Design Modification for Solar Crop Dryer

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ABSTRACT: Solar drying system is a useful solar energy technology for developing countries. In this study, solar crop dryer is designed and modified with intend to develop solar dryer technology and dry various types of fruits and vegetables. This solar crop dryer system which is reliable, require less space and affordable by small-scale firm and farmer to produce high quality product in Lashio region. The main parts of this solar dryer are concrete floor, iron frame, drying chamber consisting of three steps drying trays and polycarbonate sheet. The base of the dryer is a concrete floor with an area of 5.4 x 4.8 m^2. The system is 3.1m in width, 4.3m in length and 2.1m in height, with a loading capacity about 30kg of fresh fruits or vegetables. The roof of the solar crop dryer is covered with polycarbonate sheets and it is designed in the parabolic shape of facilitate the construction. Six 12V DC fans powered by 40 W solar cell modules were used to ventilate the dryer. The drying air temperature is average 19.7-28.2˚C in July at Lashio. The dryer was installed at Technological University (Lashio), Northern Shan State.

KEYWORDS: *design modification, solar crop dryer, concrete floor, tray, monitoring system*

1. INTRODUCTION

Considerable losses of agricultural products occur in developing countries due to improper drying. This is due to the fact that most of the farmers in these countries are still using natural sun drying method to dry their agricultural products. Although this method requires negligible investment cost, the products being dried are usually susceptible to damage by insects and animals and adverse weather conditions. Therefore, an appropriate dryer is required to properly dry these products. As most of the developing countries are situated in the tropics and subtropics which receive relatively abundant of solar radiation and most of farm size is small, the use of a solar dryer is still considered to be a feasible solution of the drying problems in the tropics and subtropics [1].

Among the existing solar dryers, the greenhouse type solar dryer has a number of advantages over other types of solar dryers. This is because of the fact that the greenhouse solar dryer has a simple structure, large loading capacity and relatively good thermal performance. In addition, greenhouse solar dryer is based on the technology of agricultural greenhouse, which has been already well developed, both in terms of materials and construction method. Greenhouse type solar dryers have been successfully used in the industrialized countries. However, greenhouse solar dryer has received little attention for application in the developing countries [1].

In principle, air is heated by solar radiation and naturally circulated by pressure gradients which promote vertical airflow. Consequently, these dryers require no electrical or mechanical components because the natural convection driving force is based only on temperature difference or changes in air density. Thus, product quality can be improved while reducing wasted produce and minimizing the use of traditional fuels [7].

drying of agricultural goods is essentially the evaporation of moisture from the crop, thus reducing the product's moisture content so that deterioration no longer occurs. Each agricultural crop has different experimentally determined levels of moisture content that is considered safe for preservation. In a normal drying process, the product is placed in an environment in which supplied heat evaporates moisture from the product and air flow then removes the water vapor [7].

In this study, the objectives are to maintain the solar dryer technologies, modify the solar dryer and apply in practice.

2. THEORETICAL BACKGROUND

2.1 Solar Dryer

To address the numerous drawbacks of open sun drying, solar dryers have been developed. Several researches have been done to improve solar drying technology by employing auxiliary source of heating, forced and natural circulation to achieve the desirable drying characteristics. During solar drying, moisture is evaporated from the products by solar heated air temperature of 50 to 60°C in the drying chamber because of solar radiation trapped inside the dryer. Solar drying has proven to enhance the product quality considerably, minimize crop losses and shorten drying time for a given commodity as likened to the traditional methods of drying.

Solar dryers also have the advantage of optimizing energy and time while occupying less space for producing better quality dried products with almost zero energy cost. Solar dryers are categorized based on the mode of heat transfer, air flow and structure of dryer. Fig 1 shows the classification of solar dryers [10].

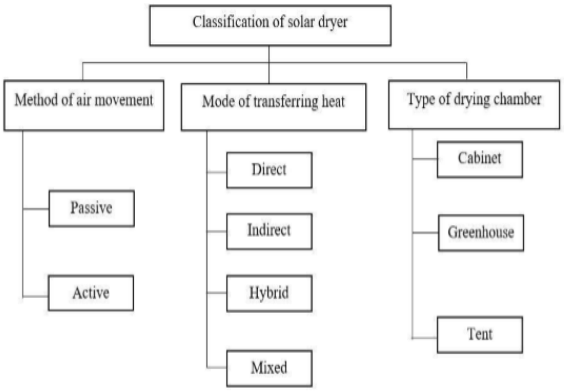


Fig 1. Classification of solar dryers

2.2 Greenhouse Solar Dryer

Greenhouse dryers are used in several applications. The greenhouse solar dryer works under the principle of greenhouse effect, it permits short wavelength solar radiations from the sun while trapping the long wavelength solar radiations inside the drying chamber. This type of dryer principally functions either in active mode (forced convection) or passive mode (natural convection). The passive mode greenhouse solar dryer uses a ventilator or chimney to provide natural movement of air entering inside the dryer. While in the active mode greenhouse solar dryer, exhaust fan is used for extracting humid air outside the dryer.

Modifications in greenhouse solar dryers have been classified on the basis of airflow, dryer structure, covering material, north wall and the dryer floor to improve performance and efficiency. [10]

2.3 Data for Proposed Area

Lashio has a humid subtropical climate, marked by heavy rain from May to October. In Lashio, the summers are short, hot and mostly cloudy and the winters are short, cool, dry and mostly clear. The temperature typically varies from 20˚C to 35˚C.

In this study, solar crop dryer is installed at Technological University (Lashio). It is located in latitudes 23.0312257˚N and longitudes 97.773555˚E. There are several farmlands around this area. Many people make a living as a farmer. It is an area where many seasonal crops are grown. This season is the time for the abundance of jack fruit, pineapple and quince fruit.

Fig 2. Location of solar crop dryer

3. DESIGN DEVELOPMENT

3.1 Previous Design

In this study, solar crop dryer is implemented at Technological University in September, 2019 as shown in Fig 3. It is utilized to dry chilies, potato, onion and quince fruit.

Fig 3. Previous solar crop dryer design

The experimental runs were conducted in September, 2019. Quince fruit, potato, onion and chili were dried in the green house solar dryer to investigate the dryer potential. The products were placed on the trays inside the dryer. Each day, the experiment was started at 9:00 am and lasted until 5:00 pm. The drying was continued on subsequent days until the desired moisture content was reached. The moisture content during drying was estimated from the weight of the product samples and the estimated dried solid mass of the samples. The quince fruit, potatoes, onion and chili are used to test the dryer is shown in Fig 4.

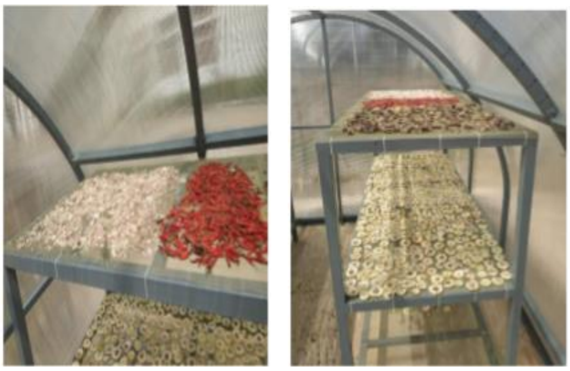


Fig 4. Test with quince fruit, potatoes, onion and chili inside the solar crop dryer

Now, this area receives a lot of rain during the rainy season. Currently, due to the uneven foundation and heavy rain, rainwater is entering the solar crop dryer. As a result of the catchment, the inside of the solar crop dryer becomes hot and humid, then causing bad breath and the growth of insects. So, the quality of the products cannot get as expectation in the rainy season. Therefore, the current solar crop dryer needs to be modified. Fig 5 shows catchment area inside the solar crop dryer.

Fig 5. Catchment condition inside the solar crop dryer

In addition, insects and algae grow in the catchment area inside the solar crop dryer as shown in Fig 6 and Fig 7.

Fig 6. Insects and algae grow inside the solar crop dryer

Fig 7. Algae grow inside the solar crop dryer and uneven concrete floor

The cause of the catchment is surface of the concrete floor is rough and cracked, uneven of left side floor level shown in Fig 8. There is no exit vent to keep out water, insects and dusts.

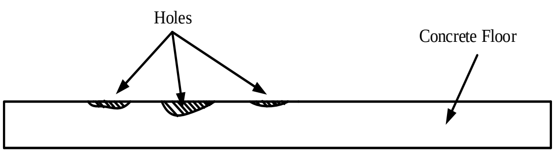


Fig 8. Uneven of concrete floor level

The design of the tray is square shape and has three steps. There have four trays inside the solar crop dryer. This design is chosen because of expensive of the polycarbonate sheet, many available to dry fruits and vegetables. The amount of radiation that falls on the tray varies slightly from level to level. The top level of the floor is closest to the roof, so radiation is good and temperature is high. The temperature and humidity between the middle and lower level are slightly different than top level because of shaded and the sun direction shown in Fig 9 and Fig 10. Therefore, the tray design must be changed to a staircase design so that the temperature is almost the same at all levels.

Fig 9. Shaded tray

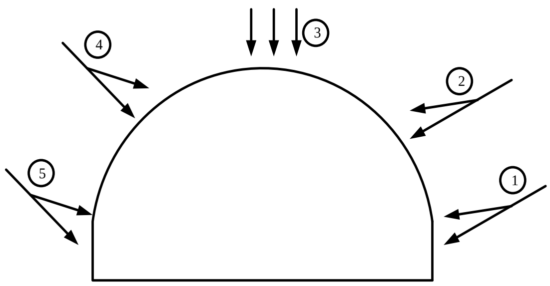
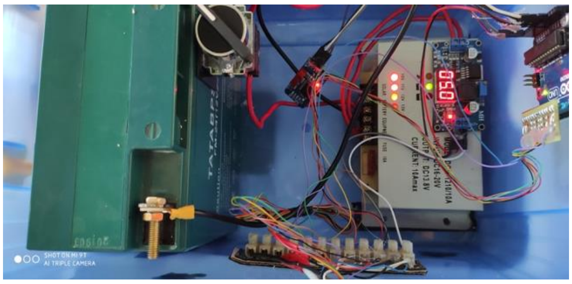


Fig 10. The sun direction that rise from 1 to enter 5

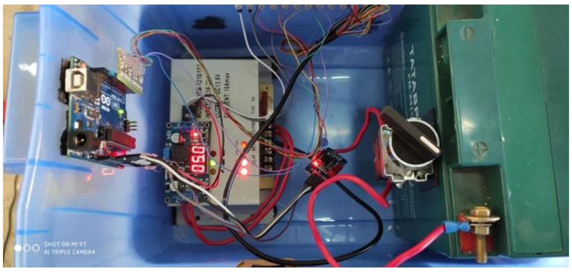
So, the temperature and humidity of the left and right side is slightly different inside the solar crop dryer.

3.2 New Design

The new design describes a design idea need to change the foundation and the drying tray. Therefore designing and modifying a new solar crop dryer is necessary to use annually and sustainably. Then, the temperature and humidity sensor are used to monitor and record the hourly data for temperature and humidity inside the solar crop dryer and the ambient temperature and humidity. The monitoring system have temperature and humidity sensor, control circuit using Arduino Mega and P10 board display to show the values of temperature and humidity. Fig 11and 12 show control circuit and display board of monitoring system. This control system will control the fun as a requirement.



(a)



(b)

Fig 11. Control circuit of the monitoring system

Fig 12. P10 board display of the monitoring system

The original solar crop dryer is modified to allow for the inlet vents along the full length of both sides of the base and exit vents to keep out water, insects and dusts. Then, GI hollow pipes made up of galvanized steel are used for tray.

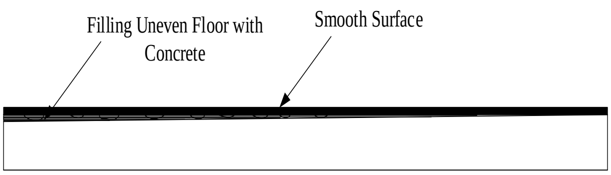


Fig 13. Modified uneven floor

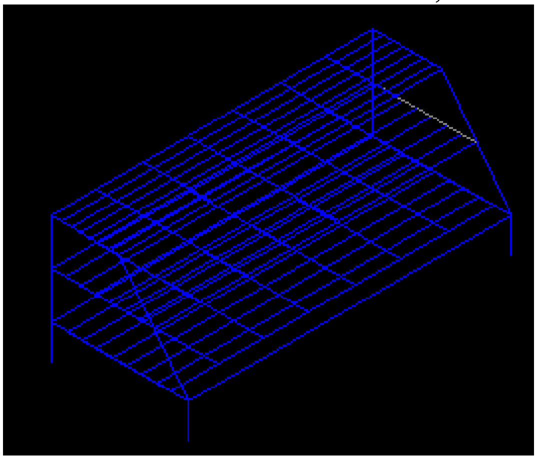


Fig 14. Modified Drying Tray

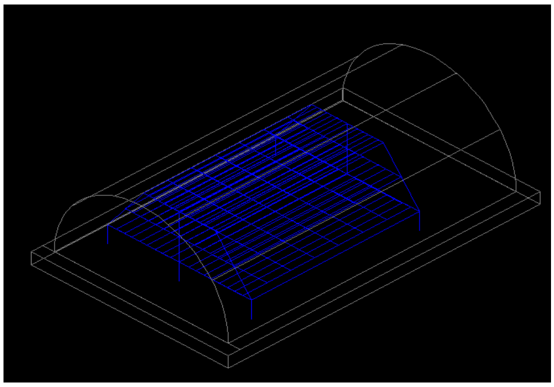


Fig 15. Layout of modified drying tray inside the solar crop dryer

4. ANALYSIS

In this study, temperature and humidity are measured using the monitoring system. Fig 16 shows the average temperature in July. In this figure, left side means the sun rise location and right side means sun set location. In the morning, right side temperature is slightly higher than left side inside the solar crop dryer. In the evening, left side temperature is slightly higher than right side inside the solar crop dryer. The gray color is ambient temperature around the proposed area.

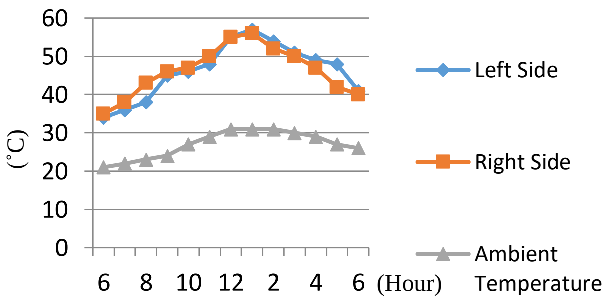


Fig 16. Temperature condition for proposed area

Fig 17 shows the average humidity in July. In this figure, left side means the sun rise location and right side means sun set location. In the morning, left side humidity is slightly higher than right side inside the solar crop dryer. In the evening, right side humidity is slightly higher than left side inside the solar crop dryer. The green color is ambient temperature around the proposed area. Temperature is reversely by humidity.

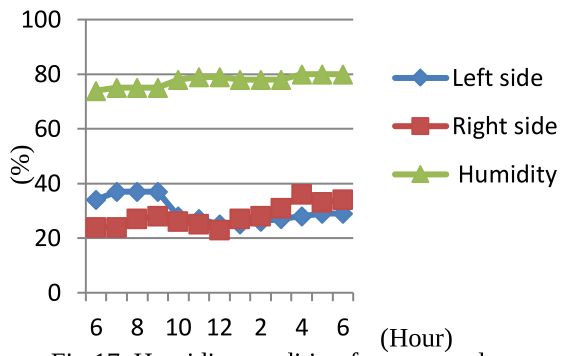


Fig 17. Humidity condition for proposed area

The inlet and outlet temperature for solar crop dryer at this duration are 41˚C and 38˚C. Fig 18 and 19 show the comparisons between before and after tray design in which quince fruit is checked at 7 hour drying time.

Fig 18. Upper, middle and lower level before tray design

In Fig 18, the color of quince fruit at the upper level is the best and at the lower level is slightly pale in color. It means the amount of radiation that falls on the tray varies slightly from level to level before changing of tray design.

After changing of tray design, Fig 19 shows the colors of quince fruit at the upper level and at the lower level are nearly the same because the temperature is almost the same at all levels.

Fig 19. Upper, middle and lower level after tray design

Fig 20 shows overall result to compare between before and after tray design at 26 hour drying time. In this figure, lower row represents before changing tray design and upper row represents after changing tray design.

Fig 20. Overall result comparing between before and after tray design

Table 1 shows experimental result and observation for solar crop dryer.

Table 1. Experimental result and observation at 26hr in solar crop dryer

parameter	unit	value
Initial weight	kg	11.5
Final weight	kg	1.79
Initial moisture content	%	84.4
Final moisture content	%	9.37

Table 2 shows experimental result and observation for open sun drying

Table 1. Experimental result and observation at 38hr in open sun drying

parameter	unit	value
Initial weight	kg	6.5
Final weight	kg	2.1
Initial moisture content	%	84.4
Final moisture content	%	13.69

. According to Table 1 and Table 2, drying time of open sun drying is more than solar crop dryer. And then, the final moisture content of all quince fruits for open sun drying is more increased than solar crop dryer. So, quince fruit for open sun drying is paler in color shown in Fig 21 that mean it is needed to take more time for drying.

Fig 21. Quince fruit drying for open sun drying

4. CONCLUSIONS

The project is beneficial and best suited for that local community. This project intend to local agricultural products in local. After that, it will be investigated with seasonal fruits and vegetables for experimental results. The results will be contributed to farmers and people.

The collection efficiency of solar drying system will calculated using the climatic condition which includes ambient temperature, solar radiation, relative humidity, air velocity and atmospheric pressure. The hourly variation of the temperature inside the solar dryer is higher than surrounding temperature during the observation period and it depends on the intensity of radiation received on earth surface maximum. After modifying the design of solar crop dryer, the product mass will be changed. The previous design, the loading capacity of solar crop dryer is 30kg and the modification design, the loading capacity of solar crop dryer will be 22.5 kg according to the tray design.

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Door Opening and Closing System using Sensor for Automatic Sliding Door System Design

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ABSTRACT*:* Today, with the development of better electronic technology, several automatic systems are the most widely used in the world. Automatic door and door control system is one of the most desirable domestic purpose to facilitate access control system. In this paper, describes the door opening and closing system using sensor for automatic sliding door system design. An automatic door is an automatically movable barrier installed at the entrance of a room or building to restrict access, open the door. The door sliding system is automatically to open or close the door using sensor when someone enters and leaves the building. Sensors are detected when people approach the doors and sends a signal to the transistor, in turns gives interrupt signal to a programmable microcontroller, the output signal form the microcontroller is fed to the DC motor which is used to open and close the door. Nowadays, the automatic doors sliding system can be used for large density areas such as supermarkets, banks, hotels, hospitals, airports, and condo buildings or added to any door to facilitate entry or exit from homes or office without operator and no waste of time.

KEYWORDS: *Operator, DC motor, PIC microcontroller, Sensors, Sliding door system*

1. INTRODUCTION

TODAYS, opening and closing of doors have been always a boring job, especially in places where a person is always required to open the door for visitors such as hotels, shopping malls and theatres. Here is a solution to open and close the door i.e., movement sensed automatic door opening and closing system. Nowadays, the population is increasing in megacities around the world due to the high density of population and public spaces. These places have great difficulty in using manual doors. The manual doors are often practical because they are too difficult to open, especially with the full hand or pushing a stroller. Therefore, faced with the problems of fear of installing the doors to be saved and easier to access more convenience than manual doors. And then, by using the sliding door system, it can reduce the human labor and wages to send the door inside and outside due to the conversion from manual system to automatic system. This paper includes operator, operation of sensors and motor, relays, system of module circuit, timers concerning with the door sliding system. In automatic door sliding system using main controller circuit has four activators (sensors). The first two sensors are inside and outside the room and other two sensors are bedsides the room. The system will also generate an alarm when the door is opened or closed. Power supply is one of the essential elements of any piece of electrical and electronic equipment. This is because it provides power to energize all the electrical or electronic equipment depends open proper and reliable functioning of the power supply. In general, the power supply will be able to deliver the regulated power at specific voltage and current level meeting the equipment requirements.

2. GENERAL THEORY OF AUTOMATIC DOOR SLIDING SYSTEM

2.1 Automatic Sliding Door

The designed automatic sliding door is composed of the operator and the door frame as shown in Fig.1. The sliding door operator of the automatic door system, is located in a space at the top of the door frame. [8]

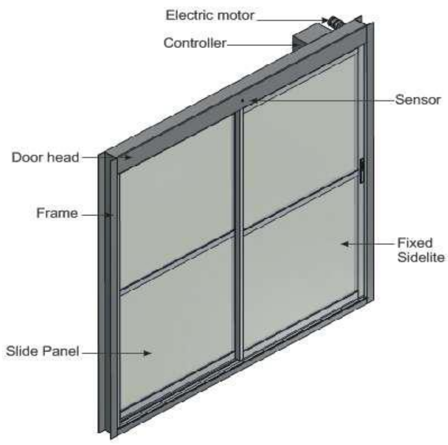

Fig 1. Automatic sliding door [8]

2.2 Sliding Door Operator

The sliding door operator in Fig.2 consists of the main components of power supply, motor, belt pulley system, sensor, microcontroller and battery. The power from the supply is first sent to the power source, and then the power source is distributed the power to the motor, sensors, and microcontroller. The rechargeable battery is charged by the charging circuit from the power supply and acts as an auxiliary power supply in the case of power failure. The electric motor is used to drive the system. The motor drives the pulley at one end of the belt and the fixed pulley at the other end. [8]

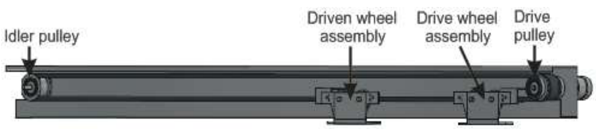

Fig 2. Sliding door operator [8]

The door frame has two panels; one is fixed and the other can slide. The sliding panel is attached to the operator belt. To open the door, the motor rotates the pulley, which in turns the belt, and the door is dragged. The reverse occurs to close the door**.** [8]

2.3 Operation of Automatic Door Sliding System

Automatic sliding doors have flat sliding panels horizontally and linearly, with different configurations. The automatic door sliding system consists of sensing system, main controller circuit and motor. For automatic door sliding system, module circuit is used as main controller. Sensors are used to detect that someone is approaching the sliding doors. Motors are used to achieve the required positions for rotating forward and reverse direction. In addition, the program switch can also be used in door sliding system that selects a door sliding position. This system is used the automatic two ways position of the program switch. Module circuit has four activators (sensors) in which two sensors are edge detectors. The first two sensors are inside and outside of the room and other two sensors are beside of the room.

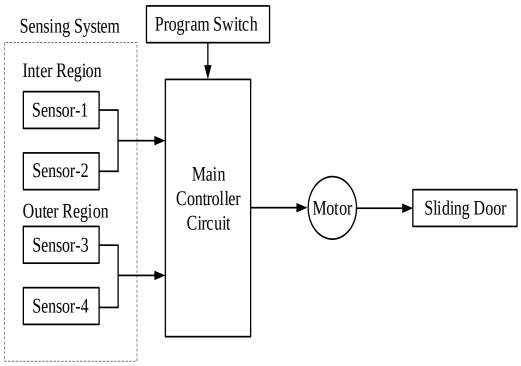

Fig 3. Overall system of automatic door sliding system [3]

When a person approaches the sensor outside or beside of the room, the operation will start. As soon as the person reaches in front of the sensor outside or beside of the room, the module circuit receives the signal through the signal conditioning circuit and then the main controller is to drive the DC motor through the motor driver. After that, the door opens automatically. After the person had passed through the door and waited for a three second delay, the door closes automatically. And then the person will arrive to the room. When the person arrives in front of the second sensor inside or beside of the room, the circuit of the main module receives the signal and is to drive the motor. So, the door opens automatically and a three second delay is expected. The door closes automatically.[3]

2.4 Sensor used in Automatic Sliding Door System

Automatic sliding door is used sensors such as photodiode, phototransistor, light dependent resistor (LDR) that are detected to operate the control system. In this system, the photo-transistors are used as the photo-sensors. Instead of phototransistor, light detecting resistor, infrared sensors can be used. A photo detector is an optoelectronics device that absorbs optical energy and converts it to electrical energy, which usually manifests as a photocurrent.

Fig.4 shows one type of phototransistor, which is made by placing a photodiode in the basic circuit of an NPN transistor. Phototransistors may be of the two-terminal type, in which the light intensity on the photodiode alone determines the amount of conduction. They may be of the three-terminal type, which have an added base lead that allows an electrical bias to be applied to the base. [3]

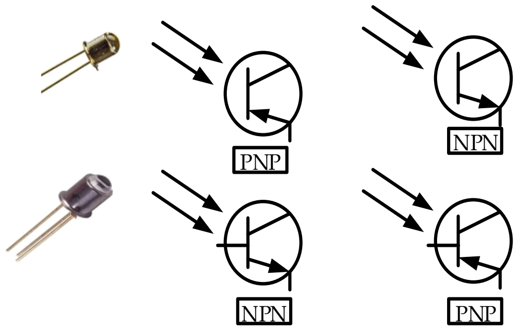

Fig 4. Construction and symbol of 2 and 3- terminal phototransistors [3]

3. AUTOMATIC SLIDING DOOR MOTOR

The electric motor usually includes the DC motor, the brushless DC motor, the stepper motor and the AC motor are used in the motion control system. Most DC motors are used as an automatic motor with sliding doors. One of the most attractive features of DC motors compared to AC motors is the ease with which they can be varied. Basically, five different types of DC motors are used in industry: separately excited DC motor, series wound, shunt wound, compound wound, and permanent magnet. When choosing a DC motor for a particular application, several factors must be considered. First determine what allowable change in speed and torque can be for changing load. Each type of motor has advantages that are useful for certain applications. Motor and DC specifications should always be checked to determine the specific speed and torque of the system. For sliding door system, permanent magnet motor is the best choice. Fig.5 shows a permanent-magnet (PM) DC motor. The motor is made up of two main parts: a housing containing the field magnets and an armature consisting of coils of wire wound in slots in an iron core and connected to a commutator. [2][3]

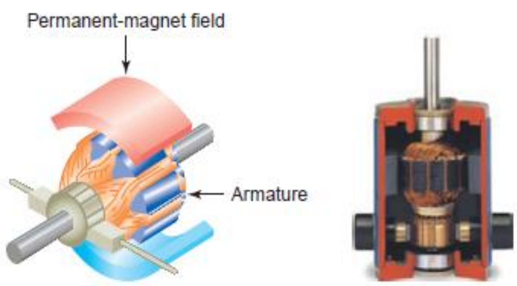

Fig 5. Permanent magnet DC motor [2]

PM motors produce high torque compared to wound-field motors. However permanentmagnet motors are limited in load-handling ability and for this reason used mainly for low-horsepower applications. The force that rotates the motor armature is the result of the interaction between two magnetic fields (the stator field and the armature field). To produce a constant torque from the motor, these two fields must remain constant in magnitude and in relative orientation. [2]

4. ELECTRICAL COMPONENTS OF POWER SUPPLY FOR AUTOMATIC DOOR SLIDING SYSTEM

In this power supply and control circuit, the following components are comprised and they perform the power conversion and control for automatic sliding door system.

- Transformer
- Diode and rectifier
- Capacitors and filter
- Voltage Regulator
- DC-DC Converter

In this paper, only the important components such as transformer, rectifier, regulator are described.

A. Transformer

A transformer is a device that transfers energy from one AC system to another. A transformer can accept energy to one voltage and deliver it at another voltage. This permits electrical energy to be generated at relatively low voltages and transmitted at high voltages and low currents, thus reducing line losses, and to be used at safe voltages. [2]

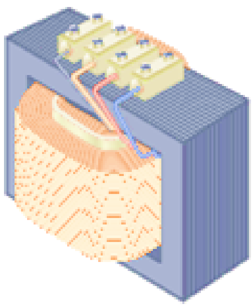

Fig 6. Transformer [2]

Design specifications of transformer are given below:

E.M.F equation

$E_1 = 4.44\, f T_1\, B_m\, A_i$ volts (1)

$E_2 = 4.44\, f T_2\, B_m\, A_i$ volts (2)

The e.m.f per turn, $E_t = 4.44\, f\, B_m\, A_i$ volts (3)

Where, E_1 = induced e.m.f in primary winding (V)
E_2 = induced e.m.f in secondary winding (V)
f = frequency of supply (Hz)
A_i = net cross-sectional area of the core (m^2)
B_m = maximum value of main flux (Tesla)
T_1 = number of turns in the primary winding (turns)
T_2 = number of turns in the secondary winding (turns)

E.M.F per turn equation, $E_t = k\,(KVA/phase)$ volts (4)

Where, E_t = e.m.f per turn
k = factor

A suitable value of the factor, k can be taken depending upon the type of transformer.

For single phase transformers,

$Q = 2.22\, f\, B_m\, \delta K_w\, A_w\, A_i \times 10^{-3}$ kVA (5)

Where, Q = output of single-phase transformer (kVA)
δ= average value of current density (A/m^2)
A_w = window area (m^2)
K_w = window space factor [3]

B. Rectifier

The full wave bridge rectifier shown in Fig.7 is made up of four diamond-shaped diodes.

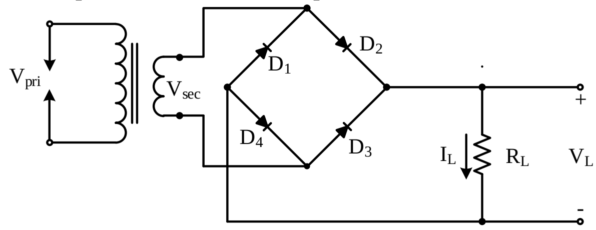

Fig 7. Full-wave bridge rectifier [3]

The transformer secondary is connected to the two corners of the diamond, and the load is connected to the other corners. When the top of the secondary winding is positive, diodes D2 and D4 are positive (forward-biased); current flows through diode D2, then through load and diode D4. The other two diodes are OFF.

When the bottom of the winding is positive, diodes D3and D1 are now forward-biased and turn ON; similarly, diodes D2 and D4 are now OFF. Thus, the full voltage between both ends of the transformer secondary winding is utilized and current flows during both halves of the input cycle. The full-wave bridge rectifier makes the most efficient use of the transformer, when compared to the half-wave and the full-wave rectifiers. [3]

C. Regulator

One of the most importance functions of switching type power supplies is the control or regulation of the supply voltage used to power electronic circuitry. The most common types of switching regulator is a three-terminal system that accepts an unregulated DC input voltage and provides a regulated DC output voltage. The 78xx series of IC regulators is representative of three-terminal devices that provide a fixed positive output voltage. The 7800 series can produce output current in excess of 1 A when used with an adequate heat sink. The 78L00 series can provide up to 100 mA, the 78M00 series can provide up to 500 mA, and 78T00 series can provide in excess of 3 A. There are many types of IC regulators, among them, LM78xx series is shown in Fig.8. [3]

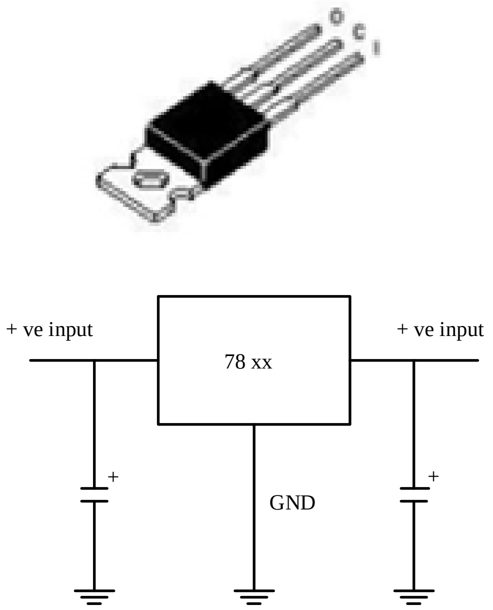

Fig 8. The 78xx series three-terminal fixed positive voltage regulator [3]

5. POWER SUPPLY CIRCUIT

There are two types of power supply for automatic sliding door system. They are unregulated DC and regulated DC. The regulated +5 V DC is supplied for microcontroller and sensors that control the battery power and DC permanent magnet motor. The regulated DC is obtained from 220 VAC 50 Hz by step down transformer, full-wave bridge rectifier and capacitor filtering circuit. Block diagram of a regulated power supply system as shown in the Fig.9. [3]

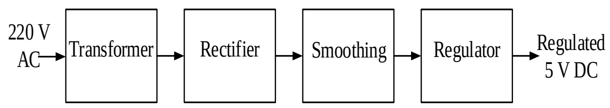

Fig 9. Block Diagram of a Regulated Power Supply System [4]

6. HARDWARE IMPLEMENTATION OF CONTROL SYSTEM

The main components of the system are:

- PIC Microcontroller
- Sensors
- Liquid Crystal Display (LCD)
- Motor Driver (H-bridge L293)

A. PIC Microcontroller

In this paper, PIC 16F887 microcontroller is used as receiver module to receive the data from transmitter module and to control motor driver to drive DC motors. And the path of each table for the desired workplace is stored in external EEPROM which is the output pin of this. Fig.10, describes the pin configuration of PIC 16F887 microcontroller. State of pins such as input or output analog or digital can be controlled by software coding. The demonstration model uses DC motor for door control. A lot of control and I/O routines are needed to develop while PIC coding.

Feature of PIC 16F887 Microcontroller,

- Architecture: 8 bit
- Program Memory (Flash): 14 kB (8 k Words)
- RAM: 368 byte
- EEPROM: 256 byte
- Pin: 40 (Pin I/O : 36)
- Max. CPU frequency: 20 MHz (5MIPS)
- Internal Oscillator: 8 MHz, 32 kHz

Peripherals of PIC 16F887 Microcontroller,

- A/D Converters: 1 (14 channels)
- Capacitive Touch Channels: 11
- Comparators: 2
- CCP Module: 1x CCP, 1x ECCP, 10-bit PWM resolutions
- Timers: 2x8-bit, 1x16-bit
- Comm. Peripherals: 1x A/E/USART , 1x MSSP (SPI/I2C)

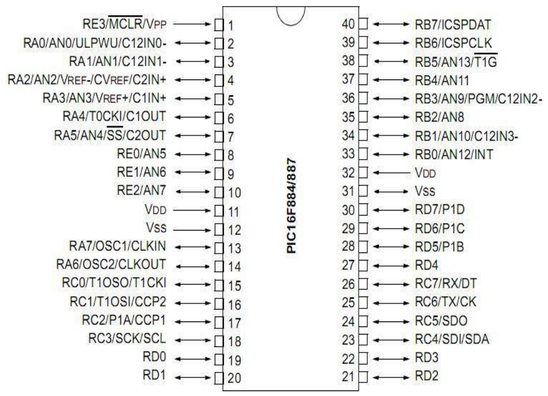

Fig 10. Pin Configuration of PIC 16 F887 Microcontroller

B. Sensors

1. Photo-diode

The photo diode consists of normal P-N junctions with a transparent window through which light can enter. A photo-diode is usually operated in reverse bias and can be used as a variable resistance element controlled by the incident light. The schematic symbol is shown in Fig.11.

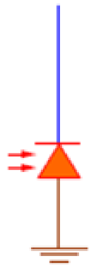

Fig 11. schematic symbol of photo-diode [1]

2. Phototransistor

A phototransistor has a photosensitive collector-base p-n junction. When there is no incident light, the collector-emitter current is very small. When the light is fall, a base current is generated that is directly proportional to the light intensity. This produces a collector current which is then a measure of the light intensity. [3]

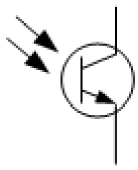

Fig 12. Schematic Symbol of Phototransistor [3]

3. Light Dependent Resistor (LDR)

A light dependent resistor (LDR) or photo resistor is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices. They are also called as photo conductors, photo conductive cells or simply photocells. They are made up of semiconductor materials having high resistance. [6]

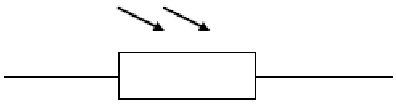

Fig 13. Schematic Symbol of Light Dependent Resistor (LDR) [4]

C. Liquid Crystal Display (LCD)

In this paper, a 2x16 LCD is used for the display of the values sensed by the various messages from the microcontroller. Liquid crystal display (LCD) has material which combines the properties of both liquid and crystals. They have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an order form similar to a crystal. The LCD can be operated in two different modes:4-bit and 8-bit modes. In this paper, LCD is used to display the door condition such as opened, closed, opening or closing. [10]

Fig 14. LCD Display [10]

D. Motor Driver L293 IC

Sometimes the direction of rotation needs to be changed. The direction changing is typically implemented using relays or a circuit called H-bridge. H-bridge circuit design, there are four transistors (such as BJT, FET, MOSFET, etc) are connected as a squared bridge circuit. Each edge of two transistors is connected to one pole of motor. The L293 is an integrated monolithic circuit in a 15 – lead Multi watt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at lower voltage. In this paper, Fig.15 shows L293 motor driver are used for running the motor forward or reversed.

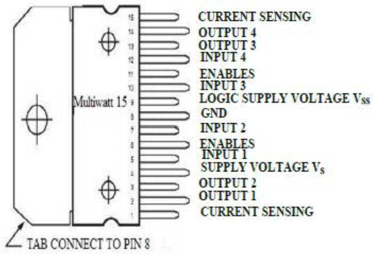

Fig 15. Pin Connection of L293 Motor Driver [9]

7. FLOW CHART FOR CONTROL SYSTEM

In the operation of control system, the PIC 16F887 microcontroller will be used to control the sliding door control system. This microcontroller is programmed by using C programming. In this paper, the electronic safe is assumed to use the DC motor to open and close the door. The flow chart for automatic door sliding control system is shown in Fig.16. In this circuit, two sensors are used to detect the person for opening and closing the door and another two sensors (edge detectors) are used for motor control and two kinds of output are motor and display. When the sensors are operated, the running of motor is forward direction to open the door and the running of motor is reverse direction for closing the door. If sensors from inside or outside or both are operated while closing, the motor are rerunning to open the door.

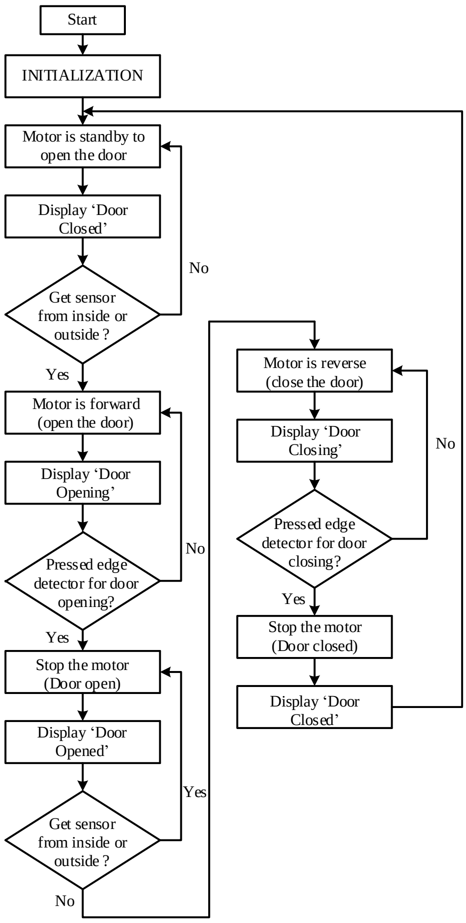

Fig 16. System Flow Chart [9]

7.1 Test and Results of Automatic Sliding Door System

When the power is supplied to the circuit, the door is standby to open the door. Firstly, the program initializes the inputs, outputs and variables to open the door. The message "Door Closed" will play on LCD screen in Fig.17.

Fig 17. Displaying the door is completely closed.

When sensor inside or outside or both are operated, the door opening until pressing the edge detector for door opening. "Door Opening" will display on LCD screen in Fig.18.

Fig 18. Displaying whether the door is opening.

When the edge detector for door opening is pressed, the motor running stop. The door still open, "Door Opened" will display on LCD screen in Fig.19.

Fig 19. Displaying the door is completely opened.

When sensor inside and outside are not operated, the door closing until pressing the edge detector for door closing. "Door Closing" will display on LCD screen in Fig.20.

Fig 20. Displaying whether the door is closing.

When the edge detector for door closing is pressed, the motor running stop. The door closed, "Door Closed" will display on LCD screen in Fig.21.

Fig 21. Displaying the door is completely closed

8. CONCLUSIONS

This paper delivered a mature approach for door opening and closing system using sensor for automatic sliding door system design. The architecture of PIC16F887A microcontroller device and its associated peripheral modules have been presented initially. The theoretical background of the components used in this system and automatic sliding door designs are also included. The sensor for sensing and switches is used as input devices. The photoelectric sensor is used for detecting the human body in and out of the situation. The sensor is sensitive and reliable and is not affected by environmental factors. To complete the system design, the program development such as flow chart diagrams is also described. Opening and closing of the door may be done with various kinds of components such as motor and solenoid valve. L293 motor driver is used to drive the DC motor. Motor on/off is limited by edge detector. Forward, reverse and stop processes of motor can be controlled by software program. The general operation and efficiency of the system depends on the presence of the person entering through the door and their proximity to the door. And then, can conclude that this is a simple and low-cost architecture of automatic door opening and closing system but having lots of benefits such as can conserve energy, reduces human efforts, saves time, etc.

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Design Calculation of Power Factor Correction for Kyaing Tong Distribution Substation

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ABSTRACT*:* Capacitor banks are commonly connected to the power system to enhance its reliability by providing voltage support, improving power factor, and increasing the system capacity. The main objective of this paper is using a capacitor bank for improvement of power factor and design calculation of capacitor bank size is presented. The location of power factor improvement with capacitor bank at low tension side is 33/11kV Kyaing Tong Substation (1) in Myanmar. Improving the power factor means reducing the angle of lag between supply voltage and supply current. Capacitor installed near the loads in a plant are the most economical and also can be installed between the contactor and the overload relay, the upstream circuit breaker and the contactor also install at the main distribution bus. So, by installing shunt capacitor in distribution circuits to improve voltage profiles, reduce line loading and losses. The rapid development and relative economy led to stability and voltage control by shunt capacitors and a wide range of different solution has been developed.

KEYWORDS: *power factor, capacitor bank, voltage profile, stability*

1. INTRODUCTION

The power factor correction means bringing the power factor of an ac circuit nearer to one by using the equipment which absorbs or supply the reactive power to the circuit. Usually, the power factor correction can be done by using the capacitor and the synchronous motor in the circuit. The power factor correction will not change the amount of true power, but it will reduce the apparent power and the total current drawn from the load. The power factor represents the fraction of total energy use for doing useful work, and the remaining energy is stored in the form of magnetic energy in the inductor and capacitor of the circuit. The value of power factor lies between -1 to +1.

Utilities today are faced with ever more stringent reactive requirements from wholesale power and transmission delivery providers. The need to increase system capacity, improve voltage profiles, increase efficiency, and reduce losses necessitates that utilities provide needed reactive compensation at economic voltage levels to maximize the effectiveness and efficiency of existing facilities. 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.

To reduce losses in the distribution system, and to reduce the electricity bill, power factor correction, usually in the form of capacitors, is added to neutralize as much of the magnetizing current as possible. Capacitors contained in most power factor correction equipment draw current that leads the voltage, thus producing a leading power factor. Typically, the corrected power factor will be 0.92 to 0.95. Some power distributors offer incentives for operating with a power factor of better than 0.9, for example, and some penalize consumers with a poor power factor. There are many ways that this is metered but the net result is that in order to reduce wasted energy in the distribution system, the consumer is encouraged to apply power factor correction. The most economical value of power factor lies between 0.9 and 0.95. If the value of power factor lies below 0.8 (approx), then it draws more current from the load. [4]

2. ACTIVE POWER, REACTIVE POWER AND APPARENT POWER

Real power is the actual power supplied to a circuit or equipment which includes the power supplied to do the actual work and also the real power loss (I^2R) which appears in the form of heat. Therefore, it is a part of total power supplied, which is used to do the actual work- to run a motor, heat a home, or illuminate an electric light bulb. Reactive power is fundamental for the AC circuit as it builds up the electromagnetic fields in the AC equipment- magnetic fluxes in transformers, generators and motors, magnetic and electrical fields in transmission lines, etc.

With just active power in the system, we can light resistive bulbs only, but the other electrical machines like fans, washing machines, which have motors, will not work. Reactive power is the power which oscillates back and forth between source and load. And it is possible because an AC load comprises of components that are capable of storing energy: Inductor stores energy in the form of magnetic field and capacitor stores energy in the form of electric field. During one half cycles the inductor or capacitor stores energy and in the next half it delivers this stored energy back to the source. Thus, Reactive power is a circulating power in the electrical system. Since the Reactive power is trapped in the AC network, it cannot be converted to another form of energy or produce useful work.[3]

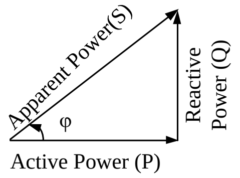
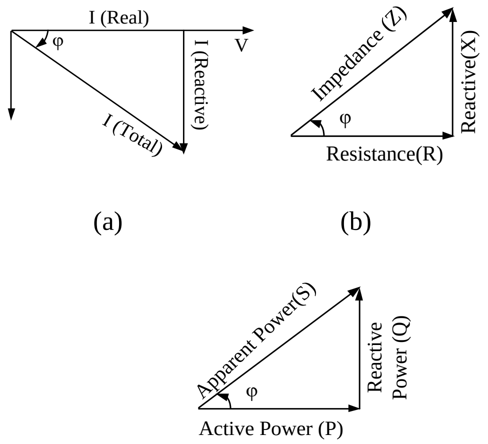


Fig 1 Power triangle

3. POWER FACTOR

In a dc circuit, there is no phase difference between voltage and current: thus, power supply to the dc load is



(a) (b)

(c)

Fig 2 (a) Phasor diagram (b) Impedance Triangle, (c) Power triangle

simply the product of voltage across the load and current flowing through it i.e., P=VI. In ac circuit, there exists a phase difference between applied voltage and current when the load is inductive or capacitive. The cosine of this phase difference (cos ∅), is termed as power factor. A load with a power factor of 1.0 result in the most efficient loading of the supply and a load with a power factor of 0.5 will result in much higher losses in the supply system.

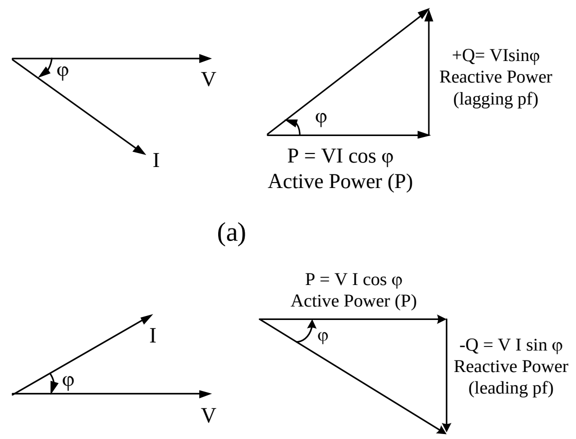
3.1 Leading and Lagging Power Factor

Power factor signifies the amount of active power available out of the total Power. In other words, it is a measure of how efficiently the current is being converted into useful work, and is the good indicator of effect of load current on efficiency of supply system. It is a general practice to describe power factor as lagging, leading or unity on the basis of the circuit under consideration.

If the load is purely resistive, these two quantities: voltage and current reverse their polarity at the same time. In this case, only active power is transferred just like in the dc system. Whereas ac system with inductive load (for example: motors, transformers etc., or capacitive load draws a current that is not in phase with the supply voltage. Such current can be resolved into two components: namely, cosine component (I cos ∅, in phase with voltage) and sine component (I sin ∅, in quadrature with voltage).

When current lags behind the voltage (inductive circuit): the power factor of the circuit is called 'lagging'. Induction motors, coils, lamps, etc. are inductive load. When current leads the voltage (capacitive circuit): the power factor of the circuit is called 'leading'. A few examples of capacitive loads include Synchronous condensers, capacitor banks. Pure Resistive load draws current which is exactly in phase with the supply voltage. Therefore, such load has unity power factor, e.g. Incandescent lamp.

There is also a difference between a lagging and leading power factor. The terms refer to whether the phase of the current is leading or lagging the phase of the voltage. A lagging power factor signifies that the load is inductive, as the load will "consume" reactive power, and therefore the reactive component Q is positive as reactive power travels through the circuit and is "consumed" by the inductive load. A leading power factor signifies that the load is capacitive, as the load "supplies" reactive power, and therefore the reactive component Q is negative as reactive power is being supplied to the circuit.[2]



(a)

(b)

Fig 3 Phasor diagram showing of

(a) lagging power factor

(b) leading power factor

3.2 Causes of Low Power Factor

A poor power factor can be the result of either a significant phase difference between the voltage and current at the load terminals, or it can be due to a high harmonic content or distorted/discontinuous current waveform. A poor power factor due to an inductive load can be improved by the addition of power factor correction, but, a poor power factor due to a distorted current waveform requires a change in equipment design or expensive harmonic filters to gain an appreciable improvement.

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. [3]

4. POWER FACTOR CORRECTION

Power factor correction usually means the practice of generating reactive power as close as possible to the load which requires it, rather than supplying it from a remote power station. Most industrial loads have lagging power-factors that they absorb reactive power. The load current therefore tends to be larger than is required to supply the real power alone. Only the real power is useful in energy conversion and excess load current represents a waste to the consumer, who has to pay not only for the excess cable capacity to carry it but also for the excess Joule loss produced in the supply cables.[6]

4.1 Capacitor Banks

The most common type of PFC is used shunt capacitor banks. It is the simplest method and applied at areas where large inductive loads (lagging currents) are present. Static capacitors are used which produce capacitive reactance that cancels out the inductive reactance of the lagging current. These banks can be star connected or delta connected. A control system is usually provided which monitors the power factor and switches the capacitors ON or OFF.

4.2 Synchronous Condensers

When a synchronous motor is over excited, it draws leading current. In a way, it behaves like a capacitor. When such a motor is over excited and run at no load, it is called a synchronous condenser. The most attractive feature is that it allows step less pf correction. In a static capacitor, the leading kVAR supplied are constant. But in a synchronous condenser, we can vary the field excitation and hence control the amount of capacitive reactance produced. Synchronous Condensers are used in large factories, industries and major supply substations.

4.3 Phase Advancers

It can be used only for Induction Motors. It can be known that stator winding draws lagging current in a motor. This current is drawn from the main supply. Hence, to improve power factor, we supply this lagging current from an alternative source. This alternative source is the phase advancer. A phase advancer is basically an ac exciter. It is mounted on the same shaft as the main motor and connected in the rotor circuit. It supplies exciting ampere turns to the rotor circuit at slip frequency. This improves the power factor. Another attractive feature is that if we supply more amp-turns than needed, the motor will operate in an over excited state (leading power factor).[1]

5. DESIGN CALCULATION FOR SIZE OF CAPACITOR BANKS

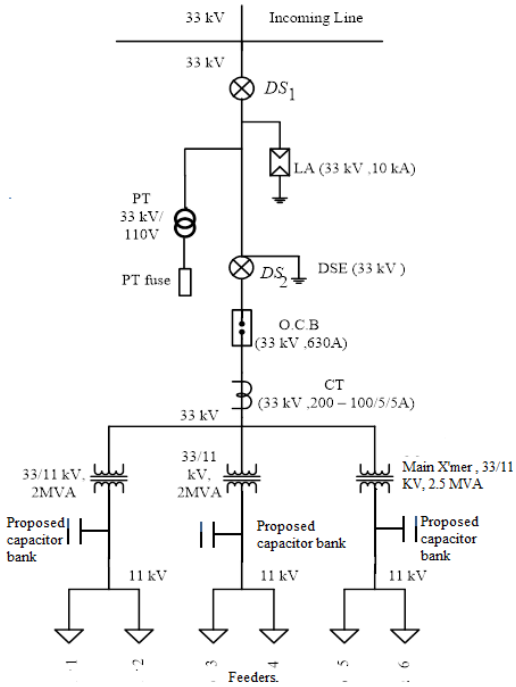


Fig 4 One line diagram for Kyaing Tong distribution substation

The incoming lines of Kyaing Tong distribution substation 1 is three conductors of ACSR Ostrich constitute at 50Hz single circuit three-phase line arranged as shown in Fig 4. The conductor has 26 strands and its size is 300 mcmil. The length from Generation source to Kyaing Tong Substation (1) is 21.14 km. At 20˚C for aluminum ρ is 17 Ω-cmil / ft and with an increase of 2 % concentrically stranded conductors. T =228 for hard-drawn aluminum of 61 % conductivity for the variation of resistance of metallic conductor with temperature.

The direct current resistance is given by the formula is

$$R_{dc} = \frac{\rho L}{A}\,\Omega \qquad (1)$$

The variation of resistance of metallic conductors with temperature is

$$\frac{R_2}{R_1} = \frac{T + t_2}{T + t_1} \qquad (2)$$

The alternative current resistance is given by the formula is

$$R_{ac} = K.R_{dc} \qquad (3)$$

K is a function of X

$$X = 0.063598\sqrt{\frac{\mu f}{R_{dc}}} \qquad (4)$$

f = frequency of transmission line

μ = permeability (1.0 for non-magnetic material)

To find inductive reactance

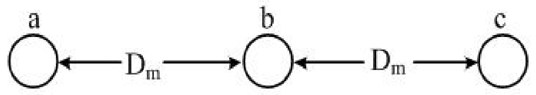


Fig 5 Typical arrangement of conductors of a single-circuit three phase line

$$L = 0.7411 \, \text{Log} \frac{D_{meq}}{D_s} \text{ mH / mile / phase} \qquad (5)$$

$$D_{meq} = \sqrt[3]{D_m \times D_m \times (D_m + D_m)} \qquad (6)$$

The inductive reactance, $X_L = 2\pi f L$ (7)

To find the impedance of 11 kV low voltage side

$$\frac{Z_1}{Z_2} = \left[\frac{N_1}{N_2}\right]^2 \qquad (8)$$

For Project, 2500 kVA Transformer

% impedance = 6.51%, power factor = 0.85, S = 2500 kVA

The actual power, $P_L = S \times \cos\varphi$ (9)

The reactive power, $Q_L = P_L \times \tan\varphi$ (10)

The line current, $I_n = \frac{MVA}{\sqrt{3}\,kv}$ (11)

The line voltage, $E_n = \frac{11 \times 10^3}{\sqrt{3}}$ (12)

Transformer impedance, $Z_{tr} = E_n/I_n \times$(% impedance)(13)

Impedance for 11 kV low voltage side $Z_s = Z_2 + Z_{tr}$ (14)

$$|E|^2 = \left[V + \frac{R_s P_L + X_s Q_L}{V}\right]^2 + \left[\frac{X_s P_L - R_s Q_L}{V}\right]^2 \qquad (15)$$

$$\Delta V_R = \frac{R_s P_L + Q_L X_s}{V}, \; \Delta V_X = \frac{X_s P_L - R_s Q_L}{V} \qquad (16)$$

$$\text{Line current}, I_L = \frac{P_L - jQ_L}{V} \qquad (17)$$

$$\text{Voltage Regulation} = \frac{|E| - |V|}{|V|} \qquad (18)$$

E =No load voltage

V = Full load voltage

R_s = Resistance for 11 kV low voltage side

X_s = Reactance for 11 kV low voltage side

5.1 Uncompensated Condition

Impedance of 33 kV high voltage side = 4.5 + j6.9 Ω

Impedance of 11 kV low voltage side = 0.5 + j3.9167 Ω

2500 kVA, 33/11 transformer, power factor = 0.85,

E =11

The actual power P_L = 2.125 MVA

The reactive power Q_L = 1.317 MVA

$$|E|^2 = \left[V + \frac{R_s P_L + X_s Q_L}{V}\right]^2 + \left[\frac{X_s P_L - R_s Q_L}{V}\right]^2$$

$$V = 10.35\text{kV}$$

$$\Delta V_R = \frac{R_s P_L + Q_L X_s}{V}, \; \Delta V_X = \frac{X_s P_L - R_s Q_L}{V}$$

$$\Delta V = \Delta V_R + j\Delta V_X = 0.601 + j0.7405 \text{ V}$$

$$\text{Line current}, I_L = \frac{P_L - jQ_L}{V} = 0.242 \angle 4.024 \text{ kV}$$

Power factor = 0.85 (lagging)

$$\text{Voltage Regulation} = \frac{|E| - |V|}{|V|} = 5.97\%$$

5.2 To install capacitor bank at low voltage side of substation for voltage improvement from 10.35 kV to 10.8 kV

Impedance of 11 kV low voltage side = 0.5 + j3.9167 Ω

The actual power P_L = 2.125 MVA, E =11kV, V=10.8kV

$$|E|^2 = \left[V + \frac{R_s P_L + X_s Q_s}{V}\right]^2 + \left[\frac{X_s P_L - R_s Q_s}{V}\right]^2$$

$$Q_s = 0.209 \text{ MVAR}$$

The required size of capacitor bank

$Q_r = Q_{s\ (uncorrected)} - Q_{L(corrected)}$

$= -\ 1.1085$ MVAR

$$Q_r = \frac{V^2}{X_C} = \frac{V^2}{\frac{1}{2\pi fc}}$$

$\omega = 2\pi f$, f= frequency

The required capacitance, $c = \frac{Q_r}{V^2\omega} = \frac{1.1085}{(10.35)^2 \times 2\pi \times 50} =$ 32.94μF (to get this, capacitors can be connected in series/parallel as required for the most economical condition)

$$\Delta V_R = \frac{R_S P_L + Q_S X_S}{V} \qquad \Delta V_X = \frac{X_S P_L - R_S Q_S}{V}$$

$$\Delta V = \Delta V_R + j\Delta V_X = 0.174 + j0.76097\ \text{kV}$$

$$\text{Supply voltage, } E = V + \Delta V = 10.94 + j0.76097\ \text{kV}$$

$$\text{Line current, } I_S = \frac{P_L - jQ_S}{V} = 0.1968 - j0.102\ \text{kA}$$

$$\text{The compensator current, } I_r = \frac{-jQ_r}{V} = j0.1026\ \text{kA}$$

The line current flow into the load ,$I_L = I_s - I_r$

$= 0.1968 - j0.2046$ kA

$$\text{Power factor} = 0.88\ (\text{lagging})$$

$$\text{Voltage regulation} = \frac{|E| - |V|}{|V|} = 1.851\%$$

After compensation the supply voltage from 10.35 kV to 10.8 kV, the power factor increased from 0.85 (lagging) to 0.88 (lagging). Also the voltage regulation changes from 5.97 % to 1.851%. The required capacitor bank size is 1.1085 MVAR , its capacitive value is 32.94μF and connected in parallel to the circuit. The size of the required capacitor banks for improving to 10.9 kV and 11 kV can also be calculated similarly.

Table 1 Calculation Result of Capacitor Banks and Power Factor according to the supply voltage

Supply Voltage (kV)	Size of Capacitor (MVAR)	Power Factor (After Correction)	Load Voltage (kV)	Load (MW)
10.8	-1.1085	0.88 (lagging)	11	2.5
10.9	-1.245	0.994 (lagging)	11	2.5
11	-1.317	0.999 (lagging)	11	2.5

Table 2 Calculation Result of Power Factor Correction and Voltage Regulation with Capacitor Banks

	Source-Substation	Source-Substation	Source-Substation
Distance (km)	24.14	24.14	24.14
Voltage (kV)	33-11	33-11	33-11
Voltage Regulation Before P.F.C	5.97%	5.97%	5.97%
Voltage Regulation After P.F.C	1.85%	0.917%	0
Voltage (kV) Before P.F.C	10.35	10.35	10.35
Voltage (kV) After P.F.C	10.8	10.9	11
Power Factor Before P.F.C	0.85 (lagging)	0.85 (lagging)	0.85 (lagging)
Power Factor After P.F.C	0.88 (lagging)	0.994 (lagging)	0.999 (leading)
Size of Capacitors (MVAR)	-1.1085	-1.245	-1.317
Required capacitance (μF)	32.94	36.995	39.13
Conductor size	300 (mcmil)	300 (mcmil)	300 (mcmil)

Fig. 6 represents the required size of capacitor bank for improving the voltage from 10.35 kV at the low voltage side of the transformer to some specified supply voltage. The specified voltage is between 10.8 kV to 11 kV and the corresponding capacitor bank ranges start from 1.1085 MVAR to 1.3175 MVAR.

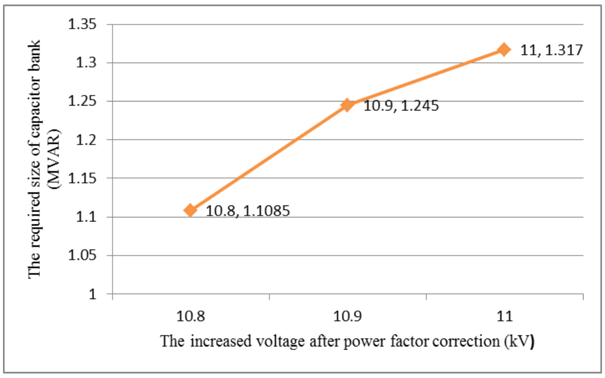


Fig 6 The required size of capacitor bank for the specified voltage

Fig. 7 illustrates the voltage regulation after power factor correction for the voltage range from 10.8 kV to 11 kV. At first, the voltage regulation (at 10.8 kV) is 1.85% and according to increasing voltage it is gradually slow down to zero for improving to unity power factor.

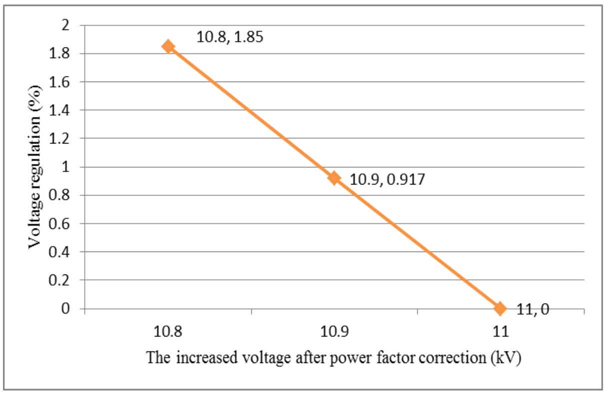


Fig 7 The decreasing voltage regulation with increasing voltage

Fig. 8 shows the increasing power factor by improving the supply voltage by installing capacitor banks. The power factor between the voltage 10.8 kV and 10.9 kV is significantly increased and gradually approached to unity till 11 kV.

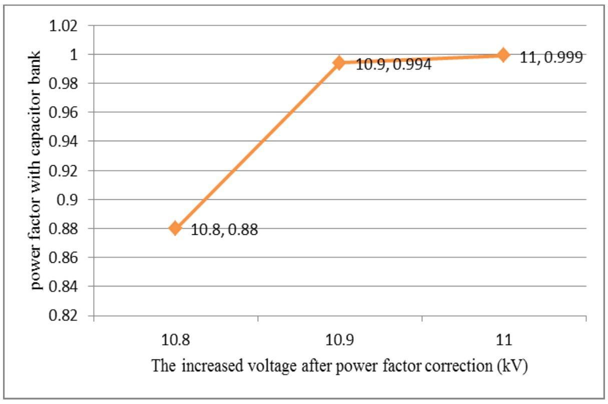


Fig 8 The increasing power factor with the increased voltage

6. CONCLUSIONS

This paper presented a power factor correction for an existing power distribution network in Kyaing Tong. Shunt capacitor is used for power factor correction. Generation source 33 kV bus transmission substation connected the Kyaing Tong distribution substation (1) which applied 2.5MVA, 33/11 kV transformer. This line is radial line system. Before power factor correction at the 2.125MW load condition, voltage regulation is 5.97% and power factor is 0.85(lagging). The line resistance and inductive reactance are 0.5Ω and 3.9167Ω. After power correction (load compensation), voltage regulation is 1.85% and power factor is 0.88(lagging). The size of capacitor is 1 MVAR. The capacitor size for improving the voltage regulation to 0.97% with power factor 0.994(lagging) is 1.245 MVAR. For improving the power factor 0.999(lagging) with a voltage regulation nearly 0%, the required capacitor bank size is 1.317 MVAR.

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Comparison of Maximum Power Point Tracking Techniques for Solar PV System

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ABSTRACT*:* The need for renewable energy sources is on the rise because of the acute energy crisis in the world today. Solar energy is a vital untapped resource in a tropical country like ours. The main hindrance for the penetration and reach of solar PV systems is their low efficiency and high capital cost. To extract maximum obtainable solar power from a PV module will be a challenge for solar Photovoltaic (PV) system. Therefore, Maximum Power Point Tracking (MPPT) technology becomes an important role in solar PV systems. It can maximize the output power of a PV system for a given set of conditions. This paper presents in details comparative study between two most popular algorithms of MPPT which are Incremental Conductance (INC) and Perturb and Observe (P&O) in order to optimize the efficiency of the solar generator. These MPPT techniques will be compared by using MATLAB/SIMULINK tools. Simulation results of both controllers will be carried out as PV mean powers, mean voltages, duty cycles and DC voltages. Finally, the best MPPT algorithm will be chosen from these results.

KEYWORDS: *Solar photovoltaic (PV) systems, Maximum Power Point Tracking (MPPT), Incremental Conductance (INC), Perturb and Observe (P&O), MATLAB/SIMULINK.*

1. INTRODUCTION

Global demand for energy is rapidly evolving and natural energy resources such as uranium, petroleum, and gas decreased due to a great diffusion and development of the industry in recent years. The increase in energy costs and environmental constraints are pushing for the development of technological solutions allowing better control of the resources and the exploitation of the renewable energies in specific photovoltaic energy. Photovoltaic energy is a clean and renewable energy resource. Moreover, solar panels are a silent energy producer because there is absolutely no noise when converting sunlight into electricity [1]. The photovoltaic systems' manufacturing process has been improving continuously over the last decade and photovoltaic system have become an interesting solution. Precisely, photovoltaic systems are constituted from arrays of photovoltaic cells (panel), choppers (mainly buck-boost or boost DC/DC converter), MPPT control systems and storage devices (batteries) and/or grid connections. A typical solar photovoltaic PV system is shown in Figure 1 as below [2].

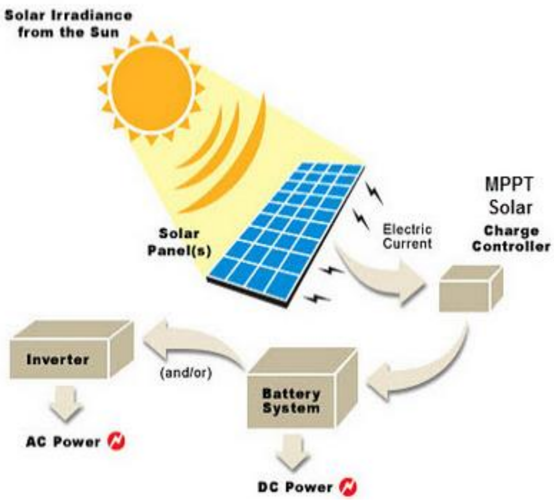

Fig 1. A Typical Solar PV System

But, as solar energy is diffuse (less than 1kW/m2), and photovoltaic cell efficiency is theoretically limited to 44%, efforts need to be strengthened on the energy transfer. These include the design of the photovoltaic system and the energy management by seeking the Maximum Power Point (MPP) [3].

The main contribution of this paper is to propose a comparison of MPPT techniques. Firstly, the solar photovoltaic systems will be introduced in order to focus on the MPPT key factors. Then, some of the most used MPPT techniques will be explained and Incremental Conductance (INC) and Perturb and Observe (P&O) will be presented in details. Finally, comparisons of the simulation for these two techniques will be performed using MATLAB/SIMULINK software.

2. THEORETICAL BACKGROUND

Renewable sources of energy acquire growing importance due to its enormous consumption and exhaustion of fossil fuel. Also, solar energy is the most readily available source of energy and it is free. Moreover, solar energy is the best among all the renewable energy sources since it is non-polluting. Energy supplied by the sun in one hour is equal to the amount of energy required by the human in one year. Photovoltaic arrays are used in many applications such as water pumping, street lighting in rural town, battery charging and grid connected PV systems.

PV modules generate DC current and voltage. However, to feed the electricity to the grid, AC current and voltage are needed. Inverters are the equipment used to convert DC to AC. In addition, they can be in charge of keeping the operating point of the PV array at the MPP. This is usually done with computational MPPT algorithms.

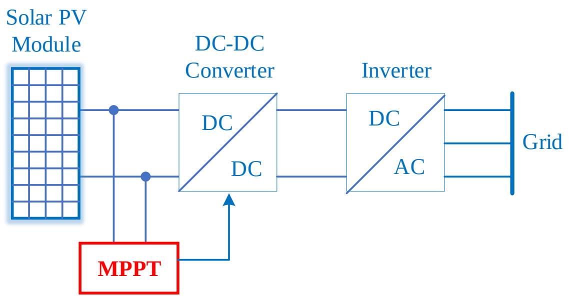

Fig 2. Grid Connected Solar PV System with MPPT Algorithm

MPPT algorithms are necessary in PV applications because the maximum power point of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array.

The most widely-used MPPT techniques are described in the following sections:

- Constant Voltage (CV) Method
- Open Voltage (OV) Method
- Temperature Methods
- Incremental Conductance (INC) Methods
- Perturb and Observe (P&O) Methods
- Three Point Weight Comparison
- Short-Current Pulse Method
- Fuzzy Logic Method
- Sliding Mode Method
- Artificial neural network Method

Among these techniques, the Incremental Conductance (INC) and Perturb and Observe (P&O) algorithms are the most common and it is presented in the following sections. But these techniques have the advantage of an easy implementation but they also have drawbacks [4].

2.1 Perturb and Observe (P&O)

Perturb and Observe (P&O) technique has been selected to implement a MPPT control algorithm due to its simplicity and the possibility to introduce improvements. In this algorithm, PV-output voltage (V_k) and PV output current (I_k) are sensed. Then power is calculated (P_k) and compared with the power value calculated in the previous sample (P_{k-1}) in order to get ΔP_k. If the results of ΔP_k is zero the system is working in MPP. Otherwise and according to the sign of ΔP_k and to the sign of ΔV_k the command voltage to control the duty cycle of the converter, will be decreased or increased in order to force the working point of the PV module towards the MPP [5]. The algorithm is illustrated in the flowchart shown in Figure 3.

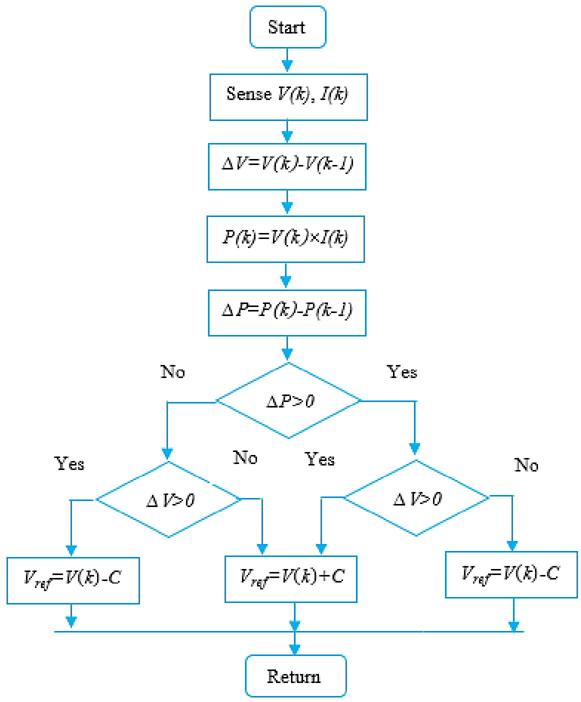

Fig 3. Flowchart of Perturb and Observe (P&O) Method [5]

2.2 Incremental Conductance (INC)

The Incremental Conductance (INC) algorithm is derived by differentiating the PV module power equation with respect to voltage and setting the result equal to zero. This is shown in the following equations.

$$P = VI \qquad (1)$$

Differentiating Equation (1) with respect to ΔV,

$$\Delta P / \Delta V = (\Delta VI) / \Delta V \qquad (2)$$

From Equation (2), the basic equations of this method are as follows:

$$\Delta I / \Delta V = -I / V,$$

$$\Delta P / \Delta V = 0 \text{ at MPP} \qquad (3)$$

$$\Delta I / \Delta V > -I / V,$$

$$\Delta P / \Delta V > 0 \text{ left of MPP} \qquad (4)$$

$$\Delta I / \Delta V < -I / V,$$

$$\Delta P / \Delta V < 0 \text{ right of MPP} \qquad (5)$$

Figure 4 shows the flow chart of the Incremental Conductance (INC) method [5].

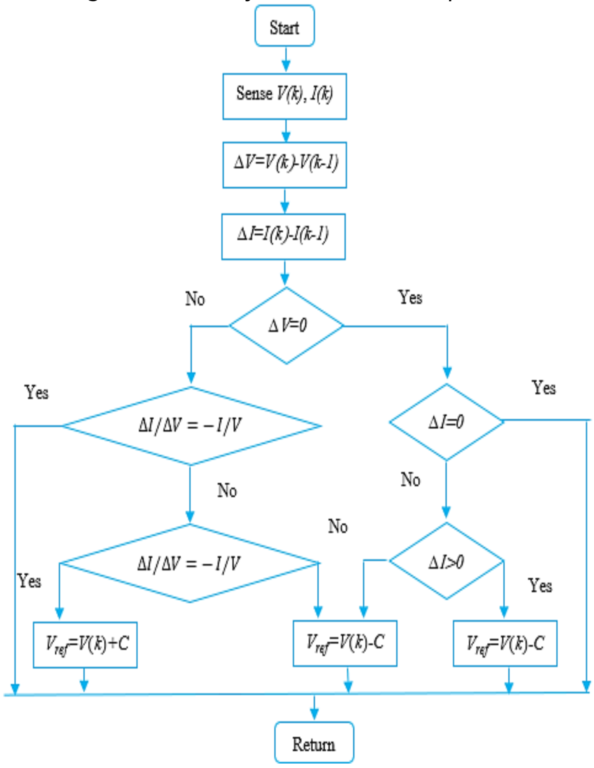

Fig 4. Flowchart of Incremental Conductance (INC) Method [5]

3. SIMULATION MODEL FOR PROSED SYSTEM

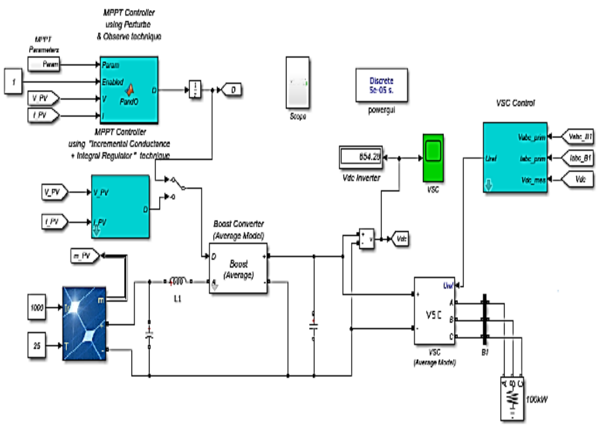

Fig 5. Simulation Diagram of PV System with MPPT Controllers Using Either Perturb and Observe (P&O) Method or Incremental Conductance (INC) Method

In this paper, the simulation model proposes a 100.7kW PV array and 273.5V is connected to three phase loads via a DC-DC boost converter and a three-phase voltage source converter (VSC). In order to confirm the PV system, computer simulations were carried out by using MATLAB/SIMULIMK.

The PV array delivers a maximum of 100.7kW at 1000W/m2 sun irradiance and 25-Degree Celsius sun temperature because the output of the PV array depends on temperature and irradiation.

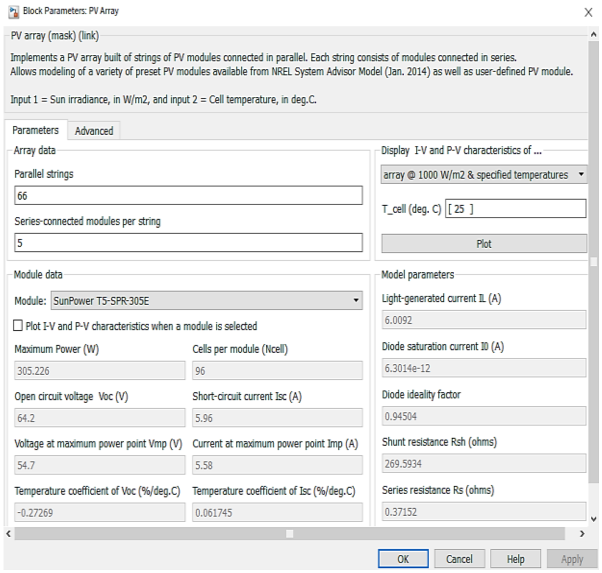

Fig 6. Input Data of The Solar PV System in MATLAB/SIMULINK

As the input of the simulation model of this paper, the type of PV modules is chosen as SunPower T5-SPR-305E. The PV array consists of 5 series connected modules per string and 66 parallel strings. There are 96 photovoltaic cells per modules. The PV array generated voltage of about 273.5V. The open-circuit voltage (V_{oc}) of one module is 64.2V and short-circuit current (I_{sc}) of one module is 5.96A. And then, voltage and current at maximum power for one module is V_{mp} is 54.7V and I_{mp} is 5.58A respectively as shown in above Figure 6.

Maximum Power Point Tracking (MPPT) is used to track the maximum power for the whole PV system. Maximum Power Point Tracking (MPPT) is implemented in the boost converter by means of a SIMULINK model as shown in Figure 5.

To compare the performances of these two Maximum Power Point Tracking algorithms, program files are built by using the flowcharts of above Figure 3 and Figure 4 and inserted in the MPPT controller blocks as shown in Figure 5.

Either Perturb and Observe (P&O) or Incremental Conductance (INC) algorithm is used to get the comparison of the performances of these two Maximum Power Point Tracking controllers for the proposed solar PV system.

4. SIMULATION RESULTS

In this paper, Perturb and Observe (P&O) method and Incremental Conductance (INC) method are used for MPPT controllers of solar PV system. Simulation results of PV system with MPPT techniques such as Perturb and Observe (P&O) method and Incremental Conductance (INC) are compared in Figure 7, Figure 8, Figure 9 and Figure 10. To assure that the whole system is stable till the end time, simulation time is set as 0 to 3sec.

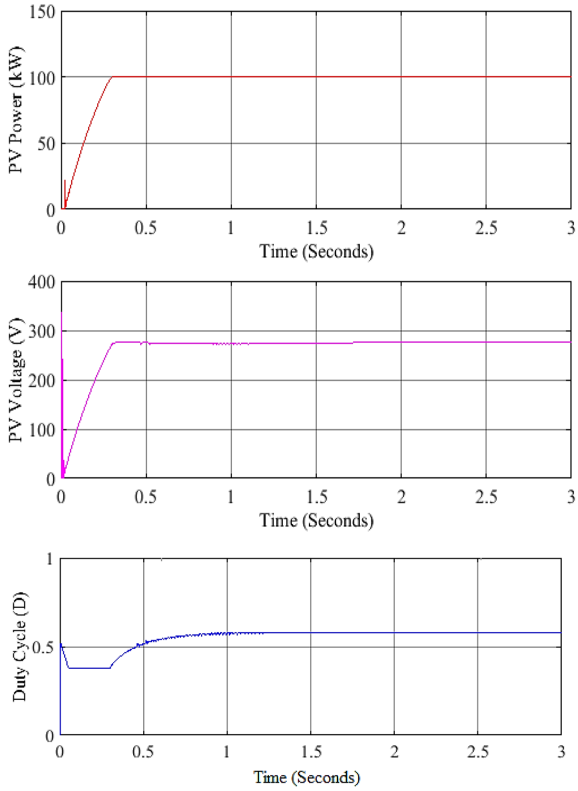

Fig 7. The Simulation Results of PV Mean Power, Mean Voltage and Duty Cycle (Perturb and Observe (P & O) Method)

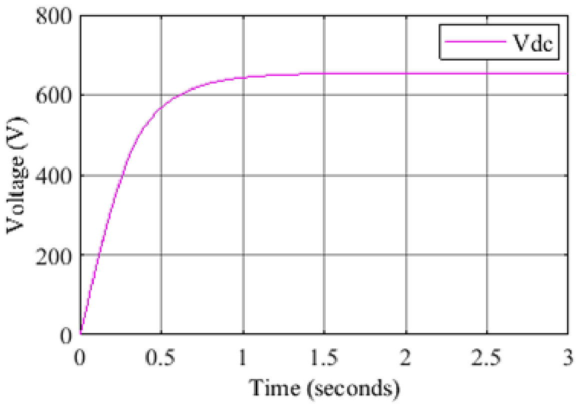

Fig 8. The Simulation Result of DC Voltage with Perturb and Observe (P & O) Method

For P&O controller as shown in Figure 7 and Figure 8, the output PV array voltage is 273.5V and PV array output power is 100.33kW. At t=0.5 sec, MPPT is enabled. The MPPT regulator starts regulating PV voltage by varying duty cycle in order to extract maximum power.

Maximum power (100.33kW) is obtained when duty cycle is D=0.58. After t =1.5sec, the whole system becomes the stable condition.

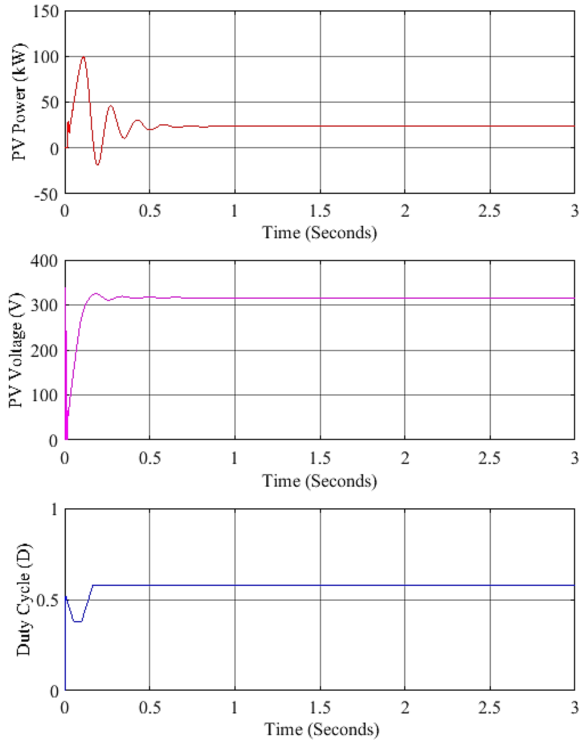

Fig 9. The Simulation Results of PV Mean Power, Mean Voltage and Duty Cycle (Incremental Conductance (INC) Method)

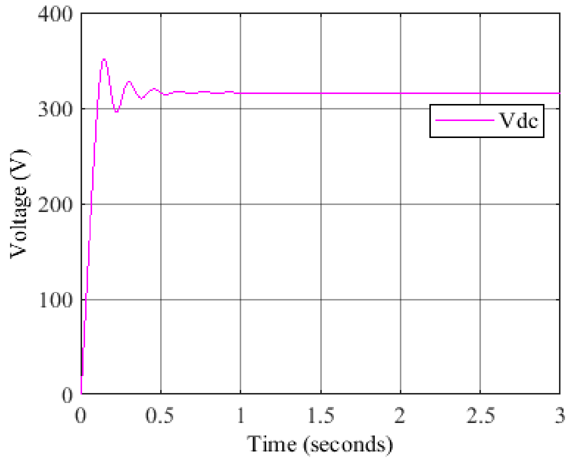

Fig 10. The Simulation Result of DC Voltage with Incremental Conductance (INC) Method

For INC controller as shown in Figure 9 and Figure 10, the output PV array voltage is 316.38V and PV array output power is 23.46kW. At t =1 sec, MPPT is enabled. The MPPT regulator starts regulating PV voltage by varying duty cycle in order to extract maximum power. Maximum power (23.46kW) is obtained when duty cycle is D=0.58. After t =1sec, the whole system becomes the stable condition.

Table 1 Comparison of Output Values Between Perturb and Observe (P&O) and Incremental Conductance (INC)

Controller	PV Power (kW)	PV Voltage (V)	Duty Cycle	VDC (V)
P&O	100.33	273.5	0.58	654.28
INC	23.46	316.38	0.58	316.38

Table 1 shows the overall comparison for P&O and INC Controllers. For the output voltages of these controllers, P&O give a value of 273.5V and incremental conductance give value of 316.38V. The simulation results of Figure 7 and Figure 9 show that duty cycles for both controllers are almost the same. From the simulation results, controller that connected with Boost converter which will give a stable output before 1second is the Incremental Conductance (INC) controller. But Perturb and Observe (P&O) controller can achieve maximum output voltage and power values that better than Incremental Conductance (INC) controller.

5. CONCLUSIONS

This paper has presented the comparison of two most popular MPPT controller, Perturb and Observe (P&O) Controller and Incremental Conductance (INC) Controller. This paper focus on comparison of PV system which will connected with these controllers. From these cases, the best controller for MPPT is Perturb and Observe (P&O) controller. This controller gives a better output value and the efficiency of the MPPT system employed in solar photovoltaic system can be optimized.

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DESIGN AND EVALUATION OF CAPACITOR BANKS FOR POWER FACTOR IMPROVEMENT IN DISTRIBUTION SUBSTATION

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ABSTRACT*:* In designing capacitor bank at substation level, the study on the load characteristics is important. According to important and nature of the load, the type of capacitor bank should be selected. In this paper, the capacitor bank design is executed for the distribution substation which is supplying mostly to industrial zone and partially to domestic loads. Since the loads are not critical, the switch capacitor banks are designed in this paper. The loads are divided into three types as base load, average loads and peak load. The capacitor bank for base load is proposed to connect all over the time and that for average load is to operate with time switch. The capacitor bank for peak load will be operated with current switch since industrial loads can attribute storage in some period such as holidays. In the capacitor bank designing, IEEE standard 18-1992 is utilized as reference. All design calculations and selections are according to this standard. After the design execution, the performance evaluations are also carried out. All possible outcomes from capacitor bank installations are presented. The payback period is also described. The calculation executed in this paper based on real time data of Hlaingtharyar distribution substation No. (1) during 2019.

KEYWORDS: *Daily load cycle, Fixed Capacitor Bank, Time Switch Capacitor Bank, Current Switch Capacitor Bank, Power factor improvement, Voltage rise*

1. INTRODUCTION

In the power distribution industry today, utility companies are trying to come up with a solution to increase the efficiency of distributed power. One way of achieving this task is buy improving the power factor of a system by adding power factor correction capacitors. Power factor improvement is a very important aspect of power distribution. Without a good power factor, there cannot be an efficient means of transmission of electricity over long distances due to the losses associated with current flowing through a wire.

In order to achieve maximum efficiency, power factor should be increased as close to unity as possible. But economical and technical constraints should also be considered in power factor improvement. In power systems, the reactive power compensation is provided locally at all voltage levels using fixed capacitors, switched capacitors, substation capacitor banks or static VAR compensators. Whatever the nature of the compensation, capacitors are the common elements in all the devices.

The power factor correction approach using shunt capacitors has been employed for the past several decades. The capacitor banks used for power factor correction include fuses, circuit breakers, protective relaying, surge arresters and various mounting approaches. The designing of capacitor bank should be taken into account these parameters. Power factor correction at substation is an appropriate means by which to improve the power quality of the system. Its application is dependent though on the size of the installation and the extent that power factor correction needs to be applied. The opportunity however exists to make a significant environmental contribution whilst simultaneously providing economic benefit. Within a cost conscious market, payback considerations are also important.

2. THEORETICAL BACKGROUND

2.1 Capacitor Bank for Distribution Substation

For power factor improvement at distribution substation the use of static capacitor bank give better performance than that of synchronous capacitor. The reactive demand of the load varies over a day and a typical reactive demand for a day. It is evident from Fig 3 that it will require a continuously variable capacitor to keep the compensation at economically optimum level throughout the day. However, this can only be approximated by switched capacitor banks. Usually one fixed capacitor and two or three switched units will be employed to match the compensation to the reactive demand of the load over a day. The value of fixed capacitor is decided by minimum reactive demand.

Automatic control of switching is required for capacitors located at the distribution substation. Automatic switching is done usually by a time switch or voltage controlled switch. The time switch is used to switch on the capacitor bank required to meet the day time reactive load and another capacitor bank switched on by a low voltage or high current signal during peak along with the other two banks will maintain the required compensation during peak hours.

Shunt capacitors applied to distribution systems are generally located on the distribution lines or in the substations. The distribution capacitors may be in pole mounted racks, pad mounted banks, or submersible installations. The distribution banks often include three to nine capacitor units connected in three phase grounded wye, ungrounded wye or in delta configuration. The distribution capacitors are intended for local power factor correction by supplying reactive power and minimizing the system losses. The distribution capacitors can be fixed or switched depending on the load conditions. The following guidelines apply:

- Fixed capacitors for minimum load condition.

- Switched capacitors for load levels above the minimum load and up to the peak load.

The base load and peak load conditions are common in most utilities. Usually, the fixed capacitors satisfy the reactive power requirements for the base load and the switched capacitors compensate the inductive kVAR requirements of the peak load [1].

2.2 Sizing of Capacitor Bank for Distribution Substation

To obtain the best results, shunt capacitors should be located where they produce maximum loss reduction, provide better voltage profile and are closed to the load. The allocation of capacitor bank at the distribution substation is the best choice from utility side. Usually, the capacitor banks are placed at the location of minimum power factor by measuring the voltage, current, kW, kVAR and kVA on the feeder and substation to determine the maximum and minimum load conditions. Many utilities prefer a power factor of 0.95. The peaks and valleys in the kVAR demand curve make it difficult to use a single fixed capacitor bank to correct the power factor to the desired level. If a unity power factor is achieved during the peak load, then there would be leading kVAR on the line during off-peak condition, resulting in an over-corrected condition. Over-correction of power factor can produce excess loss in the system, similar to the lagging power factor condition.

Overvoltage condition may occur during leading power factor condition causing damage to the equipment. Therefore, a leading power factor is not an advantageous condition. In order to handle such conditions, fixed capacitors are used to supply the constant kVAR requirements and switched capacitors are used for supplying the kVAR for the peak load conditions. Specifically, this will prevent over-correction of the power factor. Fig 3 shows the selection approach for the fixed and switched capacitors. The capacitive kVAR required to correct the given power factor to the desired level can be calculated as shown below.

$$MVAR_C = P \times [\tan(\cos^{-1} PF_i) - \tan(\cos^{-1} PF_f)] \quad (1)$$

where

$MVAR_C$=Rating of capacitor bank (kVAR or MVAR)
P = Real power demand (kW or MW)
PF_i = initial power factor and
PF_f = final power factor

The above relation is mostly expressed in the form of a chart by manufacturer. To determine the needed capacitive reactive power, select the multiplying factor that corresponds to the present power factor and the desired power factor. Then multiply this factor by the kW load of the system. Select a kVAR bank close to the required kVAR. The capacitance of the capacitor bank must also be known for power quality considerations such as harmonic problems. The capacitance of capacitor bank can be calculated from the reactive power rating as follow:

$$C = \frac{MVAR/3}{2\pi f \times V_L^2} \quad (2)$$

where

C = capacitance per phase (F)
$MVAR$ = Rating of capacitor bank
f = System frequency (Hz)
V_L = Line voltage (V)

The line currents before and after compensation with capacitor bank must also be known for the calculation of line losses, saving energy cost, voltage drop at the station and release of power system capacity. The line current for the given real power demand at corresponding power factor is as follow:

$$I_L = \frac{P}{\sqrt{3} \times V_L \times PF} \quad (3)$$

where

I_L = Line current on feeder (A)
P = real power demand (W)
V_L = Line voltage (V)
PF = power factor

2.3 Parameter of Distribution Substation Under Study

For design and evaluation of capacitor bank, the detailed study is carried out at Hlaingtharyar distribution substation No.(1). The single line diagram of Hlaingtharyar distribution Substation No.(1) is described in Fig 1.

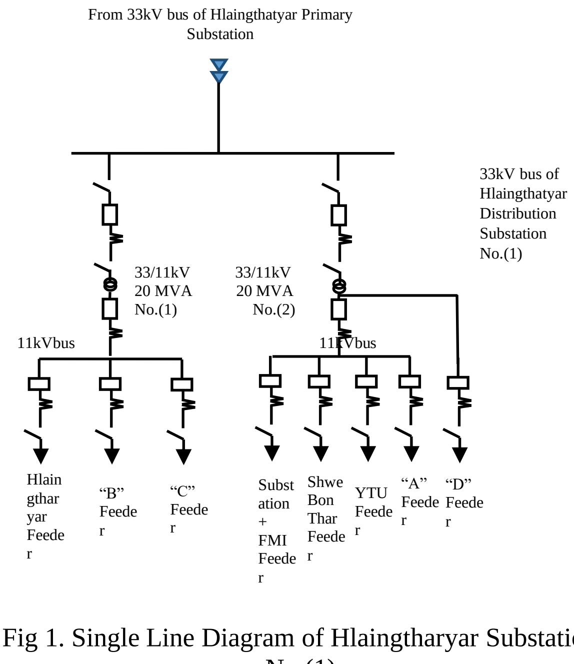

Fig 1. Single Line Diagram of Hlaingtharyar Substation No.(1)

The incoming line of substation No.(1) is taken from 33kV bus of Hlaingtharyar Primary Substation which is located at west of Hlaingtharyar township. Substation No.(1) comprise two number of 20 MVA, 33kV/11kV transformer. There are eight number of 11kV main distribution feeder which are connected to two separate 11kV busbar of substation No.(1) as shown in Fig 1. The capacity and parameters of each distribution feeder are expressed in Table 1.

In Table 1, A, B, C and D feeders provide the electricity to industrial zones. The loads connected to Shwe Bon Thar Feeder are still in construction and consume zero power from the station. The remaining feeders feed the power to domestic, commercial and office loads of Hlaingtharyar township. Total maximum load of substation No.(1) is about 25 MVA, among them the industrial load is 2.5 times larger than that of other loads. The design calculation and evaluation of capacitor bank based on these data.

Table 1. Capacity and Parameters of Distribution Feeders

Feeder Name	Maximum Load (MW)	Feeder Cable (mm^2)	Length of Feeder (mile)
Incoming 33kV Feeder	-	185	7.95
Hlaingtharyar Feeder	4.0	95	26.0
"B" Feeder	4.33	95	4.1
"C" Feeder	5.5	95	6.7
Station + FMI Feeder	1.25	95	2.0
Shwe Bon Thar Feeder	-	95	1.1
YTU Feeder	2.0	95	10.2
"A" Feeder	4.42	95	7.1
"D" Feeder	3.0	95	2.9

Fig 2 describe the typical daily load demand curve at Hlaingtharyar Substation No.(1), during October, 2019. The load cycle pattern is dominant by characteristics of the industrial loads. The maximum load demand occurs at factories operation time i.e. from 8:00 to 17:00. During this period, the demand is reduced between 11:00 and 13:00 which is the lunch time of the factories. After 17:00, the domestic loads are increased and the demand is nearly constant until 23:00 hour. Between 23:00 and the next day 7:00 am, both industrial and domestic loads demand are minimum as shown in Fig 2.

The changes in MVA demand cause the variation in feeder line current. The more line current flow leads to the larger voltage drop and line losses on the feeder. The substation bus voltage variation for various MVA demand is shown in Fig 3.

Daily Load Data at Hlaingtharyar Substation (1): 5 Days and Average

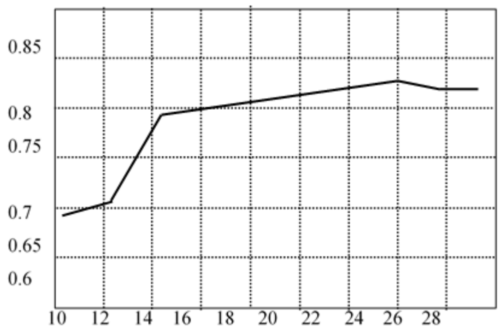

Fig 2. Typical Daily Load Cycle for Sizing of Capacitor Bank

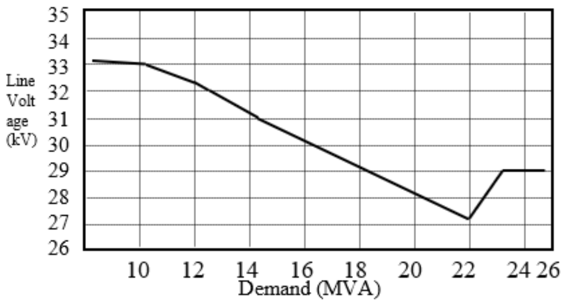

Fig 3. MVA Demand versus Line Voltage

The installation of capacitor bank can reduce the reactive current and hence total current flow in the feeder. Therefore capacitor bank installation can maintain the bus voltage at nearly regulated value and save line power losses. Again the change in MVA demand and the type of load cause different power factor at the substation. The variation of power factor with respect to MVA demand is described in Fig 4 [2].

MVA Demand Vs Power Factor at Hlaingtharyar Substation (1): typical Daily Load Cycle

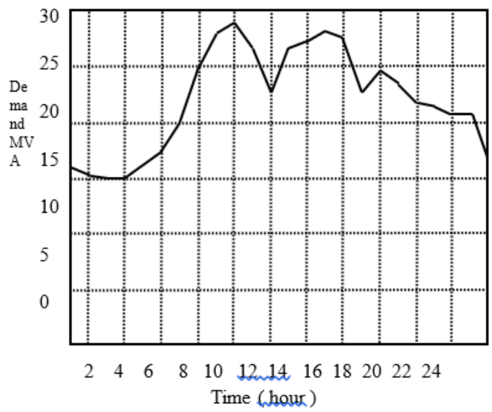

Fig 4. MVA Demand versus Power Factor

3. EXPERIMENT

3.1 Power Factor Improvement for Hlaingtharyar Substation No.(1)

To obtain effective and efficient power factor correction, one fixed capacitor bank and two switch capacitor bank scheme is executed in this paper. This scheme is simple to operate and require less maintenance. In addition, it can provide cost effectiveness compared to static switch capacitor bank and static var compensator (SVC). The fixed capacitor bank is to improve power factor at base load condition. One of switch capacitor bank is time operated to provide suitable reactive power during factory hours and the other is current operated for power factor correction during peak load conditions. Power factor improvement scheme is described in Fig 5.

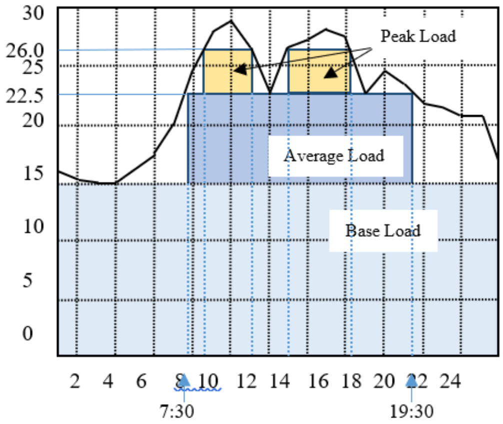

Fig 5. Power Factor Improvement Scheme

The fixed capacitor bank operate 24 hours and must cover the base load demand of 15 MVA. The time switched capacitor banks switch on at 7:30 and off at 19:30 and provide reactive power for the next 7.5 MVA demand. The time switched capacitor bank is operated when the substation total current exceed 393.5 A at the 33 kV incoming line. In the typical daily load cycle graph, the switches on duration of this capacitor bank correspond to 8:30 to 11:00 in morning and 13:00 to 16:15 in evening. All capacitor banks are to be connected at 33 kV so that all distribution feeders obtain necessary reactive power for power factor correction. The intended power factor after compensation for all capacitor bank is 0.95 (lagging) since it is the optimal value for reactive power compensation. The design parameters for the capacitor banks are designated in Table 2.

Table 2. The Design Parameter for Capacitor Banks

	Fixed Capacitor Bank ($MVAR_{C1}$)	Time Switch Capacitor Bank ($MVAR_{C2}$)	Current Switch Capacitor Bank ($MVAR_{C3}$)
Load Demand, P(MW)	11.925	18.54	21.32
Initial PF, PF_i	0.795	0.820	0.820
Final PF, PF_f	0.950	0.950	0.950
Switch On Time	0:00	7:30	8:30, 13:00
Switch Off Time	24:00	19:30	11:00, 16:15
Initial Line Voltage (kV)	31.75	27.9	29

3.2 Design Calculation for Capacitor Bank

For the improvement of power factor three capacitor banks are to be installed at 33kV bus. The detail design calculations for the size of capacitor banks are executed. Formerly, the reactive power rating of capacitor bank is obtained as follow:

$$MVAR_C = P_1 \times [\tan(\cos^{-1} PF_i) - \tan(\cos^{-1} PF_f)] \quad (4)$$

Assuming three capacitors of the capacitor bank are connected in delta, the capacitance per phase of the capacitor bank is

$$C = \frac{MVAR/3}{2\pi f \times V_L^2} \quad (5)$$

For the future design calculations, the currents are also calculated as follow:

$$\text{Initial line current, } I_i = \frac{P}{\sqrt{3} \times V_L \times PF_i} \quad (6)$$

$$\text{Final line current, } I_f = \frac{P}{\sqrt{3} \times V_L \times PF_f} \quad (7)$$

$$\text{Saving in current, } \Delta I = I_i - I_f \quad (8)$$

(a) Voltage rise at station busbar

The voltage rise at station busbar with the installation of capacitor bank is as follow.

Voltage rise at incoming feeder,

$$VD_{Feeder} = \frac{kVAR_C}{10(kV)^2} X_{Feeder} \quad (9)$$

Voltage rise at the transformers,

$$VD_{Transformer} = \frac{kVAR_{C1}}{kVA_{Transformer}} (\% X_{Transformer}) \quad (10)$$

Total voltage rise at station busbar is

$$VD_{Feeder} = VD_{Feeder} + VD_{Transformer} \quad (11)$$

(b) Losses reduction

The reduction in loss on the feeder depend upon the loss factor (LF) of the typical load. To obtain LF, the load factor (LDF) is formerly calculated as follow.

$$LDF = \frac{\text{Average Demand}}{\text{Peak Demand}} \quad (12)$$

Then the loss factor is calculated as follow:

$$LF = 0.15\, LDF + 0.85\, LDF^2 \quad (13)$$

Then, the total reduction in loss on feeders is

Loss reduction = Incoming feeder ∑ Distribution feeder

$= 3 \times [(I^2_{i(HT)} - I^2_{f(HT)})R_{HT}] \times LF + \sum 3 \times$
$[(I^2_{i(Feeder)} - I^2_{f(Feeder)}) \times R_{Feeder}] \times LF \quad (14)$

(c) Release of substation capacity

Due to improvement in power factor, the demand current is reduced. This reduced current with operating voltage gives the saving of substation capacity. It is equivalent to the saving of the installation cost for generation, transmission and distribution components with this capacity. Release of substation capacity with capacitor bank is as follow:

Saving Capacity =

$$\left\{\left(\frac{(kVAR_C \times \sin\varphi_i)}{kVA} - 1\right) + \sqrt{\left[1 - \left(\frac{kVAR_C \times \cos\varphi_i}{kVA}\right)^2\right]}\right\} \times kVA \quad (15)$$

The design calculations are carried out by the above procedure. The resulting design data for capacitor banks are described in Table 3 [3].

Table 3. The Design Data of Capacitor Banks

	Fixed Capacitor Bank	Time Switch Capacitor Bank	Current Switch Capacitor Bank
$MVAR_C$ (MVAR)	5.18	1.85	0.874
C (μF)	4.87	1.95	0.974
Initial line current, I_i (A)	262.43	395.6	454.9
Final line current, I_f (A)	220.5	340.72	391.8
Saving in current, Δ I (A)	41.93	54.88	63.1
Voltage rise at station busbar (%)	4.52	7.29	7.98
Losses reduction (kW)	526.2	406.7	537.7
Saving substation capacity (MVA)	2.50	3.26	3.73

4. Evaluation for Profit with Capacitor Bank Installation

The increase in benefits for each kVAR of additional compensation decrease rapidly as the system power factor reaches close to unity. This fact prompts an economic analysis to arrive at the optimum compensation level. Different economic criteria can be used for this purpose. The annual financial benefit obtained by using capacitors can be compared against the annual equivalent of the total cost involved in the capacitor installation. The decision also can be based on the number of years it will take to recover the cost involved in the Capacitor installation. A more sophisticated method would be able to calculate the present value of future benefits and compare it against the present cost of capacitor installation. In this paper, three obvious benefits by the installation of capacitor bank at distribution substation for power factor correction are calculated: (i) loss reduction (ii) improvement in substation bus voltage and (iii) release of power system capacity. The saving in annual energy cost due to reduced real power losses on the feeders is described in Table 4.

Table 4. Annual Saving at Distribution System

Sr.No	Type of Load	Reduced Power (kW)	Operation Duration (hours)	Unit Charge (kyats per kWh)	Energy Cost (kyats in millions per year)
1	Base Load	526.2	24 × 365	25.00	115.24
2	Average Load	406.7	12 × 365	25.00	44.53
3	Peak Load	537.7	5.75 × 365	25.00	28.21
Total saving per annual					187.98

The installations of capacitor bank provide better voltage profile at the substation. Energy consumption is also increased with improved voltage. Exact value of the increased consumption can be worked out from knowledge of elasticity loads of the concerned feeders with respect to voltage. Let it be ΔE_c then annual revenue increase due to this will be ΔE_c times to cost of energy. The new bus voltage after installation of capacitor bank compared to that before installation of capacitor bank is described in Fig 6.

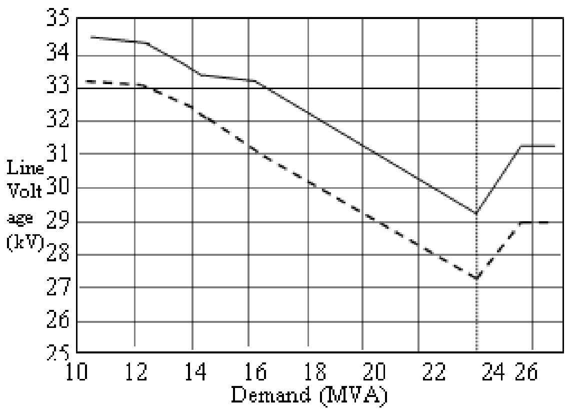

Fig 6. The Substation Bus Voltage Profile: Before and After Installation of Capacitor Bank

In today's rapidly expanding world, system capacity is always a concern for utilities companies. Capacitor use on a power system reduce voltage drop, current present on transmission lines, and energy losses. When all of these reductions are combined, a much more efficiently operating power system is obtained. Besides reducing the costs of transmitting power, the system capacity is increased. The system saving in capacity is about 3 MVA; this means that the additional 3 MVA load at Hlaingtharyar can be provided from the substation. For these additional loads, the capital and running cost of generation, transmission, distribution and other related costs are saved by the installation of capacitor bank.

For the calculation of payback period, the following data are taken from previous design calculations.

Installed Capacity of Capacitor bank = 8 MVAR

Total saving per annual = 187.98 kyats in millions/year

The following cost data are taken for capacitor bank installation. These data are applicable for the installation of capacitor bank ranging from 5 MVAR to 15 MVAR [4].

Cost of capacitor bank = Ks. 50,000,000.00 per MVAR

Installation cost = Ks. 4,000,000.00 per MVAR

Accessories = Ks. 2,500,000.00 per MVAR

Life duration = 10 years

Interest rate = 5 %

The total investment for the installation of 8 MVAR is obtained as follow:

Table 5. Data for Total Investment Cost

Sr. No.	Description	Rate (kyats in millions per MVAR)	Quantity (MVAR)	Cost (kyats in millions)
1	Capacitor bank	50	8	400
2	Installation	4.0	8	32
3	Accessories	2.5	8	20
Grand Total				452

The present worth of saving with capacitor bank installation during 10 years can be obtained as follow:

$$\text{Present worth factor (PWF)} = \frac{1}{(1+i)^n} \qquad (16)$$

where

n = Life duration and i = Interest rate

$$\text{Therefore, PWF} = \frac{1}{(1+0.05)^{10}} = 0.614$$

The present worth of the saving per year is obtained by multiplying the saving with the present worth factor.

Present worth of saving= 0.614 × 187.98

=144.4 kyats in million per year

Then the payback period can be simply calculated as follow:

$$\text{Payback period} = \frac{\text{Total Invesment}}{\text{Saving per Year}} \qquad (17)$$

$$= 452 \div 114.4$$

$$= 3.95 \text{ years}$$

In actual, the payback period may be smaller than this value since the scrap value is neglected in this calculation. By the installation of capacitor bank, the surplus values can be obtain which cannot be calculated such as the rise of voltage at load terminals, increase in life duration of power system components (transformers, feeders, etc) and release of substation capacity [5].

5. CONCLUSIONS

During recent years increasing attention has been paid to minimizing the energy costs and inefficiencies in electric power system. When designing a capacitor bank compensation, it is attempted to achieve the most economical solution, in which the savings achieved in equipment costs and transmission losses are significantly greater than the procurement cost of the reactive power. The cost of installing capacitors, the effect of power factor correction on the voltage level and the requirements of the electricity supply authority in regard to overcompensation, should also all be taken into account.

In this paper the designing and evaluation of capacitor bank for power factor correction is carried out at Hlaingtharyar Distribution Substation No (1). The theories related to the design sizing and evaluation of capacitor banks are described in details with necessary illustrations, tables and equations.

For the capacitor bank sizing and performance evaluation for power factor improvement, the data collection at the distribution substation under study is executed during October, 2019. The typical load daily cycle curve is formerly obtained and the optimal compensation scheme is carried out. The design calculations for the size of capacitor banks, its capacitances, the line currents before and after compensation are achieve. The detail calculations are also made for performance evaluation such as reduction of energy loss, improvement in voltage profile, and release of substation capacity. They are very helpful for the consideration in economic benefits of the installation of capacitor bank for power factor correction.

By the compensation scheme presented in this paper, the many benefits can be obtained by the system. The most interesting one is saving of energy cost due to losses on the feeders. It is amount to kyats 188 million per annual. After the compensation, the substation voltage is relatively improved. It provides the better power quality of the system and attracts the more power demand at the substation. The next point for motivation of capacitor bank installation is over 3 MVA saving of the system. It is equivalent to installation of 3 MVA generation station at Hlaingtharyar which is to be consider in comparison with capacitor bank installation cost. The payback period is shorter than 4 years. Finally, it is confidence that the design sizing and performance evaluation of capacitor banks presented in this paper will be helpful for understanding and applications of power factor improvement at distribution substation in power system.

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CALCULATION OF THE EXISTING DISTRIBUTION FEEDER PERFORMANCES IN KYAING TONG SUBSTATION

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Abstract: The main function of a distribution system is to receive electric power from large, bulk power sources and to distribute electric power to consumers at various levels. This paper is intended to calculatethe distribution system for existing distribution of Kyaing Tong substation. The main aim of this paper is to study the distribution system, to describe the function of components and to calculate the voltage regulation, line losses and line efficiency in this substation. The results of one of five feedersby using MATLAB Program are described. And then, the study of daily load utilization for Kyaing Tong substation is shown**.**

KEYWORDS: *Voltage Regulation, Line Efficiency, Line Losses, Power Demand.*

1. INTRODUCTION

In every country, developed and developing, the electric power consumption has continued to raise, the rate of growth being greater in the developing countries on account of the comparatively low base. This in turn has led to the increase in the number of power stations and their capacities and consequent increase in power transmission lines from the generating stations to the load centers.

The three main processes necessary for electricity supply are generation, transmission and distribution of electric power. Any AC power system begins with a generating source. Electric generators are devices that convert energy from a mechanical form into an electrical form. Power is generated in power stations and is transmitted over many different distances depending on the location of the stations relative to their consumers. The distribution system can be either overhead or underground. It is usually overhead, though for higher load densities in cities or metropolitan areas, it is underground. The voltage regulation of the underground cable system is more efficient as compared with the overhead.

2. MAIN PARTS OF DISTRIBUTION SYSTEM

Distribution system can be divided into six parts:

(1) sub-transmission circuits
(2) distribution substations
(3) distribution or primary feeders
(4) distribution transformers
(5) secondary circuits
(6) consumers' service connecting and meters or consumers' services[3].

2.1 Classification of Distribution Systems

1.According to voltage: the distribution system may be primary or secondary. The primary distribution is done at 11kV and the secondary at 440V.

2.According to the kind of currents: it may be carrying DC or AC.

3.According to service: it may serve a house (domestic) or an industry.

4.According to construction: it may go along roads with poles, insulators, etc., or underground in trenches.

5.According to connection schemes: the distribution scheme may be of three type,

i.Radial scheme

ii.Ring main scheme

iii.Interconnected scheme.

2.2 Size and Location of Substation

The location of distribution substations are decided by power to be distributed over a given distance, voltage of the system, voltage drops and voltage regulation to be maintained.

The sizes of the transformers are dictated by the capacity of each circuit, standard sizes of transformers are chosen.

Sub-transmission circuits should reach as near the load as possible and practicable in order take advantage of the subtransmission voltage before it is stepped down.

2.3 Distribution Substation

Distribution substation normally serves its own load area, which is a subdivision of the area served by the distribution system. At the distribution substation the sub-transmission voltage is reduce for general distribution throughout the area.

The substation consists of one or more power transformer banks together with the necessary voltage regulation equipment, buses, and switchgear. The equipment, required for a substation, is given below:

1. Transformers
2. Busbars
3. Insulators
4. Oil circuit breakers (O.C.Bs)

5. Air break switches
6. Fuses and relays
7. Control boards
8. Control room
9. Power line carrier communication system

Other equipment used in a substation are:

1. Isolators
2. Instrument transformers
   (i) Current transformer (CT)
   (ii) Potential transformer (PT)
3. Other measuring instruments

2.4 Calculation of Distributor Sizes

Distributors are conductors that are tapped for supplying loads to consumers. The main requirement of these conductors is to supply power to consumers at the rated voltage within the permissible voltage variation. The voltage at the last consumer connected across the distributors should not fall below the minimum prescribed value.

The distributors are fed from the feeding points or substations. The types of load on the distributors are concentrated loads at various points of tapping of the service mains. If the loads are uniformly distributed such as street lighting loads of equal sizes at equal distances, they may be represented as uniformly distributed load per unit length of the distributor.

In practice, it may be that the loads are both concentrated at various points as well as uniformly distributed. The voltage drops that occur due to such loads can be worked out and the voltage at the terminals of the last consumer can be found out [4].

2.5. Types of Fault

The types of fault that can occur depends on the distribution system-single line to ground fault, double line to ground fault and line to line fault are common to single phase, two phase and three phase systems. The three phase faults are (very rare) characteristic only of three phase systems (less than about 5% to total faults).

A fault in an electrical power system is the unintentional and undesirable creation of a conducting path (a short-circuit) or a blockage of current (an open-circuit). The short-circuit fault is typically the most common and is usually implied when most people use the term fault.

The causes of faults include lightning, wind damage, trees falling across lines, vehicles colliding with towers or poles, birds shorting out lines, aircraft colliding with lines, vandalism, small animals entering switchgear, and line breakers resulting from excessive ice loading. Power system faults can be categorized as one of four types. The single line to ground faults result when one conductor falls to ground or contacts the neutral wire. Single line to ground faults is relatively frequent (more than about 70%). Double line to ground faults result when two conductors fall and are connected through ground, or when two conductors contact the neutral of a three phase/two phase grounded system.

Line to line faults result when conductors of a two phase or three phase system are short circuited. Balanced three-phase and the first three types constitute severe unbalanced operating conditions [1].

2.6 Voltage Regulation

The regulation is the change in voltage at the receiving end when full load is thrown off, the sending end conditions remaining constant. It is usually expressed as a percentage of the voltage at the receiving end.

The method of voltage regulation used on distribution systems are:

1. Transformer taps, 2, 5, 7 % taps are generally used.
2. Automatic-control induction-type voltage regulators.
3. Boosters.
4. Automatic tap-changers and boosters.
5. Shunt capacitors.

Automatic voltage boosters are less expensive than induction regulators and are important in improving the service in low-density areas, particularly on long, rural lines.

Automatic tap changing on-load is also used with large distribution transformers and power transformers in substations to control the voltage on a bus or feeder.

For satisfactory operation, operation of regulators on distribution circuit must be coordinated with the system design and the regulator setting may be determined to give the best results.

The distribution system may be designed with the following limitations:

1. 1.8% voltage drop is allowed between the primary of the first transformer and end of the secondary of last transformer with maximum load on the circuit and the maximum load on the last transformers and secondary.
2. Regulators are set up to provide a voltage, at the primary of the first transformer of about 4 % more than the normal voltage.

When automatic control is used for the distribution system, the contact making voltmeters are set to the value of the standard voltage to be maintained.

$$V.R = \frac{V_S - V_R}{V_R} \times 100 \qquad (1)$$

If the receiving end voltage is much less than the sending end voltage, the regulation is said to be poor [2].

3. Electrical Parameters of Substation

3.1 Resistance

The effective resistance of a conductor is

$$R = \frac{\text{Power loss in conductor}}{|I|^2} \qquad (1)$$

Directive current resistance is given by the formula

$$R_o = \frac{\rho L}{A} \quad (2)$$

Where,

ρ = resistivity of conductor (Ω-m) or (Ω-cmil/ft)

L = length (m) or usually given in ft

A = cross- sectional area (m^2) (or)

A = circular mil; (cmil)

At 20°C for hard-drawn copper ρ is 10.66 Ω-cmil/ft (or) 1.77×10^{-8} Ω-m.

At 20°C for aluminum at 20°C ρ is 17.00 Ω-cmil/ft (or) 2.83×10^{-8} Ω-m.

The resistance can be calculated by

$$\frac{R_2}{R_1} = \frac{T + t_2}{T + t_1} \quad (3)$$

Where,

R_1, R_2 = the resistances of the conductor at temperatures t_1 and t_2

T = Operation temperature of conductor

t_1, t_2 = Conductor temperature

T = 234.5 for annealed copper of 100% conductivity

T = 241 for hard-drawn copper of 97.3% conductivity

T = 228 for hard-drawn aluminum of 61% conductivity [3].

3.2 Skin Effect

The resistance of non-magnetic conductors varies not only with temperature but also with frequency. As the frequency of alternating current increases, the non-uniformly of distribution becomes more pronounced. As increase in frequency causes non-uniform current density. This phenomenon is called skin effect. Skin effect is due to the current flowing nearer the outer surface of the conductor as results of non-uniform flux distribution in the conductor. This increases the resistance of the conductor by reducing the effective cross-section of the conductor through which the current flows.

Skin effect is a function of conductor size, frequency, and relative resistance of the conductor material. The following formula should be used to consider the skin effect in resistance calculation [3].

$$R_{ac} = kR_{dc} \quad (4)$$

Where,

K is a function of X.

$$X = 0.063598\sqrt{\frac{\mu f}{R_{dc}}} \quad (5)$$

Where,

F = frequency (Hz)

μ = permeability (1.0 for non- magnetic material)

R_{dc}=dc resistance in ohms per mile

3.3 Line Losses

Line losses are a result of passing current through an imperfect conductor such as copper. The conducting material has characteristic impedance that produces a voltage drop along the line proportional to the current flow.

The resistive component (R) of the impedance (Z) contributes to active power losses (P_{loss}).

The line losses can be calculated based on the measured current load as:

$$P_{loss} = I^2R \quad (6)$$

Where, I = current

R= resistance

For a three phase system, the losses for each phase are calculated separately according to the measured current as:

$$P_{loss} = 3\,I^2R \quad (7)$$

3.4 Efficiency

When the load is impressed on a line, along with V.D, power loss occurs in the line due to impedance. This causes the power at the receiving end to be less than the power at the sending end. The ratio of the receiving end power to the sending end power of a line is called its efficiency. This is also expressed as percentage.

$$\text{Efficiency} = \frac{V_R\cos\phi}{V_R\cos\phi + \sqrt{3}IR}\times100 \quad (8)$$

The line efficiency should be high. So, means are adopted to keep line losses as small as possible [7].

4. DISTRIBUTION SYSTEM OF KYAING TONG SUBSTATION

The three generating station of Nam Wop (1), Nam Wop (2) and Nam So are produced the large power source. And then, step up 33 kV and income to Kyaing Tong substation. Kyaing Tong substation is distribution substation and distributed 11 kV to the load sides as outgoing feeders. In this substation, there are three main transformers and separated six feeders.The 33kV bus stepped down to 11kV by 2 MVA and 2.5MVA stepped down transformers.

5.DESIGN AND CALCULATION OF ELECTRICAL PARAMETERS

5.1 Choice of Conductor size and Circuit Breakers

The installed capacities rating of Feeder (1), and Feeder (2) are 0.5 MW, 1 MW . So, the total power using is approximately 1.5 MW.

By comparing to existing and future condition, it should be installed 2 MVA transformer rating Kyaing Tong Substation.

System installed capacity = 2 MVA

System voltage (HV side) = 33 kV

Apparent power, $S = \sqrt{3}V_L I_L$

Rated current, $I = \frac{2\times10^3}{\sqrt{3}\times33}$ = 34.99 A

For 33 kV rated voltage, 35 mm^2 ACSR conductor is selected. But 150 mm^2 ACSR conductor size has being installed for 33 kV rated voltage in Ministry of Electrical Power (MOEP). That conductor size is suitable for future.

System installed capacity = 2 MVA

System voltage (LV side) = 11 kV

Apparent power, $S = \sqrt{3}V_L I_L$

Rated current, $I = \frac{2\times10^3}{\sqrt{3}\times11}$ =104.97A

For 11 kV, the conductor size for 11 kV rated voltage is 35 mm^2 ACSR conductor.

(i) For Feeder (1)

The total power demand for existing load is 0.5 MW.

Power, P = 0.5 MW

$$P = \sqrt{3}\,V\,I\cos\theta$$

$$I = \frac{0.5\times10^3}{\sqrt{3}\times11\times0.8}$$

Rated current, I = 32.8 A

Rated current for Feeder (1) is 94.47 A.

(ii) For Feeder (2)

The total power demand for existing load is 0.5 MW.

Power, P = 0.5 MW

$$P = \sqrt{3}\,V\,I\cos\theta$$

$$I = \frac{1\times10^3}{\sqrt{3}\times11\times0.8}$$

Rated current, I = 65.607 A

For 11 kV rated voltage, 35 mm^2 ACSR conductor is chosen according to Appendix Table A1. But the suitable conductor size for 11 kV rated voltage is voltage 95 mm^2 ACSR conductor according to MOEP restriction.

For circuit breakers, to determine the equivalent per unit impedance of the power supply. The capacity as the oil circuit breakers is 33 kV, 630 A, 35 kV and rated breaking current is 20 kA. The specifications are:

Installed capacity of power transformer = 2 MVA.

The highest level = $20\times33\times\sqrt{3}$ =1143.15 MVA

=1200 MVA (Choice)

Base MVA= 100 MVA

Base voltage = 33 kV

% of impedance = 6.49%

Base impedance, $Z_{base} = \frac{(kV)^2}{\text{Base MVA}} = \frac{(33)^2}{100}$

= 10.89 Ω :

$$a = \frac{V_1}{V_2} = \frac{33}{11}$$

= 3 p.u

$Z_{base} = 3^2\times10.89$ =98.01 Ω

Base Current, $I_{base} = \frac{\text{Base MVA}}{\sqrt{3}\times kV}$

$$= \frac{100\times10^3}{\sqrt{3}\times33} = 1749.54\ A$$

Actual Short-circuit current,

$$I_{sc} = \frac{\text{Fault MVA}}{\sqrt{3}\times\text{Base kV}} = \frac{1200\times10^3}{\sqrt{3}\times33} = 20994.55\ A$$

Per unit curren t = $\frac{\text{Actual short circuit current}}{\text{Base current}}$

$$= \frac{I_{sc}}{I_{base}} = \frac{20994.55}{1749.54}\ \text{p.u} = 12\ \text{p.u}$$

Per unit voltage, $V_{p.u} = \frac{\text{Base kV}}{\text{Actual kV}} = \frac{33\,kV}{33\,kV} = 1$ pu

Per unit impedance , $Z_{p.u} = \frac{V_{p.u}}{I_{p.u}} = \frac{1}{12} = 0.08$ p.u

Rated current of the transformer,

$$= \frac{\text{Installed capacity (MVA)}}{\sqrt{3}\times\text{rated voltag}} : I_{rated} = \frac{2\times10^3}{\sqrt{3}\times33}$$

= 34.99 A

Actual impedance of the transformer,

$$Z_{actual} = \frac{\%\,Z\times kV}{100\times\sqrt{3}\times\text{rated current}} = \frac{6.49\times33\times10^3}{100\times\sqrt{3}\times34.99}$$

= 35.34 Ω

Per-unit transformers impedance, $Z_{p.u} = \frac{Z_{actual}}{Z_{base}}$

$$= \frac{35.34}{98.01}$$

= 0.36 Ω

Total impedance, Z_{total} = 0.08+0.36 = 0.44 p.u

Per-unit current, $I_{total} = \frac{V_{p.u}}{Z_{p.u}} = \frac{1}{0.44}$

= 2.27 p.u

Actual current, $I_{actual} = I_{total} \times I_{base} = 2.27 \times 1749.54$

$I_{actual} = 3971.45A$

The dynamic or momentary short circuit current for equipment design shall be computed by multiplying the r.m.s value of the symmetrical short circuit current by the factor $1.8\sqrt{2}$.

Initial short-circuit, $I_i = 1.8 \times \sqrt{2} \times I_{actual}$

$= 1.8 \times \sqrt{2} \times 3971.45 = 10109.66$ A

Breaking capacity MVA, $= \sqrt{3} \times I_I \times kV$

$= \sqrt{3} \times 10109.66 \times 33$

$= 577.84$MVA

Therefore, 1200 MVA Oil Circuit Breaker is chosen.

For vacuum circuit breaker, to determine the equivalent per unit impedance of the power supply generator, the voltage range and breaking capacity of circuit breaker at MEPE is 11 kV and 1000 MVA. The specifications are:

The highest level $= 25\times11\times\sqrt{3} = 476.3$ MVA

=1000 MVA (Choice)

Base MVA = 100 MVA

Base voltage= 11 kV

Base impedance, $Z_{base} = 3.92\ \Omega$

Per- unit transformer impedance $= \dfrac{10.89}{3.92}$

$= 2.78$ p.u

Base Current, $I_{base} = \dfrac{\text{Base MVA}}{\sqrt{3}\times kV} = \dfrac{100\times10^3}{\sqrt{3}\times11} = 5248.64$ A

Actual Short-circuit current, $I_{sc} = \dfrac{\text{Fault MVA}}{\sqrt{3}\times \text{Base kV}} = \dfrac{1000\times10^3}{\sqrt{3}\times11} = 52486.38$ A

Per unit current, $I_{pu} = \dfrac{\text{Actual short circuit current}}{\text{Base current}}$

$= \dfrac{I_{sc}}{I_{base}} = \dfrac{52486.38}{5248.64} = 10$ p.u

Per unit voltage, $V_{pu} = \dfrac{\text{Actual kV}}{\text{Base kV}} = \dfrac{11\,kV}{11\,kV} = 1.0$ p.u

Per unit impedance, $Z_{pu} = \dfrac{V_{pu}}{I_{pu}} = \dfrac{1}{10} = 0.1$ p.u

Total impedance, $Z_{total} = 0.1 + 2.78 = 2.88$ p.u

Per -unit current, $I_{total} = \dfrac{V_{pu}}{Z_{total}} = \dfrac{1}{2.88} = 0.347$ p.u

Actual current, $I_{actual} = I_{total} \times I_{base} = 0.347 \times 5248.64$

$= 1821.27$ A

The dynamic or momentary short circuit current for equipment design shall be computed by multiplying the r.m.s value of the symmetrical short circuit current by the factor $1.8\sqrt{2}$.

Initial short circuit, $I_{sc\,(actual)} = 1.8\times\sqrt{2} \times I_{actual}$

$= 1.8\times\sqrt{2} \times 1821.27$

$= 4636.22$ A

Breaking capacity MVA $= \sqrt{3} \times I_{sc} \times kV$

$= \sqrt{3} \times 4636.22 \times 11$

$= 88331.85$ kVA

Therefore, the installed interrupting capacity of 11 kV side Vacuum Circuit Breaker (VCB) is 12 kV, 630 A, I_{sc} = 25 kA, and the actual fault current is calculated as 1821.27 A and fault MVA is 88.33 MVA, for synchronous faults.

For circuit breakers, to determine the equivalent per unit impedance of the power supply. The capacity as the oil circuit breakers is 33 kV, 630 A, 35 kV and rated breaking current is 20 kA.

5.2 Calculation of Voltage Regulation, Line Losses and Line Efficiency

At 11 kV side, there are five outgoing feeders. These feeders are overhead lines.According to the result data, the voltage regulation of 95mm^2 ACSR cable is more efficient than the used of 35 mm^2 ACSR cable at 11 kV outgoing side.

Table 1. Result Data of using 95 mm² Conductor Sizes in Kyaing Tong Substation (Existing)

Feeder Name	Power demand (MW)	Rated Voltage (kV)	Voltage Regulation (%)	Line Efficiency (%)
Feeder 1	0.5	10.975 kV	0.22	99.3
Feeder 2	1	10.692 kV	2.87	95
Feeder 3	1	10.913 kV	0.79	98.63
Feeder 4	0.769	10.559 kV	4.17	93.29
Feeder 5	1	10.675 kV	3.03	94.9

Table 2. Result Data of using 35 mm² Conductor Sizes in Kyaing Tong Substation

Feeder Name	Power demand(MW)	Rated Voltage (kV)	Voltage Regulation (%)	Line Efficiency (%)
Feeder 1	0.5	10.816 kV	1.69	72.52
Feeder 2	1	10.356 kV	6.21	87.72
Feeder 3	1	10.816 kV	1.69	96.3
Feeder 4	0.769	10.083 kV	9.1	82.97
Feeder 5	1	10.316 kV	7.2	86.91

5.3 Result Data of Outgoing Feeder 2 in Kyaing Tong Substation by using MATLAB

The result data of outgoing feeder 2 in Kyaing Tong substation can be illustrated by using MATLAB Program as shown inFigure 1 and Figure 2.

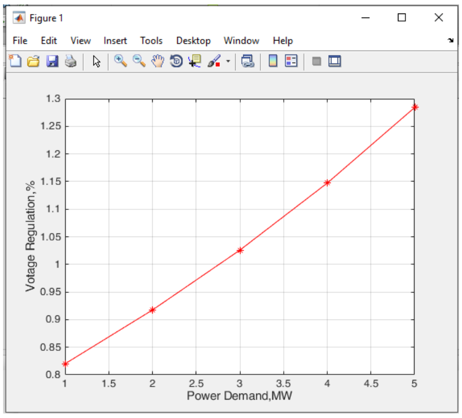

Fig 1. Result of Voltage Regulation for Feeder 2

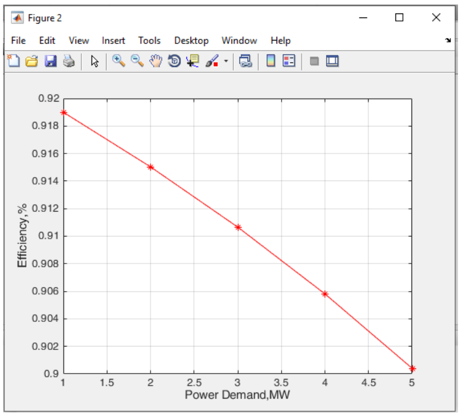

Fig 2. Result of Efficiency for Feeder 2

5.4 Load Utility of Kyaing Tong Substation

The three generating stations of Nam So, Nam Wop (1) and Nam Wop (2) are income to the Kyaing Tong distribution substation. And then, Kyaing Tong substation gives back 11 kV for each outgoing feeders. The sums of outgoing loads utilization are nearly equal to the supply loads. Figure 3 is daily load utility curve of outgoing side of Kyaing Tong substation.

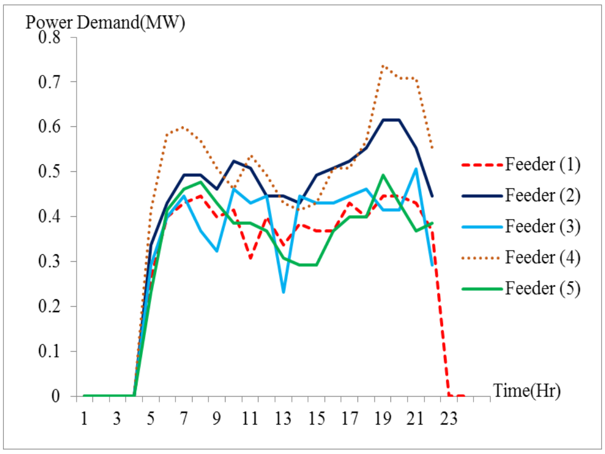

Fig 3. Daily Load Utility Curveof Outgoing Side

6. CONCLUSIONS

In this paper, design of circuit breaker, the calculations of voltage regulation, line losses and line efficiency of each outgoing feeder are described. The voltage regulation of 95mm^2 ACSR cable is more efficient than the used of 35 mm^2 ACSR cable at 11 kV outgoing side. And then, the large cable size decreases the line losses and better efficiency.The result of outgoing feeder 2 are described. Moreover, the distribution system of the substation and daily load utility curve is shown in this paper. This paper emphasizes on the distribution system of Kyaing Tong substation.

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