Evaluation and Validation on the Reliability and Robustness of Smart Socket Outlet for Hall of Residences Usage

Mohamad Fauzi Omar, Harizan Che Mat Haris, Nooritawati Md. Tahir

Abstract:This paper presents the validation and evaluation of the 3-pin socket outlet for student hall of residence specifically university halls appliances. It is a new method of reducing the electricity usage in residences at the same time increasing the safety aspect for the socket. Smart Socket Outlet is a project that has safety and economic aspects. Different with others, Smart Socket Outlet will cut the supply when current flow reaches the maximum amount that has been pre-set. This socket is able to improve in safety aspect to overcome over flow of current. This system also has potential to reduce the electricity usage in student residents. By applying this Smart Socket Outlet, consumer will be more secured and at the same time electricity usage will decrease.

***Keywords:** current limitation, economic, overcurrent protection, safety, trip automatically.*

I. INTRODUCTION

Nowadays, technology is very important in our daily life. The technology mostly gives an advantage to people. As seen from the world's fastest growing developed, people became increasingly busy with their daily activities and this is the main factor. The 3-pin socket is a common home appliance used in Malaysia. The questions usually being asked is about the safety of the user. This is because there are several cases that effect the death caused by the 3-pin socket for example, burning caused by higher current demand or lot of equipment plugin using one socket. Smart socket outlet for energy management efficient is designed specially to control power usage at student residents and collages. Unapproved production of the electrical appliances has increase the energy consumption and causing the electricity bill increased. Therefore, a smart outlet socket is designed to prevent the non-authorize usage of electrical appliances and overcome electrical line tripping.

3 pin plugs consists of three pins. The 3-pin plugs are designed so that electricity can be supplied to electrical appliances safely. Each wire has its own specified colour and each pin must be correctly connected to the three wiresin the electrical cable.

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For the safety aspect, fuse is installed at the 3-pin plug. Fuse is an electrical safety device that operates to provide overcurrent protection of an electrical circuit. Its essential component is a metal wire or strip that melts when too much current flows through it, thereby interrupting the current. It is also a sacrificial device which means once a fuse has operated it is an open circuit, and it must be replaced or rewired, depending on type.

By referring to standard regulation from SIRIM Berhad formerly known as the Standard and Industrial Research Institute of Malaysia (SIRIM), there are no safety features for overcurrent problem at the socket. The connection of 3-pin socket is directly from the main source and connects to 3-pin plug. Fig. 1 shows the earth pin socket, neutral pin socket and live pin socket behind the socket.

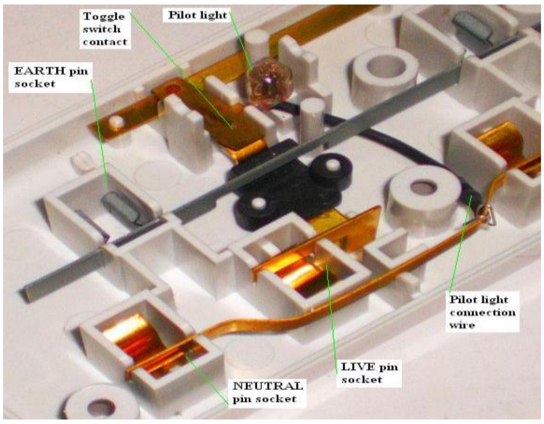

Fig. 1: The 3-pin socket connection (behind)

Generally, overcurrent is any current load that exceeded the safety rating of equipment or the capacity of a conductor[1]. Overcurrent may result an overload, a short circuit, or a ground fault. Overcurrent does not always cause fire. In electrical system, transmission and distribution are exposed to overcurrent problem. In an electric power system, overcurrent is a condition where a large amount of electric current flow through a conductors [2].

This situation will lead to generating of heat, and the risk of fire or damage to equipment. The factor that can causes this overcurrent problem is short circuits, excessive load, transformer inrush current, motor starting, incorrect design, or a ground fault. Therefore this socket proposed the smart socket that provides a means for protecting the electric circuit from short circuits which may occur in the particular electrical appliance which is connected in the circuits[3].

Fig. 2 shows the example of damage cause by overcurrent problem.

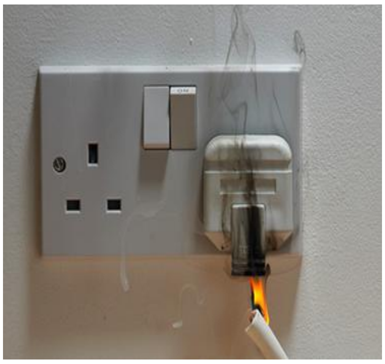

Fig.2: Example of 3-pin plug burned

Thermistor can be divided into two categories depends whether the TCR is positive or negative. Those with a positive temperature coefficient are called PTC and those with negative temperature are called NTC thermistor[4]. Temperature coefficient of resistor is actually the electrical resistivity of all materials that affected by temperature. The change of the resistance has a bearing on electrical and electronic circuits. At the same time, it can give rise to significant changes. As a result, of its importance the temperature coefficient of resistance is quoted for materials, the commonly used materials being widely available. Basically, the resistance value will increase when the number of collisions that occur between the charge carriers and atoms in the material increase. As the temperature increases so do the number of collisions and therefore it can be imagined that there will be a marginal increase in resistance with temperature. When the resistor cools down, its resistance diminishes, the current grows and the temperature reaches again the value corresponding to the phase transformation[5].

Accidental home fires lead to life and property losses. Electrical fault is one of the causes of residential fires, and its potential hazard is increasing as more electrical appliances are found in each household unit nowadays [6]. AC power plugs and sockets are devices that allow electrically operated equipment to be connected to the primary alternating current(AC) power supply in a building. Electrical plugs and sockets differ in voltage and current rating, shape, size and type of connectors. A variety of different systems of plugs and sockets have been standardized, and different standards are used in different parts of the world. In this country, normally the 3-pin 13 Ampere socket in home appliance used. The 13 Ampere limitation current is used to ensure the electrical appliance and the user are in safe condition. Overloading load or the over limit current will cause the unwanted accident for example fire and electric shook. There are several cases have been recorded related to fire caused by socket for example, fire cause by overloading at socket, short circuit, and others, for instance as in Fig. 3.

Fire supervisor, Corporate Management Division, JBPM, Mohd Haikal MD Kasri said “Electricity usage that exceed the prescribed rate and violating the instructions of installed meter panel resulting the large power flows that cannot be handle and causing the short-circuit events” [8].

Dengar jeritan anak minta tolong

"mah tu musnah terbakar," katanya.

Litar pintas punca kebakaran

Komander operasi, Shaidallah Osman berkata, pihaknya menerima panggilan pada jam 4.23 pagi dan jentera pertama tiba pada jam 4.42 pagi melibatkan Balai Bomba dan Penyelamat ...tari Jaya dan Batu Arang.

Fig. 3 : Newspaper cutting from Berita Harian [7].

Fig. 4 shows the number of electrical accident cases happen during year 2002 to year 2010. Many others factor that lead to this accident. People awareness with this problem is still lacking in society and this causes many lives lost. Electric lines are the main fire sources (almost 50%) in the electrical fires.

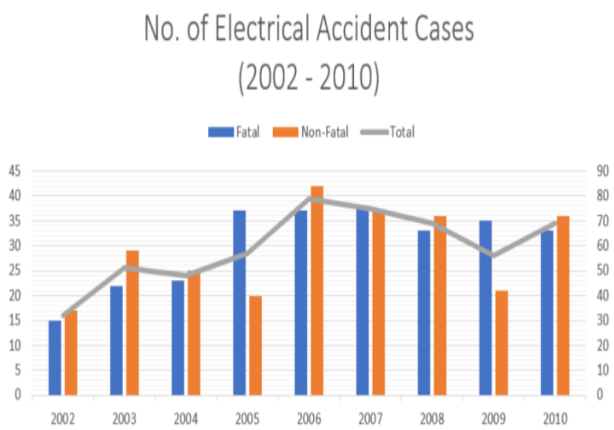

Fig. 4: No. of Electrical Accident Cases. [9]

Next, based on Fig. 5, the number of consumer that are involved in the cases has increased from 2002 to 2003 and decrease gradually in year 2004 and 2005. In year 2006, the cases once more increased and decreased in year 2007 until 2009 and increase again in 2010. For fatalities, it showed that almost the same with the fatal cases but a slide different in year 2005 where is it increase extremely, in 2009 its increase and lastly decrease in 2010. Secondly, the use of electrical appliances, electrical equipment and electrical facilities is also an important cause of electrical fires. Table I shows the comparison between Malaysia and other countries with regards to electrical accident cases.

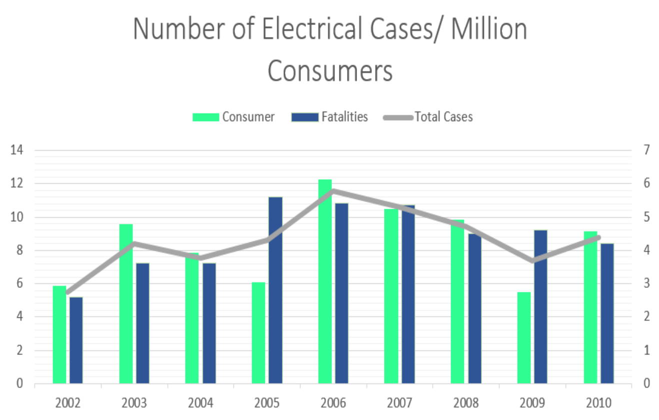

Fig. 5: No. of Electrical Accident Cases. [9]

Table I:Comparisons of electrical accident cases with other countries[10]

	Million Population	Case Accident	Over Million Population	Case Death	Over Million Population
Japan (2007)	128	136	1.062	14	0.120
Singapore (2008)	4.8	3	0.62	2	0.410
United Kingdom (2005)	59	3272	55.45	46	0.780
Malaysia (2010)	28	69	2.464	33	1.178
Korea (2007)	48	617	12.84	68	1.410
France (2007)	60	4100	68.4	100	1.700
Spain (2007)	44	5012	113.37	162	3.620

In addition, the lighting apparatus is also very prominent. The main cause of electrical fires is the short circuit fault (about 51%)[10] .

Hence, in this paper, the smart switch socket outlet is proposed to be installed in student residence. Therefore, the objectives of this project are:

1.To measure the rated temperature for smart socket to operate

2. To measure the time taken for smart socket to trip when it reached 5 A.

3.To measure the time needed for smart socket to return to initial condition.

II. METHODOLOGY

A. Flowchart for the process.

Fig. 6 shows the flowchart of the smart switch socket outlet. Firstly, current flow through the socket when load is connected. If the load current is higher than the pre-set limit current, the socket will automatically cut the supply. There is a minimum and maximum current that are allowed to flow in this smart socket. The testing is planned to test the maximum and minimum current that can operate, the minimum and maximum temperature that can operate and the time taken for smart socket to trip.The testing will conduct by setup the equipment first. Then the circuit will connect to the smart switch socket outlet and run the test. All the result will be observed and recorded lastly will tabulate the data.

B. Testing

There are two types of testing conducted. The first one is monitoring in time, the second one is monitoring in temperature.

i) Monitoring in time

In this testing, the time taken of the socket to trip is recorded to determine the specific time based on specific load. The time taken for socket to trip will be manipulated by specific amount of load. This experiment was conducted using variable resistor in order to attain the various loads and next will be testing using the actual for example laptop, water heater, smartphone, and iron since these are all the common electrical appliances used by students in student residence.

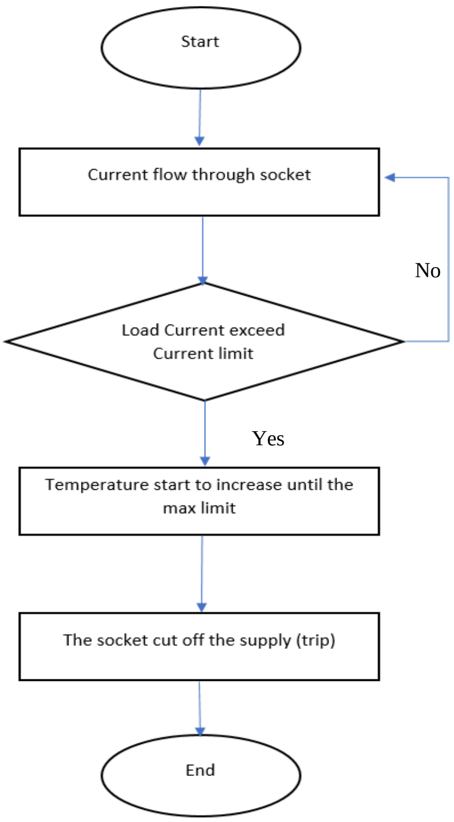

Fig. 6: Flowchart for the process

$$\Delta\text{time} = \text{tripping time} - \text{Initial Time} \quad (1)$$

$$\text{Rate of change} = \frac{\Delta\text{temperature}}{\Delta\text{time}} \quad (2)$$

ii) Monitoring in temperature

In this testing, the temperature of the socket is recorded to determine the range of standard operating temperature. The maximum temperature will be recorded as the highest temperature when the socket is trip.The minimum temperature is set to 0°. This experiment is conducted using variable resistor to test the various load and next will be testing using the actual electrical appliances namely laptop, water heater, smartphone, and iron.

$$\Delta temp = \text{Final Temperature} - \text{Initial Temperature} \quad (3)$$

$$\text{Rate of change} = \frac{\Delta temp}{\Delta time} \quad (4)$$

Equation (1) is use to find the changing in time where the tripping time will be minus the initial time. Equation (3) is used to compute the changing in temperature where the final temperature will minus the initial temperature. Then equation (2) and (4) is used to fine the rates of changes of temperature due to time where the Δt is get from equation (1) and must be divide by time which is the time taken for socket to trip for specific load current.

C. Product Overview

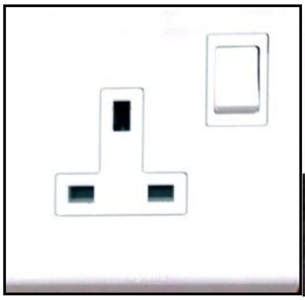

Fig. 7: Front view **Fig. 8: Rear view**

Fig.7 shows the front view of the product. Similar with the existing socket because this entire socket is regulated by Suruhanjaya Tenaga Malaysia (ST)under standard home appliances. Household electrical appliances and plugs, socket outlets, adaptors and connection units, flexible cords and cables regulated by ST is the most regulated area with 34 regulated electrical products[11]. Fig.8 shows the rear view of the product. Here the additional circuit was applied and connected to live terminal to allow cut off supply.

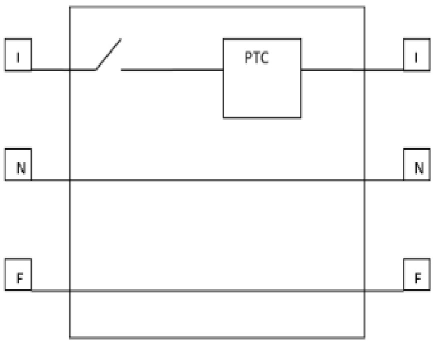

Fig. 9: Circuit diagram for smart switch socket outlet

As mentioned earlier, the temperature coefficient of resistance can react to cut the various level of current. By referring to Fig.9**,** the PTC component is installed at the live wire. This connection is made because live wire is the incomer for the supply. This PTC component then will be covered with the insulation

D. Error in experiment.

There are some errors that cannot be neglected in the experiment for example the temperature surrounding. This temperature surrounding will affect the time taken for socket to cool down. This error cannot be neglect due to the room temperature in the laboratory is unpredictable. Others error that cannot be neglect is the temperature at the smart socket itself.

The temperature coefficient resistor component was design to install and covered by casing made by 3D printed. While the next experiment was conduct, the temperature coefficient resistor component inside the covered side is not exactly same temperature recorded as outside. Due to the closed space and the heat released by the temperature coefficient resistor absorb by the 3D printed cover. This is because; the flow of heat is all-pervasive. It's an active to some degree from another in everything[12].

III. RESULT AND DISCUSSION

A laboratory test has been conducted to test the effectiveness of the product. This testing involved the use of adjustable load resistor, High tech multi meter Fluke series 435, Fluke 59 Mini Infrared Thermometer and Clamp meter.

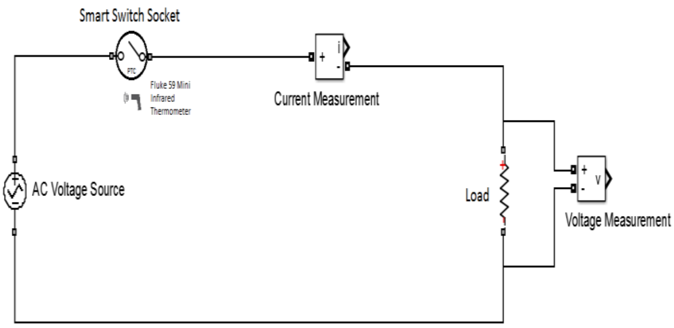

Fig. 10: Circuit diagram for testing.

The circuit connection was designed as in Fig. 10. The connection start with ac voltage supply connected to smart switch socket and connected to load. The multi meter fluke 435 series is used to capture the signal is connected parallel with the load. The clamp meter is also used to monitor the value of current. Lastly the Fluke 59 Mini Infrared Thermometer was used to capture the temperature reading at the smart socket.

A. Rate of change of temperature with time due to various load current.

From the result data for monitoring in temperature in Table II, the load current was setting to capture from 0.8A to 5.3A. From load current 0.8A to 2.3A, there is no tripping happen due to no increasing of temperature happen. Start from load current 2.8A to 5.3 A there tripping happen due to increasing of temperature in positive temperature coefficient (PTC) component.

The increasing initial temperature and final temperature was record and the different between these two is mark as ΔTemp. The ΔTemp only exist start load current 2.8A to 5.3A. The average data ΔTemp was record 30.3°C but there are some increasing and decreasing due to error in the experiment.

Table II: Experiment result for monitoring in temperature.

Current (A)	Voltage (V)	Temperature		ΔTemp (C°)
		Initial	Trip	
0.8	230	25.8	-	-
1.3	230	28.6	-	-
1.8	230	30.6	-	-
2.3	230	35.6	-	-
2.8	230	42.6	73.4	30.8
3.3	230	42.8	73.4	30.6
3.8	230	45.8	73.4	27.6
4.3	230	39.4	73.4	34
4.8	230	41.4	73.4	32
5.3	230	46.6	73.4	26.8

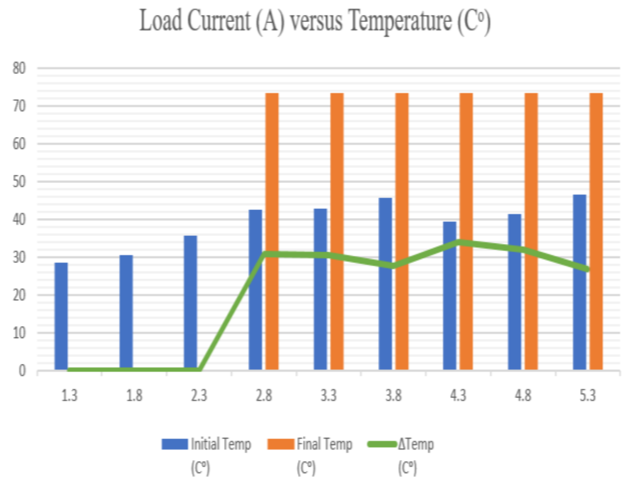

Fig. 11: Graph load current versus temperature

Based on the graph in Fig. 11, the different between final temperature and initial temperature was mark as ΔTemp. The data recorded that from load current 1.3A to 2.3A, there was no tripping happen due to no increasing of temperature in PTC. The temperature start to increase and finally reach the max temp which is 73°C and the temperature coefficient resistor automatically cut off the supply. Fig. 12 shows the linear line start from load current 2.8A to 5.3A. However, there are some decreasing at load current 3.8A and increasing at load current 4.3A due to some error.

From the result data for monitoring in time in Table III, the time taken for smart socket to trip was record from load current 0.8A to 5.3A. The different between tripping time and initial time was mark as ΔTime. The ΔTime are recorded happen at load current 2.8A to 5.3A. The average rate of increasing time every 0.5A in ΔTime from 2.8A to 5.3A is 71 second. However, there are some increasing and decreasing happen because of error in experiment.

Table III: Experiment result for monitoring in time.

Current (A)	Voltage (V)	Time		ΔTime (S)
		Start	Trip	
0.8	230	10:34:48 am	-	-
1.3	230	10:46:12 am	-	-
1.8	230	10:56:28 am	-	-
2.3	230	11:07:18 am	-	-
2.8	230	11:18:12 am	11:25:46 am	454
3.3	230	11:38:07 am	11:41:39 am	212
3.8	230	11:52:09 am	11:53:43 am	94
4.3	230	12:05:48 pm	12:07:11 pm	83
4.8	230	12:18:23 pm	12:19:13 pm	50
5.3	230	12:28:12 pm	12:28:41 pm	29

Fig. 12 shows the data show the decreasing of time from initial time to trip time for smart socket. The ΔTime was recorded decreasing gradually from current load 2.8A to 5.3A. This result show the inversely proportional for the load current and time take for smart socket to trip.

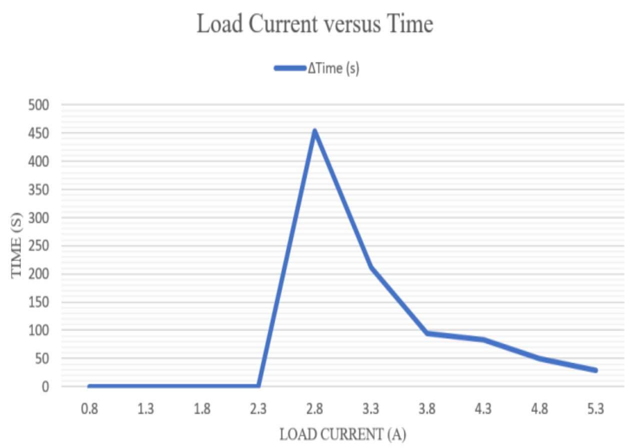

Fig. 12: graph load current versus time

From Table IV and Fig. 13 shows the rate of change of temperature due to time for every various load current. The result show the increasing of rate of change is directly proportional with the load current at the same time its inversly proportional to the time taken for the smart socket to trip. In other words, the increasing of load current will cause the smart socket to trip earlier. As a result, the rate of change of temperature will increase as the increasing of the load curent.

Table IV: Rate of change of temperature due to time.

Current	ΔTemp (C° initial - C° trip)	ΔTime	$\Delta Temp^{\circ}/\Delta Time$
0.8	-	-	-
1.3	-	-	-
1.8	-	-	-
2.3	-	-	-
2.8	30.8	454	0.06784
3.3	30.6	212	0.14435
3.8	27.6	94	0.29362
4.3	34	83	0.40964
4.8	32	50	0.64000
5.3	26.8	29	0.92414

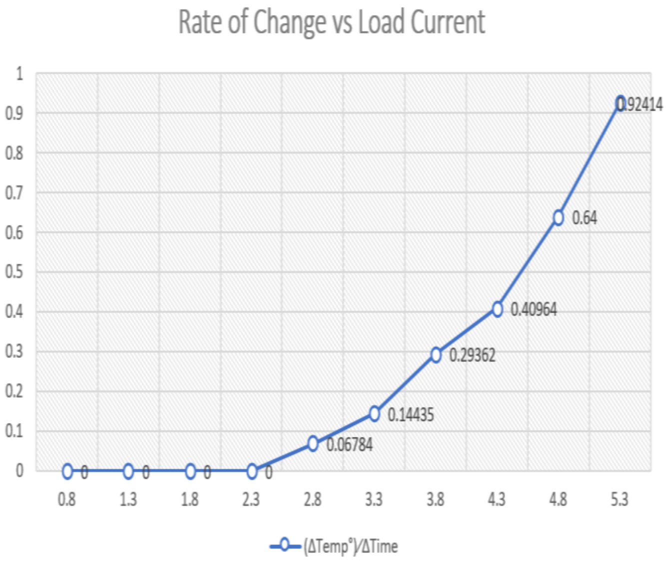

Fig.13: Rate of change versus load current

B. Cooling time for Smart Switch Socket Outlet

Table V: Cooling time for smart socket switch outlet

Current	Voltage	Temperature (C°)				
		Trip	30s	60s	90s	120s
0.8	230	-	-	-	-	-
1.3	230	-	-	-	-	-
1.8	230	-	-	-	-	-
2.3	230	-	-	-	-	-
2.8	230	73.4	79.6	84.2	89.2	91.4
3.3	230	73.4	85.4	91.8	96.4	97.2
3.8	230	73.4	86.4	93.4	96.8	98.0
4.3	230	73.4	88.4	94.2	96.4	98.2
4.8	230	73.4	94.4	99.0	102.6	104.4
5.3	230	73.4	96.5	100	103.9	105.2

In this testing, the temperature of the smart socket is monitor from the tripping time until 120 second by recording every 30 second. Based on the objective this smart switch socket outlet will function same as a relay that can cut off the supply when its reach the limitation current and it will cooling down to the rated temperature. Based on Table V, the data shows the cooling time for various load current from load current 2.8A to 5.3A.

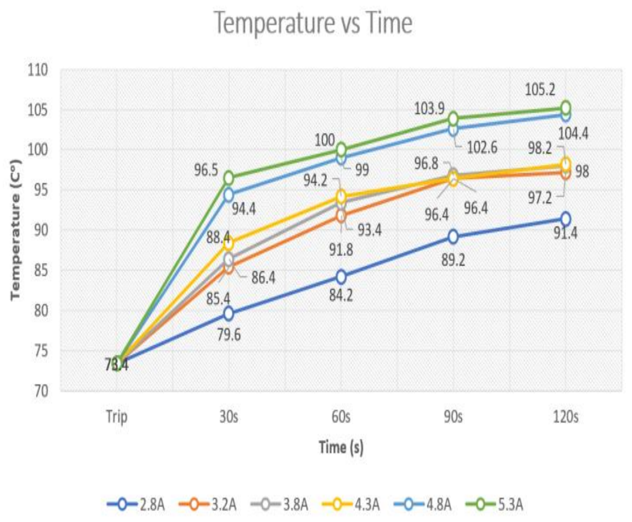

Fig. 14 : Cooling temperature versus load current

Fig. 14 shows the graph of the cooling for the smart socket after it trip. Unfortunately, the result is not as expected. The temperature of the smart socket continually increases after trip.

Table VI: Rate of change of cooling temperature due to time

Load Current	Temp (C°)	Time (S)	$Temp^{\circ}/Time$
2.8	91.4	120	0.76167
3.3	97.2	120	0.81
3.8	98.0	120	0.81667
4.3	98.2	120	0.81833
4.8	104.4	120	0.87
5.3	105.2	120	0.87667

Table VI and Fig. 15shows the rate of change of cooling temperature due to time for every various load current. The result showed the increasing of rate of change is directly proportional with the load current and at the same time it was inversely proportional to the time taken for the smart socket to trip. In other word, the increasing of load current will once again cause the smart socket to trip at earlier time. As a result, the rate of change of temperature will increase as the increasing of the load curent.

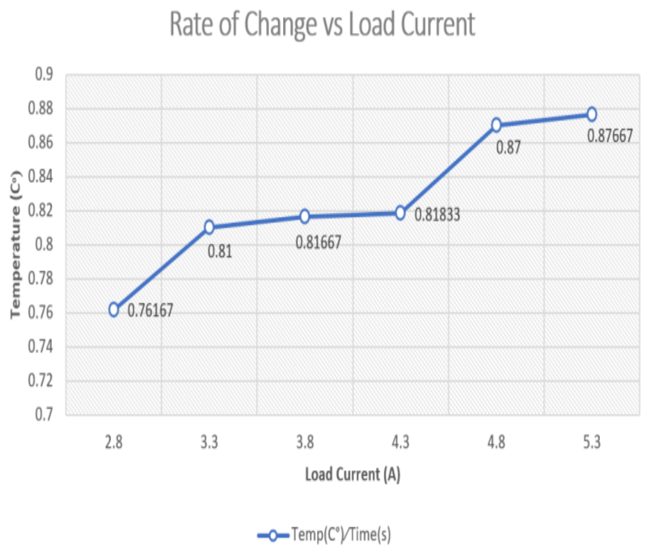

Fig. 15 : Rate of change versus load current

C. Actual Load

Table VII: Result experiment for the test using actual load.

Load	Current (A)	Temperature		ΔTemp	Time		ΔTime (S)
		Initial	Trip		Start	Trip	
Laptop	0.04	26.8	-	-	1:11:05 pm	-	-
Smartphone	0.01	26.4	-	-	1:24:38 pm	-	-
Water heater	3.59	34.8	73.0	38.2	12:47:40 pm	12:49:57 pm	137
Iron	4.24	29.4	-	-	12:08:30 pm	-	-
All	7.34	58.8	73.4	14.6	1:12:10 pm	1:12:21 pm	11

In this experiment, the temperature and time taken for smart socket was monitored using actual load. This time, the load was chosed by the common appliance that normally student used in the residance. the result shows that the laptop, smart phone and iron do not affect the smart socket except the water heater. This happened because the load current for the water heater is 3.59A.

Refering to the testing using various load current, these smart switch socket outlet tripped if the current exceed 2.8A constantly. As for the iron, the load current is 4.24A but the socket is not trip. This is because the iron only force the current if the temperature are unmatched with temperature needed. In other words, the current is not constantly forced. At the same time, the temperature increase and decrease simutaneously.

Referring to Table VIII, the rate of change of the temperature with time for the actual load was recorded. The rate of change for water heater is 0.278832 and the rate of change for all the appliances was 1.327272. This result is acceptable because if referring to the various load tests, the load current at 5.3A, the rate of change is at 0.87667 and the load current for all appliances is 7.34A, the rate of change is at 1.327272. The differences between these two loads current and rate of change is acceptable.

Table VIII: Rate of change of actual load temperature with time

Current	ΔTemp (C° initial - C° trip)	ΔTime	$^{\Delta Temp^{\circ}}/_{\Delta Time}$
Laptop	-	-	-
Smartphone	-	-	-
Water Heater	38.2	137	0.278832
Iron	-	-	-
All	14.6	11	1.327272

IV. CONCLUSION

This product is targeting for all domestic users. Nevertheless this product is beneficial to all type of users. For example, the number of electrical appliances used by students in collages can be controlled and thus will save the usage of electricity in campus and avoiding electrical fire. The safety of this socket has been designed to avoid overcurrent. This socket can also reduce the cost of energy usage by limiting the current flow through socket.

This product has very high potential for international market. However the cooling method of the product needs to be changed. Based on the experiment, the cooling process is inconsistent upon reaching the max temperature. This problem could cause the product highly potential to blow and will cause other problems such as fires.

This product can perform better with several improvements. First, the casing that is used to cover the temperature resistor component needs a hole for easier flow of heat released. This will expedite the cooling process. Next, the components of the temperature coefficient resistor need to be revised due to increasing of the temperature upon tripping.

This temperature coefficient resistor component is only able to limit current at maximum of 2.8A versus the stated objective of this socket is to limit the current flow to 5A. The circuit need to be revised or fully redesigned. The smart switch socket outlet also can add a little LCD screen to display the current reading for better monitoring.

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