ENERGY EFFICIENCY IMPROVEMENT FOR FACULTY OF TECHNICAL AND VOCATIONAL EDUCATION BUILDING

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Energy efficiency becomes important matter due to correlate to sustainability and money. The ministry of Education Malaysia has urged all education center to conserved energy. Energy wastage tends to occur in Malaysian universities mainly due to inefficient use of energy and lack of awareness among building users. In this research, the researcher has analyse the building energy consumption and identify potential energy improvement that can be made in Faculty Technical and Vocational Education Universiti Tun Hussein Onn Malaysia. Suitable method to reduce energy consumption have been proposed without compromising user comfort in order to improve energy efficiency. The options of the proposed improvement method have been simulated using DIALUX and MATLAB/SIMULINK before the selection is done. This research have found that the most efficient lighting system for FPTV is using LED T8 replacement. The power factor correction have calculated and simulated. The researcher also has proposed the suitable method on management perspective to improve energy efficiency.
ABSTRAK

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<td>Alternating current</td>
</tr>
<tr>
<td>BEMS</td>
<td>Building Energy Management System</td>
</tr>
<tr>
<td>CAFM</td>
<td>Computer Aided Facilities Management</td>
</tr>
<tr>
<td>CFL</td>
<td>Compact fluorescent lamp</td>
</tr>
<tr>
<td>CRI</td>
<td>Color rendering index</td>
</tr>
<tr>
<td>DC</td>
<td>Direct current</td>
</tr>
<tr>
<td>EEI</td>
<td>Energy Efficiency Index</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilation and Air conditioning</td>
</tr>
<tr>
<td>kWh</td>
<td>Kilowatt hour</td>
</tr>
<tr>
<td>LED</td>
<td>Light emitting diode</td>
</tr>
<tr>
<td>LPW</td>
<td>Lumen per watt</td>
</tr>
<tr>
<td>m</td>
<td>meter</td>
</tr>
<tr>
<td>UV</td>
<td>Ultra violet</td>
</tr>
<tr>
<td>UTHM</td>
<td>Universiti Tun Hussein Onn Malaysia</td>
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<td>Universiti Teknologi Malaysia</td>
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CHAPTER 1

INTRODUCTION

1.1 Project Background

Electrical energy plays an important role in the developments of Malaysia economics. It is widely used in sectors such as industrial, domestic, commercial, government building, public lighting and mining sectors. Growth in these sectors has been indebted for the increase in energy consumption. The increase in the number of commercial buildings and residential area development projects has a great impact to the national development but it also increases the energy demand [1]. Recognising that the development should run in parallel with environmental sustainability, various policies and methods are made available to help preserve the environment. Since the energy crisis in 1970, engineers, architects and building developers are better equipped to design and maintain buildings more efficiently to reduce energy consumption and electricity usage [2]. To encourage sustainable building practice, The Malaysian Standard MS 1525:2007, Code of Practice on Energy Efficiency and use of Renewable Energy for Non – Residential Buildings has been introduced. The Standard briefly describes the engineering, architectural, landscaping and site planning aspects in designing to optimize the energy efficiency of a non-residential building [2].

The development of Malaysia has also led to the development and growth of higher education institutions to accommodate the growing number of local as well as international students. Currently, each state in Malaysia has at least one public or
private higher education institution. The Malaysian Ministry of Education (MOE) and The Malaysian Ministry of Higher Education (MOHE) has urged all education centers to play their role to save the electric energy [3]. This is in line with the efforts of the Ministry of Energy, Green Technology and Water (MEGTW) to initiate energy-saving programmers’ in all government departments [4]. For efficient use of energy, all parties should support the program initiated by the authorities and the continuous improvement program to sustain the initiative.

At present, environmental sustainability is seen as the way forward by various parties to make life better without polluting the environment. The sustainability concept has been introduced widely in various sectors such as government, private sector and also in education [5]. The awareness of the sustainability concept in Malaysia especially in the higher education institutions is gaining momentum [6] and awareness programs have been initiated in Malaysia with a view towards creating a sustainable environment.

1.2 Problem Statements

Energy wastage tends to occur in Malaysian universities mainly due to inefficient use of energy and lack of awareness among building users [3]. Inefficient used of energy include the use of high energy consumption appliances, the use of appliances that can cause low power factor to the electrical installation system.

In the university context, energy wastage can cause high expenses on electrical energy. Energy waste is money waste. It’s not only involving the money but waste of energy means contribute to environmental damage such as global warming without any payback to citizen.

In this context, energy efficiency initiative should be taken so that the high efficient of energy usage can be achieve. It’s is not only can contribute to the sustainable development but there’s some cost saving on energy usage can be made and it’s become the motivation factor to this project.
1.3 Project Objectives

The main objective of this research is to conduct a feasibility study and data collection on current energy usage, building load profiling, power factor and the possible power quality events for FPTV building. Using these inputs, the researcher will suggest the method to improve the energy efficiency of the building. Its measurable objectives are as follows:

a) To analyse the building power consumption
b) To improve the overall power factor of the building
c) To propose proper energy saving methods on management perspective

1.4 Project Scopes

This project is primarily concerned with the building energy efficiency in public Universities in Malaysia. However the researcher will only concentrate the building energy efficiency improvement at Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia. The scopes of this project are:

a) To reduce energy consumption by replacing the ineffective loads as well as the number of the loads. There are three categories of loading to be focused in this project:
   i.  Lighting
   ii.  Air conditioner
   iii.  Office appliances
b) To improve power factor of the systems installation base on:
   i.  Reducing Q consumption
   ii.  Compensate Q in the system
c) To propose energy saving method by considering the user behaviour such as:
   i.  Switch ON and OFF the lighting
   ii.  Switch ON and OFF air conditioner
   iii.  Switch ON and OFF computer
CHAPTER 2

LITERATURE REVIEW

2.1 Energy efficiency

Energy efficiency refers to the physical performance of specific end uses or energy services such as lighting, heating, cooling, and motor drive. Energy efficiency is usually measured by the output quantity per unit of energy input (miles per gallon or lumens per watt, for example). Because energy is one of several factors of production (labor, capital, and materials are others), energy efficiency improvements contribute to greater energy productivity and economic efficiency [4]. Greater energy efficiency is achieved by replacing load from conventional to energy efficient product, upgrading electrical system to energy efficient system, or maintaining existing equipment to reduce the amount of energy needed.

2.2 Energy efficiency index

Energy Efficiency Index (EEI) is a tool used to track the performance of energy consumption. The measurement of EEI depends on the use of energy in a particular application[1]. Generally, the EEI can be defined in terms of an energy component and a factor related to the energy using component of the organization as given in equation (1). Examples of factors related to energy use are as listed below:

i) Weight of product produced
ii) No. of item produced

iii) Weight of raw material used

iv) Period of production

v) Period of plant usage

vi) Floor area of building

vii) No. of in-patient bed per night (hospital building)

viii) No. of occupied room per night (hotel building)

\[ EEI = \frac{\text{Energy Input}}{\text{Factor Related to the Energy Using Component}} \]  \hspace{1cm} (2.1)

For a building, the definition of EEI is tied to the size of the building and is generally considered as energy used per unit of building floor area which can be determined using Equation (2.2). EEI is expressed in kWh/m\(^2\).

\[ EEI = \frac{\text{Total energy used (kWh)}}{\text{Gross Floor Area (m}\^2\text{)}} \]  \hspace{1cm} (2.2)

The EEI is important in energy efficiency improvement program as it is used as a key performance indicator. EEI is used by Universiti Teknologi Malaysia as a key performance indicator for their energy management programmes [1]. Figure 2.0 show the EEI at UTM.

![Figure 2.1. Energy Efficiency Index (EEI) in UTM](image-url)
2.3 Energy efficient product

There are a lot of energy efficient products in the market. It can be divided by at least four main categories for building applications:

i. Lighting
ii. Cooling and ventilation
iii. Heating
iv. Monitoring system

2.3.1 Efficient Lighting Systems

Light-emitting diodes (LEDs) are semiconductor diodes that emit light when current flows through them. They are available as narrowband light sources in "colors" ranging from the infrared to the near UV, and, with the addition of a phosphor coat, as a white light source with color temperatures ranging from 3200 to 12,000 °K and color rendering index CRI values ranging from 60 to over 90. Rated efficacies range up to 30 LPW for white LEDs, which is superior to that of incandescent lamps.

Light-emitting diodes have advantages over small incandescent lamps that are leading to their increasing dominance for battery-operated lighting. Their usable life ranges from 6000 to 50,000 h (at 70% lumen maintenance). Small standard flashlight bulbs have thin filaments and can only manage 8-10 LPW and 15-30 h of lamp life.

Light-emitting diodes are durable, require less expensive optics for good beam control, and are available with high color temperatures, which lead to higher perceived brightness and better visibility in low light conditions. The power supplies used in the more expensive lights significantly increase the fraction of battery power available to provide useful amounts of light. LED bike lights and flashlights have battery lives that are a factor of 10 greater than those of comparable standard incandescent lights, and a factor of 3-5 greater than those of halogen lamps. The use of a flashing mode can increase this advantage even further.

Light-emitting diodes are also replacing incandescent lamps in traffic signal lights and dynamic sign and color displays. Light-emitting diodes have the advantage over incandescent lamps in these applications because filtering incandescent lamps to produce colors reduces their efficacy to the 2-3 LPW range, while switching on and
off reduces their life. Light emitting diodes are also replacing incandescent and fluorescent light sources in exit signs. As discussed Section 12.2.6, EPAct 2005 contains standards for traffic and pedestrian signals that require LED technology, and for exit signs that require LED technology or technology with similar efficacies.

Manufacturers have announced that higher LPW white LEDs will be available in the near future. This is comparable to the efficacy of small fluorescent lamps, and the industry target of 150 LPW by 2012 would make LEDs more efficacious than all but monochromatic LPS lamps. In fact on April 2013 Philip announce that they are achieve 200 LPW for their latest LED prototype. Research continues on organic LEDs (OLEDs), which are cheaper, but less efficacious than standard LEDs, and on manufacturing techniques to reduce the cost per unit of standard LEDs while increasing their wattage. The lack of toxic mercury in LEDs could make them preferable to small fluorescent lamps in a few years time, even if they are a bit more expensive, and their efficacy is no higher [5].

Nowadays, electronic ballasts for fluorescent lamps are popular in many lighting systems. Typical electronic ballasts consist of two power stages. The first stage is a power factor corrector for regulating the dc-link voltage. The second stage is a half-bridge series resonant parallel-loaded inverter for ballasting the lamp. Driving of the inverter switches can be accomplished by two methods. The first is to use a self-oscillating circuit, in which a saturable transformer drives the switches. Typical switches are bipolar transistors. The second is to use a ballast integrated circuit (IC) and the switches are usually MOSFETs. The self-oscillating inverter is the dominant solution, because the circuit is simple, robust, and cost effective. Actually, electronic ballasts are basically switching power supplies that eliminate the large, heavy, 'iron' ballast and replace it with an integrated high frequency inverter / switcher. Current limiting is done by a very small inductor, which has sufficient impedance at the high frequency. For simplify the circuit of electronic ballast and reduced its cost, some single-stage electronic ballasts have been proposed by integrating PFC circuit into the inverter stage to perform both functions of the PFC and a resonant inverter. By sharing the active power switch and the control circuit, the component count can be effectively reduced [5].
2.3.2 Inverter Air-conditioner

An inverter in an air conditioner is used to control the speed of the compressor motor to allow continuously regulated temperature. By contrast, traditional air conditioners regulate temperature by using a compressor that is periodically either working at maximum capacity or switched off entirely. Inverter-equipped air conditioners have a variable-frequency drive that incorporates an adjustable electrical inverter to control the speed of the motor and thus the compressor and cooling output. Figure 2.1 show the advantage of inverter air conditioner.

![Figure 2.1 – Comparing inverter-non inverter air conditioner](image)

The variable-frequency drive uses a rectifier to convert the incoming alternating current (AC) to direct current (DC) and then uses pulse-width modulation in an electrical inverter to produce AC of a desired frequency. The variable frequency AC drives a brushless motor or an induction motor. As the speed of an induction motor is proportional to the frequency of the AC, the compressors runs at different speeds. A microcontroller can then sample the current ambient air temperature and adjust the speed of the compressor appropriately. The additional electronics add to cost of equipment and operation. Conversion from AC to DC, and then back to AC, can cost as much 4 - 6% in energy losses for each conversion step.
Eliminating stop-start cycles increases efficiency, extends the life of components, and helps eliminate sharp fluctuations in the load the air conditioner places on the power supply. Ultimately this makes inverter air conditioners less prone to breakdowns, cheaper to run, and the outdoor compressor is generally quieter than a standard air conditioning unit's compressor [5].

While at the beginning of the 1990s inverter air conditioners had some drawbacks, these have been mostly overcome, the conversion losses are lower and filters suppress most of the electromagnetic interference generated in inverters. Since permanent-magnet motors are used, rather than conventional squirrel cage induction motors, motors use less power and no current is required for magnetizing the rotor. Inverter-based air conditioners are therefore more energy efficient. 100% of air conditioners in Japan use DC inverter compressors. For conventional households where each indoor unit is connected to a single dedicated outdoor unit, inverters are the preferred option, as partial loading is the common mode there. The higher initial expense is balanced by lower energy bills. In a typical setting the pay-back time is about two years (depending upon the usage). For more modern installations where an outdoor unit is connected to multiple indoor units there are better options also available.

2.3.3 Heating, Ventilation and Air conditioning (HVAC)

Heating, Ventilation and Air conditioning (HVAC) system is the most common system throughout Malaysian universities. With HVAC system, electricity is used to generate cooling air for lowering room-temperature. The efficiency of HVAC system can be improved through two structural approaches:

(a) better HVAC control system and plant, and

(b) better insulation.

HVAC control system is a computerized climate control system for indoor environment. Basically, the system uses central controllers to monitor remote terminal unit. The latest system allows remote access from a web browser indeed. Since many existing HVAC systems are manually operated, adapting remotely
operated HVAC control system, by local universities, can assure better energy efficiency. Besides, Malaysian Universities should take initiative to upgrade their HVAC plants. This can be achieved through installation of smaller and more efficient heating and cooling equipments to match the buildings operating load [3]. The size of an appropriate HVAC plant can be determined after detail energy audit. Building insulation is the method of preventing heat or cold air from escaping and entering the building. In order to increase the effectiveness of any hot or cold system, one can adopt the use of insulation into a particular system [3]. Heat and cool air is transferred from one material to another by conduction, convention and/or radiation. Insulators are used to minimize the transfer of such energy. Insulation is an important common element to improve energy efficiency in Malaysian buildings that uses a large proportion of total monthly energy consumption. A building such as a lecture hall should be well insulated as it can save on the monthly electrical bills by reducing the cooling air generated by the air conditioning system from flowing to outside. Besides, insulation does not require complicated maintenance, upkeep, or adjustment.

2.3.4 Monitoring system

One of the simplest and most effective methods of conserving energy is to operate equipment whenever it is needed. Energy savings can be achieved without affecting occupant comfort by turning the equipment off. Best still, the equipment can be switched off automatically when there is no one using it. Energy consumption can be monitored and managed properly through tools such as motion sensor, Building Energy Management System (BEMS) and Computer Aided Facilities Management (CAFM) [3].

Motion sensor can be used for many purposes in university, including security and energy savings. A sensor automatically turns lights on when movement is detected and off when movement stops. New building Universiti Tun Hussein Onn Malaysia such as Faculty Technical and Vocational Education have install the kind of sensor. Universiti Teknologi Malaysia also has taken initiatives to install motion sensors in some of its toilets. The lighting will turn on automatically when they
sensed movement in the toilets. This would definitely reduce unnecessary energy cost.

Building Energy Management System (BEMS) is a microcomputer systems used for controlling and monitoring building services plant [3]. Also, it can be implemented for monitoring other buildings electronic appliances. BEMS system can also be used for better energy monitoring and saving. Several institutions have invested in building energy management systems (BEMS) to control and monitor the building’s temperatures. The results reveal that it can reduce energy-use, up to 20 percent [3].

On the other hand, Computer Aided Facilities Management (CAFM) is a combination of Computer-Aided Design (CAD) or relational database software with specific functions to manage facilities. The CAFM can assist facility manager to plan, monitor and review the facilities management process. Although CAFM differ from BEMS, both of them, however, could be integrated for better energy performance. The tasks can be performed by the CAFM querying the BEMS, or by a form of integration [3]. Different types of CAFM system are currently available in the market, including Archibus and Maximo. Universities may select any of them, based on their suitability and cost.

2.4 Description of Previous Methods – Management Perspective

Energy efficiency improvement programs have been initiated by some Universities in Malaysia, such as Universiti Teknologi Malaysia, (UTM). There are several projects have been conducted under the UTM’s Transformation program on energy saving, which focused on projects that can be easily implemented and involving low investment. Electricity tariff study, energy management awareness campaign, energy consumption monitoring system and energy efficient lighting retrofits are among the projects carried out under this program. UTM has also taken the steps to establish an energy management committee at the university level. All the members of the UTM Energy Managements Committee have undergone an Energy Manager Training conducted by Green Tech Malaysia. The approach used is to identify which faculty
is use the highest energy. The energy efficiency improvement starts at Faculty of Electrical Engineering, FKE which the higher energy consumed. FKE first started the energy management program in 2011 with the establishment of the Faculty’s Energy Management Committee. The energy efficiency awareness campaign was then launched by the dean via email to the academic and nonacademic staff. Talks were also held to encourage and support the campaign. During the campaign, posters, reminders, stickers and signage were placed at laboratories, offices, lecture halls and other relevant places. Table 2.1 shows some initiative taken to support the campaign [1]

Table 2.1: energy saving strategies in the faculty of Electrical engineering FKE, UTM

<table>
<thead>
<tr>
<th>Targeted Place</th>
<th>Initiative Taken</th>
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<tbody>
<tr>
<td>Laboratories</td>
<td>1. Switch off lights and computers when leaving the laboratory</td>
</tr>
<tr>
<td></td>
<td>2. Switch off unnecessary lights during lunch hour or when there are no laboratory</td>
</tr>
<tr>
<td></td>
<td>sessions</td>
</tr>
<tr>
<td></td>
<td>3. Lit up small area only</td>
</tr>
<tr>
<td></td>
<td>4. Use network printer</td>
</tr>
<tr>
<td>Lecture Hall and Lecture Room</td>
<td>1. Switch-off split unit air-conditioners,</td>
</tr>
<tr>
<td></td>
<td>LCD projectors as well</td>
</tr>
<tr>
<td></td>
<td>as computer when a class finishes</td>
</tr>
<tr>
<td></td>
<td>2. Use lecture rooms with split unit air-conditioner only for weekend classes</td>
</tr>
<tr>
<td></td>
<td>3. Reallocating classes in the evening so that the class will be</td>
</tr>
<tr>
<td></td>
<td>conducted inside a lecture room with</td>
</tr>
<tr>
<td></td>
<td>split unit air-conditioner</td>
</tr>
<tr>
<td>Office</td>
<td>1. Switch off lights and computer when leaving the office</td>
</tr>
<tr>
<td></td>
<td>2. Switch off lights and computer during lunch hour</td>
</tr>
<tr>
<td></td>
<td>3. Switch off split unit air conditioner when leaving the office</td>
</tr>
<tr>
<td></td>
<td>4. Switch off all unnecessary lights and equipment during lunch hour</td>
</tr>
</tbody>
</table>

There are also a research at Universiti Teknologi Mara, UiTM where by the project concentrate on air conditioner energy usage. Several energy saving opportunities were proposed in this study. Proposal of electric energy saving opportunity is categorized into the two, one is saving opportunity by improving occupants’ behaviors and another one is saving opportunity by means of technical
measures. Improving human behavior is possible through training, poster campaigns, sign, published, tip, guideline, monitoring and control and technical measures which is occupancy sensor should be used in classroom and lecturer office to avoid wastage of cooling energy. The temperature set point and flow rate should be according to the design specification and comply with Malaysia Standard [7].

2.5 Power Factor

Power factor of an AC electrical power system is defined as the ratio of the real power flowing to the load, to the apparent power in the circuit, and is a dimensionless number between -1 and 1. Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power. A negative power factor occurs when the device which is normally the load generates power which then flows back towards the device which is normally considered the generator.[8]

In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor.

Linear loads with low power factor (such as induction motors) can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, distort the current drawn from the system. In such cases, active or passive power factor correction may be used to counteract the distortion and raise the power factor. The devices for correction of the power factor may be at a central substation, spread out over a distribution system, or built into power-consuming equipment.
Figure 2.3 - Instantaneous and average power calculated from AC voltage and current with a zero power factor

Figure 2.3 show the instantaneous and average power calculated from AC voltage and current with a zero power factor ($\varphi = \pi/2$, $\cos \varphi = 0$). The blue line shows all the power is stored temporarily in the load during the first quarter cycle and returned to the grid during the second quarter cycle, so no real power is consumed.

Figure 2.4 - Instantaneous and average power calculated from AC voltage and current with a 0.71 power factor
Figure 2.4 show the instantaneous and average power calculated from AC voltage and current with a lagging power factor \((\varphi = 45^\circ, \cos\varphi = 0.71)\). The blue line shows some of the power is returned to the grid during the part of the cycle labelled \(\varphi\).

In a purely resistive AC circuit, voltage and current waveforms are in step (or in phase), changing polarity at the same instant in each cycle. All the power entering the load is consumed (or dissipated). Where reactive loads are present, such as with capacitors or inductors, energy storage in the loads results in a time difference between the current and voltage waveforms. During each cycle of the AC voltage, extra energy, in addition to any energy consumed in the load, is temporarily stored in the load in electric or magnetic fields, and then returned to the power grid a fraction of a second later in the cycle. The "ebb and flow" of this nonproductive power increases the current in the line. Thus, a circuit with a low power factor will use higher currents to transfer a given quantity of real power than a circuit with a high power factor. A linear load does not change the shape of the waveform of the current, but may change the relative timing (phase) between voltage and current.

Circuits containing purely resistive heating elements (filament lamps, cooking stoves, etc.) have a power factor of 1.0. Circuits containing inductive or capacitive elements (electric motors, solenoid valves, lamp ballasts, and others) often have a power factor below 1.0.

### 2.5.1 Power Factor Calculation

AC power flow has the three components: real power (also known as active power) \((P)\), measured in watts \((W)\); apparent power \((S)\), measured in volt-amperes \((\text{VA})\); and reactive power \((Q)\), measured in reactive volt-amperes \((\text{var})\).\(^6\)

The power factor is defined as:

\[
\text{Power factor} = \frac{P}{S} \quad (2.1)
\]

In the case of a perfectly sinusoidal waveform, \(P\), \(Q\) and \(S\) can be expressed as vectors that form a vector triangle such that:

\[
S^2 = P^2 + Q^2 \quad (2.2)
\]
If $\varphi$ is the phase angle between the current and voltage, then the power factor is equal to the cosine of the angle, $\cos \varphi$, and:

$$|P| = |S| \cos \varphi \quad (2.3)$$

Since the units are consistent, the power factor is by definition a dimensionless number between $-1$ and $1$. When power factor is equal to 0, the energy flow is entirely reactive, and stored energy in the load returns to the source on each cycle. When the power factor is 1, all the energy supplied by the source is consumed by the load. Power factors are usually stated as "leading" or "lagging" to show the sign of the phase angle. Capacitive loads are leading (current leads voltage), and inductive loads are lagging (current lags voltage).

If a purely resistive load is connected to a power supply, current and voltage will change polarity in step, the power factor will be unity (1), and the electrical energy flows in a single direction across the network in each cycle. Inductive loads such as transformers and motors (any type of wound coil) consume reactive power with current waveform lagging the voltage. Capacitive loads such as capacitor banks or buried cable generate reactive power with current phase leading the voltage. Both types of loads will absorb energy during part of the AC cycle, which is stored in the device's magnetic or electric field, only to return this energy back to the source during the rest of the cycle.

Electrical loads consuming alternating current power consume both real power and reactive power. The vector sum of real and reactive power is the apparent power. The presence of reactive power causes the real power to be less than the apparent power, and so, the electric load has a power factor of less than 1.

### 2.5.2 Power factor correction of linear loads

A high power factor is generally desirable in a transmission system to reduce transmission losses and improve voltage regulation at the load. It is often desirable to adjust the power factor of a system to near 1.0. When reactive elements supply or absorb reactive power near the load, the apparent power is reduced. Power factor correction may be applied by an electric power transmission utility to improve the stability and efficiency of the transmission network. Individual electrical customers
who are charged by their utility for low power factor may install correction equipment to reduce those costs.

Power factor correction brings the power factor of an AC power circuit closer to 1 by supplying reactive power of opposite sign, adding capacitors or inductors that act to cancel the inductive or capacitive effects of the load, respectively. For example, the inductive effect of motor loads may be offset by locally connected capacitors. If a load had a capacitive value, inductors (also known as reactors in this context) are connected to correct the power factor. In the electricity industry, inductors are said to consume reactive power and capacitors are said to supply it, even though the energy is just moving back and forth on each AC cycle.

The reactive elements can create voltage fluctuations and harmonic noise when switched on or off. They will supply or sink reactive power regardless of whether there is a corresponding load operating nearby, increasing the system's no-load losses. In the worst case, reactive elements can interact with the system and with each other to create resonant conditions, resulting in system instability and severe overvoltage fluctuations. As such, reactive elements cannot simply be applied without engineering analysis.

Figure 2.5 show an automatic power factor correction unit consists of a number of capacitors that are switched by means of contactors. These contactors are controlled by a regulator that measures power factor in an electrical network. Depending on the load and power factor of the network, the power factor controller will switch the necessary blocks of capacitors in steps to make sure the power factor stays above a selected value.

![Automatic power factor correction unit](image)

Figure 2.5 – Automatic power factor correction unit

The components numbering show in the Figure 2.5 as per below:
1. Reactive Power Control Relay;
2. Network connection points;
3. Slow-blow Fuses; 4. Inrush Limiting Contactors;
5. Capacitors (single-phase or three-phase units, delta-connection);
6. Transformer (for controls and ventilation fans)

Instead of using a set of switched capacitors, an unloaded synchronous motor can supply reactive power. The reactive power drawn by the synchronous motor is a function of its field excitation. This is referred to as a **synchronous condenser**. It is started and connected to the electrical network. It operates at a leading power factor and puts Vars onto the network as required to support a system's voltage or to maintain the system power factor at a specified level.

The condenser's installation and operation are identical to large electric motors. Its principal advantage is the ease with which the amount of correction can be adjusted; it behaves like an electrically variable capacitor. Unlike capacitors, the amount of reactive power supplied is proportional to voltage, not the square of voltage; this improves voltage stability on large networks. Synchronous condensers are often used in connection with high-voltage direct-current transmission projects or in large industrial plants such as steel mills.

For power factor correction of high-voltage power systems or large, fluctuating industrial loads, power electronic devices such as the Static VAR compensator or STATCOM are increasingly used. These systems are able to compensate sudden changes of power factor much more rapidly than contactor-switched capacitor banks, and being solid-state require less maintenance than synchronous condensers.
CHAPTER 3

METHODOLOGY

3.1 Project Methodology

This research is adopting approach involving identify the potential to improve energy efficiency in the electrical installation at Faculty of Technical and Vocational Education, UTHM by assessing the current energy usage. The researcher will study the suitable method for the energy efficiency improvement through a simulation work and site measuring work. The project’s Gantt chart is given in Appendix A. The research is conducting in phase’s basis as follows:

Phase 1: Energy usage assessment and power factor measurement

- To access on energy usage at Faculty of Technical and Vocational Education
- To measure average power factor
- To explore current approach on energy saving/energy efficiency improvement program if any

The Figure 3.1 shows how the phase 1, energy usage assessment to be carried out
Figure 3.1 – Energy usage assessment

The measurement will be done at the power meter placed at every level of block A as shown in the Figure 3.2.

Figure 3.2 - Load distribution
Figure 3.3 shows how the phase 1, power factor measurement to be carried out.

Figure 3.3 – Power factor measurement

**Phase 2: Energy efficiency improvement proposal**

- To identify and propose potential energy efficiency improvement activities by different types of load.
  
  i. Lighting
  
  ii. Air conditioner
  
  iii. Office appliances

- To study and propose power factor correction to the electrical installation system
- To do simulation work on energy improvement proposal

Figure 3.3 shows how the phase 2, energy improvement proposal to be carried out.
Phase 3: User behaviour towards energy efficiency

- To identify and propose best practise towards achieving high energy efficiency

Figure 3.4 shows how the phase 3, energy improvement by improving user behaviour to be carried out.

Figure 3.5 – Energy efficiency via user behaviour improvement
3.2 Expected Results

The expected results of this project are:

(i) A significant energy saving can be proposed for Faculty of Technical and Vocational Education and the evidence of the proposal effectiveness can be shown by simulation.

(ii) A significant power factor improvement can be proposed for Faculty of Technical and Vocational Education and the evidence of the proposal effectiveness can be shown by simulation.

(iii) A good user behaviour can be proposed to Faculty of Technical and Vocational Education towards achieving energy efficiency.
CHAPTER 4

DATA ANALYSIS AND RESULTS

4.1 Preamble

This chapter presents the data and results according the part of project implemented. Results from phase 1 to phase 3 will be described here. Phase 1 is energy assessment. This is then followed phase 2 is energy improvement proposal and the last is phase 3 which will be described on user behaviour towards energy efficiency.

4.2 The results

The phase 1 is divided by three parts. The first one is energy usage assessment. The part two is power factor measurement and part three is exploring the approach on energy saving or energy improvement activities at Faculty of Technical Education.

4.2.1 Energy usage assessment

Energy usage assessment is conducted by collecting the data from the power meter installed at every level of the building from 10 April 2013 to 27 April 2014. Even the meter install at all floor level data collected at the meter located at the ground floor and third floor. This is because the floor occupied by admin office and the second to five floor is occupied by lecturer. It is enough to take only one floor for admin and one floor for lecturer. The results of are shown in Table 4.1 and table 4.2.
REFERENCES


