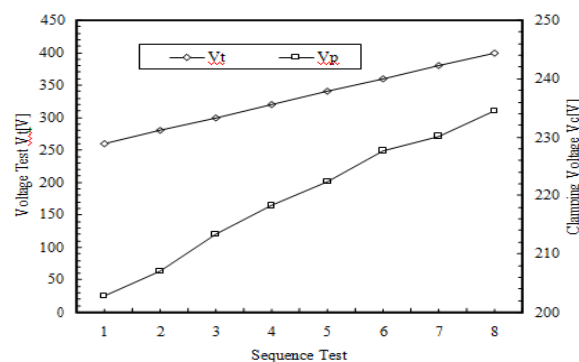


Fig. 16 Comparison graph of voltage test and clamping voltage

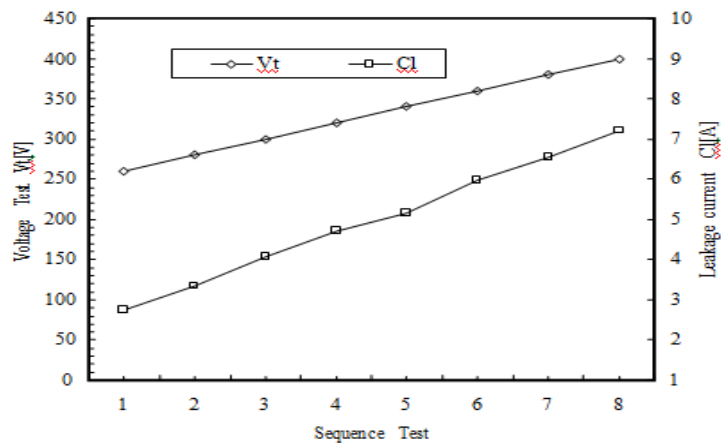


Fig. 17 Comparison graph of voltage test and leakage current

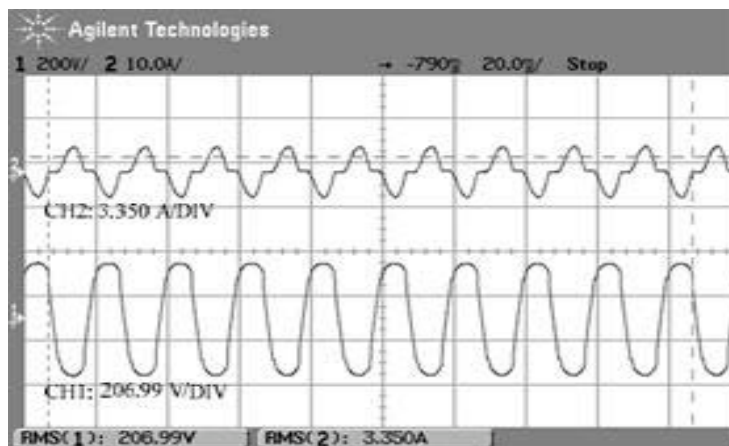


Fig. 18 Output signal of current and voltage test at 280V

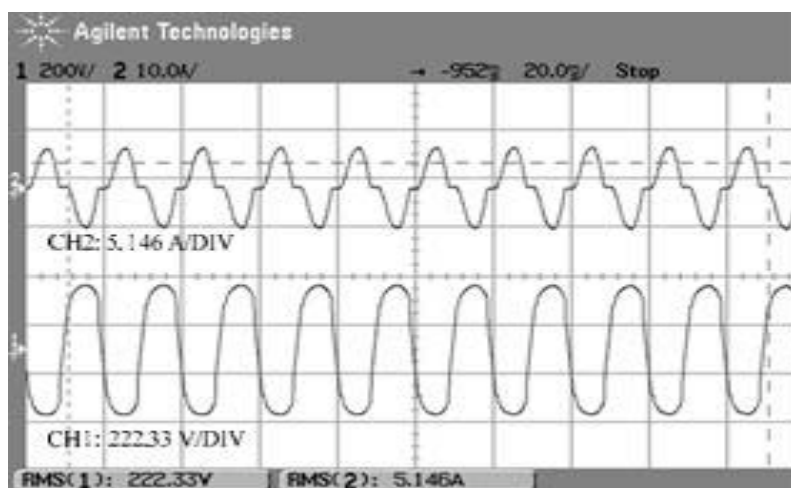


Fig. 19 Output signal of current and voltage test at 340 V

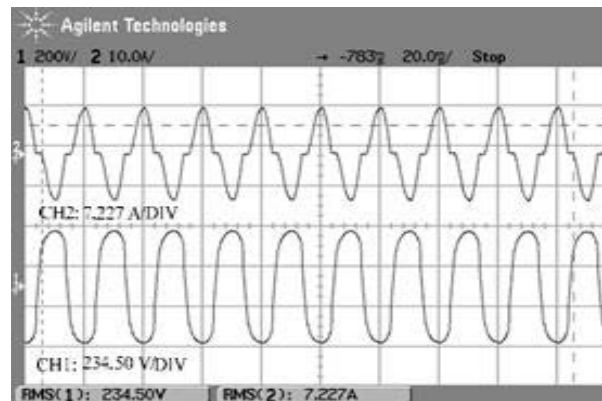


Fig. 20 Output signal of current and voltage test at 400V

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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