POWER FACTOR CORRECTION FOR RESIDENTIAL

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SUPERVISOR DECLARATION

I hereby declare that I have read through this report entitle "Power Factor Correction for Residential" and found that it has been comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power).

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Date : 8/6/2017

Power Factor Correction For Residential

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A report submitted in fulfilment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

I declare that this report entitle "Power Factor Correction for Residential" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature for any other degree.

Signature : ....

Name : NORHAZIMI BIN ISMAIL

Date : 8/6/2017

Dedicated to my beloved parent (Ismail Bin Zakaria and Zah Binti Mohamed), friends and lecturers for their never ending helps

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ABSTRACT

Nowadays, demand on electricity power among the residential consumer is increasing due to the many factors especially climate changes. Increase in temperature for example will increase the usage of air conditioners, hence will also increase the electricity bills among the households consumer. Due to this problem, people are starting to find ways to reduce electricity bills by not having to sacrifice their comfort. As a response, energy saver devices have started to emerge in our market. The capability of this device to reduce electricity bills are not proven yet because some claims this device is effective to reduce electricity bills, but others claim this device does not serve its purpose at all. Therefore, the objective of this research is to explore the truth about the capability of this device and also to study its effect when applied to the domestic electrical system. Experimental test was conducted in laboratory environment by using resistive load bank and inductive load bank to imitate the residential load of single phase system. During the experimental test, two different brand of energy saver were tested to prove the capability of this device whether or not it will reduce electricity bills. Based on the result of the experimental test, the device only manage to reduce the current and reactive power of the system while at the same time the power factor and total harmonic distortion were increased. However, the active power stays the same which means no effect at all in decreasing the electricity bills. Further studies also showed that the energy saver will cause for damage on the appliances in the long run due to the increment of total harmonic distortion generated in the system.

ABSTRAK

Pada masa kini, permintaan terhadap kuasa elektrik dalam kalangan pengguna domestik semakin meningkat disebabkan oleh beberapa faktor terutamanya faktor perubahan cuaca. Dengan meningkatnya suhu persekitaran, sebagai contoh ianya akan menyebabkan pennguna akan menggunakan penghawa dingin secara maksimum dan akan menyebabkan bil elektrik mereka meningkat. Oleh itu, masyarakat mula mencari jalan untuk mengurangkan bil elektrik mereka tanpa perlu mengorbankan keselesaan mereka. Maka dengan itu, alat jimat elektrik mula muncul dalam pasaran sekarang. Kesahihan tentang keberkesanan alat jimat elektrik mampu untuk jimatkan elektrik ini masih belum terbukti kerana sesetengah pegguna menyatkan alat jimat eletrik mamput untuk jimatkan bil elektrik, tetapi sesetengah lagi menyatakan alat ini tidak befungsi seperti mana yang dinyatakan. Oleh itu objektif kajian ini ialah untuk mengkaji tentang kebolehan sebenar alat jimat elektrik dan untuk mengkaji kesan meggunakan alat jimat eletrik kepada pegguna domestik. Ujikaji telah dijalankan di dalam persekitaran makmal dengan menggunakan "resistive load bank" dan "inductive load bank" dengan meniru gaya system satu fasa pegguna domestik. Semasa ujikaji dijalankan, dua jenis jenama alat jimat elektrik yang berbeza diuji untuk membuktikan kebolehan sebenar alat ini samada mampu menjimatkan elektrik ataupun tidak. Bedasarkan keputusan ujikaji, alat ini hanya mampu mengurangkan arus dan "reactive power" didalam system dan pada masa yang sama "power factor" dan "total harmonic distortion" didalam system meningkat. Walaubagaimanpun, "active power" didalam system tetap tidak berubah dan hal ini memberi makna tidak ada berlakunya pengurangan bil elektrik. Ujikaji ini juga menunjukan kesan peggunaan alat ini mendatangkan kesan yang buruk terhadap peralatan elektrik dirumah oleh kerana peningkatan "THD" di dalam system.

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CHAPTER 1

1.0 INTRODUCTION

The history of electricity had been found hundred years ago by Benjamin Franklin famous kite experiment in 1752 [1]. This experiment have shown just how little we know about electricity and afterwards a revolution of electricity grown tremendously to find new ways to use it in order to improve our lives. In 1831, one of first breakthrough in electricity occurred when British scientist Michael Faraday discovered the basic principles of electricity generation [1]. Based on the experiment of Franklin and others, he created induce electric current by moving magnet inside coils of copper wire. The discovery of this principle has revolution and this principle is used in our modern power plant today to produce much stronger currents on much larger scale of generation.

There are several ways to produce electricity which is, some of the stations run on the power of coal and steam, while others run on the power of the wind or falling water. Some even use the power of the sun alone to generate electricity. In order to produce electricity it needed energy resources. Energy resources can be classified as renewable energy and non renewable energy. Basically to distribute electricity to the consumer it needs to undergo a several steps as show in figure 1.1. Firstly electricity needs to generate at power station. Then the transmission process will take place due to the most power stations far away from consumer. The length of transmission process normally hundreds kilometre away before arrive at distribution. At distribution process, it will distribute the electricity to the consumer. All of this step so expansive.

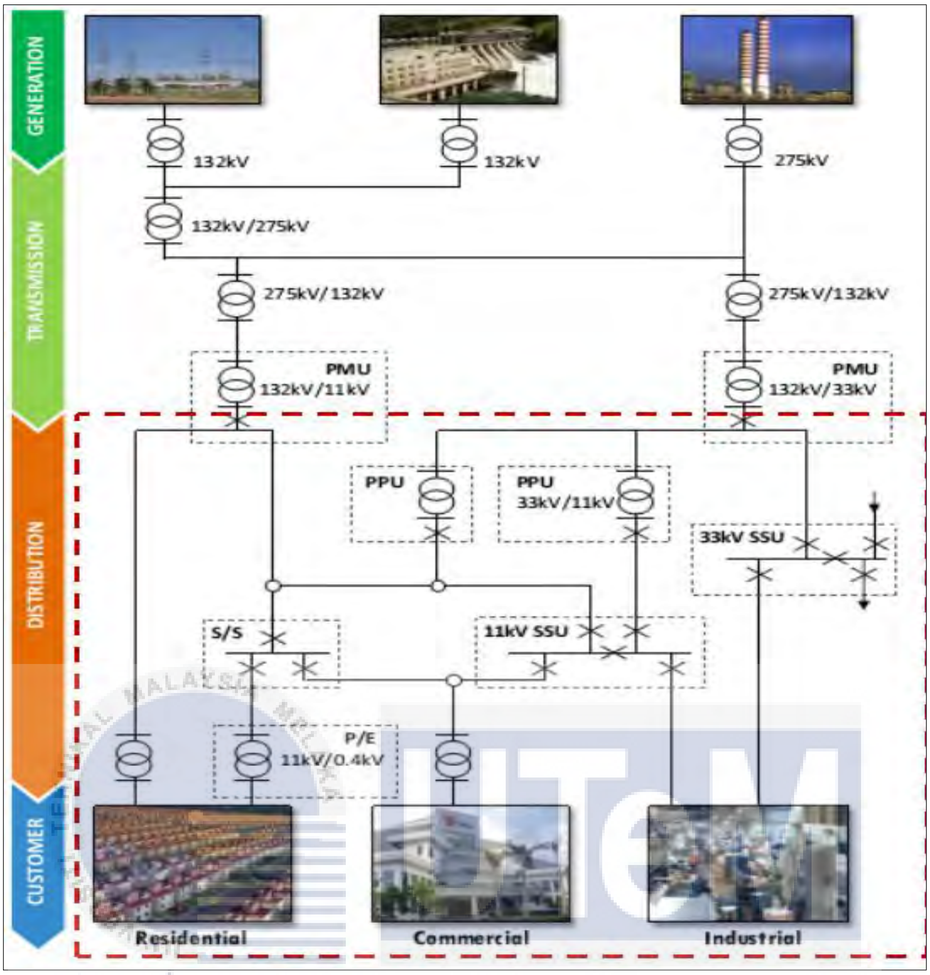

Figure 1.1: Example of electricity provider network system.

To generate electricity and to transfer it to consumer will cause high expenditure. As we know, electrical power system is the expensive in term of capital investment and operating cost contrast to other systems. In order to refund this capital, the electricity provider will charge the consumer base on electricity tariff rate based on kW/hour of their usage. In Malaysia, there are several types of Tenaga Nasional Berhad (TNB) customers which are residential, commercial and industrial. The tariff rate will be different for all of the type of the customers. The focus of this research will focus on residential only.

As conclusion, the bills of electricity base on tariff rate and the power usage by the consumer. Nowadays the power usage by consumer was increasing and the electricity tariff is unpredictable. All of this will make the increasing bills for the consumer. In order to reduce electricity bills, consumers start to find ways to reduce their electricity bills. Because of this problem, energy saving device had emerged in our market. The ability of this device still in questionable. Base on retailer website, it claim the energy saver can be reduce 330% of currently electricity bills [11][12].

1.1 MOTIVATION

Population in human race is always rising. As the population rise, the demand for electricity also increases as well. So, electricity provider needs to generate more electric to fulfil the demand by the customers. The cost to generate high scale electric power is very expansive because almost all of the sources power is limited and the cost is unpredictable. It's also costly to transfer electric power to the consumer. However, the cost will be responsibility by the electric consumer through to billing charges by the tariff rate that was set by electric power provider.

The change in climate also affected the increasing of the electricity bills. For example, during el-nino that cause increasing in ambient temperature or global warming will make many households use their air conditioners more than usual. Due to this action, their electricity bills are increase more than usual. Hence, there's demand for a start to find a way to control or reduce electricity consumption among consumers. Peoples are willing to invest to reduce the electricity bills by purchasing the energy saver that already exist in our market even they did not know the true capability of that device whether it can save electricity bill or not. Another that, the effect of energy saver to the system is also unknown whether it risks electrical appliances at home or not.

To ensure the investment that made by consumers is worthy, study on energy saver device need to be conduct to prove the real capability of the energy saver device in order to make sure the people are not be fooled by the claim of the energy saver can reduce an electricity bills.

1.2 PROBLEM STATEMENT

There are tons of product that been claimed as the 'energy saver' had been released in the market nowadays. The availability of the power/energy saver in the market had caused for mixed reaction from the consumers. Some claimed that it can be reduce up to 30% of the electricity bills which seem to be a really smart saving. The other half claimed that the device does not serve its purpose at all, which is not worth the hype at all. This research hence tries to demystify the two contrasting consumer responses with practical experimental approach

1.3 OBJECTIVE

1. To identify the working mechanism/operation of the commercial energy saver.

2. To determine the effectiveness of the energy saver on the different type and sizes of loads (R, L, R+L)

3. To recognize the impact of the energy saver on home appliances.

1.3 SCOPE OF PROJECT

The research will focus on the following scope:

a. The focus of this research will be for single phase residential only.
b. This research will be conducted on two different brands of energy saver available in the market.
c. This study will be conducted in laboratory environment with resistive and inductive load banks in term of kW and kVar.

CHAPTER 2

LITRATURE REVIEW

2.0 Introduction

This chapter covers the research theoretical part that relate on this research work. Information from the literature review is very important on this research to explain briefly about theoretical part that relate on this research.

2.1 Theory and Basic Principles

2.1.1 Power Factor Correction

Power factor is the ratio between active power (kW) to apparent power (kVA) that exists in electrical equipment or in complete electrical installation system [2]. High of power factor means how effective electrical power is being used. Power factor also can be defining the cosine of the phase angle between active power (kW) and apparent power (kVA). The following figure 2.1 will show the power triangle and the relationship of power factor between active power and apparent power.

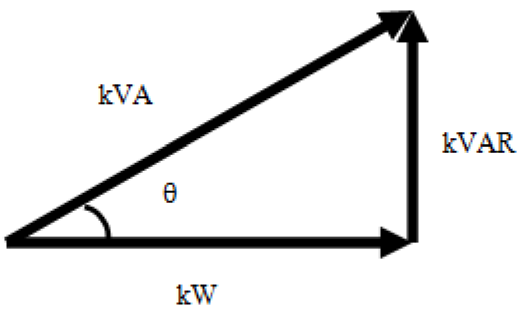

Figure 2.1: Power Triangle.

$$\text{Power Factor} = \cos\theta = \frac{adjacent}{hypotenuse} = \frac{kW}{kVa} \qquad (2.1)$$

In order to improve the efficiency and to reduce losses, power factor correction need to be apply. Power factor correction is the ways to restore the power factor to unity in order to reduce losses and meanwhile it supposed to reduce electricity bills [2]. In real world, usually power factor correction form in capacitors to neutralize magnetizing current. If capacitor connected to the circuit that nominally lagging power factor it will reduce the circuit lags proportional to make the circuit become nearly of unity power factor [2]. When apparent power (kVA) is greater than real power (kW), the utility must supply the excess reactive current plus the working current, for this case capacitors will work as reactive current generators by providing the reactive current to reduce the total amount of current in system must draw from the utility [3]. In figure 2.2 illustrate that when capacitor is connected into the nominally lagging system, it will reduce the lagging power factor to become near to unity.

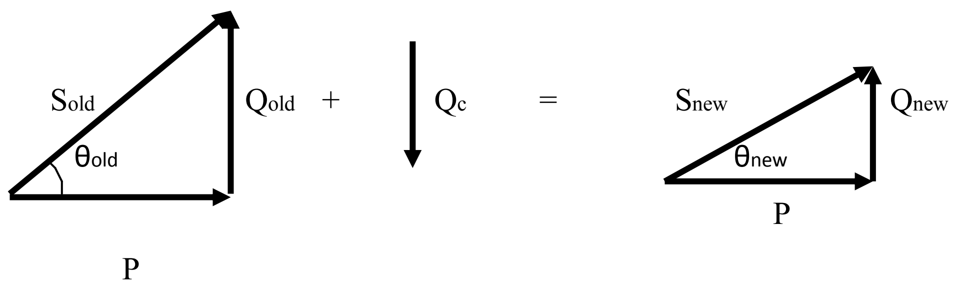

Figure 2.2: Illustration when capacitor is added to the system

There so many benefit of power factor correction which is reduced electric utility bills, increased efficiency of the system, improved voltage and reduce losses.

2.1.2 Total Harmonic Distortion

Most of our electrical system from generation to distribution, electricity is produce in alternating current (AC). A pure sinusoidal voltage sinusoidal voltage produced by an ideal AC generator built with finely distributed stator and field winding that operate in a uniform magnetic field since the first AC generator evolve hundreds years ago, electrical systems have experienced harmonics [5]. Harmonic distortion is the change of waveform of the supply voltage from the ideal sinusoidal [4]. When different waveform distortion together in power supply system, a new reference waveform called Total Harmonic Distortion (THD) is produced. An ideal of single phase of voltage supply 240V at frequency 50Hz with a sinusoidal waveform shown in figure 2.3.

Figure 2.3: Ideal sinusoidal waveform

The actual of electricity system can be departing from the ideal sinusoidal waveform in several respects. In figure 2.4 (a) shows a distortion of one cycle occasionally due to the switching of power factor correction capacitor on the power system and this not harmonic distortion [4]. Figure 2.4 (b) and (c) shows the form of harmonic distortion, giving flat-topped and notching effects respectively [4].

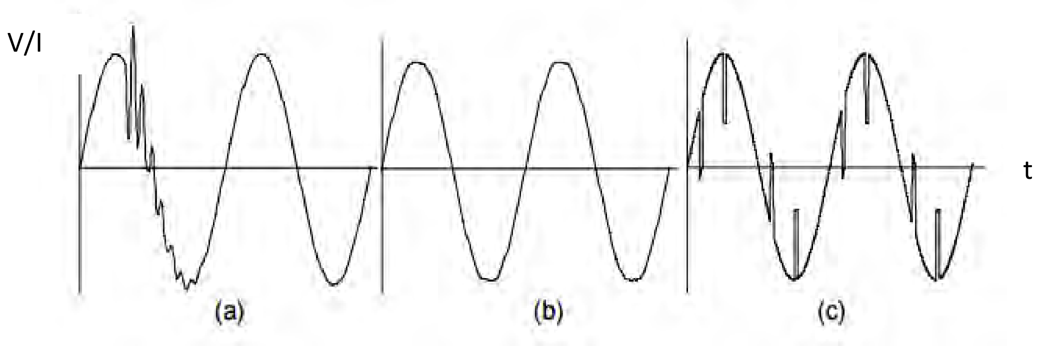

Figure 2.4: Types of voltage distortion: (a) Non-harmonic distortion, (b) flat-top harmonic distortion, (c) notching harmonic distortion. [4]

Harmonic distortion occurred when power system at normal electrical current waveform had installed by nonlinear loads. For example of nonlinear load are personal computer, battery charger, printer, motors and drives, television and etc. The large types of nonlinear loads that connected on power system come from electronic equipment. All of this nonlinear load will draw current in high amplitude short pulse that create significant distortion in the electrical current and voltage waveform that called as harmonic distortion and it measured as total harmonic distortion (THD) [4].

This harmonic distortion will effect on the electrical equipment depending their method of operation. Most types of household electrical appliances as example incandescent light and heater will not effected at all. But induction motor winding will over heated by harmonic and cause accelerated degradation of insulation and loss of life spam [6]. In supply system, transformers and power factor correction is the most effected by harmonic. Transformers are affected by distorted current waveform which cause overheating that will reduce the life span and capacitor are affected by applied voltage waveform that cause overheating of dielectric with lead to high risk of explosion [6]. As a conclusion, harmonics will affect the equipment to overheating and reduction in their life span.

2.1.3 Type of Household Load

In household electricity system there are four types of load that consume electrical energy and convert it into another form of energy. Four types of load that consist at household are resistive load, capacitive load, inductive load and combination load.

- Resistive load

  Resistive load is the loads that consume electrical power without any losses which means current wave remains in phase with the voltage wave and the power factor is unity [7]. For examples of resistive load are incandescent lamps and electric heater.

- Capacitive load

  Capacitive load is a load that will affect the current wave leading to the voltage wave and the power factor of capacitive load is leading [7]. Examples of capacitive loads are power bank, electronic circuit that use a capacitor which is in television, radio, mobile phone and etc.

- Inductive load

  Inductive load is a load that causes the current wave lagging to the voltage wave and the power factor of inductive load is lagging [7]. An inductive load is any electrical appliances that use electric motor and coil, for example is fans.

- Combination load

  In household electrical system, most of load are not purely resistive, purely capacitive or purely inductive. Many of electrical appliances are use several of combination loads which are resistors, inductors and capacitors [7]. Their power factor is less than unity and either lagging or leading. Example of combination load is fans and air conditioner.

2.1.4 TNB Electricity Bills

Tenaga Nasional Berhad (TNB) is the only electricity provider had in Malaysia. The bills of electricity only consider on total of consumption active power per hour (kW/h) in month that measured by meter that provide by TNB base on electricity tariff rate had set by TNB.

TNB had classified of their customers to three types which is residential, commercial and industrial. All of these types of their customer had different charge of electricity tariff rate and different method of bills calculation. Residential customers can be classified as house, grocery store and etc that only use electricity for domestic consumer. For residential, there is only one penalty charge which is late payment penalty charge. For commercial customers is defined as a customer occupying or operating that provide services which are hotel, educational institution, hospital and etc. Lastly, an industrial customer means customers that involved in manufacturing of good and product. For example is a factory. For commercial and industrial customer there are two type of penalty charge which are Maximum Demand (MD) charge and power factor penalty charge.

This research only focuses on residential customers only. In table 2.1 shows the tariff that set by TNB for residential customers. Electricity bills was calculated base on tariff rate set by TNB on table 2.1

Table 2.1: Tariff rate for residential customers [8].

	TARIFF CATEGORY	UNIT	CURRENT RATE (1 JAN 2014)
	Tariff A - Domestic Tariff		
	For the first 200 kWh (1 - 200 kWh) per month	sen/kWh	21.80
	For the next 100 kWh (201 - 300 kWh) per month	sen/kWh	33.40
1.	For the next 300 kWh (301 - 600 kWh) per month	sen/kWh	51.60
	For the next 300 kWh (601 - 900 kWh) per month	sen/kWh	54.60
	For the next kWh (901 kWh onwards) per month	sen/kWh	57.10
	The minimum monthly charge is RM3.00		

Example how to calculate electricity bill:

Typical household total consumption = 650kWh

1) First 200 kWh (1-200 kWh) per month: (200 x 21.80)/100 = RM43.60
2) Next 100 kWh (201-300 kWh) per month: (100 x 33.40)/100 = RM 33.40
3) Next 300 kWh (301-600 kWh) per month: (300 x 51.60)/100 = RM154.80
4) Next 300 kWh (601-900 kWh) per month: (50 x 54.6)/100 = RM27.30

Total bills = RM(43.60 + 33.40 + 154.80 + 27.30) = RM259.10

2.1.5 Energy Saver Device

Energy saver is a device that emerged in the market nowadays for the purpose to reduce electricity bills. The capability of this device to reduce electricity bills still not proven yet and it is become rumours among the consumers respond whether it can reduce electricity bills or not. There is several type of energy saver device that emerged in market nowadays. Figure 2.5 show the example of energy saver devices that had in market nowadays. In figure 2.6 and 2.7 show the circuit and schematic circuit of energy saver.

Figure 2.5: Energy saver device.

Figure 2.6: Equipment of energy saver device.

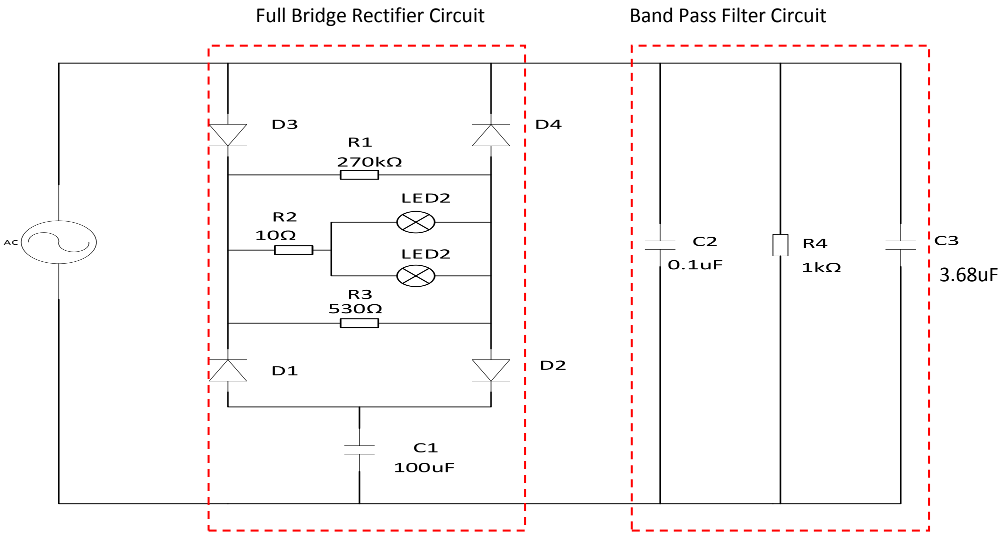

Figure 2.7: Schematic circuit of energy saver device.

Based on figure 2.6, in schematic circuit of energy saver can be dividing by two part which are full bridge rectifier part and band pass filter part. Rectifier circuit is used to convert the ac current to dc current [9]. The purpose of rectifier circuit in the energy saver device circuit is to make the LED function when the energy saver device switch on the circuit. Basically, the function of LED is to signals to us that energy saver device in running. Figure 2.7 show the basic circuit of the full wave bridge rectifier.

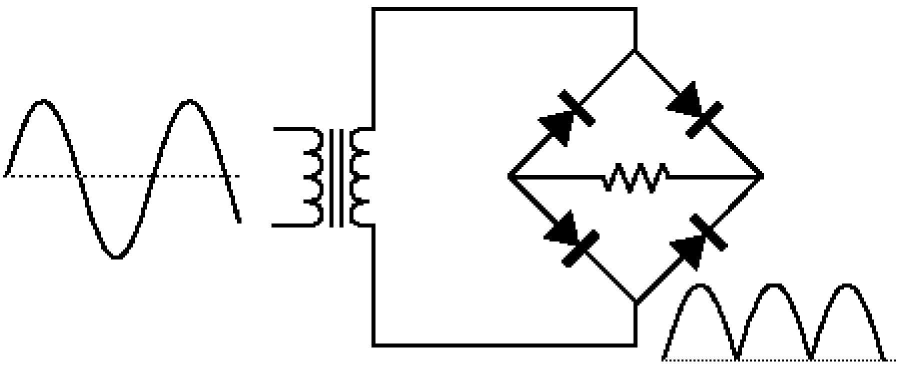

Figure 2.8: Full wave bridge rectifier [9].

For band pass filter circuit is used to remove the unwanted frequency from the signal when energy saver is installed in the system. For more understanding, filter circuit in this energy saver is use to reduce the total harmonic distortion in the system. Band pass filter is allows the frequencies in particular range to pass un attenuated which means limit noise bandwidth for application when it is known the input signal of interest only occurs in restricted frequency range [10]. Figure 2.8 and 2.9 show the basic of band pass filter.

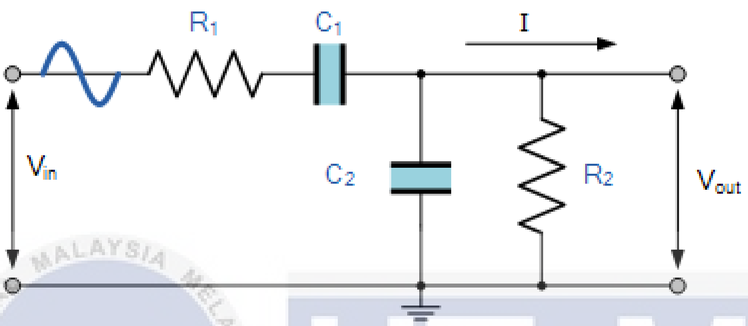

Figure 2.9: Band pass filter circuit [10].

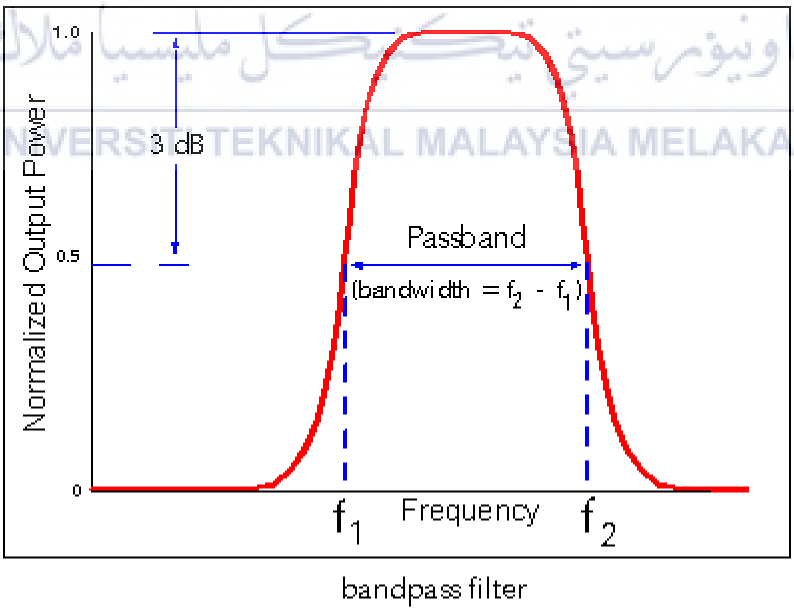

Figure 2.10: Band pass filter [10]

2.2 Summary of Review

Generally, this chapter review the basic knowledge that relate in this research. This chapter explain about the power factor correction, total harmonic distortion, type of household load, TNB electricity bills and energy saver devices. The information about basic knowledge that reviewed on this chapter basically came from previous work by researcher. All of the information that been use by previous researcher are important and helpful make this research can be done and succeed.

CHAPTER 3

METHODOLOGY

3.0 Introduction

In this chapter, the research methodology is focused on the basic theory of the power factor correction for residential which explain all the flow of this research and the test conducted on energy saver. The flow of this research will illustrate by flowchart and briefly explanation about this research.

3.1 Gantt Chart

In order to success complete this research, planning project had been made by using Gantt chart table as shown in table 3.1.

Table 3.1: Gantt Chart

PROJECT PLANNING (GANTT CHART)																																								
Week / Project Activity	**SEM I**																			**SEM BREAK**					**SEM II**															
	SEPT				**OCT**				**NOV**				**DEC**				**JAN**			**FEB**					**MAR**				**APR**				**MAY**				**JUNE**			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Research for Literature Review																																								
Purchase Hardware																																								
Develop Project Methodology																																								
Experimental Test (test 1)																																								
Result and Analysis																																								
FYP Seminar 1																																								
Experimental Test (test 2 & 3)																																								
Result and Analysis																																								
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Submission of full complete report																																								

3.2 Methodology Flowchart

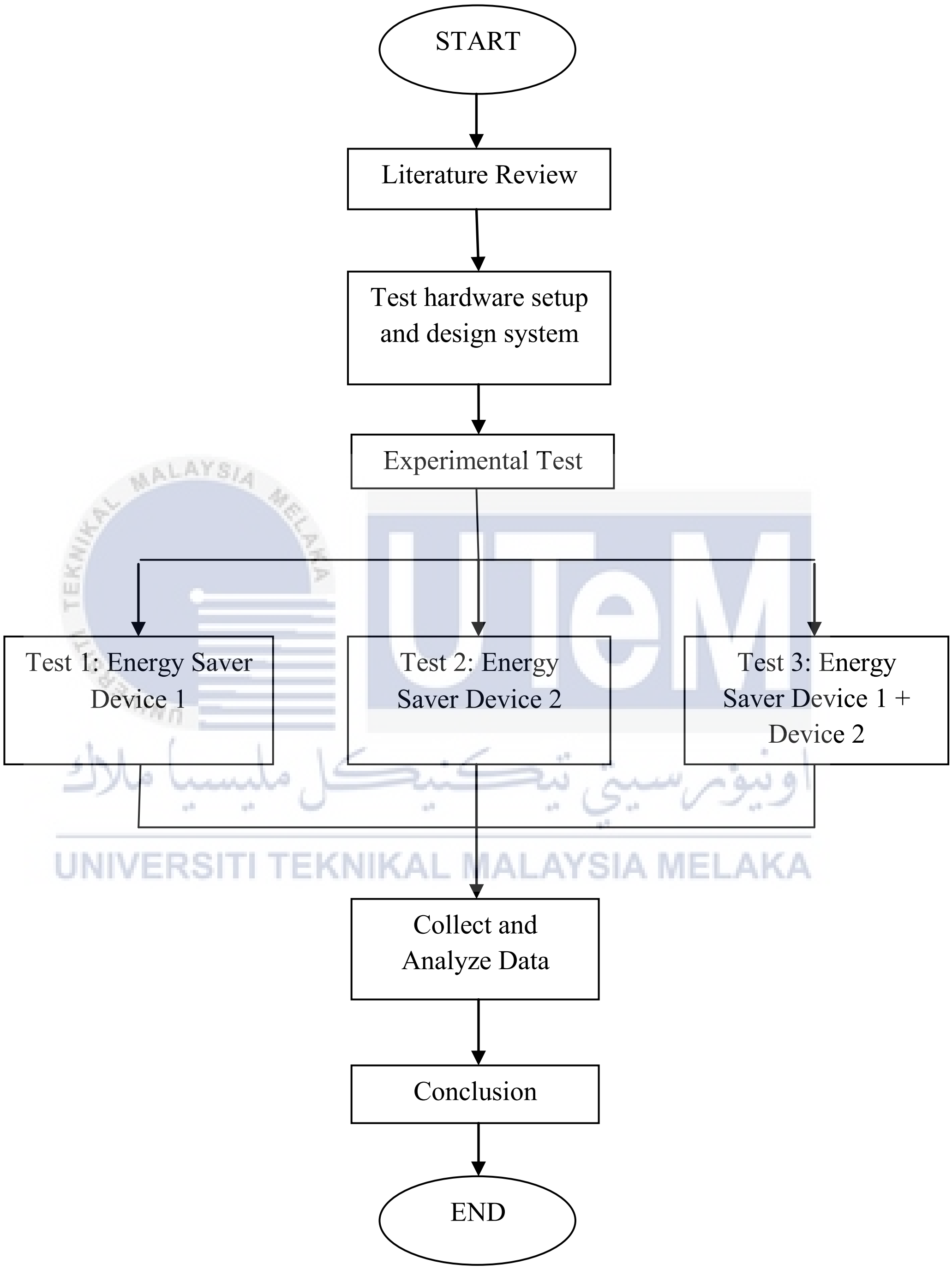

Figure 3.1: Flowchart of Methodology.

By referring to Figure 3.1, the first method to this research is doing the literature review. In literature review, there is research background about basic theory of power factor correction, total harmonic distortion, type of household load, TNB electricity bills on residential and energy saver devices. All the information about basic theory came out from the journal, websites, book, articles that written by previous researchers. All of this information is important to ensure this research is on the right path.

Before conduct an experimental test, hardware must be setup and system must be design imitate to house load. In figure 3.2 show the block diagram of the system that imitate to the residential load and in figure 3.3 show the actual design system that been setup before conduct an experimental test.

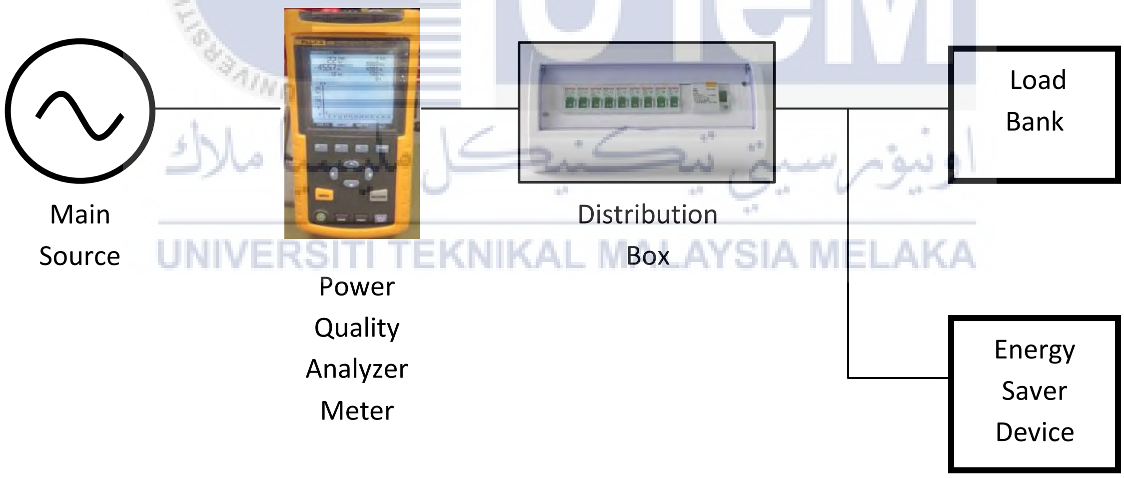

Figure 3.2: Block diagram of design system.

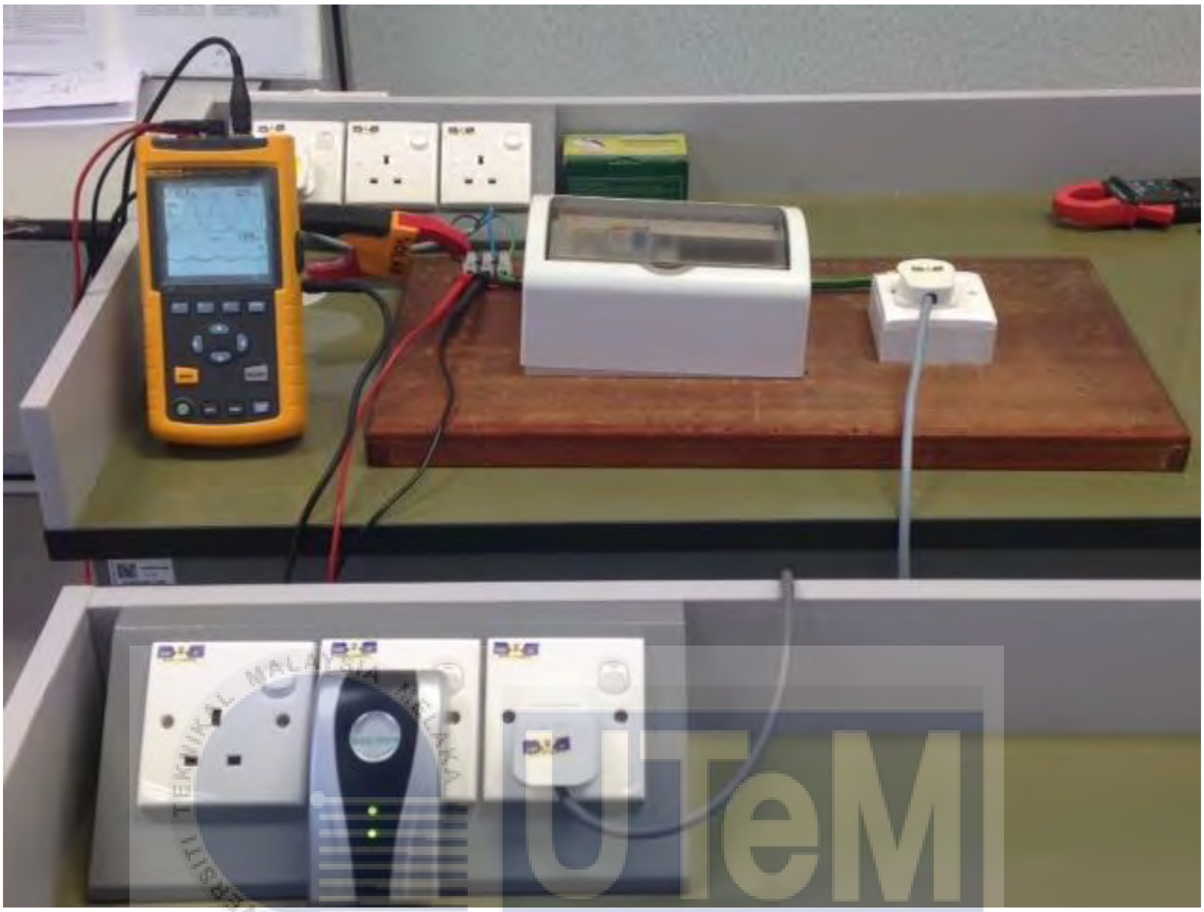

Figure 3.3: Actual Circuit System Imitate to Residential Load.

The equipments had been used while conduct his experiment which is:

a) Power Quality Analyzer Meter

Power quality analyzer meter used to measure all the data during this experiment.

Figure 3.4: Power quality analyzer meter.

Table 3.2 show the reliability of data for fluke 43B power quality analyzer base on it datasheet.

Table 3.2: Reliability of data for fluke 43B power quality analyzer [13].

Input Characteristics	Ranges	Accuracy
Input impedance	1 MΩ, 20 pF	
Voltage rating	600 Vrms, CAT III	
Volt/ Amps/ Hertz		
True-rms voltage (AC+DC)	5.000V, 50.00V, 500.0V, 1250V*	±1%
True-rms current (AC+DC)	50.00A, 500.0A,5.000kA, 50.00kA	±1%
Frequency	10.0Hz to 15.0kHz	±0.5%
Power		
W, VA, VAR reactive power 1 phase and 3 phase, 3 conductor balanced loads.	250W, 2.50kW, 25.0kW, 250kW, 2.50MW, 25MW, 250MW, 625MW, 1.56GW	±2% ±4%
PF power factor	0.00 to 1.00	±0.04
Harmonics		
Volts, Amps, Watts	Fundamental	V,A ± 3% W ± 5%

b) Distribution box

Figure 3.5: Distribution box.

c) Load bank

Load bank used as a load in system to imitate the residential load.

Figure 3.6: Resistive and Inductive load bank.

d) Energy saver device

There are two types of energy save device had been use which are energy saver device 1 and energy saver device 2.

Figure 3.7: Energy saver device 1 and device 2.

After finish design a system and setup the hardware, experimental test has been conduct at laboratory. Experimental test can be dividing in three different tests which are test 1, test 2 and test 3. Test 1 is test on energy saver device 1, test 2 is test on energy saver device 2and lastly test 3 is a test on combination energy saver device 1 and device 2. The experimental test will discuss in detail in section 3.3.

Lastly, after finish conduct an experimental test, the measured data will record and analyzed. The conclusion will be discussed base on analyzing on measured data recorded.

3.3 Experimental Test

Experimental test on energy saver device is the most important part. This experiment is conduct at laboratory. Before running a test on energy saver device, circuit system must be design imitate to residential load. The inductive load bank and resistive load bank has applied to the circuit system to imitate to residential load because most of the household loads is resistive load, inductive load or combination load which is inductive resistive load. Power meter is use to measure a data that needed during conduct an experimental test. The data that will be evaluate are, voltage (V), current (A), active power (kW), reactive power (kVar), power factor and total harmonic distortion (%). The experimental test will conduct by three different test which is Test 1 (test on energy saver device 1), Test 2 (test on energy saver device 2) and Test 3 (test on energy saver device1+2).

3.3.1 Test 1 (test on energy saver device 1)

Experimental test during test 1 is energy saver device 1 will be installing in the circuit system by plug in at the socket. In figure 3.8 show the block diagram when energy saver device 1 install in circuit system. The measured data will be collect on by different load, different rate of load and different type connection of load. The range of load bank is (100 – 1000) W or VAR. The measurement data will be collect on two different conditions which are while energy saver device turn off and while energy saver device turn on.

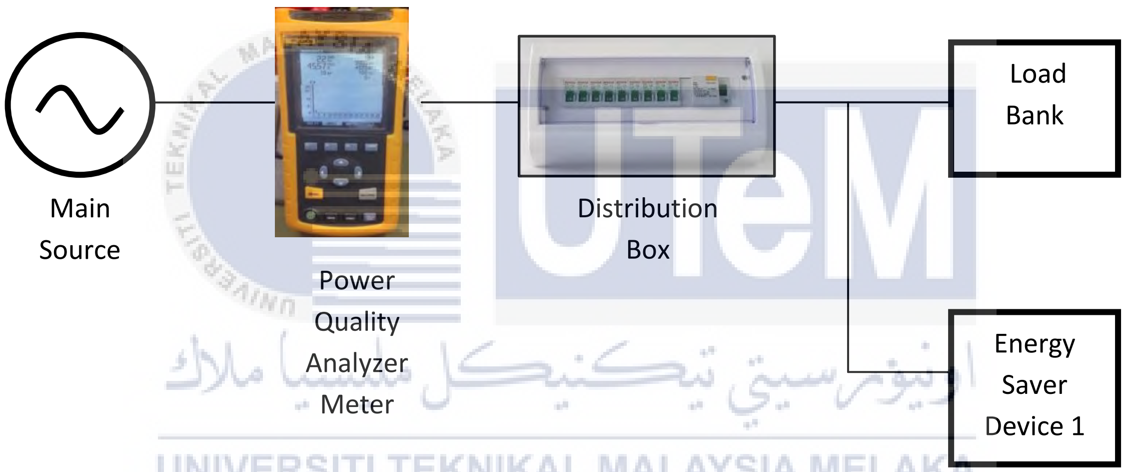

Figure 3.8: Block diagram of design system.

a. Pure resistive load.

Pure resistive load will be installing in system by Resistive Load Bank (kW). The measurement data will be collect on the different rate of resistive load bank from 100W to 1000W that had been set up. Figure 3.9 show the block diagram of the Resistive Load Bank (W) in the system.

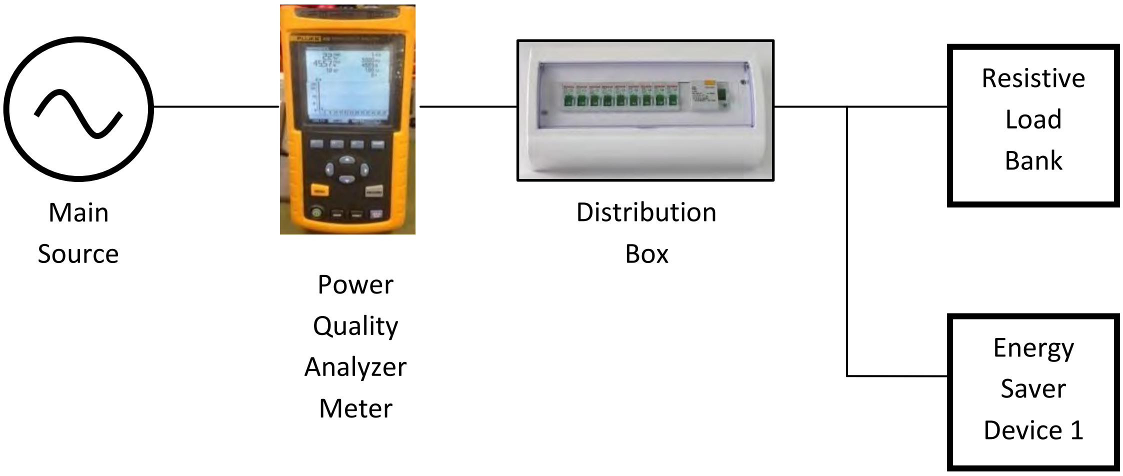

Figure 3.9: Block diagram of resistive load bank install in system.

b. Pure inductive load.

Inductive Load Bank (VAR) will install in the system as a pure inductive load for the system. The data measured from 100VAR to 1000VAR. Figure 3.10 show the block diagram of inductive load bank in the system.

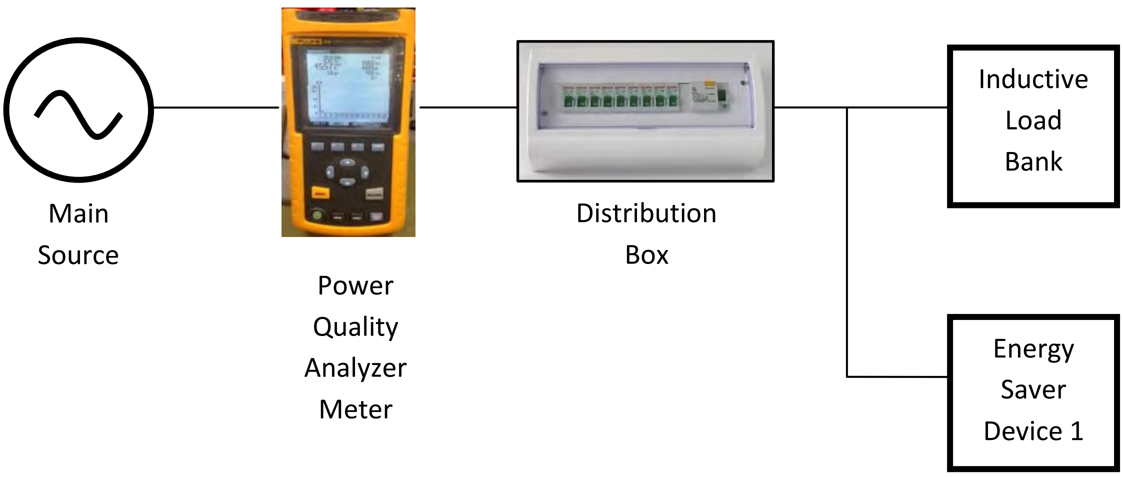

Figure 3.10: Block diagram of resistive load bank install in system.

c. Resistive load parallel connection with inductive load.

Resistive Load Bank (W) connected in parallel to Inductive Load Bank (VAR) that applied in the system. Figure 3.11 show the block diagram of parallel connection of load bank. The measured data will be collect on three different rate of load bank that set up which are:

I. Resistive load equal to inductive load (W = VAR).

Range of resistive and inductive load bank is from 100 to 1000 (W and VAR)

II. Resistive load greater than inductive load (W > VAR).

Range of resistive load bank is from 100 to 1000 (W) and inductive load bank is from 50 to 300 (VAR).

III. Resistive load less than inductive load (W < VAR).

Range of resistive load bank is from 50 to 300 (W) and inductive load bank is from 100 to 1000 (VAR).

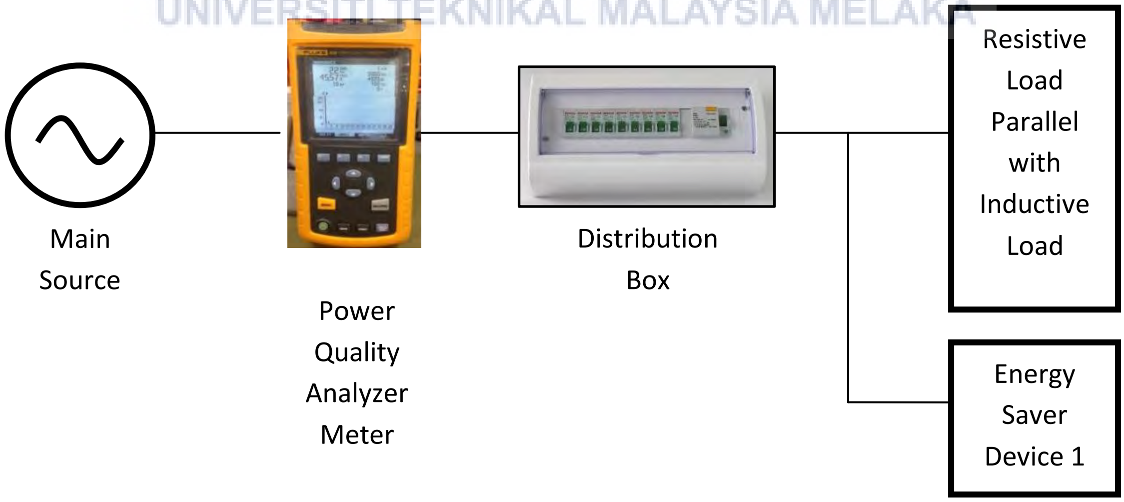

Figure 3.11: Block diagram of resistive load bank in parallel with inductive load bank install in system.

d. Resistive load series connection with inductive load.

Resistive load bank are connected in series with inductive load bank. Figure 3.12 show the block diagram of series connection of load bank. The measured data will be collect on three different rate of load bank that set up which are:

I. Resistive load equal to inductive load (W = VAR).

Range of resistive and inductive load bank is from 100 to 1000 (W and VAR)

II. Resistive load greater than inductive load (W > VAR).

Range of resistive load bank is from 100 to 1000 (W) and inductive load bank is from 50 to 300 (VAR).

III. Resistive load less than inductive load (W < VAR).

Range of resistive load bank is from 50 to 300 (W) and inductive load bank is from 100 to 1000 (VAR).

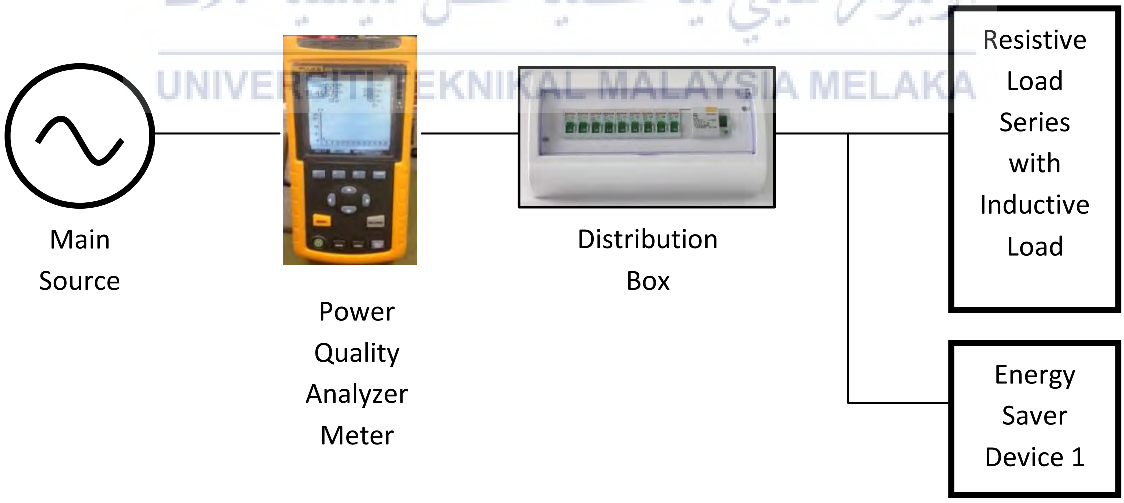

Figure 3.12: Block diagram of resistive load bank in series with inductive load bank install in system.

3.3.2 Test 2 (test on energy saver device 2)

Experimental test during test 2 is replacing the energy saver device 1 to the energy saver device 2. The test procedure during test 2 is same as test 1. The method used to measured the data also same as test 1. Figure 3.13 show the block diagram of the system during conduct a test 2.

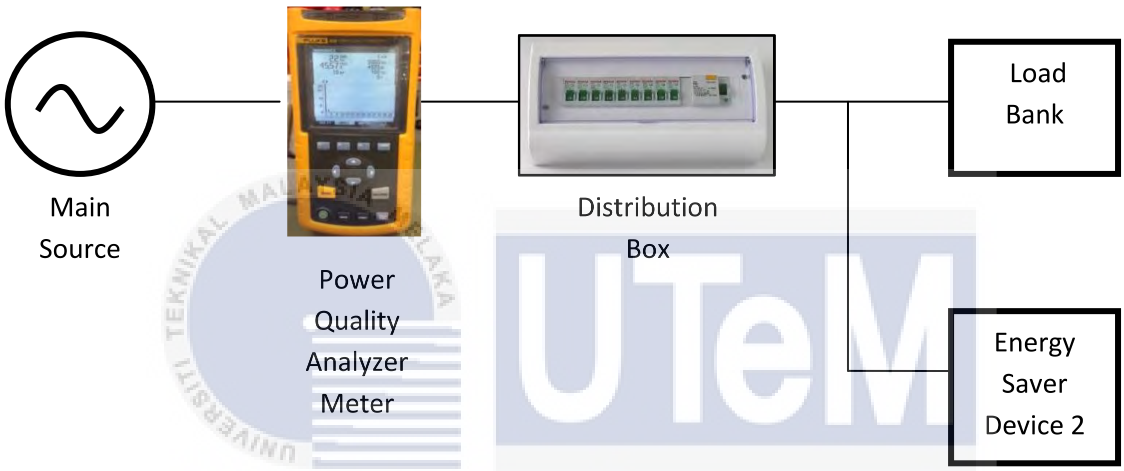

Figure 3.13: Block diagram of design system.

3.3.3 Test 3 (test on energy saver device 1 + device 2)

In this test, all the procedure and method of measurement data still same as test 1. The difference is the system will be installing by 2 energy saver devices. Block diagram of the system test 2 shown in figure 3.14.

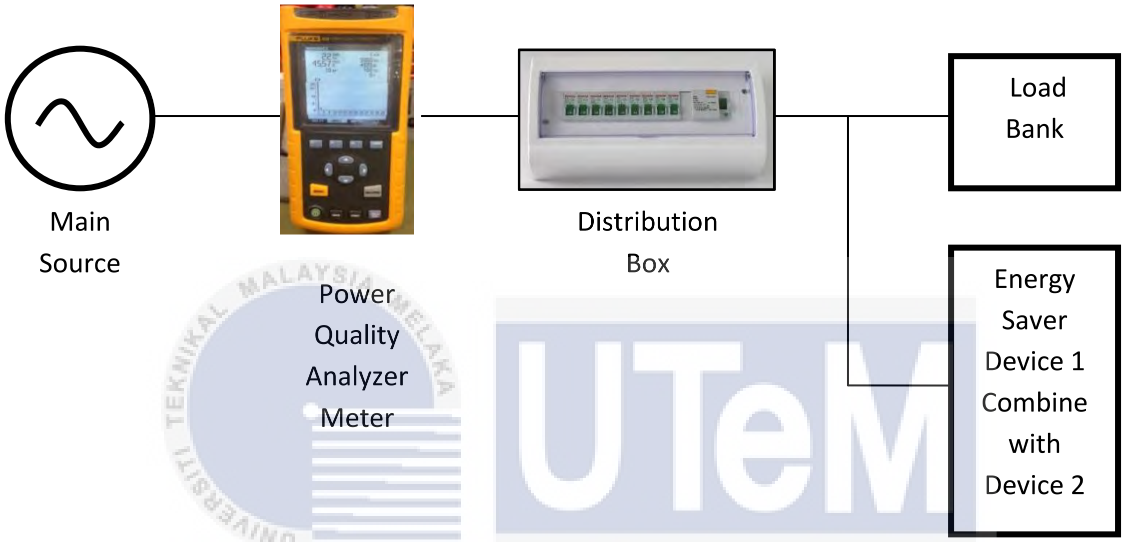

Figure 3.114: Block diagram of design system.

CHAPTER 4

RESULT AND DISCUSSION

4.0 Introduction

The purpose of experimental test on energy saver device is to determine the truth of the capability energy saver device weather it can reduce electricity bills or not. For final year project 1 (FYP1), the experimental test only conduct on test 1 which is test on energy saver device 1. The others test was conducted on FYP2. The data of experimental test on energy saver device 1 was measured using power meter. The collected data will be tabulated and analyzed in this chapter.

4.1 Result

In this part, the result will tabulate base on measured data collected during experimental test on energy saver. This result will determine the truth of the capability energy saver device. Before record the measurement data, main source at laboratory has been observed.

Voltage : 250V

Frequency : 50Hz

P.F : 0.85

4.1.1 Experimental test 1

I. Pure resistive load

Table 4.1: Measurement data for pure resistive load.

Resistive Load Bank (W)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	252.0	250.4	0.43	0.49	107	106	3	64	1	0.86	0.7	2.7
200	250.0	250.1	0.84	0.88	211	207	5	65	1	0.95	0.8	1.8
300	247.9	247.9	1.25	1.27	310	309	7	66	1	0.98	0.8	1.4
400	247.9	248.1	1.66	1.68	414	412	8	68	1	0.99	0.8	1.1
500	247.9	247.8	1.98	1.98	490	488	9	69	1	0.99	0.8	1.0
600	247.4	247.4	2.38	2.40	591	590	10	70	1	0.99	0.8	1.0
700	246.7	246.5	2.80	2.80	690	687	10	71	1	1	0.7	0.8
800	246.4	246.5	3.01	3.01	742	739	11	71	1	1	0.8	0.8
900	246.1	246.1	3.40	3.40	836	836	13	72	1	1	0.8	0.8
1000	245.7	245.5	3.79	3.79	933	933	14	74	1	1	0.8	0.8

Comparison by calculation for highest load:

R = 1000W V = 250V P = 933W Q = 14VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{933+j14}{250} = 3.73A \angle 0.85^0$ p.f = CosΘ = Cos(0.85) = 0.99

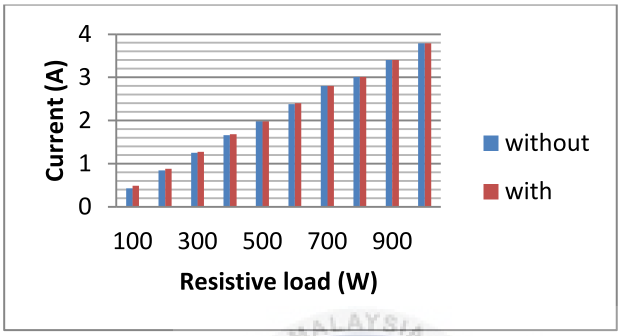

Figure 4.1: Comparison of current values without and with energy saver.

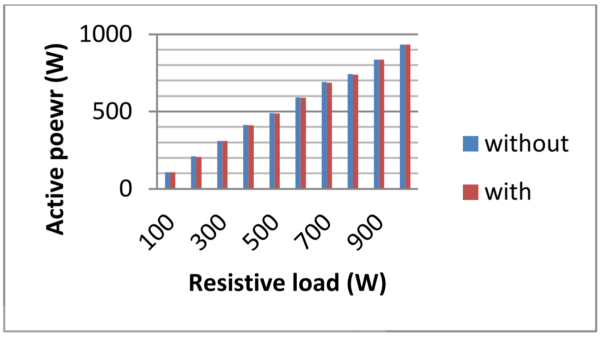

Figure 4.2: Comparison of active power values without and with energy saver

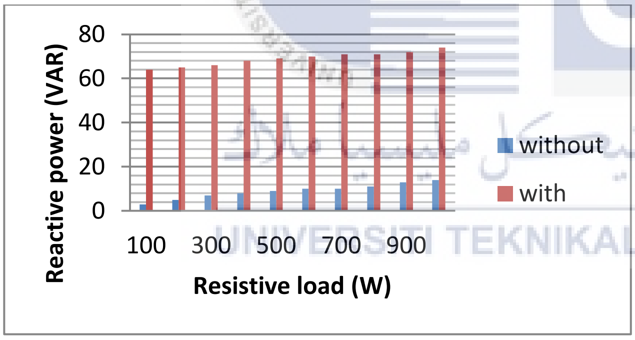

Figure 4.3: Comparison of reactive power without and with energy saver.

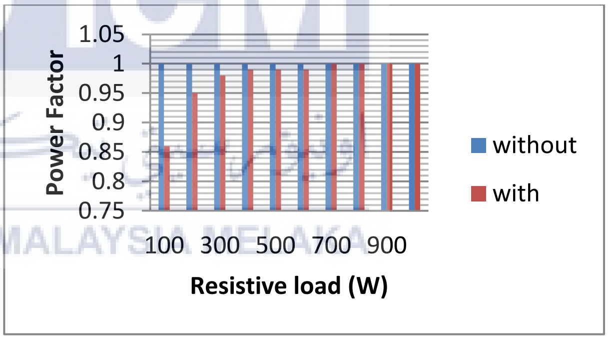

Figure 4.4: Comparison of power factor without and with energy saver.

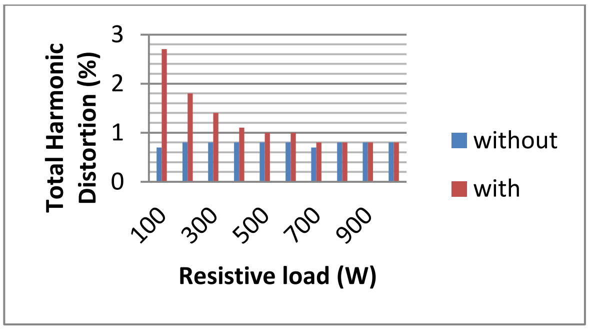

Figure 4.5: Comparison of total harmonic distortion without and with energy saver.

Based on collected data, the data have been analyzed by graphical method comparison of two different condition of the system which is without energy saver and with energy saver. The data had been analyzed are current, active power, reactive power, power factor and THD as shown in figure 4.1, 4.2, 4.3, 4.4 and 4.5. For resistive load, current that consume in the system without and with energy saver, there are only have a few difference while in lower load which mean the current is lower during without energy saver due to power factor of the system is high compare to with energy saver. Meanwhile, when load up to 500W and above, there no any difference for these two types of condition. For active power consume at 100W to 1000W resistive load, there are no any differences between these two conditions but the reactive power increased drastically almost 70% when the system with energy saver. The THD of the system also increased when the system with energy saver but when load at 800W the THD does not change at all.

II. Pure inductive load

Table 4.2: Measurement data for pure inductive load.

Inductive Load Bank (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	248.0	248.2	0.42	0.18	15	14	103	45	0.14	0.30	3.1	9.6
200	248.0	248.3	0.87	0.63	23	22	215	56	0.11	0.14	2.2	3.6
300	248.1	248.0	1.30	1.06	37	36	322	262	0.11	0.14	2.7	3.6
400	248.2	247.7	1.57	1.33	36	35	390	329	0.09	0.11	2.6	3.1
500	247.7	247.7	2.12	1.88	42	41	524	465	0.08	0.09	2.1	2.4
600	247.8	247.9	2.55	2.31	57	56	629	570	0.09	0.10	2.3	2.5
700	247.5	247.4	3.00	2.75	67	65	739	679	0.09	0.10	2.0	2.3
800	247.3	247.1	3.42	3.18	81	80	843	782	0.10	0.10	2.2	2.4
900	250.9	250.6	3.98	3.73	94	93	994	929	0.09	0.10	2.2	2.5
1000	250.4	250.3	5.03	4.79	117	116	1260	1200	0.09	0.10	2.3	2.4

Comparison by calculation for highest load:

L = 1000VAR   V = 250V   P = 117W   Q = 1260VAR

S = IV   S = P + jQ

$I = \frac{S}{V} = \frac{117+j1260}{250} = 5.03A \angle 84.69^0$ p.f = CosΘ = Cos(84.68) = 0.09

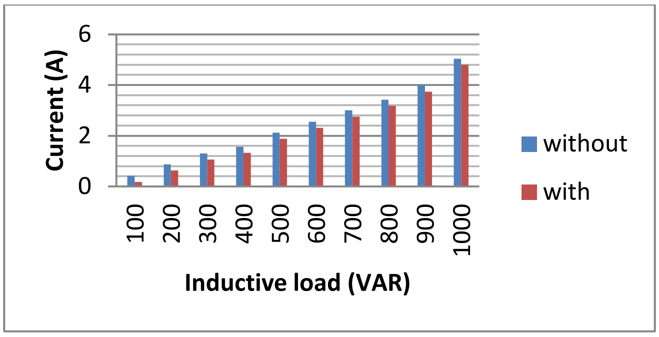

Figure 4.6: Comparison of current values without and with energy saver

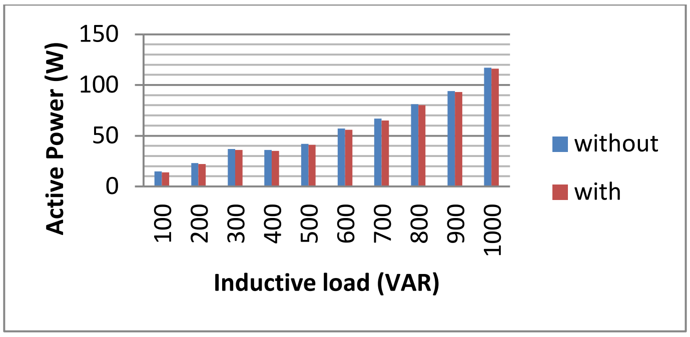

Figure 4.7: Comparison of active power values without and with energy saver

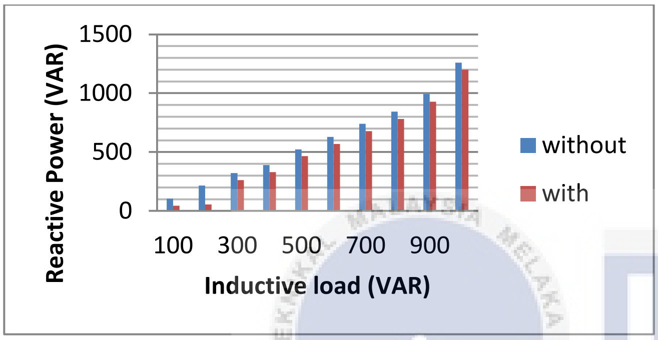

Figure 4.8: Comparison of reactive power values without and with energy saver.

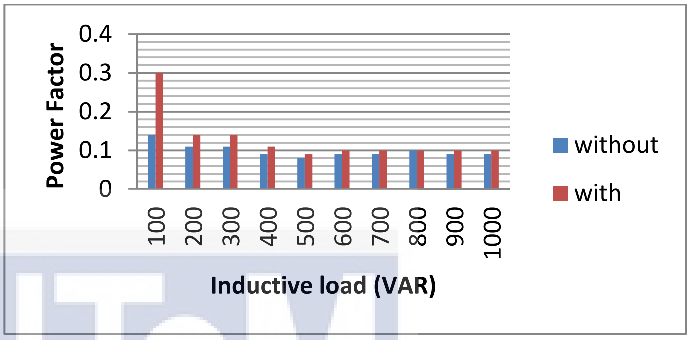

Figure 4.9: Comparison of power factor without and with energy saver.

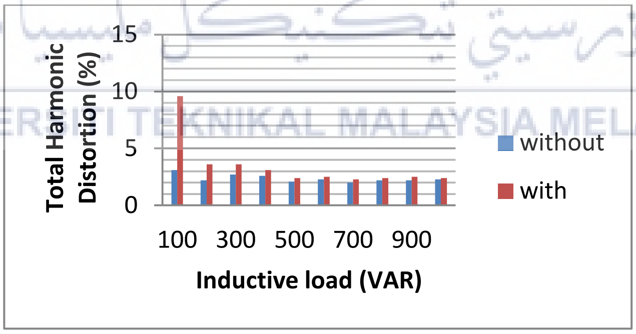

Figure 4.10: Comparison of total harmonic distortion without and with energy saver.

For inductive load, the collected data was analysed base on graphical method as shown in figure 4.6, 4.7, 4.8, 4.9 and 4.10. By referring the graph of current, current in system during pure inductive load shown the current is decrease when energy saver is applied in the system due to the increasing in power factor. Active powers still not have much difference whether the system without energy saver or with energy saver. Meanwhile, for pure inductive load, when the power factor is increase while the system with energy saver, it drive the decreasing of reactive power which means reduce losses in the system. The THD also increased when the system with energy saver, but when the inductive load in the system become higher, the difference of increasing THD becomes smaller.

III. Resistive load parallel connection with inductive load

a) Resistive load equal to inductive load (W =VAR)

Table 4.3: Measurement data for resistive load equal to inductive load.

Resistive (W) = Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	249.9	250.0	0.63	0.51	122	121	103	44	0.76	0.94	2.0	3.6
200	249.5	249.5	1.26	1.11	234	232	213	152	0.74	0.84	1.6	2.2
300	249.0	249.1	1.89	1.73	345	349	316	257	0.74	0.81	1.8	2.2
400	248.6	248.5	2.37	1.72	452	449	380	320	0.77	0.81	1.8	2.0
500	248.2	248.0	2.98	2.81	535	531	512	452	0.72	0.76	1.3	1.5
600	249.6	249.6	3.62	3.46	658	658	620	561	0.73	0.76	1.5	1.6
700	249.0	249.2	4.13	3.95	725	720	731	671	0.70	0.73	1.6	1.7
800	248.6	248.5	4.73	4.56	832	831	830	770	0.71	0.73	1.7	1.8
900	250.0	249.8	5.39	5.22	954	947	954	889	0.71	0.73	1.6	1.7
1000	248.4	249.4	5.81	5.67	1040	1050	1000	950	0.72	0.74	1.4	1.6

Comparison by calculation for highest load:

R= 1000W L = 1000VAR V = 250V P = 1040W Q = 1000VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{1040+j1000}{250} = 5.77A \angle 43.87^0$ p.f = CosΘ = Cos(43.86) = 0.72

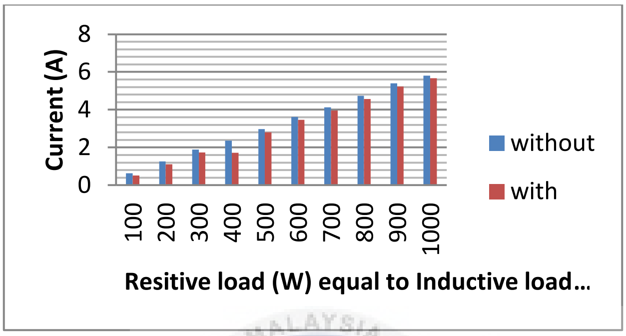

Figure 4.11: Comparison of current values without and with energy saver

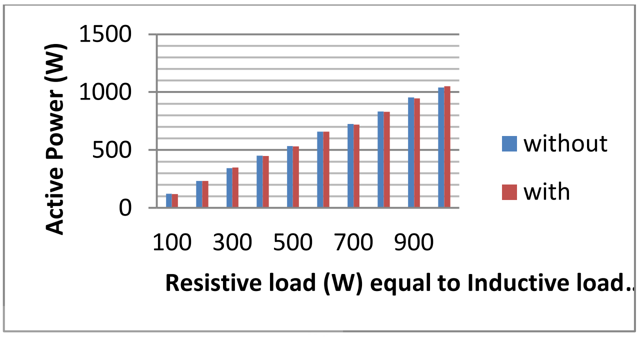

Figure 4.12: Comparison of active power values without and with energy saver

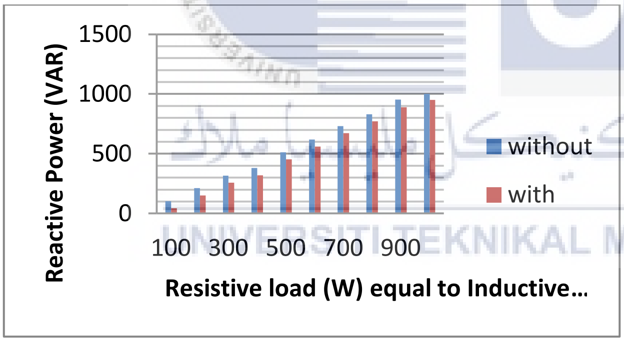

Figure 4.13: Comparison of reactive power values without and with energy saver.

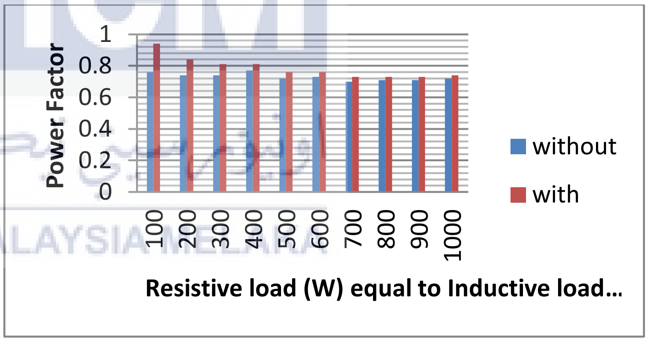

Figure 4.14: Comparison of power factor without and with energy saver.

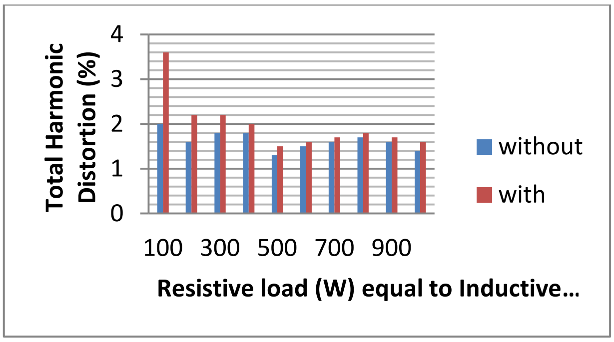

Figure 4.15: Comparison of total harmonic distortion without and with energy saver.

For parallel connection load, there are three different parts. For this part, resistive load equal to inductive load and the measured data has been recorded in table 4.3. The graphs on figure 4.11, 4.12, 4.13, 4.14 and 4.15 had shown the analyzed of measurement data. For the current of the system during this part, when the system with energy saver, the current was reduce due to the increasing of power factor. Meanwhile the graph of active power shown there are no differences between system without energy saver and system with energy saver. By the way, the reactive power has decrease when the system with energy saver. Another that, THD in the system also increase when the system installed by energy saver.

b) Resistive load greater than inductive load (W > VAR)

Table 4.4: Measurement data for resistive load greater than inductive load.

Resistive (W) > Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 // 50	252.3	253.4	0.50	0.46	117	116	50	14	0.92	0.99	1.5	3.7
200 / / 50	251.0	251.8	0.90	0.87	222	220	48	18	0.98	1	1.2	2.2
300 // 50	251.4	251.4	1.31	1.29	326	328	46	18	0.99	1	1.1	1.5
400 // 100	250.8	250.7	1.78	1.74	437	436	99	39	0.98	1	1.1	1.5
500 // 100	250.8	250.6	2.10	2.05	518	514	97	38	0.98	1	1.2	1.3
600 // 100	250.8	250.2	2.50	2.47	621	619	95	36	0.99	1	1.1	1.3
700 // 200	250.0	250.2	2.86	2.77	687	680	205	145	0.96	0.98	1.1	1.1
800 // 200	250.0	249.7	3.22	3.17	781	779	203	143	0.97	0.98	1.0	1.1
900 // 200	249.5	249.6	3.61	3.57	880	880	200	140	0.98	0.99	1.0	1.1
1000//300	249.2	249.1	4.17	4.09	993	991	303	243	0.96	0.97	1.1	1.3

Comparison by calculation for highest load:

R= 1000W   L = 300VAR   V = 250V   P = 993W   Q = 303VAR

S = IV   S = P + jQ

$I = \frac{S}{V} = \frac{993+j303}{250} = 4.52\ A \llcorner 16.96^0$ p.f = CosΘ = Cos(16.96) = 0.956

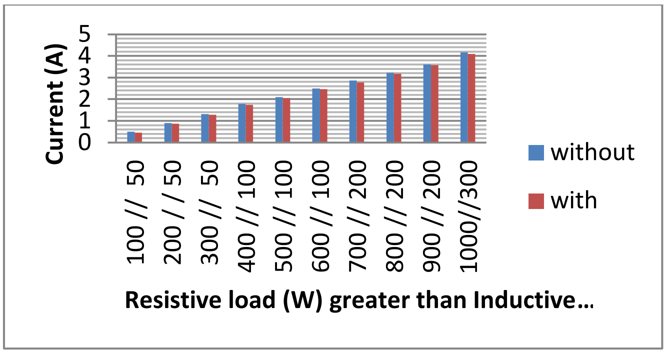

Figure 4.16: Comparison of current values without and with energy saver

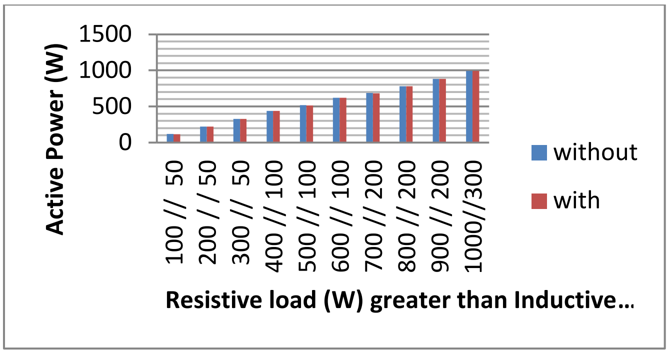

Figure 4.17: Comparison of active power values without and with energy saver

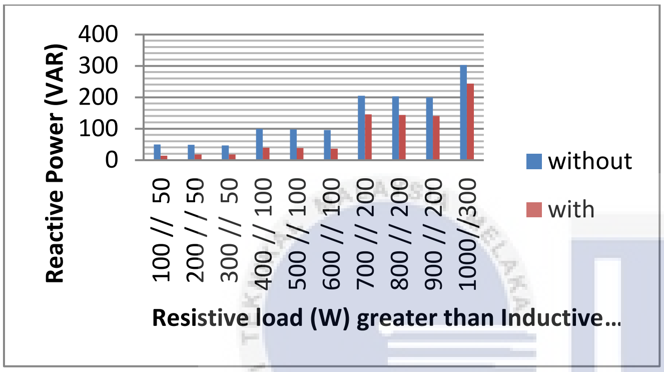

Figure 4.18: Comparison of reactive power values without and with energy saver.

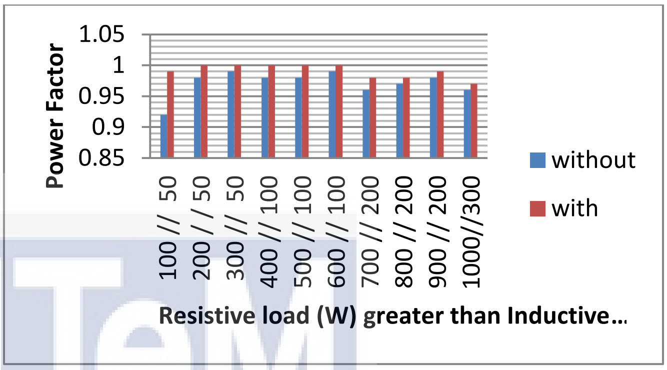

Figure 4.19: Comparison of power factor without and with energy saver.

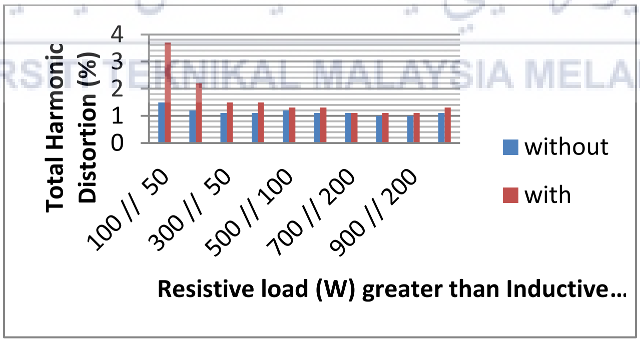

Figure 4.20: Comparison of total harmonic distortion without and with energy saver.

For figure 4.16, 4.17, 4.18, 4.19 and 4.20 show the graphs of analyzed measurement data for part resistive load greater than inductive load of parallel connection load. During this part, current in the system show the differences of decreasing when the system with energy saver. This is because the power factor of the system is increase when the system with energy saver and make the reactive power of the system decrease. Active power remains unchanged whether the system without energy saver or with energy saver. THD of the system is increased when the system with energy saver.

c) Inductive load greater than resistive load k (VAR > W)

Table 4.5: Measurement data for inductive load greater than inductive load.

Inductive (VAR) > Resistive (W)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 // 50	252.8	252.8	0.50	0.32	68	67	107	46	0.54	0.82	2.6	6.1
200 // 50	252.8	253.2	0.93	0.70	76	76	221	161	0.33	0.43	2.0	3.3
300 // 50	252.9	252.2	1.37	1.13	91	91	333	273	0.26	0.32	2.5	3.4
400 // 100	252.6	252.4	1.69	1.46	147	146	402	340	0.34	0.39	2.3	2.9
500 // 100	252.0	252.1	2.23	1.99	154	153	542	480	0.27	0.30	1.9	2.2
600 // 100	252.1	252.1	2.66	2.42	168	168	650	588	0.25	0.27	2.0	2.4
700 // 200	251.6	251.5	3.23	3.00	283	282	762	702	0.35	0.37	1.9	2.1
800 // 200	251.6	251.7	3.65	3.42	298	297	870	809	0.32	0.34	2.1	2.4
900 // 200	251.4	251.3	4.12	3.89	309	306	991	930	0.30	0.31	2.1	2.2
1000//300	250.8	250.7	4.76	4.53	421	424	1120	1070	0.35	0.37	2.2	2.3

Comparison by calculation for highest load:

R= 300W L = 1000VAR V = 250V P = 421W Q = 1120VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{421+j1120}{250} = 4.78\ A\ \angle 69.40^0$ p.f = CosΘ = Cos(69.40) = 0.35

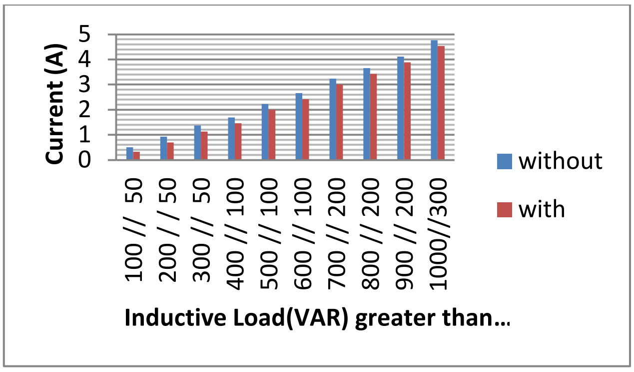

Figure 4.21: Comparison of current values without and with energy saver

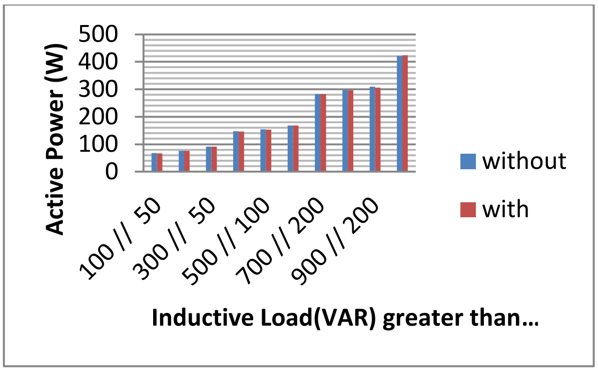

Figure 4.22: Comparison of active power values without and with energy saver

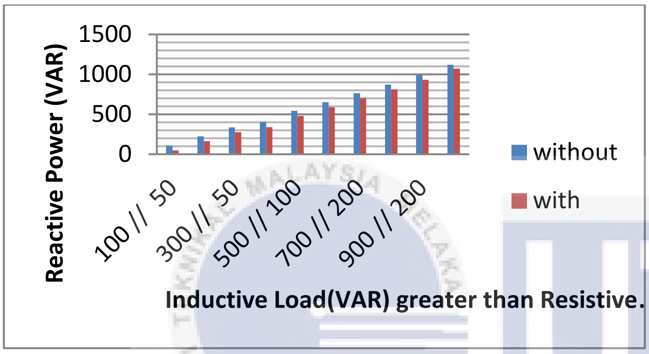

Figure 4.23: Comparison of reactive power values without and with energy saver.

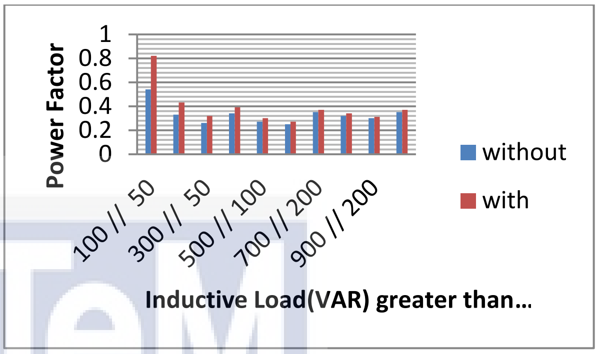

Figure 4.24: Comparison of power factor without and with energy saver.

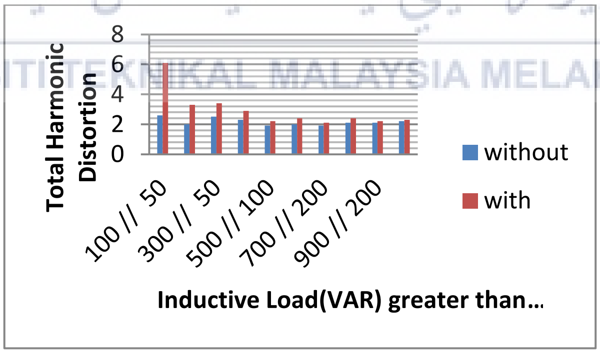

Figure 4.25: Comparison of total harmonic distortion without and with energy saver.

For this part, inductive load greater than resistive load in parallel connection in the system. The analyzed data base on graphical method in figure 4.21, 4.22, 4.23, 4.24 and 4.25 based on recorded collected data. The current of the system is decrease when the system with energy saver due the increasing of power factor and it also cause the reactive power in the system is decrease. Meanwhile, for this part, active power also remains unchanged. The THD of the system also increase when the system with energy saver.

IV. Resistive load series with inductive load

a) Resistive load bank equal to inductive load (W =VAR)

Table 4.6: Measurement data for resistive load equal to inductive load.

Resistive (W) = Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	249.0	248.7	0.27	0.21	53	51	44	18	0.77	0.95	2.6	6.8
200	248.9	249.2	0.57	0.45	109	108	92	34	0.76	0.95	2.2	4.4
300	248.7	248.9	0.85	0.71	161	160	138	78	0.76	0.90	2.5	3.6
400	248.6	248.4	1.09	0.93	196	195	189	129	0.72	0.83	2.7	3.5
500	248.5	248.3	1.34	1.19	247	246	226	166	0.74	0.83	2.3	3.1
600	248.1	248.2	1.67	1.52	312	311	273	214	0.75	0.82	2.3	2.6
700	247.9	247.8	1.89	1.74	363	362	297	237	0.77	0.84	2.4	2.8
800	247.5	247.5	2.16	2.01	414	413	340	280	0.77	0.83	2.5	2.9
900	247.5	247.9	2.46	2.31	471	471	385	327	0.78	0.82	2.4	2.7
1000	247.1	247.3	2.69	2.54	505	504	437	377	0.76	0.80	2.4	2.6

Comparison by calculation for highest load:

R= 1000W L = 1000VAR V = 250V P = 505W Q = 437VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{505+j437}{250} = 2.67\ A\ \llcorner 40.87^0$ p.f = CosΘ = Cos(40.87) = 0.756

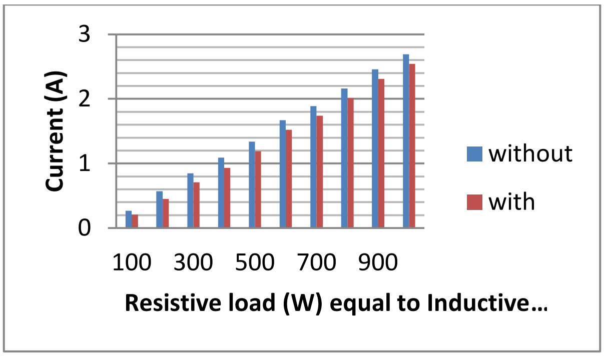

Figure 4.26: Comparison of current values without and with energy saver

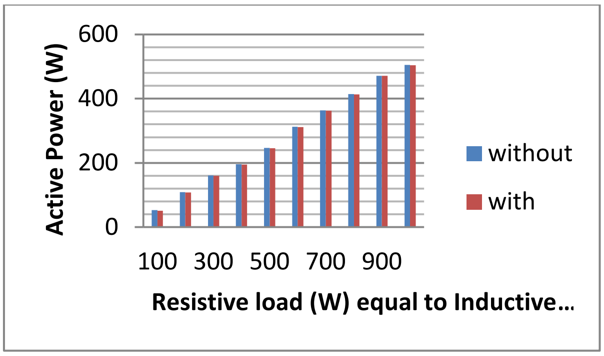

Figure 4.27: Comparison of active power values without and with energy saver

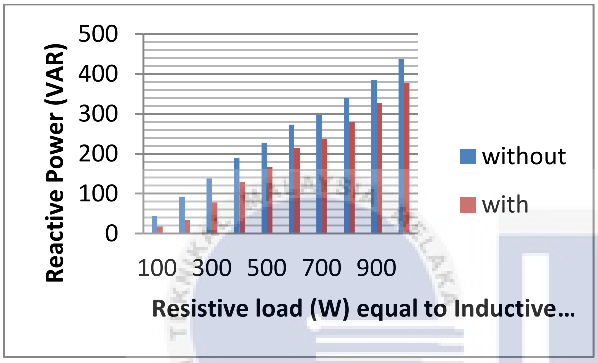

Figure 4.28: Comparison of reactive power values without and with energy saver.

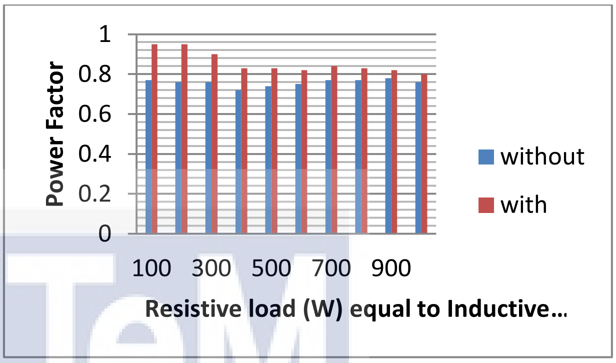

Figure 4.29: Comparison of power factor without and with energy saver.

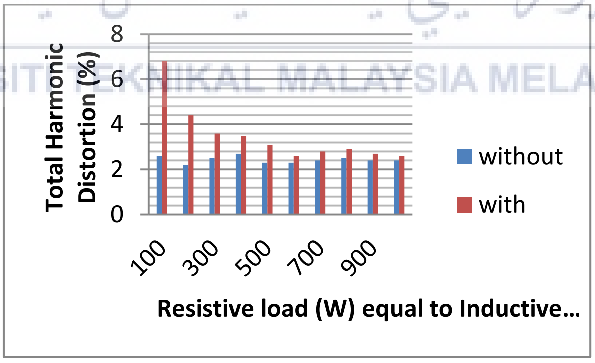

Figure 4.30: Comparison of total harmonic distortion without and with energy saver.

For series connected load also divide by three different parts. For this part, resistive load equal to inductive load. The data has been analyzed by the graphical method as shown in figure 4.26, 4.27, 4.28, 4.29 and 4.30. Current in the system is decrease when the system with energy saver because the energy saver has improved the power factor and also make the reactive power in the system decrease. Active power still remains unchanged whether the system without energy saver or with energy saver. THD of the system is increase when the system installed by energy saver.

b) Resistive load greater than inductive load (W > VAR)

Table 4.7: Measurement data for resistive load greater than inductive load.

Resistive (W) > Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 + 50	248.9	248.9	0.174	0.129	24	21	36	24	0.56	0.67	3.0	10.2
200 + 50	248.7	249.0	0.191	0.092	19	15	44	17	0.39	0.67	2.7	16.0
300 + 50	249.0	248.8	0.196	0.079	16	13	47	15	0.32	0.65	3.0	19.6
400 + 100	248.7	248.6	0.398	0.198	37	36	92	33	0.38	0.73	3.0	8.9
500 + 100	248.6	248.9	0.406	0.196	34	32	95	36	0.33	0.67	3.0	8.8
600 + 100	248.6	248.7	0.409	0.193	31	30	97	37	0.31	0.63	2.9	9.3
700 + 200	248.5	248.3	0.808	0.595	81	80	184	123	0.40	0.54	2.2	3.8
800 + 200	248.2	248.3	0.820	0.602	75	74	189	129	0.37	0.50	2.3	3.6
900 + 200	248.5	248.4	0.829	0.609	70	69	194	134	0.34	0.46	2.3	3.7
1000+300	248.2	248.1	1.201	0.988	123	122	272	211	0.41	0.50	2.6	3.5

Comparison by calculation for highest load:

R= 1000W L = 300VAR V = 250V P = 123W Q = 272VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{123+j272}{250} = 1.194\ A \angle 65.66^0$ p.f = CosΘ = Cos(65.66) = 0.41

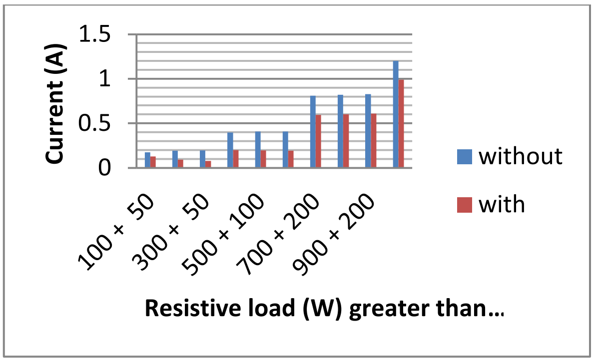

Figure 4.31: Comparison of current values without and with energy saver

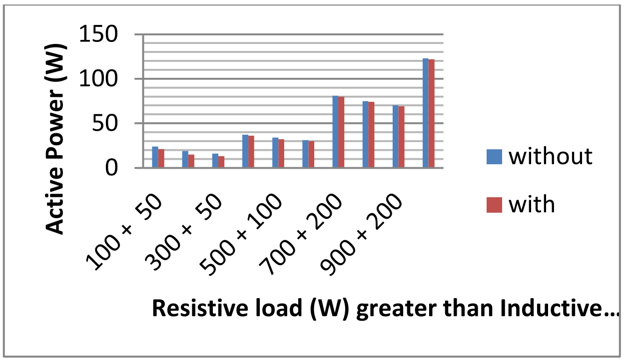

Figure 4.32: Comparison of active power values without and with energy saver

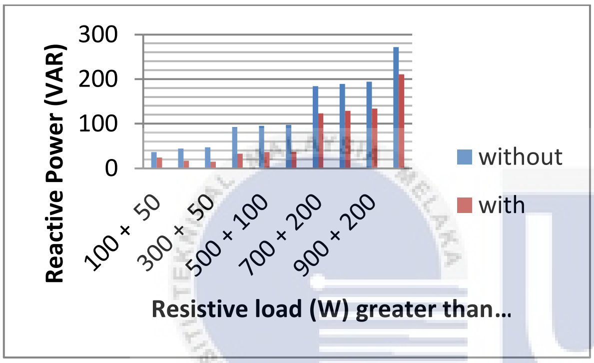

Figure 4.33: Comparison of reactive power values without and with energy saver.

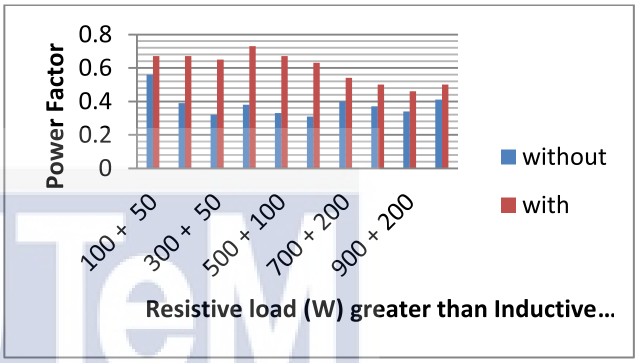

Figure 4.34: Comparison of power factor without and with energy saver.

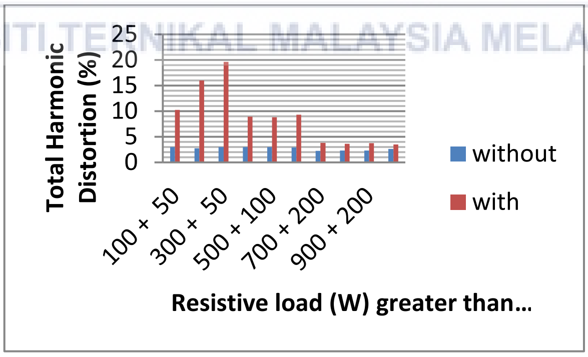

Figure 4.35: Comparison of total harmonic distortion without and with energy saver.

During this part, resistive load greater than inductive load in series connection. The analyzed data show in figure 4.31, 4.32, 4.33, 4.34 and 4.35. The current of the system is decrease when the system with energy saver due to improvement of the power factor and its also drive the reactive power in the system decrease. Fir this part, active power still remains unchanged whether the system without energy saver or with energy saver. THD in the system still increased when the energy saver is installed to the system.

c) Inductive load greater than resistive load (VAR > W)

Table 4.8: Measurement data for inductive load greater than inductive load.

Inductive (VAR) > Resistive (W)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 + 50	248.4	245.5	0.179	0.226	41	39	18	40	0.91	0.70	2.1	5.2
200 + 50	248.0	248.0	0.203	0.276	49	48	10	48	0.98	0.71	1.3	4.2
300 + 50	248.3	248.6	0.209	0.292	52	50	7	53	0.99	0.70	1.1	4.2
400 + 100	248.3	248.2	0.408	0.433	100	99	17	43	0.99	0.92	0.9	2.8
500 + 100	248.1	248.1	0.407	0.428	99	98	19	40	0.98	0.93	1.4	3.0
600 + 100	248.2	248.2	0.410	0.439	101	100	15	44	0.99	0.92	1.0	2.6
700 + 200	247.6	247.6	0.781	0.750	186	185	51	10	0.97	1	1.8	2.1
800 + 200	247.6	247.9	0.787	0.765	189	189	45	15	0.97	1	1.5	2.0
900 + 200	248.2	248.3	0.795	0.779	193	193	40	20	0.98	1	1.2	1.8
1000+300	248.0	248.0	1.160	1.113	276	275	83	24	0.96	1	1.9	2.1

Comparison by calculation for highest load:

R= 1000W L = 300VAR V = 250V P = 276W Q = 83VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{276+j83}{250} = 1.15A \angle 16.73^0$ p.f = CosΘ = Cos(16.73) = 0.957

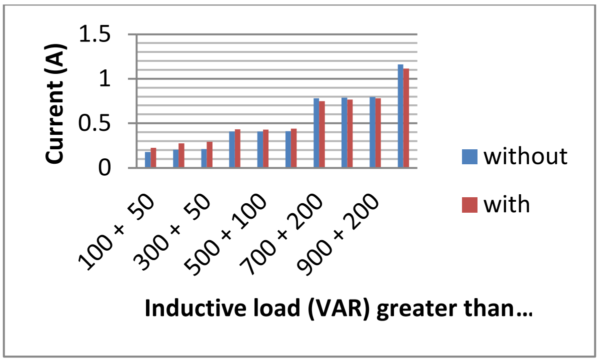

Figure 4.36: Comparison of current values without and with energy saver

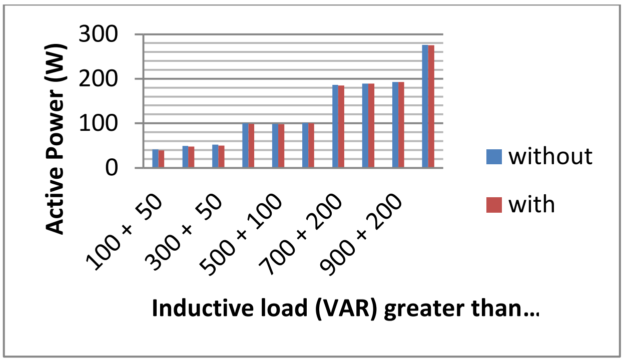

Figure 4.37: Comparison of active power values without and with energy saver

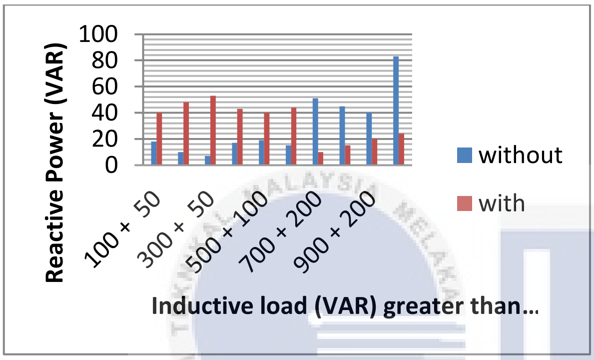

Figure 4.38: Comparison of reactive power values without and with energy saver.

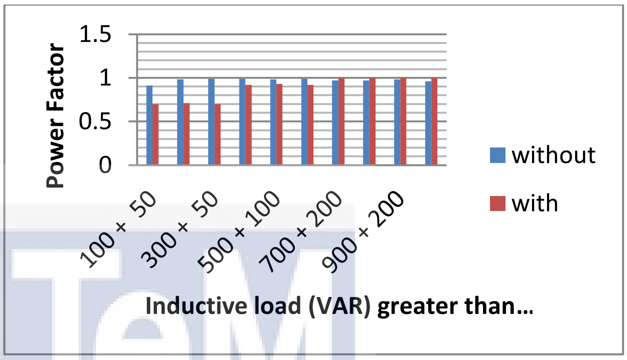

Figure 4.39: Comparison of power factor without and with energy saver.

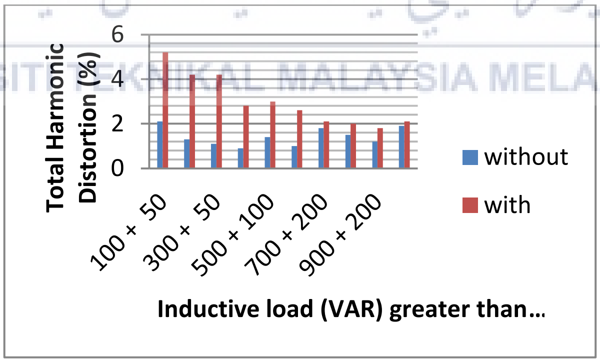

Figure 4.40: Comparison of total harmonic distortion without and with energy saver.

For the last part of the experimental test, the inductive load greater than inductive load in series connection. Figure 4.41, 4.42, 4.43, 4.44 and 4.45 shows the graph of the analyzing data. During this part, the current of the system is reducing after the system with energy saver. This is because the power factor of the system is improved when the energy saver installed in the system and it also makes the reactive power decrease. The active power remains unchanged whether the system without energy saver or with energy saver. THD of the system still increase when the system is installed by the energy saver.

4.1.2 Experimental test 2

I. Pure resistive load

Table 4.9: Measurement data for pure resistive load.

Resistive Load Bank (W)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	252.0	251.9	0.43	0.50	109	108	3	64	1	0.86	1.1	3.1
200	251.4	251.3	0.88	0.88	214	214	5	66	1	0.96	1.1	2.2
300	250.5	251.5	1.27	1.30	318	320	7	68	1	0.98	1.1	1.7
400	250.7	251.2	1.69	1.71	.25	424	8	70	1	0.99	1.0	1.3
500	250.3	250.4	2.00	2.02	506	502	10	71	1	0.99	1.1	1.3
600	250.0	250.1	2.42	2.43	606	605	11	72	1	0.99	1.0	1.3
700	250.3	250.1	2.66	2.66	666	661	12	73	1	0.99	1.1	1.2
800	249.5	249.5	3.05	3.05	761	759	12	74	1	1	0.9	1.1
900	248.8	248.7	3.44	3.45	857	855	14	75	1	1	1.0	1.1
1000	248.2	248.2	3.85	3.85	955	956	14	76	1	1	1.0	1.3

Comparison by calculation for highest load:

R= 1000W V = 250V P = 955W Q = 14VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{955+j14}{250} = 3.82\ A\ \angle 0.83^0$ p.f = CosΘ = Cos(0.83) = 0.999

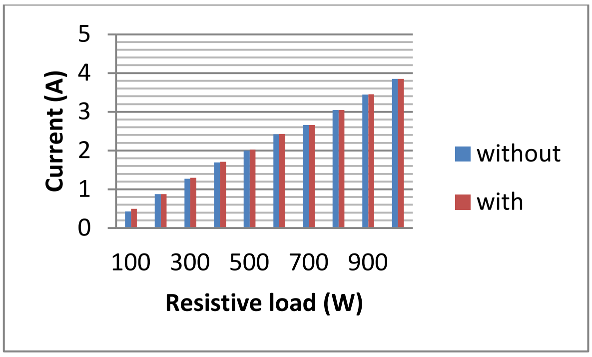

Figure 4.41: Comparison of current values without and with energy saver

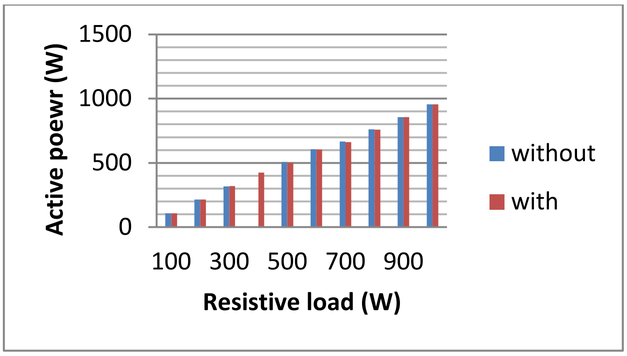

Figure 4.42: Comparison of active power values without and with energy saver

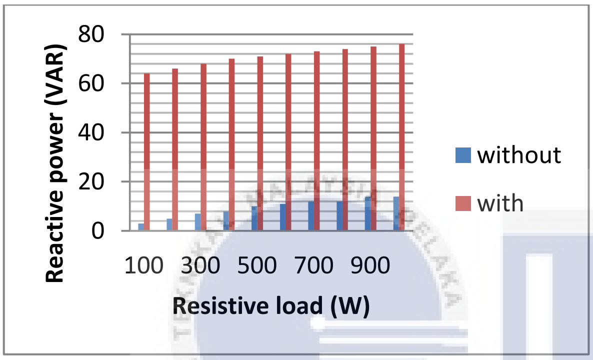

Figure 4.43: Comparison of reactive power values without and with energy saver.

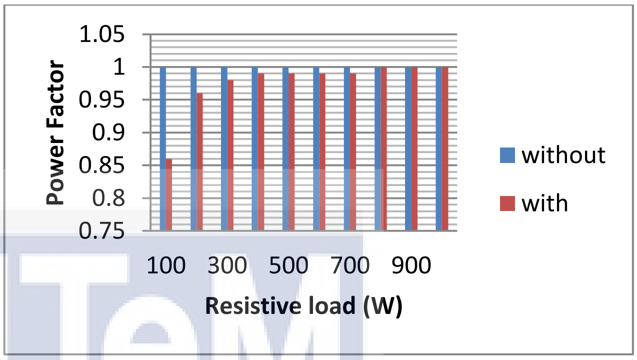

Figure 4.44: Comparison of power factor without and with energy saver.

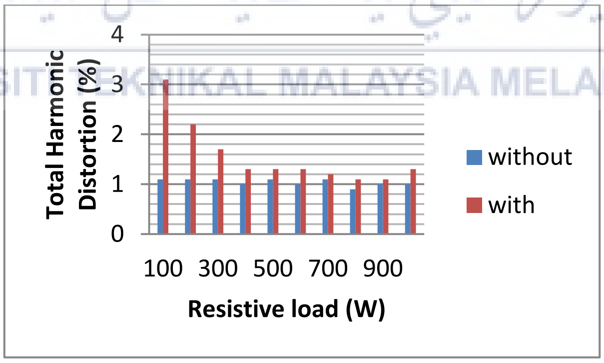

Figure 4.45: Comparison of total harmonic distortion without and with energy saver.

Based on collected data during experimental test 2 on device 2, the data have been analyzed by graphical method comparison of two different condition of the system which is without energy saver and with energy saver. The data had been analyzed still same as experimental test 1 as shown in figure 4.41, 4.42, 4.43, 4.44 and 4.45. For pure resistive load, current in the system with and without energy saver on have a few difference. The current is lower during without energy saver due to power factor is reduce when the system with energy saver. For active power consume there are not change weather the system with energy saver or without energy saver but the reactive power increased drastically almost 70% when the system with energy saver. The THD of the system also increased when the system with energy saver but when load at 800W the THD does not change at all.

II. Pure inductive load

Table 4.10: Measurement data for pure inductive load.

Inductive Load Bank (W)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	252.2	254.4	0.43	0.20	15	15	108	47	0.14	0.29	3.1	10.7
200	252.0	252.3	0.88	0.64	24	23	223	162	0.11	0.14	2.1	4.1
300	252.1	352.0	1.33	1.00	38	37	334	272	0.11	0.14	2.6	3.6
400	251.8	252.0	1.60	1.36	37	36	404	342	0.09	0.10	2.3	3.1
500	252.3	251.8	2.17	1.92	44	43	547	483	0.08	0.09	2.1	2.4
600	251.7	251.7	2.60	2.36	59	58	652	593	0.09	0.10	2.2	2.5
700	251.9	251.9	3.06	2.82	69	68	770	708	0.09	0.10	1.9	2.3
800	251.6	252.4	3.50	3.27	84	84	881	818	0.10	0.10	2.2	2.4
900	251.9	251.8	4.00	3.76	96	94	1000	944	0.09	0.10	2.2	2.6
1000	251.9	252.0	4.26	4.01	94	94	1070	1010	0.09	0.09	2.1	2.4

Comparison by calculation for highest load:

L = 1000VAR V = 250V P = 94W Q = 1070VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{94+j1070}{250} = 4.296\ A\ \llcorner 84.979^0$ p.f = CosΘ = Cos(84.979) = 0.087

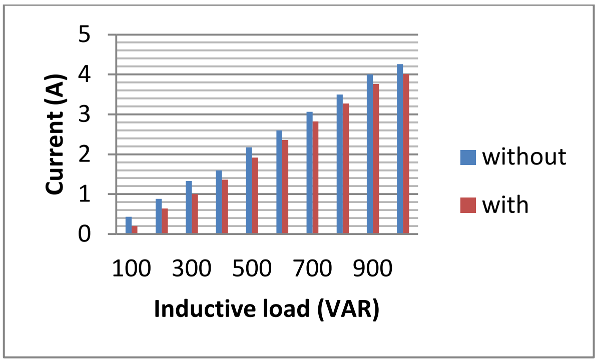

Figure 4.46: Comparison of current values without and with energy saver

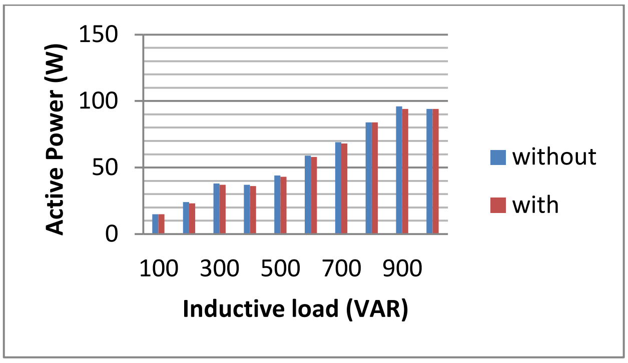

Figure 4.47: Comparison of active power values without and with energy saver

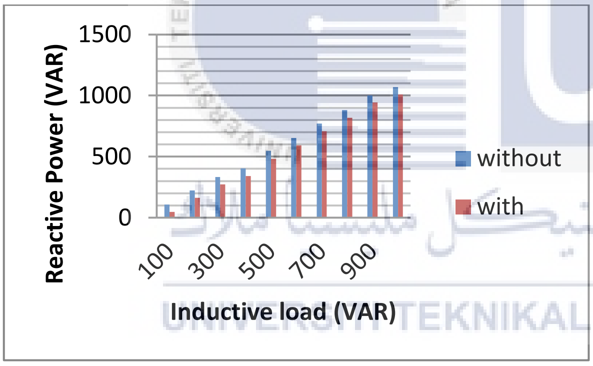

Figure 4.48: Comparison of reactive power values without and with energy saver.

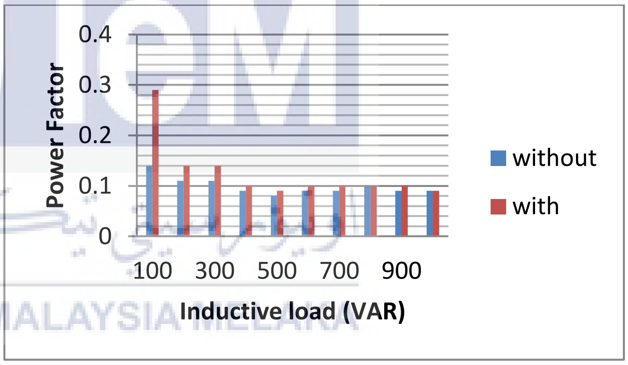

Figure 4.49: Comparison of power factor without and with energy saver.

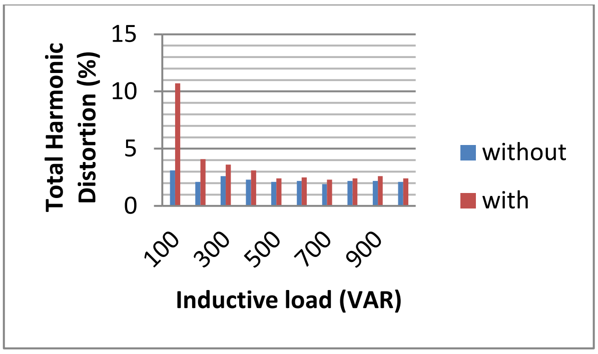

Figure 4.50: Comparison of total harmonic distortion without and with energy saver.

During pure inductive load test, the collected data has been analyzed by refer the graph shown in figure 4.46, 4.47, 4.48, 4.49 and 4.50. By referring the graph of current, current in system during pure inductive load shown the current of the is decrease when energy saver is applied because the power factor is increase when the system with energy saver. Active powers still remain unchanged weather the system with energy saver or without it. When the power factor is increase while the system with energy saver, it drive the decreasing of reactive power which means reduce losses in the system. The THD of the system also increased when the system with energy saver, but when the inductive load in the system become higher, the difference of increasing THD becomes smaller.

III. Resistive load parallel connection with inductive load

a) Resistive load equal to inductive load (W =VAR)

Table 4.11: Measurement data for resistive load equal to inductive load.

Resistive (W) = Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	252.0	251.7	0.64	0.51	124	123	105	45	0.77	0.94	2.1	4.6
200	2250.7	251.1	1.27	1.12	237	236	215	155	0.74	0.84	1.7	2.4
300	250.0	250.1	1.90	1.75	354	352	320	260	0.74	0.81	2.1	2.4
400	249.1	249.1	2.38	2.23	455	453	383	323	0.77	0.81	1.8	2.0
500	248.6	248.6	2.99	2.82	537	535	517	457	0.72	0.76	1.4	1.5
600	247.8	247.8	3.60	3.44	651	650	614	555	0.73	0.76	1.6	1.7
700	247.7	247.9	4.13	3.95	720	717	725	667	0.70	0.73	1.7	1.7
800	247.6	247.7	4.72	4.56	828	827	826	768	0.71	0.73	1.7	1.8
900	245.9	245.7	5.52	5.15	926	922	926	867	0.71	0.73	1.6	1.8
1000	245.3	245.5	5.76	5.60	1020	1020	980	920	0.72	0.74	1.5	1.6

Comparison by calculation for highest load:

R= 1000W   L = 1000VAR   V = 250V   P = 1020W   Q = 980VAR

S = IV   S = P + jQ

$I = \frac{S}{V} = \frac{1020+j980}{250} = 5.657\ A\ \angle 43.85^0$ p.f = CosΘ = Cos(43.85) = 0.721

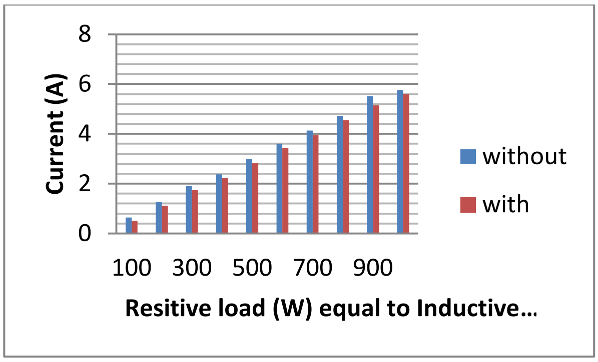

Figure 4.51: Comparison of current values without and with energy saver

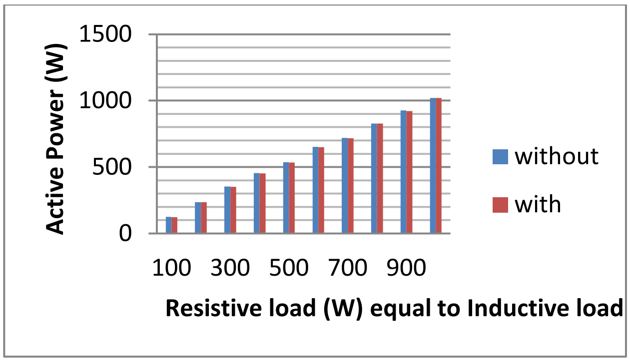

Figure 4.52: Comparison of active power values without and with energy saver

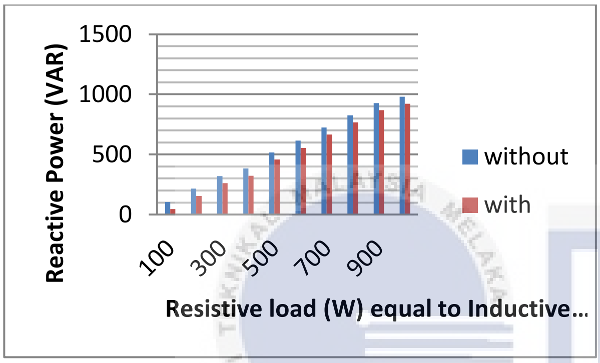

Figure 4.53: Comparison of reactive power values without and with energy saver.

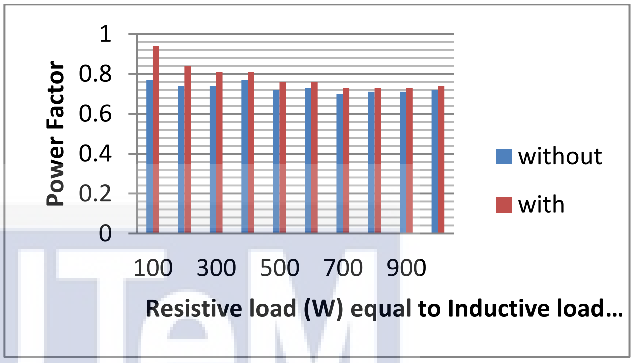

Figure 4.54: Comparison of power factor without and with energy saver.

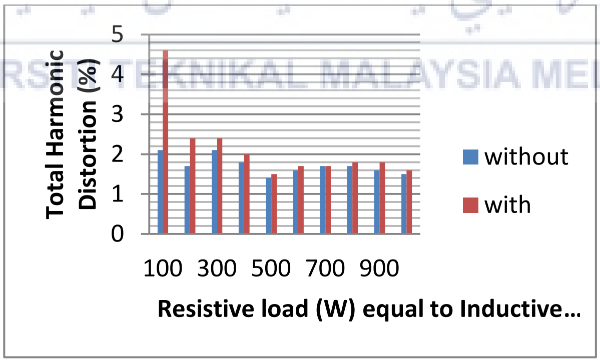

Figure 4.55: Comparison of total harmonic distortion without and with energy saver.

For parallel connection load of the resistive load equal to inductive load, the data had been analyzed base on graph as shown in figure 4.51, 4.52, 4.53, 4.54 and 4.55. For the current of the system during this part, when the system with energy saver, the current was reduce due to the increasing of power factor but the active power still shown no differences between system without energy saver and system with energy saver. By the way, the reactive power has decrease when the system with energy saver due the increasing of power factor in the system. Meanwhile THD in the system also increase when the system installed by energy saver.

b) Resistive load greater than inductive load (W > VAR)

Table 4.12: Measurement data for resistive load greater than inductive load.

Resistive (W) > Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 // 50	249.5	249.4	0.49	0.45	114	113	48	15	0.92	0.98	1.8	4.3
200 / / 50	248.8	249.2	0.89	0.88	217	216	47	16	0.98	1	1.2	2.5
300 // 50	248.6	248.7	1.30	1.29	320	319	45	17	0.99	1	1.3	2.3
400 // 100	248.3	248.3	1.78	1.73	430	429	97	39	0.98	1	1.3	2.0
500 // 100	248.0	247.9	2.09	2.04	510	505	95	37	0.98	1	1.2	1.6
600 // 100	247.6	247.4	2.48	2.45	607	606	93	35	0.99	1	1.1	1.4
700 // 200	246.9	247.0	2.82	2.75	667	664	201	142	0.96	0.98	1.1	1.5
800 // 200	246.5	246.8	3.19	3.14	761	764	197	140	0.97	0.98	1.1	1.2
900 // 200	246.2	246.1	3.58	3.53	860	859	195	133	0.98	0.99	1.0	1.2
1000//300	245.7	245.0	4.12	4.06	971	972	295	239	0.96	0.97	1.2	1.4

Comparison by calculation for highest load:

R= 1000W L = 300VAR V = 250V P = 971W Q = 295VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{971+j295}{250} = 4.059\ A \llcorner 16.89^0$ p.f = CosΘ = Cos(16.89) = 0.956

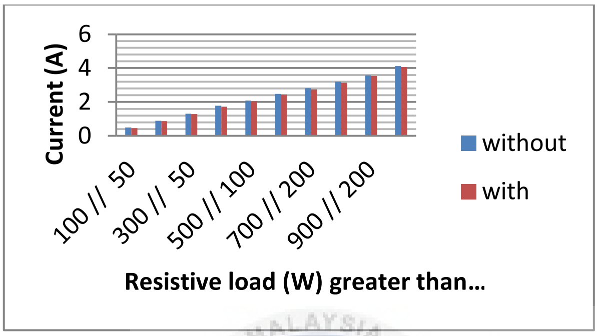

Figure 4.56: Comparison of current values without and with energy saver

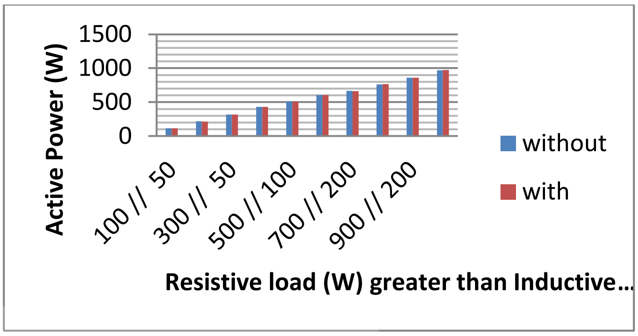

Figure 4.57: Comparison of active power values without and with energy saver

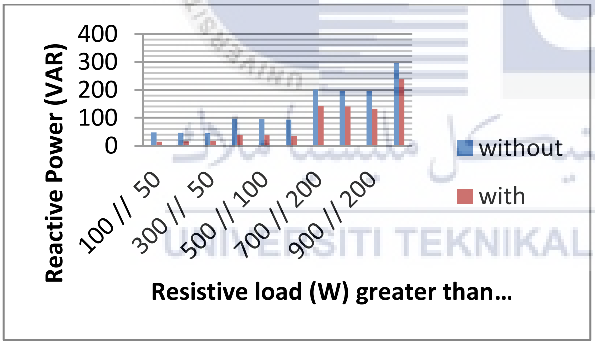

Figure 4.58: Comparison of reactive power values without and with energy saver.

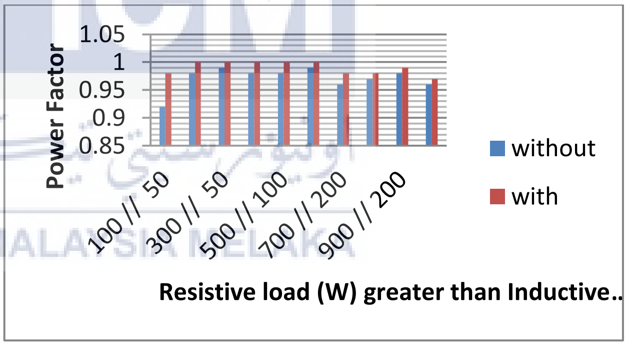

Figure 4.59: Comparison of power factor without and with energy saver.

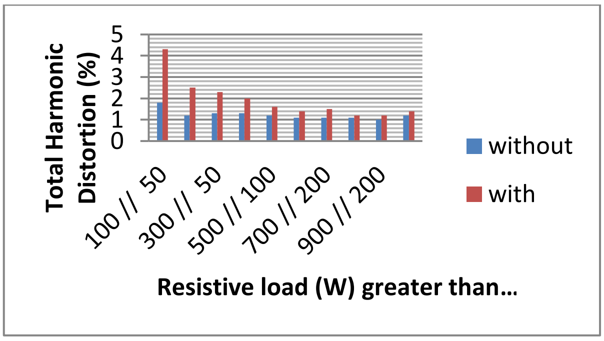

Figure 4.60: Comparison of total harmonic distortion without and with energy saver.

In figure 4.56, 4.57, 4.58, 4.59 and 4.60 show the graphs of analyzed measurement data for part resistive load greater than inductive load of parallel connection load. The current of the system during this part show the differences of decreasing when the system with energy saver due the increasing of power factor in the system and also make the reactive power of the system decrease. Active power of the system remains unchanged whether the system without energy saver or with energy saver. THD of the system is increased when the system with energy saver.

c) Inductive load greater than resistive load k (VAR > W)

Table 4.13: Measurement data for inductive load greater than inductive load.

Inductive (VAR) > Resistive (W)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 // 50	250.3	250.3	0.49	0.31	67	66	105	46	0.54	0.82	2.6	7.0
200 // 50	250.1	249.9	0.92	0.69	76	75	218	158	0.33	0.43	2.1	4.0
300 // 50	249.8	250.0	1.35	1.12	89	89	327	267	0.26	0.32	2.7	3.5
400 // 100	249.7	249.7	1.67	1.45	144	143	393	334	0.34	0.40	2.3	3.0
500 // 100	249.2	249.3	2.21	1.98	151	145	529	471	0.27	0.30	1.9	2.3
600 // 100	249.2	249.3	2.63	2.40	165	164	637	577	0.25	0.28	2.1	2.4
700 // 200	249.1	249.3	3.19	2.97	278	247	745	686	0.35	0.38	1.8	2.1
800 // 200	249.1	249.0	3.62	3.39	293	292	852	793	0.33	0.39	2.0	2.4
900 // 200	249.1	249.0	4.09	3.87	303	301	975	913	0.30	0.31	2.1	2.3
1000//300	248.8	248.8	4.45	4.23	406	405	1030	972	0.37	0.38	2.2	2.3

Comparison by calculation for highest load:

R= 300W L = 1000VAR V = 250V P = 406W Q = 1030VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{406 + j1030}{250} = 4.428\ A\ \angle 68.48^0$ p.f = CosΘ = Cos(68.48) = 0.366

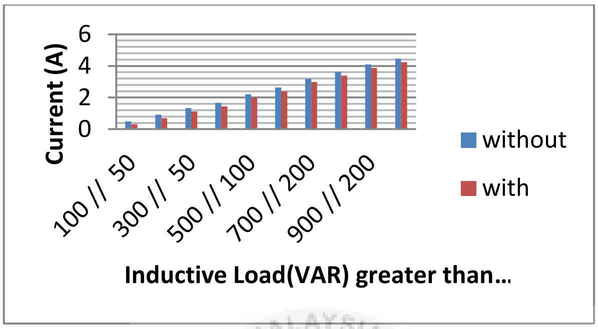

Figure 4.61: Comparison of current values without and with energy saver

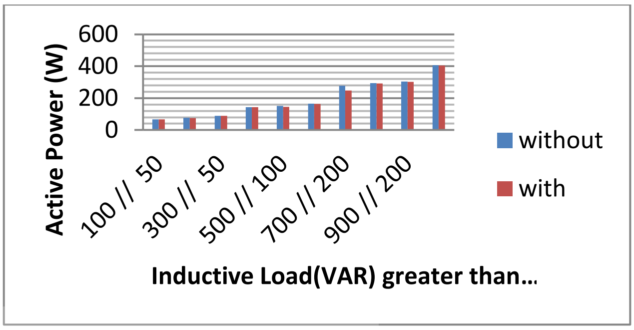

Figure 4.62: Comparison of active power values without and with energy saver

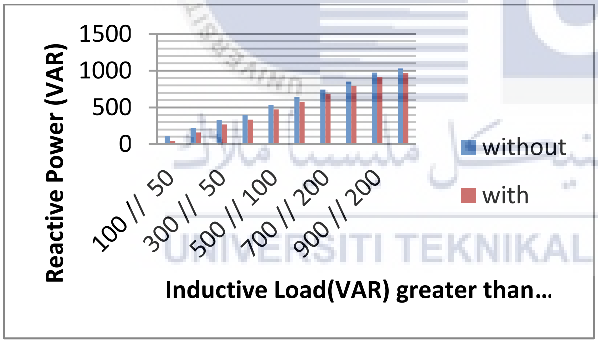

Figure 4.63: Comparison of reactive power values without and with energy saver.

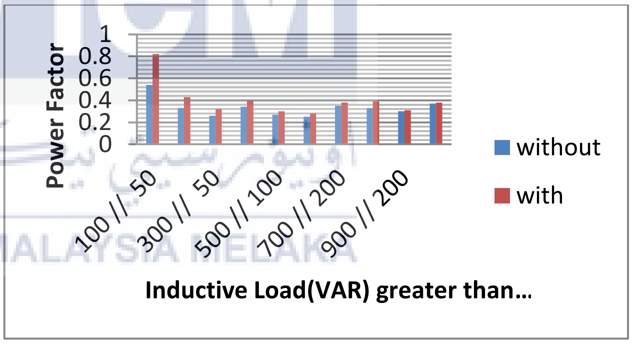

Figure 4.64: Comparison of power factor without and with energy saver.

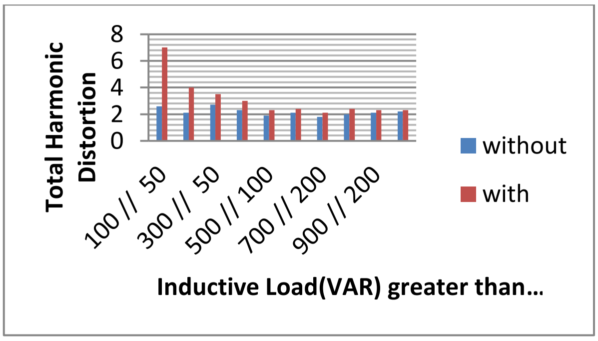

Figure 4.65: Comparison of total harmonic distortion without and with energy saver.

In this part, inductive load greater than resistive load in parallel connection in the system. The data had been analyzed base on graphical method as shown in figure 4.61, 4.62, 4.63, 4.64 and 4.65 based on recorded collected data. The current of the system is reducing when the system with energy saver because the rising power factor and it also cause the reactive power in the system is decrease. Active power in this part still remains unchanged. The THD of the system is increase when the system with energy saver.

IV. Resistive load series with inductive load

a) Resistive load bank equal to inductive load (W =VAR)

Table 4.14: Measurement data for resistive load equal to inductive load.

Resistive (W) = Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	252.2	252.2	0.28	0.21	55	53	46	16	0.77	0.96	2.7	6.8
200	252.5	252.7	0.58	0.46	113	111	96	34	0.76	0.96	2.3	4.2
300	251.8	252.3	0.86	0.73	167	166	142	81	0.76	0.90	2.8	3.7
400	252.4	252.5	1.12	0.96	204	203	197	135	0.72	0.83	2.8	3.5
500	252.2	252.1	1.43	1.27	266	264	245	183	0.74	0.82	2.7	2.9
600	251.9	251.6	1.71	1.55	319	318	292	237	0.74	0.81	2.8	3.0
700	251.3	251.7	1.93	1.78	377	376	308	246	0.78	0.84	2.3	2.6
800	251.4	251.2	2.21	2.06	431	429	353	291	0.77	0.83	2.4	2.6
900	250.8	250.9	2.51	2.36	489	489	490	338	0.78	0.82	2.6	2.7
1000	250.8	250.9	2.75	2.60	524	523	451	391	0.76	0.80	2.5	2.7

Comparison by calculation for highest load:

R= 1000W L = 1000VAR V = 250V P = 524W Q = 451VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{524+j451}{250} = 2.765\ A \llcorner 40.71^0$ p.f = CosΘ = Cos(40.71) = 0.758

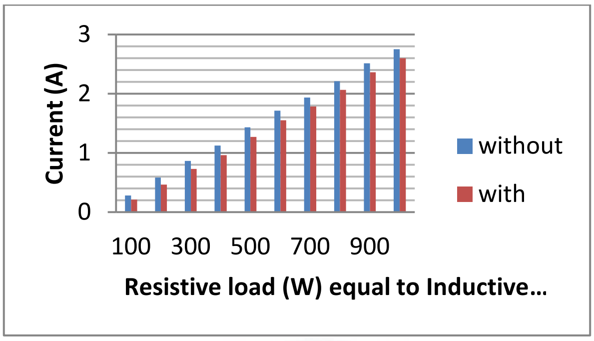

Figure 4.66: Comparison of current values without and with energy saver

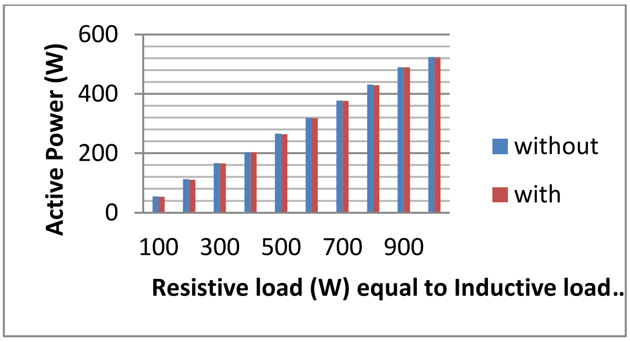

Figure 4.67: Comparison of active power values without and with energy saver

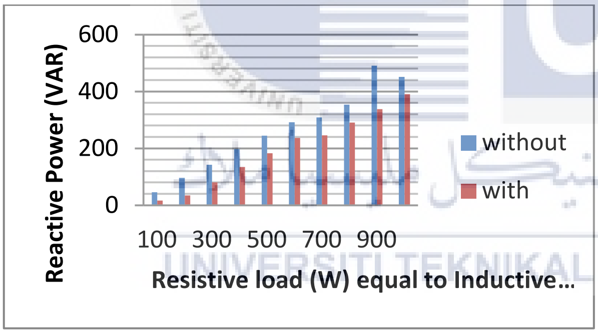

Figure 4.68: Comparison of reactive power values without and with energy saver.

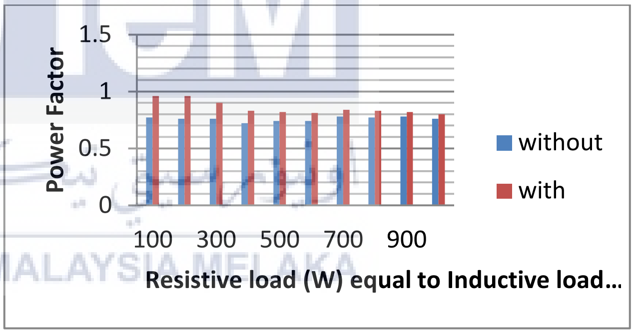

Figure 4.69: Comparison of power factor without and with energy saver.

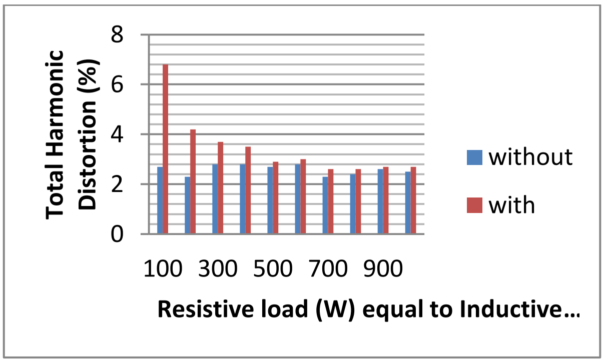

Figure 4.70: Comparison of total harmonic distortion without and with energy saver.

In series connected load also divide by three different parts. For this part, resistive load equal to inductive load. The data has been analyzed by the graphical method as shown in figure 4.66, 4.67, 4.68, 4.69 and 4.70. Current of the system is decrease when the system with energy saver due to the improvement of the power factor and also reduce the reactive power of the system. Active power still remains unchanged whether the system without energy saver or with energy saver. THD of the system is increase when the system installed by energy saver.

b) Resistive load greater than inductive load (W > VAR)

Table 4.15: Measurement data for resistive load greater than inductive load.

Resistive (W) > Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 + 50	253.5	253.1	0.180	0.132	25	22	38	26	0.56	0.67	3.0	14.9
200 + 50	253.1	252.8	0.199	0.096	20	18	46	18	0.39	0.68	3.5	18.7
300 + 50	253.1	252.8	0.204	0.083	16	13	49	16	0.32	0.65	2.7	24.7
400 + 100	252.8	252.8	0.409	0.205	39	38	96	35	0.38	0.73	2.9	10.1
500 + 100	252.9	252.9	0.415	0.202	36	34	99	38	0.34	0.68	2.9	10.2
600 + 100	253.0	253.1	0.420	0.202	33	32	101	40	0.31	0.62	2.9	10.2
700 + 200	252.2	252.4	0.827	0.610	85	84	190	129	0.41	0.54	2.2	3.9
800 + 200	253.0	252.4	0.842	0.618	79	78	198	135	0.37	0.50	2.1	3.8
900 + 200	252.5	251.9	0.850	0.623	73	72	202	139	0.34	0.46	2.2	4.0
1000+300	252.0	252.9	1.230	1.013	128	128	282	222	0.41	0.50	2.7	3.6

Comparison by calculation for highest load:

R= 1000W   L = 300VAR   V = 250V   P = 128W   Q = 282VAR

S = IV   S = P + jQ

$I = \frac{S}{V} = \frac{128 + j282}{250} = 1.238\ A\ \angle 65.58^{0}$ p.f = CosΘ = Cos(65.58) = 0.413

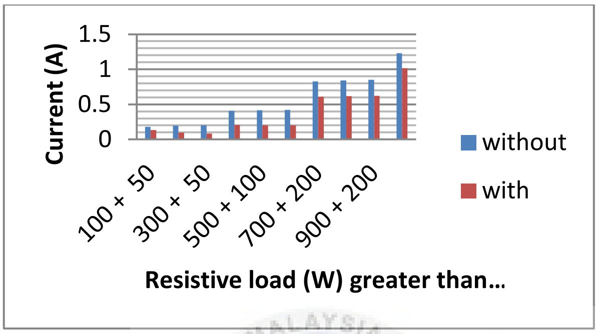

Figure 4.71: Comparison of current values without and with energy saver

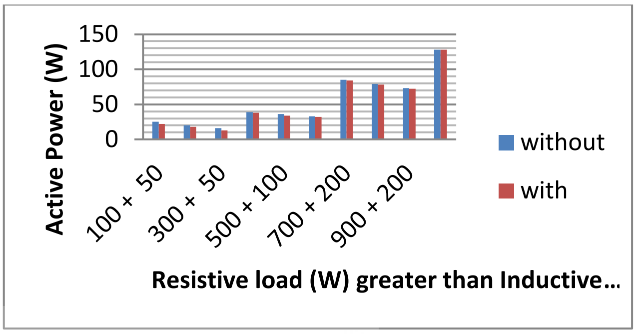

Figure 4.72: Comparison of active power values without and with energy saver

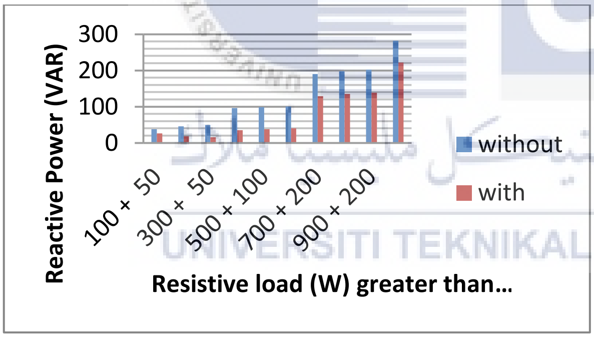

Figure 4.73: Comparison of reactive power values without and with energy saver.

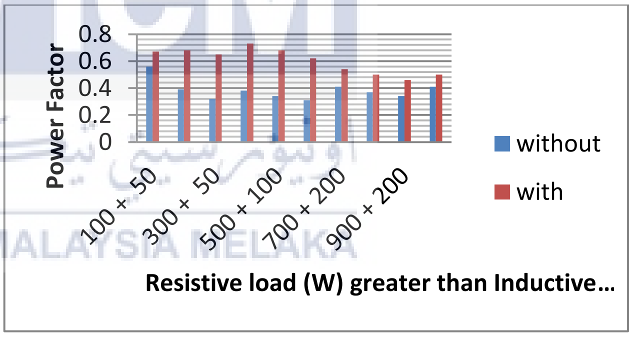

Figure 4.74: Comparison of power factor without and with energy saver.

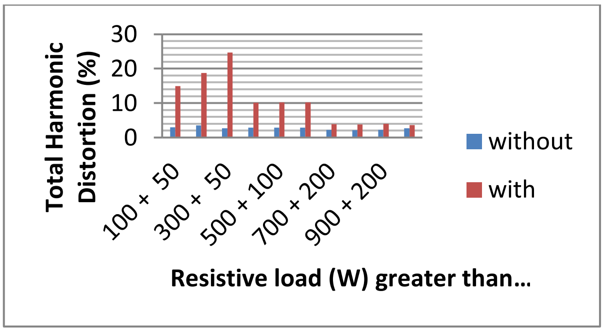

Figure 4.75: Comparison of total harmonic distortion without and with energy saver.

In this part, resistive load greater than inductive load in series connection. The data had been analyzed by referring on graph shown in figure 4.71, 4.72, 4.73, 4.74 and 4.75. Current in the system is reduce when the system with energy saver. This is because the energy saver has improved the power factor of the system and it's also drive the decreasing of reactive power in the system. For this part also, the active power still remains unchanged whether the system without energy saver or with energy saver and THD in the system still increased when the energy saver is installed to the system.

c) Inductive load greater than resistive load (VAR > W)

Table 4.16: Measurement data for inductive load greater than inductive load.

Inductive (VAR) > Resistive (W)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 + 50	252.8	252.5	0.175	0.234	41	39	17	44	0.93	0.66	2.7	6.0
200 + 50	252.7	252.6	0.196	0.278	49	47	9	52	0.98	0.67	1.2	4.9
300 + 50	252.5	252.3	0.200	0.296	50	49	6	55	0.99	0.66	1.0	4.6
400 + 100	252.4	252.4	0.407	0.415	100	98	26	37	0.97	0.94	1.6	3.4
500 + 100	252.1	251.8	0.415	0.435	103	101	20	42	0.98	0.92	1.4	3.5
600 + 100	252.1	251.9	0.421	0.449	105	104	16	46	0.99	0.92	1.4	3.2
700 + 200	251.4	251.7	0.800	0.772	194	193	53	13	0.97	1.0	1.9	2.4
800 + 200	251.7	251.6	0.806	0.784	197	196	47	17	0.97	1.0	1.8	2.1
900 + 200	251.3	251.3	0.826	0.821	205	204	31	31	0.99	1.0	1.1	4.7
1000+300	251.0	251.1	1.184	1.137	285	284	85	26	0.96	1.0	2.1	2.1

Comparison by calculation for highest load:

R= 300W L = 1000VAR V = 250V P = 285W Q = 85VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{285+j85}{250} = 1.189\ A\ \llcorner 16.61^0$ p.f = CosΘ = Cos(16.61) = 0.958

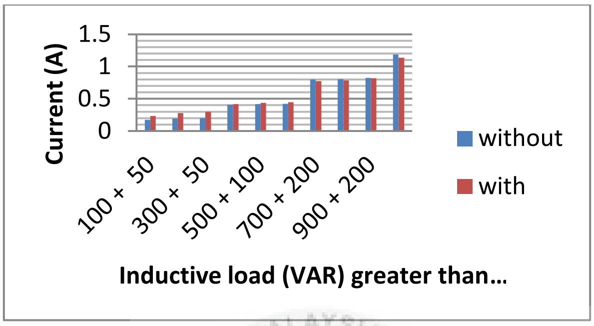

Figure 4.76: Comparison of current values without and with energy saver

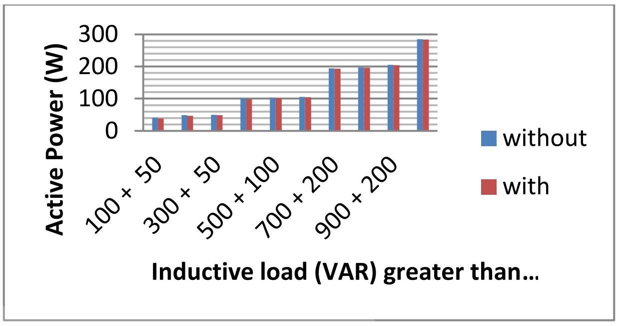

Figure 4.77: Comparison of active power values without and with energy saver

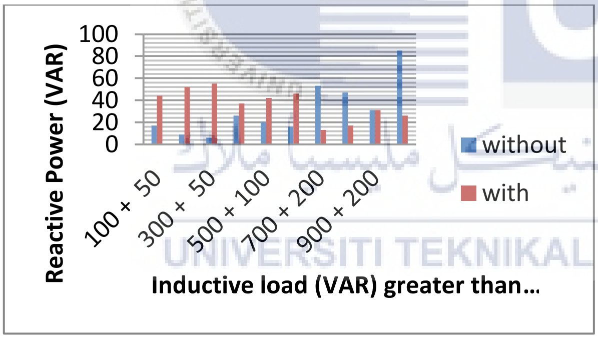

Figure 4.78: Comparison of reactive power values without and with energy saver.

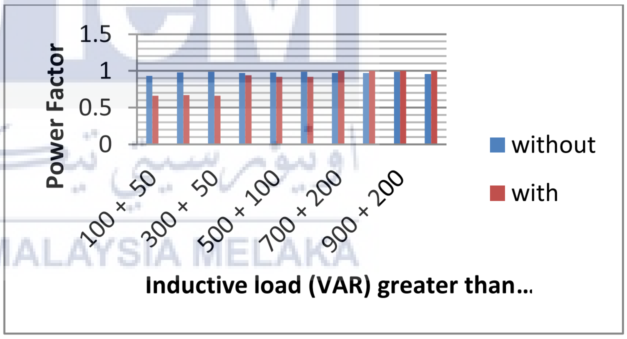

Figure 4.79: Comparison of power factor without and with energy saver.

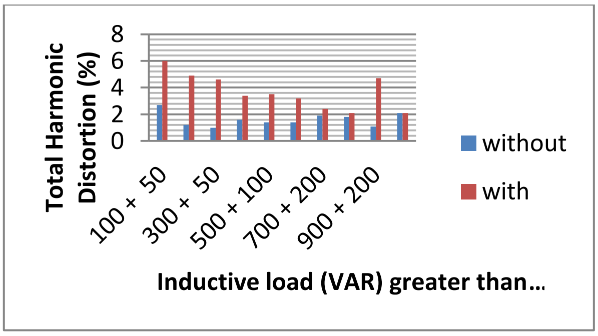

Figure 4.80: Comparison of total harmonic distortion without and with energy saver.

For the part of the inductive load greater than inductive load in series connection. Figure 4.76, 4.77, 4.78, 4.79 and 4.80 shows the graph of the analyzing data. The current of the system during this part is reducing when the system with energy saver due to the improvement of power factor of the system when the energy saver installed in the system and it also makes the reactive power decrease. The active power remains unchanged whether the system without energy saver or with energy saver. THD of the system still increase when the system is installed by the energy saver.

4.1.3 Experimental test 3

I. Pure resistive load

Table 4.17: Measurement data for pure resistive load.

Resistive Load Bank (W)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	252.0	250.8	0.43	0.65	109	107	3	125	1	0.65	1.1	6.2
200	251.4	250.8	0.88	0.98	214	212	5	127	1	0.86	1.1	4.3
300	250.5	250.1	1.27	1.36	318	316	7	128	1	0.93	1.1	3.4
400	250.7	249.4	1.69	1.76	425	420	8	129	1	0.96	1.0	2.4
500	250.3	248.9	2.00	2.07	506	498	10	130	1	0.97	1.1	2.3
600	250.0	248.4	2.42	2.47	606	601	11	131	1	0.98	1.0	2.1
700	250.3	248.4	2.66	2.70	666	659	12	131	1	0.98	1.1	2.0
800	249.5	248.0	3.05	3.09	761	756	12	132	1	0.99	0.9	1.9
900	248.8	247.5	3.44	3.48	857	850	14	133	1	0.99	1.0	1.8
1000	248.2	248.2	3.85	3.88	955	952	14	134	1	0.99	1.0	1.7

Comparison by calculation for highest load:

R= 1000W   V = 250V   P = 955W   Q = 14VAR

S = IV   S = P + jQ

$I = \frac{S}{V} = \frac{955+j14}{250} = 3.82\ A\ \llcorner 0.84^0$ p.f = CosΘ = Cos(0.84) = 0.99

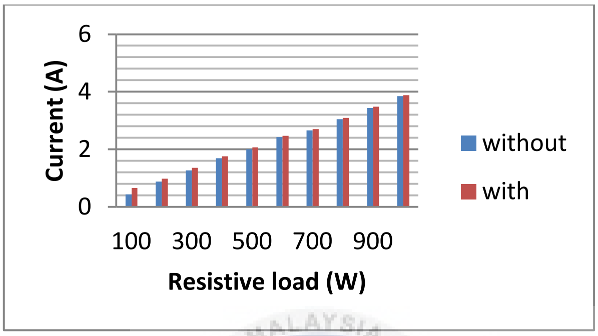

Figure 4.81: Comparison of current values without and with energy saver

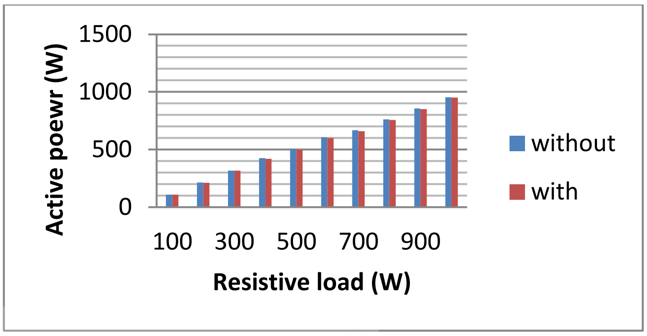

Figure 4.82: Comparison of active power values without and with energy saver

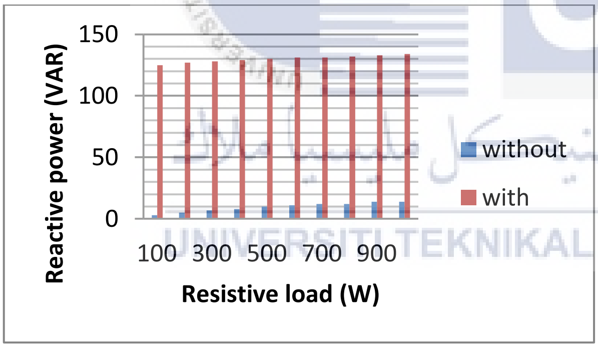

Figure 4.83: Comparison of reactive power values without and with energy saver.

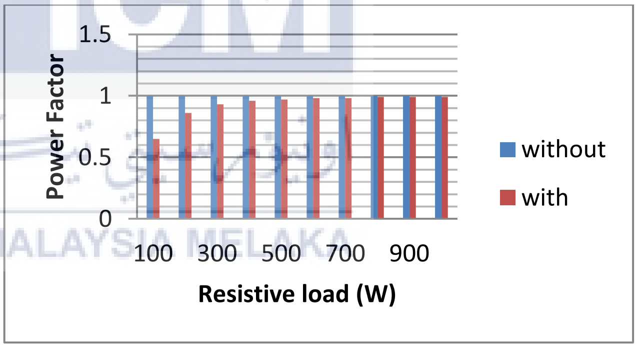

Figure 4.84: Comparison of power factor without and with energy saver.

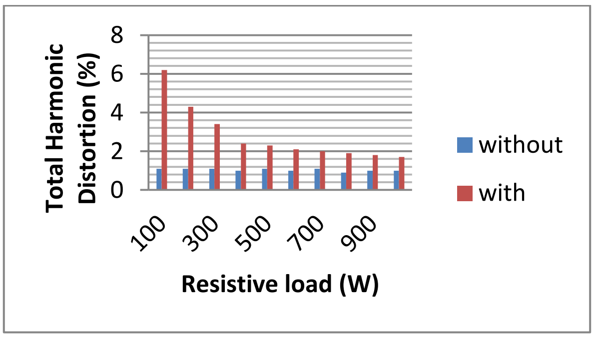

Figure 4.85: Comparison of total harmonic distortion without and with energy saver.

For the last experimental test, the data have been analyzed by graphical method comparison of two different condition of the system which is without energy saver and with energy saver. The data had been analyzed are current, active power, reactive power, power factor and THD. Figure 4.81, 4.82, 4.83, 4.84 and 4.85 show the data had been analyzed by using graphical method. For pure resistive load, there are a few differences between the system without and with energy saver due to the change in power factor is small. Base on the graph, reactive power is increase when the system with energy saver. For this part also, the active power remain unchanged whether the system without energy saver or with energy saver. The THD of the system also increased when the system with energy saver.

II. Pure inductive load

Table 4.18: Measurement data for pure inductive load.

Inductive Load Bank (W)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	252.2	251.2	0.43	0.10	15	12	108	23	0.14	0.47	3.1	25.1
200	252.0	251.3	0.88	0.41	24	22	223	100	0.11	0.22	2.1	11.2
300	252.1	251.2	1.33	0.84	38	37	334	210	0.11	0.17	2.6	6.3
400	251.8	251.1	1.60	1.12	37	35	404	279	0.09	0.12	2.3	5.1
500	252.3	251.0	2.17	1.67	44	42	547	419	0.08	0.10	2.1	3.3
600	251.7	250.9	2.60	2.11	59	56	652	527	0.09	0.11	2.2	3.2
700	251.9	250.8	3.06	2.58	69	66	770	644	0.09	0.10	1.9	2.8
800	251.6	250.6	3.50	2.58	84	81	881	753	0.10	0.11	2.2	2.9
900	251.9	250.7	4.00	3.01	96	91	1000	875	0.09	0.10	2.2	2.9
1000	251.9	250.9	4.26	3.50	94	91	1070	939	0.09	0.10	2.1	2.8

Comparison by calculation for highest load:

L = 1000VAR V = 250V P = 94W Q = 1070VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{94+j1070}{250} = 4.296\ A \angle 84.979^0$ p.f = CosΘ = Cos(84.979) = 0.087

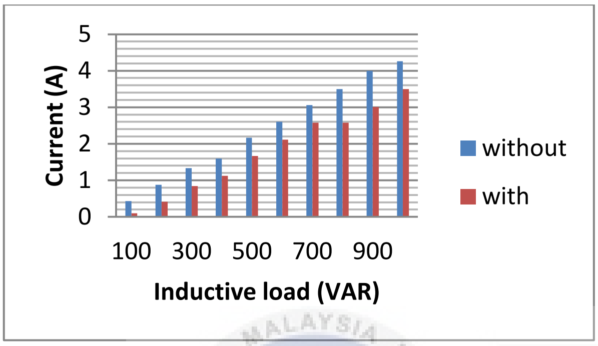

Figure 4.86: Comparison of current values without and with energy saver

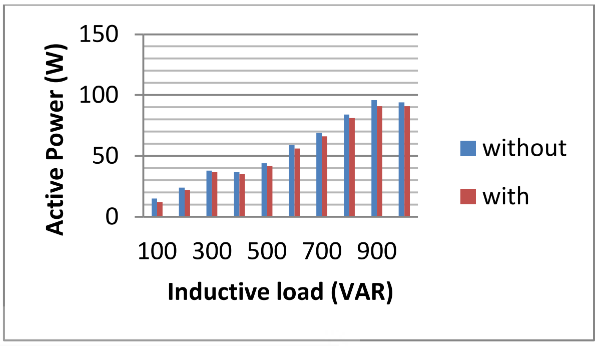

Figure 4.87: Comparison of active power values without and with energy saver

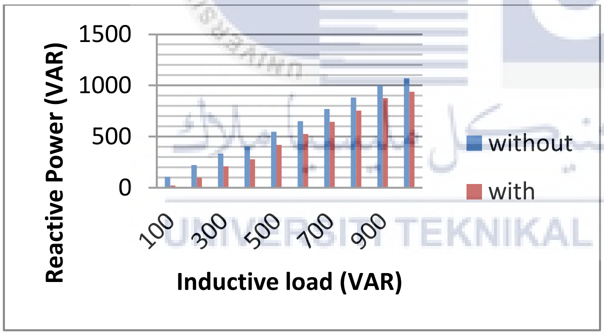

Figure 4.88: Comparison of reactive power values without and with energy saver.

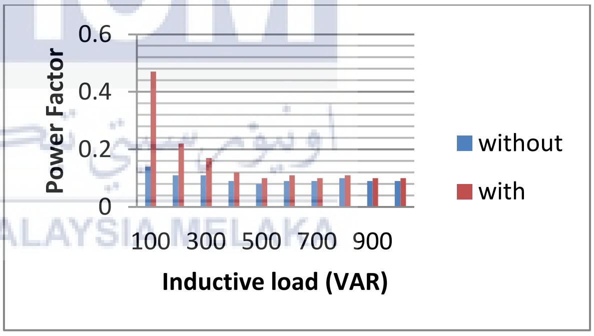

Figure 4.89: Comparison of power factor without and with energy saver.

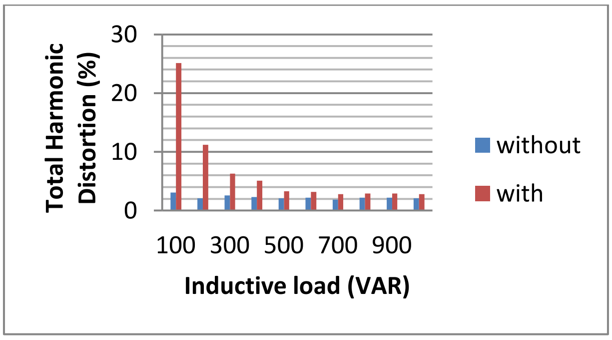

Figure 4.90: Comparison of total harmonic distortion without and with energy saver.

For inductive load, base on the collected data has been analyzed base on graphical method as shown in figure 4.86, 4.87, 4.88, 4.89 and 4.90 the current of system is decrease when energy saver is applied in the system due to the increasing in power factor and it also reduce the reactive power. Active powers not have much difference whether the system without energy saver or with energy saver and it can assume no changing. The THD also increased when the system with energy saver, but when the inductive load in the system become higher, the difference of increasing THD becomes smaller.

<u>III. Resistive load parallel connection with inductive load</u>

a) Resistive load equal to inductive load (W =VAR)

Table 4.19: Measurement data for resistive load equal to inductive load.

Resistive (W) = Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	252.0	251.1	0.64	0.49	124	121	105	20	0.77	0.98	2.1	7.7
200	2250.7	250.6	1.27	1.01	237	235	215	96	0.74	0.93	1.7	4.1
300	250.0	250.0	1.90	1.61	354	351	320	200	0.74	0.87	2.1	2.3
400	249.1	248.8	2.38	2.09	455	449	383	263	0.77	0.86	1.8	2.6
500	248.6	248.5	2.99	2.67	537	532	517	397	0.72	0.80	1.4	2.0
600	247.8	247.9	3.60	3.29	651	649	614	497	0.73	0.76	1.6	2.1
700	247.7	247.9	4.13	3.78	720	714	725	608	0.70	0.76	1.7	2.0
800	247.6	247.5	4.72	4.39	828	825	826	708	0.71	0.76	1.7	2.1
900	245.9	245.6	5.52	4.98	926	920	926	808	0.71	0.75	1.6	2.0
1000	245.3	245.3	5.76	5.44	1020	1020	980	860	0.72	0.76	1.5	1.6

Comparison by calculation for highest load:

R= 1000W L = 1000VAR V = 250V P = 1020W Q = 980VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{1020+j980}{250} = 5.657\ A\ \llcorner 43.85^{0}$ p.f = CosΘ = Cos(43.85) = 0.721

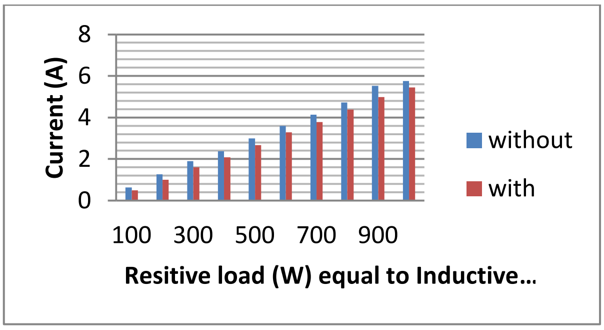

Figure 4.91: Comparison of current values without and with energy saver

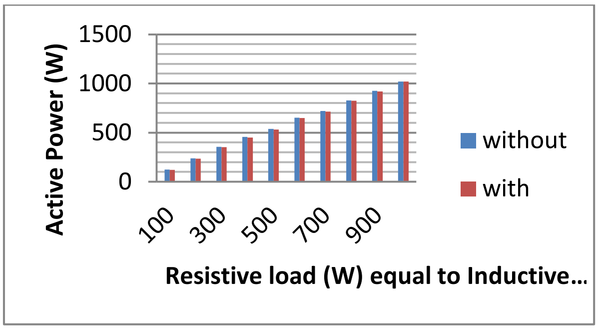

Figure 4.92: Comparison of active power values without and with energy saver

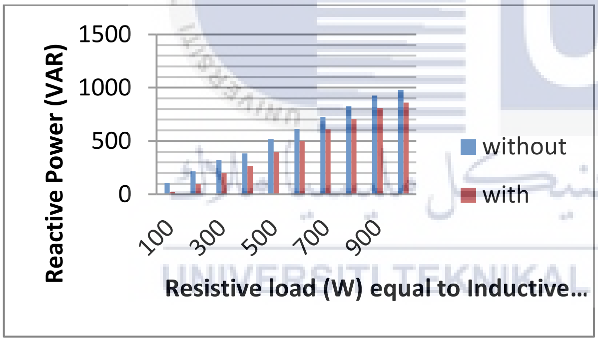

Figure 4.93: Comparison of reactive power values without and with energy saver.

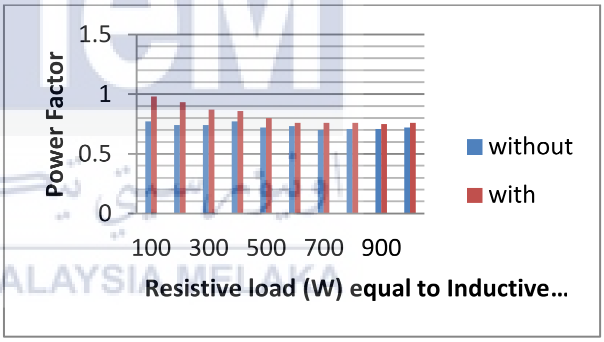

Figure 4.94: Comparison of power factor without and with energy saver.

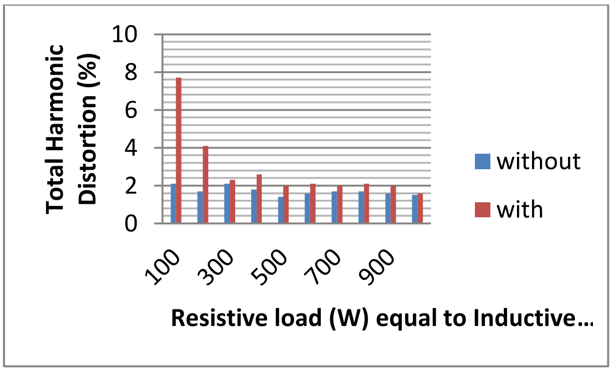

Figure 4.95: Comparison of total harmonic distortion without and with energy saver.

For this part, parallel connection load has been applied in the system, there are three different parts. For this part, resistive load equal to inductive load and the measured data has been recorded in table 4.3. The graphs on figure 4.91, 4.92, 4.33, 4.94 and 4.95 had shown the analyzed of measurement data. The current of the system during this part is reducing when the system with energy saver due to the increasing of power factor. Meanwhile the graph of active power shown there are no differences between system without energy saver and system with energy saver. By the way, the reactive power has decrease when the system with energy saver. THD in the system still increase when the system is installed by energy saver.

b) Resistive load greater than inductive load (W > VAR)

Table 4.20: Measurement data for resistive load greater than inductive load.

Resistive (W) > Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 // 50	249.5	249.7	0.49	0.53	114	112	48	73	0.92	0.84	1.8	7.7
200 / / 50	248.8	249.1	0.89	0.91	217	216	47	75	0.98	0.95	1.2	4.1
300 // 50	248.6	248.8	1.30	1.31	320	319	45	76	0.99	0.917	1.3	3.3
400 // 100	248.3	248.2	1.78	1.72	430	427	97	27	0.98	1	1.3	2.6
500 // 100	248.0	248.1	2.09	2.03	510	503	95	28	0.98	1	1.2	2.0
600 // 100	247.6	247.3	2.48	2.44	607	605	93	30	0.99	1	1.1	2.1
700 // 200	246.9	247.1	2.82	2.70	667	662	201	85	0.96	0.99	1.1	2.0
800 // 200	246.5	246.7	3.19	3.10	761	761	197	83	0.97	0.99	1.1	2.1
900 // 200	246.2	246.0	3.58	3.50	860	856	195	80	0.98	1	1.0	2.0
1000//300	245.7	246.2	4.12	4.01	971	972	295	182	0.96	0.98	1.2	1.6

Comparison by calculation for highest load:

R= 1000W L = 300VAR V = 250V P = 971W Q = 295VAR

S = IV S = P + jQ

$$I = \frac{S}{V} = \frac{971 + j295}{250} = 4.059\ A\ \llcorner 16.899^{0} \qquad p.f = Cos\Theta = Cos(16.899) = 0.956$$

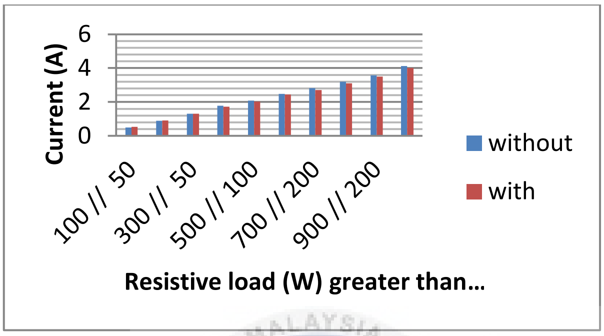

Figure 4.96: Comparison of current values without and with energy saver

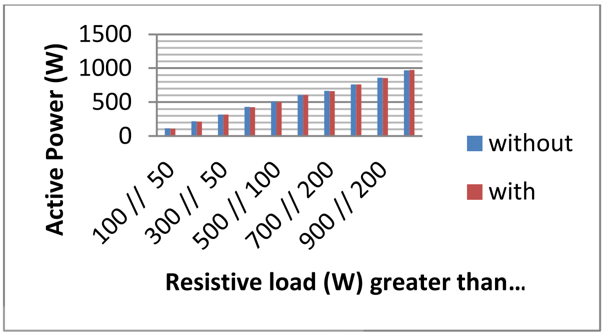

Figure 4.97: Comparison of active power values without and with energy saver

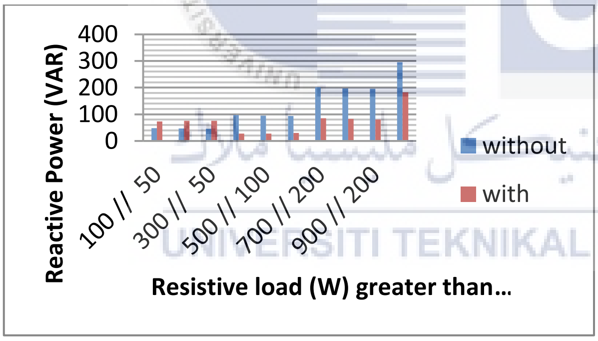

Figure 4.98: Comparison of reactive power values without and with energy saver.

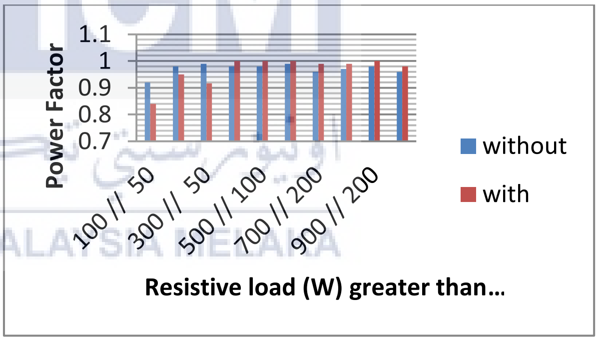

Figure 4.99: Comparison of power factor without and with energy saver.

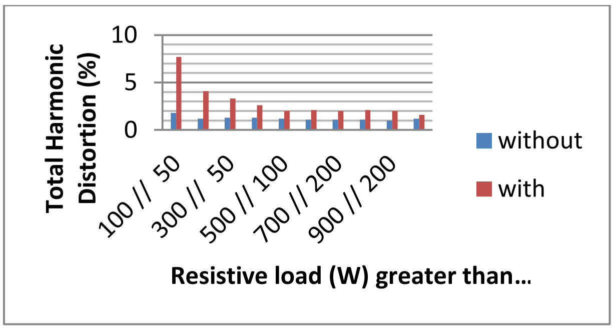

Figure 4.100: Comparison of total harmonic distortion without and with energy saver.

In figure 4.96, 4.97, 4.98, 4.99 and 4.100 show the graphs of analyzed measurement data for part resistive load greater than inductive load of parallel connection load. Current during this part show the differences of decreasing when the system with energy saver. This is because the power factor of the system is increase when the system with energy saver and make the reactive power of the system decrease. The active power of the system still remains and THD of the system is increased when the system with energy saver.

c) Inductive load greater than resistive load k (VAR > W)

Table 4.21: Measurement data for inductive load greater than inductive load.

Inductive (VAR) > Resistive (W)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 // 50	250.3	249.9	0.49	0.27	67	64	105	24	0.54	0.94	2.6	16.1
200 // 50	250.1	249.9	0.92	0.49	76	74	218	98	0.33	0.60	2.1	8.5
300 // 50	249.8	249.7	1.35	0.89	89	88	327	207	0.26	0.39	2.7	5.7
400 // 100	249.7	249.5	1.67	1.23	144	142	393	273	0.34	0.46	2.3	4.2
500 // 100	249.2	249.2	2.21	1.75	151	148	529	409	0.27	0.34	1.9	3.1
600 // 100	249.2	249.4	2.63	2.17	165	164	637	517	0.25	0.30	2.1	3.1
700 // 200	249.1	249.3	3.19	2.74	278	276	745	626	0.35	0.40	1.8	2.7
800 // 200	249.1	249.1	3.62	3.16	293	291	852	733	0.33	0.37	2.0	2.8
900 // 200	249.1	248.8	4.09	3.63	303	301	975	855	0.30	0.33	2.1	2.6
1000//300	248.8	248.7	4.45	4.00	406	404	1030	912	0.37	0.41	2.2	2.6

Comparison by calculation for highest load:

R= 300W   L = 1000VAR   V = 250V   P = 406W   Q = 1030VAR

S = IV   S = P + jQ

$I = \frac{S}{V} = \frac{406 + j1030}{250} = 4.42\ A\ \angle 68.48^0$ p.f = CosΘ = Cos(68.48) = 0.366

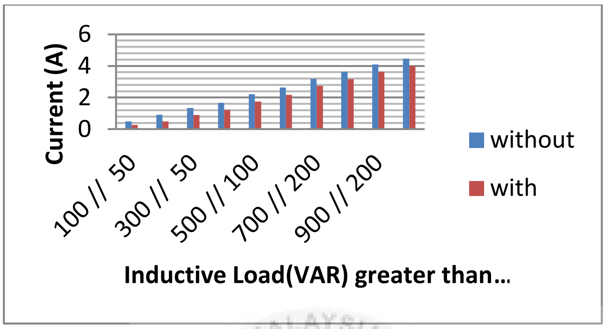

Figure 4.101: Comparison of current values without and with energy saver

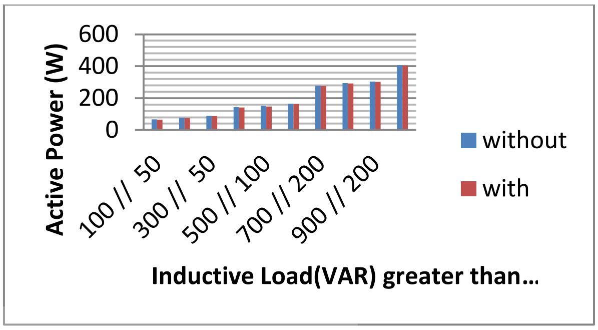

Figure 4.102: Comparison of active power values without and with energy saver

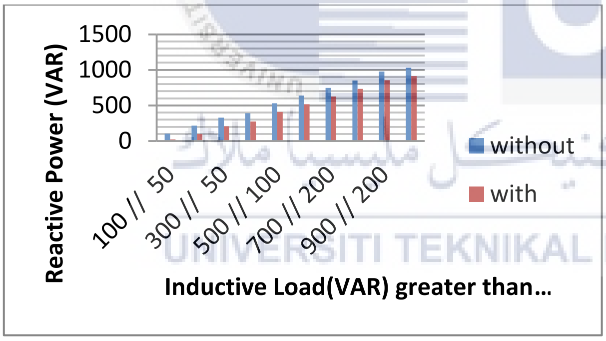

Figure 4.103: Comparison of reactive power values without and with energy saver.

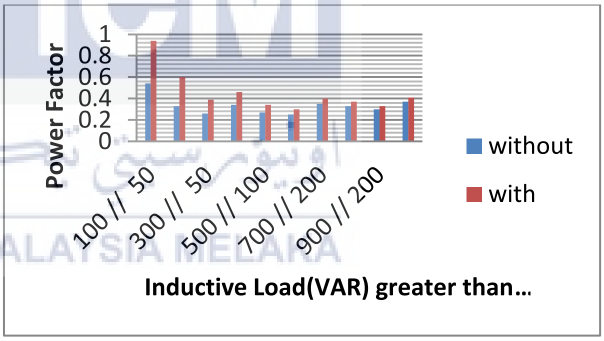

Figure 4.104: Comparison of power factor without and with energy saver.

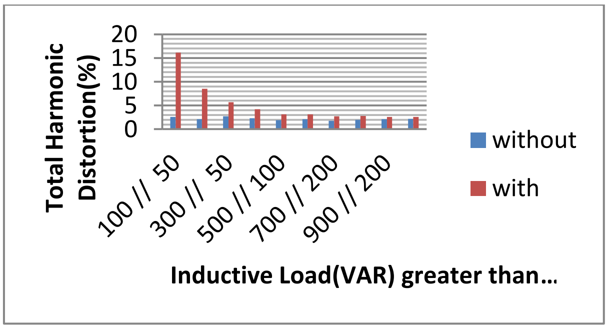

Figure 4.105: Comparison of total harmonic distortion without and with energy saver.

In part of inductive load greater than resistive load in parallel connection in the system. The data have been analyzed using graphical method in figure 4.101, 4.102, 4.103, 4.104 and 4.105. Based on graphical method the current of the system is decrease when the system with energy saver due the increasing of power factor and it also affect the reactive power in the system is decrease. For this part also, active power still remains unchanged and the THD of the system still increase when the system with energy saver.

IV. Resistive load series with inductive load

a) Resistive load bank equal to inductive load (W =VAR)

Table 4.22: Measurement data for resistive load equal to inductive load.

Resistive (W) = Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100	252.2	252.2	0.28	0.36	55	52	46	77	0.77	0.56	2.7	8.0
200	252.5	252.5	0.58	0.45	113	110	96	30	0.76	0.96	2.3	7.2
300	251.8	251.8	0.86	0.65	167	165	142	22	0.76	0.99	2.8	5.6
400	252.4	252.4	1.12	0.84	204	201	197	73	0.72	0.94	2.8	5.1
500	252.2	252.2	1.43	1.15	266	264	245	122	0.74	0.91	2.7	4.3
600	251.9	251.9	1.71	1.42	319	317	292	169	0.74	0.88	2.8	3.9
700	251.3	251.3	1.93	1.66	377	376	308	185	0.78	0.90	2.3	3.2
800	251.4	251.4	2.21	1.93	431	428	353	230	0.77	0.88	2.4	3.2
900	250.8	250.8	2.51	2.23	489	488	490	277	0.78	0.87	2.6	2.1
1000	250.8	250.8	2.75	2.46	524	524	451	331	0.76	0.85	2.5	3.1

Comparison by calculation for highest load:

R= 1000W L = 1000VAR V = 250V P = 524W Q = 451VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{524+j451}{250} = 2.765\ A\ \llcorner 40.718^0$ p.f = CosΘ = Cos(40.718) = 0.757

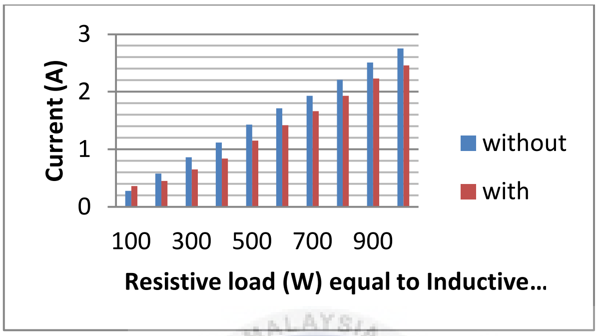

Figure 4.106: Comparison of current values without and with energy saver

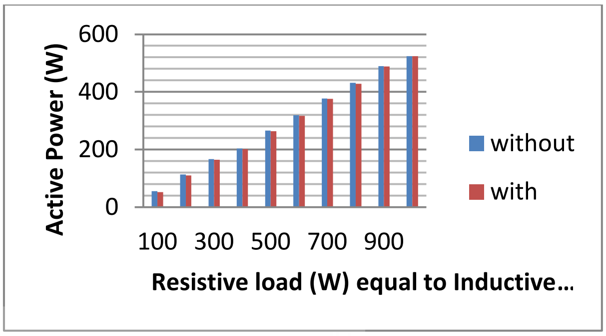

Figure 4.107: Comparison of active power values without and with energy saver

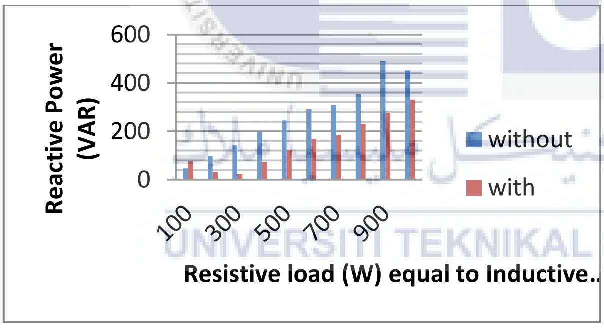

Figure 4.108: Comparison of reactive power values without and with energy saver.

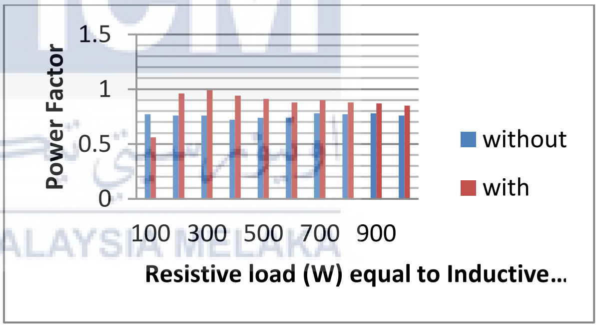

Figure 4.109: Comparison of power factor without and with energy saver.

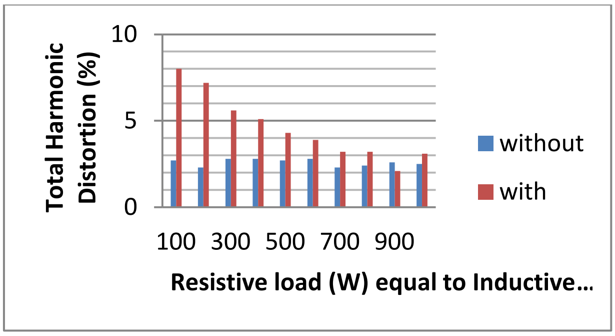

Figure 4.110: Comparison of total harmonic distortion without and with energy saver.

For series connected load also have been divided by three different parts. For this part, resistive load equal to inductive load. The data has been analyzed base on graph in figure 4.106, 4.107, 4.108, 4.109 and 4.110. The current of the system is decrease when the system with energy saver because the energy saver has improved the power factor and also make the reactive power in the system decrease. Active power still remains unchanged whether the system without energy saver or with energy saver and the THD of the system is increase when the system installed by energy saver.

b) Resistive load greater than inductive load (W > VAR)

Table 4.23: Measurement data for resistive load greater than inductive load.

Resistive (W) > Inductive (VAR)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 + 50	253.5	253.1	0.180	0.352	25	22	38	87	0.56	0.24	3.0	10.1
200 + 50	253.1	253.0	0.199	0.315	20	19	46	78	0.39	0.19	3.5	11.9
300 + 50	253.1	252.8	0.204	0.302	16	12	49	75	0.32	0.16	2.7	12.1
400 + 100	252.8	252.9	0.409	0.190	39	35	96	33	0.38	0.73	2.9	19.7
500 + 100	252.9	252.9	0.415	0.176	36	32	99	31	0.34	0.72	2.9	22.2
600 + 100	253.0	252.9	0.420	0.162	33	29	101	29	0.31	0.71	2.9	24.6
700 + 200	252.2	252.2	0.827	0.425	85	82	190	68	0.41	0.77	2.2	9.1
800 + 200	253.0	252.2	0.842	0.421	79	76	198	74	0.37	0.72	2.1	8.6
900 + 200	252.5	252.7	0.850	0.421	73	71	202	79	0.34	0.67	2.2	8.6
1000+300	252.0	252.1	1.230	0.806	128	127	282	159	0.41	0.62	2.7	5.6

Comparison by calculation for highest load:

R= 1000W L = 300VAR V = 250V P = 128W Q = 282VAR

S = IV S = P + jQ

$$I = \frac{S}{V} = \frac{128 + j282}{250} = 1.238\ A\ \angle 65.58^{0}$$ p.f = CosΘ = Cos(65.58) = 0.413

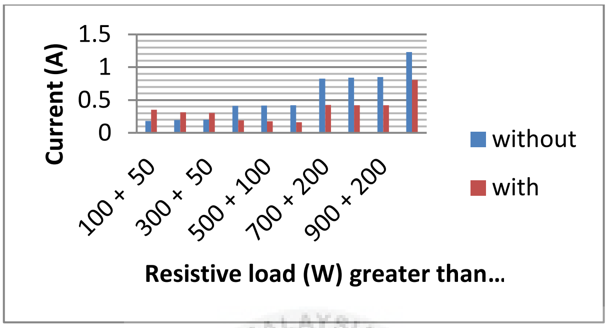

Figure 4.111: Comparison of current values without and with energy saver

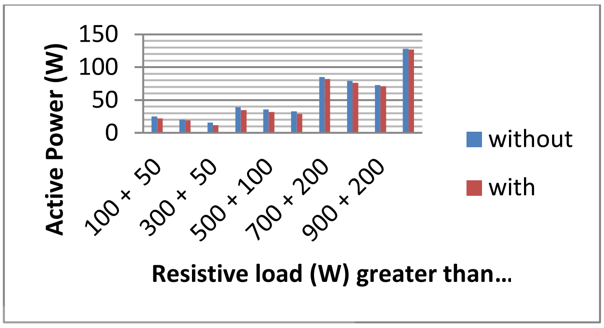

Figure 4.112: Comparison of active power values without and with energy saver

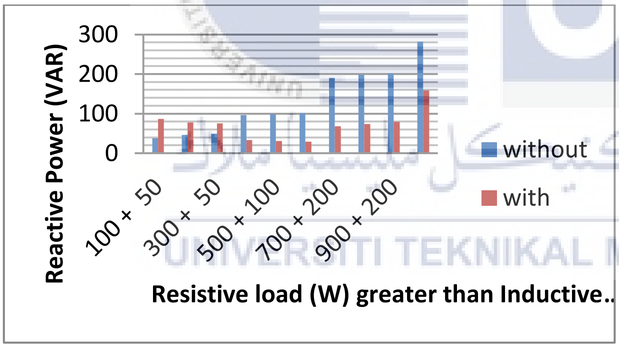

Figure 4.113: Comparison of reactive power values without and with energy saver.

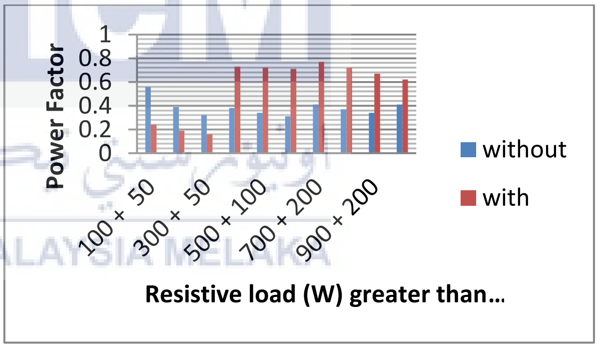

Figure 4.114: Comparison of power factor without and with energy saver.

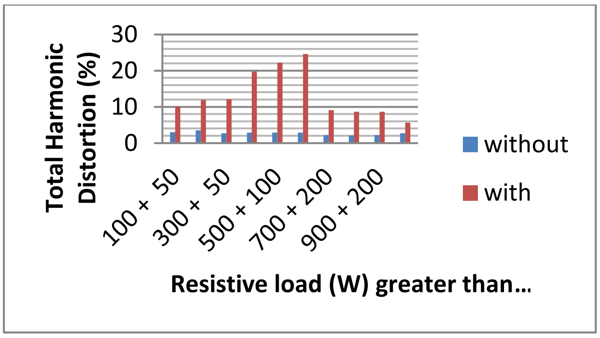

Figure 4.115: Comparison of total harmonic distortion without and with energy saver.

For the resistive load greater than inductive load in series connection. Base on graph show in figure 4.111, 4.112, 4.113, 4.114 and 4.115. During this, the current of the system also decrease when the system with energy saver because the power factor of the system is increase and the increasing in power factor also drive the reactive power in the system to decrease. The active power still remains unchanged whether the system without energy saver or with energy saver. THD in the system still increased when the energy saver is installed to the system.

c) Inductive load greater than resistive load (VAR > W)

Table 4.24: Measurement data for inductive load greater than inductive load.

Inductive (VAR) > Resistive (W)	Voltage (V)		Current (A)		Active Power (W)		Reactive Power (VAR)		Power Factor/ p.f		THD (%)	
	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w
100 + 50	252.8	252.3	0.175	0.446	41	38	17	106	0.93	0.34	2.7	10.1
200 + 50	252.7	251.9	0.196	0.488	49	46	9	114	0.98	0.38	1.2	11.9
300 + 50	252.5	252.6	0.200	0.505	50	48	6	117	0.99	0.38	1.0	12.1
400 + 100	252.4	252.3	0.407	0.549	100	97	26	98	0.97	0.70	1.6	19.7
500 + 100	252.1	252.2	0.415	0.575	103	101	20	104	0.98	0.70	1.4	22.2
600 + 100	252.1	252.2	0.421	0.591	105	103	16	108	0.99	0.69	1.4	24.6
700 + 200	251.4	251.6	0.800	0.816	194	192	53	72	0.97	0.94	1.9	9.1
800 + 200	251.7	251.6	0.806	0.838	197	194	47	77	0.97	0.93	1.8	8.6
900 + 200	251.3	251.4	0.826	0.889	205	203	31	92	0.99	0.91	1.1	8.6
1000+300	251.0	250.7	1.184	1.138	285	282	85	41	0.96	0.99	2.1	5.6

Comparison by calculation for highest load:

R= 300W L = 1000VAR V = 250V P = 285W Q = 85VAR

S = IV S = P + jQ

$I = \frac{S}{V} = \frac{285+j85}{250} = 1.189\ A\ \llcorner 16.606^0$ p.f = CosΘ = Cos(16.606) = 0.958

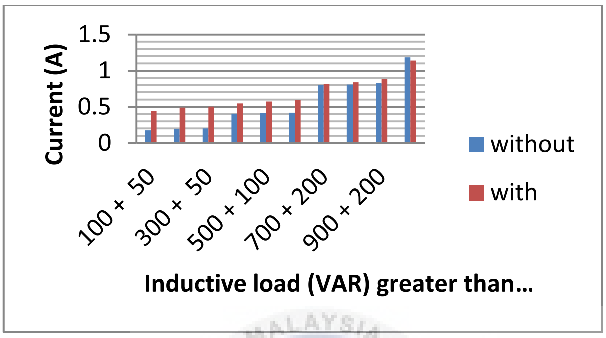

Figure 4.116: Comparison of current values without and with energy saver

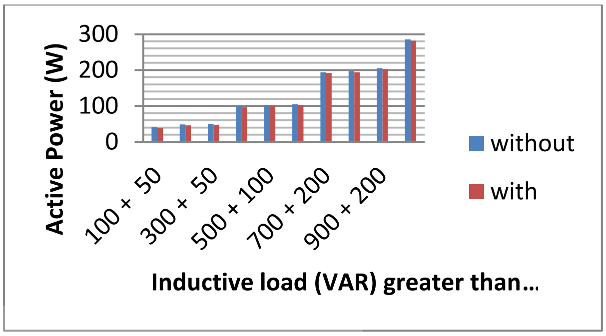

Figure 4.117: Comparison of active power values without and with energy saver

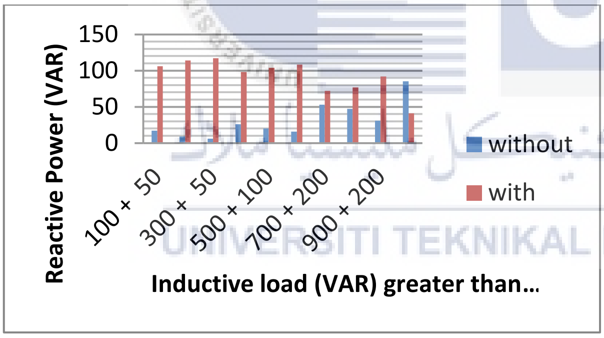

Figure 4.118: Comparison of reactive power values without and with energy saver.

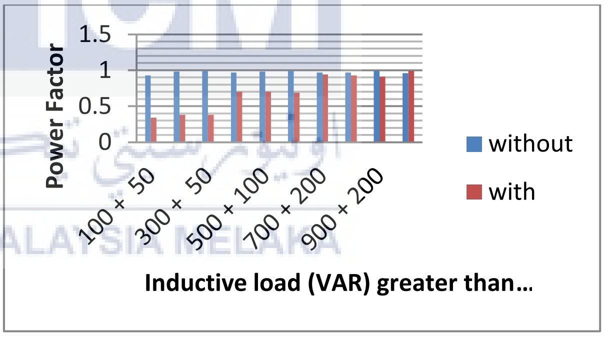

Figure 4.119: Comparison of power factor without and with energy saver.

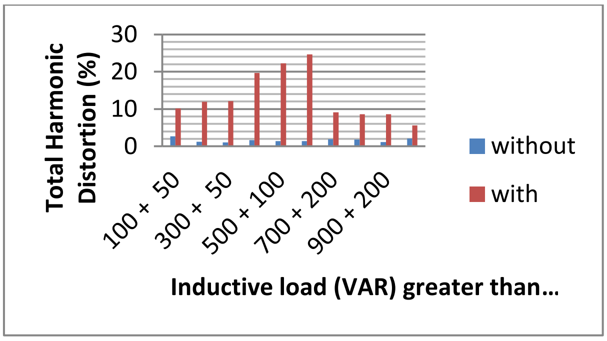

Figure 4.120: Comparison of total harmonic distortion without and with energy saver.

For the last part of the experimental test, the inductive load greater than inductive load in series connection. Figure 4.116, 4.117, 4.118, 4.119 and 4.120 shows the graph of the analyzing data. During this part, the current of the system is increase after the system with energy saver but when the high loads apply, the result is opposite. This is because the power factor of the system is reducing when the energy saver installed in the system and it improves the load of the system is increase. The reactive power is inversely proportional to the power factor. The active power remains unchanged whether the system without energy saver or with energy saver. THD of the system still increase when the system is installed by the energy saver.

4.2 Overall Discussion

For overall discussion, all experimental test has been done. The data has been recorded and analysed. Based on the result and analysed data, it is shown the capability of the energy saver device 1 and device 2. Base on analyzed data for each part for experimental test, the capability of this device is able to reduce current in the residential electricity system. This is because inside the circuit of the energy saver, it contents the capacitor bank. This capacitor bank will react as a power factor correction for the system. The function of power factor correction is to improve the power factor. When the power factor in the system was improved, it will cause the reducing of current in the system. Power factor correction also will make the system become more efficiency which means reduce loss in the system. That is why the reactive power is decreasing during the test when the energy saver is installed in the system. All of these become as benefit to us as consumer. But, the disadvantages of this energy saver device is, it will improve the total harmonic distortion of the system. As we know total harmonic distortion in the system will affect on the electrical equipment which are over heated, reduce life span and also overheating of dielectric with lead to high risk of explosion. The most important objective of this research is to prove this energy saver capable to reduce the electricity bills or not. Based on Tenaga Nasional Berhad, electricity bills for residential was calculated base on active power consumed only and not have penalty charges for lower power factor. Based on result during experimental test on energy saver device 1 and device 2, this device is not capable to reduce active power of the system. For the conclusion, energy saver device is not capable to reduce residential electricity bills.

4.3 Summary of Data

This chapter reviews all the collected data during the three different types of experimental test which is test on energy saver device 1, test on energy saver device 2 and lastly test on combination of energy saver device 1 and device. The data has been collect during the experimental test is by several type of load which is pure resistive load, pure inductive load, resistive load parallel with inductive load and resistive load series with inductive. During the combination load, the condition of load will divide by three condition which is resistive load is equal to inductive load, resistive load is greater than inductive load and inductive load is greater than resistive load. After all the data has been tabulated, the data was analyzed by using a graphical method and base on the analyzed data brief discussion about energy saver device was made.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As conclusion for FYP 2, there are 3 types of experimental test on different type of energy saver to determine to capability and the effect of energy saver. Three types of experimental test is test on energy saver device 1, test on energy saver device 2 and test on combination of energy saver device 1 and device 2.

For the test on energy saver device 1, based on analyzed data had been made, energy saver device 1 cannot reduce an electricity bills because it cannot reduce the power of the system but the current of the system is reducing due to the power factor correction when the system is applied by this device. This device also generate a total harmonic distortion when it is applied to the system which mean it will risk the electrical appliances at home.

Then test on energy saver device 2, based on analyzed data the electricity bills still cannot be reducing because there are no decreasing of the active power when the system is applied with device 2. When the system is applied by device 2, the different is only on current and reactive power which is the current and the reactive power is reducing. This device also generate a total harmonic distortion when its applied to the system.

For the last experimental test which is test on combination of energy saver device 1 and device 2. The observation based on analyzed data shows the combination of energy saver also cannot reduce an electricity bills because of the same factor during test on energy saver device 1 and device 2. The capability of this energy saver is only can reduce the current and the reactive power of the system. The energy saver device will also risk the electrical appliances because it will increase the total harmonic of the system when the energy saver is installed to the system.

So it proves the claim of the energy saver device is capable to reduce electricity bills is not true because for residential consumer, TNB only charge the electricity bills base on their power consume only. The energy saver also will affect the electric equipment to the risk due the increasing in total harmonic distortion.

5.2 Recommendation

For recommendation, for future study test on energy saver need to be conduct on three phase system to prove whether the energy saver will be able to reduce an electricity bills if it installed in three phase system. Another that test on different types of energy saver that consist in market also needs to be conducted.

Lastly, in my opinion, to save a electricity consumer need to do by their effort not by purchasing the energy saver device because this device has been prove cannot reduce an electricity bills and its also will risk our life and equipment. For example is follow the guideline that has been provide by TNB which is, use the energy saver light bulbs that consume less energy and last longer, close the window s and doors while air conditioner is on and use 5-star rated appliances are designed to run more efficiently and reduce consumption.

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