Design Calculation of Power Distribution System for Base Station Controller (BSC) in MPT Exchange

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ABSTRACT*:* This paper is purpose to design and calculate power distribution system for Base Station Controller (BSC) in MPT Exchange (Mawlamyine). Power distribution system is important role of everywhere: in industrial plant, buildings, substation and data centers. This paper described about the power equipment in electrical power system. And then, the theories and equation of power components, source and load are stated. Both AC and DC are used in BSC. BSC is required 24 hours power supply. When the power supply is off, is use the battery. If the battery is low, the Diesel Generator (DG). So, generator size, battery, DC power equipment and AC power equipment are calculated in this paper.

KEYWORDS: *Power distribution system, AC Load, DC Load, Generator Size, Battery.*

1. INTRODUCTION

Nowadays, technology is played an important role of your daily life, many people are used smart and model electronics devices such as smart phone backbone with mobile network. So, many numbers of people use that why need to renovation and expansion of their power system. For example, previous day smart phone included maximum 2000mAh battery, nowadays 4000mAh battery in smart phone because user experiences and applications are well developed by web developer and applications writers and creators. So, the power development of this system is also required.

This reason is not only for smart phone power system but also for their mobile network and backbone power system are needed to strong more and more. This is very important in Telecommunication. It will analyze and collect to learn the core power system and distributions to Direct Current (DC) load and their update system. in this process, the importance of battery is also expressed and calculated in next section. This system used to -48V for DC equipment.

2.GENERAL THEORY OF POWER DISTRIBUTION SYSTEM FOR BSC

The primary purpose of an electricity distribution system is to meet the customer's demand for energy after receiving the bulk electrical energy from transmission or sub-transmission substation. There are basically two major types of distribution substation: primary substation and customer substation. The primary substation serves as a load centre and the customer substation interfaces to the low voltage (LV) network. Customer substation is referred to a distribution room normally provided by the customer. The distribution room can accommodate a number of high voltage (HV) switchgear panel LV connection to the customer incoming switchboard.

The most common supply of electrical power worldwide, from the electrical power utility is in the form of AC at a frequency of 50 or 60Hz. Nowadays, the majority of the residential loads or commercial loads have become digital in natural and thus, require conversion of power from AC to DC. Both energy storage and the rapidly expanding renewable energy generation system require DC output. The telecommunications industry has been using -48V DC power systems with back batteries for a long time. Many telecommunications sites, particularly in urban areas, were constructed more than 30 years ago and do not conform to today's requirements for Information and Communication Technology (ICT) systems. The historical reason for using the nominal voltages of -48V DC was safety [Whitham D. Reeve (2006)].

3. POWER SOURCES AND LOADS

A system may include a number of different power sources, including prime and standby power sources and energy storage system, such as batteries.

3.1 Prime Power Sources

The most common prime power source is the commercial electric utility that serves the telecommunication facility. It is important that commercial electrical service interruptions do not affect network equipment. Other equipment may operate correctly if the interruption does not exceed a few seconds but may fail or need to be restarted on longer interruptions.

Short-time interruptions in the millisecond range may be bridged by the capacitors in rectifier and chassis power supply output filtering circuits.

Longer interruptions usually are due to electrical equipment failures, natural disasters, weather, cascading faults in large interconnected electric power grids and human error [Whitham D. Reeve (2006)].

3.2 Standby Power Sources

On a unit power or energy basis, standby power sources usually are considerably more expensive than a comparably rated prime power source and are run only when the prime power source fails. Although they may use the same basis technologies as prime power sources, standby power sources are designed to run for much shorter time periods such as hours, days, or a few weeks at a time. Standby sources run, on average, a few hours a month or year, although there are many sites that vary considerably from the average. At locations where the prime power source is reasonably reliable, standby sources may run only a few hundred hours over their lifetime, and most of that is during regularly scheduled exercising tests [Whitham D. Reeve (2006)].

3.3 Energy Storage

A battery is an electrochemical storage device that takes energy from the prime power source through the rectifier system and stores it as chemical energy. Upon failure or interruption of the prime power source or rectifier system, the battery reconverts from the chemical energy to electrical energy and powers the network equipment loads.

Batteries used in telecom systems are classified as secondary (rechargeable) and for stationary (fixed) service. Because of their different electrical characteristics, individual battery designs can be categorized to their reserve times:

(1) Batteries for short-term loading (<1h)

(2) Batteries for long-term loading (>1h)

In Valve Regulated Lead-Acid (VRLA) battery the electrolyte is immobilized as a gel or absorbed in a glass fiber mat separator between the lead plates. In Vented Lead-Acid (VLA) batteries the electrolyte is a free liquid.

A battery, or battery string, consists of a number of cells connected in series. Each cell has a nominal voltage of 2V. Modern telecommunication dc power system in the United States use 24 or 48V (or both) and the battery strings consist of 12 cells and 24 cells, respectively. Other cell counts are sometimes seen in order systems. Battery plant capacity can be increased by connecting individual strings in parallel [Whitham D. Reeve (2006)].

4. EXPLANATION AND EQUATIONS OF POWER EQUIPMENT

In telecommunication, the power distribution system is an assembly of the following equipment:

1. Step-Down Power Transformer
2. Capacitor Bank
3. Voltage Stabilizer
4. Automatic transfer switch (ATS)
5. Diesel Generator (DG)
6. Power distribution boards
7. Rectifier
8. Battery

4.1 Step-Down Power Transformer

Step-down transformer is used in both electronics and electrical domain. In electronics, many applications run on 5V, 6V, 9V, 12V, 24V, or in some cases 48V. To convert outlet voltage 230V AC to the desired low voltage level, step-down transformers are required. In electrical, step-down transformers are used in electrical distribution system which works on very high voltage to ensure low loss and cost-effective solution for long distance power delivery requirements [RAVI (2017)].

4.2 Capacitor Bank

A capacitor bank is a group of several capacitors of the same rating that are connected in series or parallel with each other to store electrical energy. The resulting bank is then used to counteract or correct a power factor lag or phase shit in an alternating current (AC) power supply. They can also be used in a direct current (DC) power supply to increase the ripple current capacity of the power supply or to increase the overall amount of stored energy [Turan Gonen (2015)].

4.3 Voltage Stabilizer

A voltage stabilizer is an electrical appliance which delivers a constant voltage to a load at its output terminals regardless of the changes in the input or supply voltage. It protects the equipment or machine against over voltage, under voltage, and other voltage surges. It is also known as automatic voltage regulator (AVR). The output voltage from the stabilizer will stay in the range of 220V or 230V in single phase supply and 380V or 400V in case of three phase supply, within given fluctuating range of input voltage [SASMITA (2019)].

4.4 Automatic Transfer Switch (ATS)

A transfer switch is an electrical switch that switches a load between two sources. Some transfer switches are manual, in that an operator effects the transfer by throwing a switch, while others are automatic and trigger when they sense one of the sources has lost or gained power.

An automatic transfer switch (ATS) is often installed where a backup generator is located, so that the generator may provide temporary electrical power if the utility source fails [Christophe P. Basso (2012)].

4.5 Diesel Generator (DG) and Generator Size

A diesel generator is the combination of a diesel engine with an electric generator to generate electrical energy. Diesel generating sets are used in places without connection to a power grid, or as emergency power-supply if the grid fails, as well as for more complex applications such as peak-lopping, grid support and export to the power grid. Set sizes range from 8 to 30 kW (also 8 to 30 kVA single phase) for homes, small shops and offices with the larger industrial generators from 8 kW (11 kVA) up to 2,000 kW (2,500 kVA three phase) used for large office complexes, factories [Annonymous (2012)].

The kVA rating of generator,

$$Rating\ of\ generator = \frac{S_{kVA}}{efficiency} \quad (1)$$

Where, S_{KVA} = apparent power

4.6 Power Distribution Boards

A distribution board (also known as panel board, breaker panel) is a component of an electricity supply system that divides an electrical power feed into subsidiary circuits, while providing a protective fuse or circuit breaker for each circuit in a common enclosure.

In telecommunication, there are two types of power distribution boards, namely AC power distribution board (ACPDB) and DC power distribution board (DCPDB). ACPDB is where the electrical supply is distributed from within the building. The main supply cable comes into the board and is then distributed to the breakers and from there to all the circuits, e.g. lights, plugs air con etc. DCPDB is the equipment in power system, is used to distribute DC power to other equipment in telecommunication [Whitham D. Reeve (2006)].

4.7 Rectifiers

The telecom rectifier systems accept input voltage from 85Vac to 300Vac generates 48V for telecom applications. The operating temperature range is from -40°C to 75°C. It output range is from 30A to 200A. Indoor power system converts AC input to -48VDC output. It mainly includes integrated power system and separated power system, and covers the rated capacity of 200A/300A/400A/600A. The system is widely applied for indoor sites such as indoor BSC, small and medium sized core network room, etc. Modern tele-communication power system required several three-phase rectifiers in parallel to obtain higher DC power with 48VDC [Whitham D. Reeve (2006)].

4.8 Battery

The results of the battery system design are

1. Choice of technology - vented lead-acid (VLA) or valve-regulated lead-acid (VRLA)
2. Total battery capacity in ampere-hours (at the nameplate rate at 25°C to 2V/cell)
3. Number of battery strings required to provide the total capacity

The choice of battery technology includes a number of considerations, such as initial and operational costs, weight, floor space requirements, anticipated growth, battery life, and reliability. The factors used to calculate battery capacity are:

1. Equipment of load current
2. Battery reserve time
3. Discharge factor (capacity factor)
4. Temperature factor
5. End-of-life factor (aging factor)
6. Design margin (uncertainty factor)

The first part requires determination of the battery final voltage (V_{BF}), which is the minimum voltage to which the battery can discharge and still maintain equipment operation. the battery final voltage is

$$V_{BF} = V_{Total} + V_{ME} \quad (2)$$

Where, V_{BF} = battery final voltage

V_{total} = total voltage

V_{ME} =minimum operating voltage of load equipment

$$V_{BF} = V_{Battrey} + V_{Primary} + V_{Secondary} + V_{ME} \quad (3)$$

Where, $V_{Battrey}$ = voltage drop in battery circuit

$V_{Primary}$= voltage drop in primary distribution circuit

$V_{Secondary}$= voltage drop in secondary distribution circuits

The final cell voltage (V_{CF}) is

$$V_{CF} = \frac{V_{BF}}{N_{Cell}} \quad (4)$$

Where, V_{CF} = final cell voltage

V_{BF}= battery final voltage

N_{cell}= the number of cells in the battery

If the total required battery system capacity is to be divided equally across two or more strings, the capacity of each string is determined from

$$AH_{String} = \frac{AH_{hour}}{N_{String}} \text{ [1]} \quad (5)$$

Where, AH_{String} = capacity of each string

AH_{hour} = individual capacity battery string

N_{String} = number of battery strings in parallel

5. CALCULATION OF DC POWER EQUIPMENT IN BSC

For GSM system,

Overall load current, I = 180 A

Load voltage, V = 48 V

Power consumed, P = V × I

= 48 ×180

= 8.64 kW

For DWDM Equipment,

Load current, I = 76A

Load voltage, V = 48V

Power consumed, P = V×I

= 48 ×76

= 3.648 kW

For router equipment,

Load current, I = 60A

Load voltage, V = 48V

Power consumed, P = V×I

= 48 ×60

= 2.88kW

For switch equipment,

Load current, I = 15A

Load voltage, V = 48V

Power consumed, P = V×I

= 48 ×15

= 0.72kW

For MSAM Equipment,

Load current, I = 15A

Load voltage, V = 48V

Power consumed, P = V×I

= 48 ×15

= 0.72 kW

For CDMA Equipment,

Load current, I = 30 A

Load voltage, V = 48 V

Power consumed, P = V×I

= 48 × 30

= 1.44 kW

For other equipment (WIFI, FTTH, etc.),

Load current, I = 40 A

Load voltage, V = 48 V

Power consumed, P = V× I

= 48 × 40

= 1.92 kW

Total power consumed for DC equipment in BSC

= 8.64 + 3.648 + 2.88 + 0.72 + 0.72 + 1.44 + 1.92

= 19.968 kW

= 20 kW (Nearly)

Table 1. Total Power for DC Equipment

No.	Name of DC Power Equipment	Power Consumed (kW)
1	GSM System	8.64
2	DWDM Equipment	3.648
3	Router	2.88
4	Switch	0.72
5	MSAM	0.72
6	CDMA	1.44
7	WIFI, FTTH, etc.	1.92
Total power consumed		19.968 ~ 20

For output power of rectifier in BSC,
Output current of rectifier, I = 2000 A
Output voltage of rectifier, V = 48 V
Output power of rectifier, P = V × I

= 48 × 2000 = 96 kW

In BSC, Total power consumed for DC Equipment is 20 kW. 96kW output power of rectifier is chosen because of network expansion and installation of new DC rack or cabinets.

6. CALCULATION OF AC POWER EQUIPMENT IN BSC

For Lighting, there are fifty-five lamps in BSC. Each lamp is 40W of four feet fluorescent lamp.

Number of lamps in BSC = 55

Total power of fifty-five lamps = 40 × 55

= 2.2 kW

For billboard lighting, LED projector billboard lighting,

200 W of eight lamps,

Total power of billboard lighting = 200 × 8 = 1.6 kW

For air conditioner,

1 HP = 0.746 kW

In BSC, Number of air conditioners = 14 of 1.5HP

For an air conditioner, power consumed = 1.5 × 0.746

= 1.119 kW

For fourteen Air Conditioners,

power consumed = 14 ×1.119

= 15.666 kW

For Stand Air Conditioners,

In BSC, Number of Stand Air Conditions = 5 of 2HP

For one stand air conditioner,

power consumed = 2 × 0.746

= 1.492 kW

For five stand air conditioners = 5× 1.492

= 7.46 kW

Total power consumed for

stand air conditioners = 15.666+7.46

= 23.126 kW

For water-pump,

Total power consumed = 300W = 0.3kW

For computers,

Number of desktops = 8 of 200W

Power consumed for desktops = 8 × 200

= 1.6 kW

Number of Laptop = 9 of 40W

Power consumed for laptops = 9 × 40

= 0.36 kW

Total power consumed for computers= 1.6 + 0.36

= 1.96 kW

For Rectifier,

In BSC, Input current of rectifier = 260A

Input voltage of rectifier = 380 V - 415 V

Input current of rectifier = 260 A

Assume input voltage of rectifier = 400 V

Input power consumed for rectifier, P = 260 × 400

= 104 kW

Total power consumed for

AC Equipment in BSC = 2.2 + 1.6 + 23.126 + 0.3 + 1.96 +106

= 133.186 kW

$$S_{kVA} = \frac{P_{kW}}{PF} = \frac{133.186}{0.8} = 166.48\text{KVA}$$

Table 2. Total Power for AC Equipment

No.	Name of AC Power Equipment	Power Consumed(kW)
1	Lighting Load	3.8
2	Air Conditioners	15.666
3	Stand Air Conditioners	7.46
4	Water-pump	0.3
5	Computers	1.96
6	Rectifier	104
Total AC power consumed		133.186

For choosing of generator, in general, the efficiency of generator is 75%

From Equation 1, KVA rating $= \frac{166.48}{0.75}$

= 221.98 kVA

So, 250kVA generator is chosen in BSC.

For choosing of transformer, total power consumed for AC power equipment is 133.186 kW and 166.48 kVA. In BSC, 200kVA transformer is chosen.

7. CALCULATION OF THE BATTERY FINAL VOLTAGE AND CELL FINAL VOLTAGE

Table 3. Parameter Setting Table

	(Parameter Table)					
Parameter Setting	Monitor Address	Factory Setting	Installation Setting	User's Setting 1	User's Setting 2	Remark
	Monitor Address	22				X' No Setti-ng
	AC Input Over-Voltage Point	485 Vac				
	AC Input Low-Voltage Point	310 Vac				
	DC Output Over-Voltage Point	58Vdc				
	DC Output Low-Voltage Point	45Vdc				
	Battery Over-Voltage Point	58Vdc				
	Battery Low-Voltage Point	45Vdc				
	Battery Rated	1000AH				

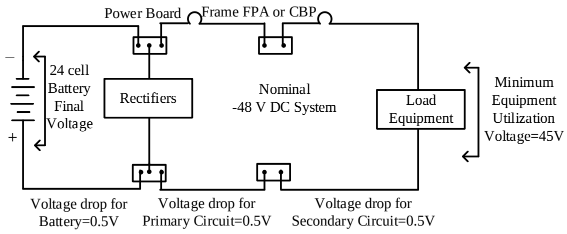

Fig 3. Circuit Diagram of Battery System

In General, $V_{Battery} = V_{Primary} = V_{Secondary} = 0.5$ V

In Figure 3, the total voltage drop is

$V_{Total} = 0.5 + 0.5 + 0.5 = 1.5$ V

In BSC, Equipment voltage is from 45 V to 58 V (From Table 3).

Assume, V_{ME} = 45 V

Numbers of cell, N_{Cell} = 24 Cell for 48 V system

From Equation 3,

The battery final voltage, V_{BF} = 1.5 + 45

= 46.5 V

From Equation 4,

The cell final voltage, VCF = 46.5/24

= 1.94 V/cell

=2V/cell (Nearly)

7.1 Calculation of Battery Capacity of Strings

In BSC, there are two strings of battery banks. The total battery capacity is 4000AH. The capacity of each string is determined,

From Equation 5, Individual battery string capacity,

$$AH_{String} = \frac{4000}{2}$$

= 2000 AH/string

8. CONCLUSIONS

In BSC, Total power consumed for DC Equipment is 20 kW. 96kW output power of rectifier is chosen because of network expansion and installation of new DC rack or cabinets. When generator is chosen, is 221.98 kVA by hand calculating. So, 250kVA generator is chosen in BSC. For choosing of transformer, total power consumed for AC power equipment is 133.186 kW and 166.48 kVA. Therefore, 200kVA transformer is chosen in BSC. The battery final voltage, V_{BF} is 46.5 V by hand calculating. This is corresponding to voltage range in Table 3. The cell final voltage, VCF is 2V/cell in BSC. In this paper, VCF is 1.94 V/cell by hand calculating. So, this take nearly 2V/cell.

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Assessment of Reliability Cost and Worth Approach to Distribution System Reliability Evaluation

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ABSTRACT*:* This paper presents the comparison of interruption costs due to electric supply interruption to access the reliability cost and worth. To analysis the reliability cost and worth, it is required to evaluate the customer interruption cost which inferred from the evaluation of reliability indices. Customer interruption costs can be divided into direct costs resulting directly from halt of supply and indirect costs resulting from a response to an interruption. The customer interruption costs are calculated by indirect cost from interruption in this research. Indirect costs are civil disobedience and looting during an extended blackout, or failure of an industrial safety device in the industrial plant, necessitating neighboring residential evacuation. In this research, indirect costs calculations from the failure of the industrial safety devices in the distribution substation are described. Load data on the feeders were collected from No (1) Pakokku distribution substation from May 2019 to April 2020 and system data were calculated on monthly basis for one year. By using protective devices, reliability improvement scheme is tested as lateral protection with fuse, feeder protection with disconnecting switches and effect of protection failure rate. By studying this research, it can be chosen the best protective devices for reliability improvement.

KEYWORDS: *comparison, improvement, interruption costs, protective devices, reliability cost and worth*

1. NTRODUCTION

Reliability assessments are the most important factor in designing and planning of distribution systems that should operate economically with minimal interruption of customer loads. Reliability indices are useful for determining what a customer can expect in terms of interruption frequencies and durations. Reliability indices are typically computed by utilities at the end of each year by using historical outage data recorded in distribution outage reports [Brown Richard E (2008)]. This is important so that utilities know how their systems are performing, but is less useful when the specific impact of various design improvement options wish to quantified and compared. The location of this research is Pakokku, Magway division and is distributed by 20MVA transformer. There are four feeders in this station and consumed by 15619 customers. It is far away 25.106 km from Yat Kyae feeder , 32.489 km from Buddha Gone substation feeder , 15.450 km far from Zalifar Plant and Industrial Zone feeder and 35.148 km far from Eastern Part of the town feeder to No (1)Pakokku substation and which are designated by A, B, C and D. These line lengths and number of consumers are very important to calculate the ENS and AENS.

2. ANALYSIS OF POWER SYSTEM RELIABILITY

Power system reliability evaluation can be used to provide a measure of the overall ability of a power system to perform its intended function. The concept of reliability can be subdivided into the two main aspects of system adequacy and system security [R. Billinton and P.Wang (1998)]. Reliability refers to the continuity of power flow when power distribution network is considered. It provides power in such manner that the system behavior carrying on without interruption. System adequacy and system security are basic concepts of power system reliability.

Power system adequacy is the ability of the system to supply all energy demand requirements at all times. System adequacy is associated with system steady-state conditions and offers information on future system behavior that can be used in system planning. System security is associated with the dynamic and transient real-time system operation, such as general and transmission line contingencies and generation uncertainties [K. Aoki, K. Nara,J T. Satoh, M. Kitagawa and K. Yarnanaka (1990)].

3. RELIABILITY COST AND WORTH

Reliability cost and worth assessment plays an important role in power system planning and operation. Reliability costs are depended on types of load and surveyed area. If interruption cost (or reliability worth) should also be taken into account, indices like the cost of energy not supplied (ENS) and the cost of power not supplied (CPNS) can be used. In this research, ENS values are compared to assess the reliability worth. Reliability worth is a useful tool in value based system operating and investment planning, to optimize the reliability level versus the total cost of providing the electricity [Wang and Peng (1999)].

The customer cost of reliability become important when a utility wishes to balance their outage is not necessarily restricted to loss of revenue by the vitality or loss of energy utilization by the customer include indirect costs imposed on customers, society and the environment due to the outage. The relation between cost and reliability can be described as shown in Fig. 1.

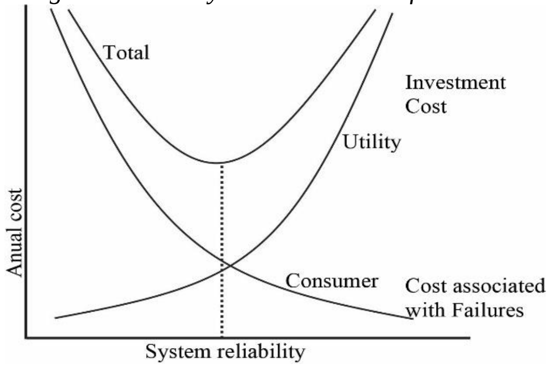

Fig 1. Total reliability costs

4. RELIABILITY EVALUATION TECHNIQUES

Power system engineers and planners have always been conscious of the need for better reliability assessment procedures. To have a better reliability condition, the two techniques are required. The techniques first used in practical application were deterministic in nature and some of these are still in use today. Although deterministic techniques were developed in order to combat and reduce the effects of random failures on a system, these techniques did not and cannot account for the probabilistic or stochastic nature of system behaviour, of customer demands and of component failures. The criteria applied to assess the composite system reliability can be categorized as deterministic or probabilistic [K. Aoki, K. Nara,J T. Satoh, M. Kitagawa and K. Yarnanaka (1990)].

4.1 Deterministic Approach

The deterministic approach is an old and simple method used by system planners to evaluate the system performance and maintain system security in different scenarios based on past experience. The main advantage of the deterministic approach is its straight forwardness to implement and the easiness to understand. However, the difficulty to determine the degree of system unreliability, which falls under more than one scenario, limits the application of this method [Wang and Peng (1999)].

4.2 Probabilistic Approach

The probabilistic approach provides a better understanding of system behavior and allocation of resources. The benefit of using the probabilistic method is in incorporating uncertain events in the system. The probabilistic approach is categorized as analytical methods and simulation methods. In this research, analytical method is used. The analytical methods represent the system behavior by mathematical models and evaluate the system reliability using direct numerical solutions [Wang and Peng (1999)].

5. BASIC POWER SYSTEM PLANNING AND RELIABILITY INDICES

The goal of a power system is to supply electricity to its customers in an economical and reliable manner. It is important to plan and maintain reliable power outages can have severe economic impact on the utility and its customers. In the distribution systems, most of the outages or failures would result in direct impact on the customers. A customer connected to an unreliable distribution system could receive poor energy supply even though the generation and transmission systems are highly reliable. This fact clearly illustrates the importance and necessity of conducting reliability evaluation in the area of distribution system is concerned with of the performance of the customer load points. A power system can be divided into the subsystems of generation, transmission, and distribution facilities according to their functions. For the purpose of conduction power system reliability assessment, these systems are combined into different system hierarchical levels or functional zones. In this research, only distribution system reliability is calculated and customer-oriented indices such as SAIFI, SAIDI, CARDI and ENS are calculated by using various protective devices and used formulae are as follows.

The system average interruption frequency (SAIFI) index,

$$\text{SAIFI} = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}} \tag{1}$$

System average interruption duration (SAIDI) index,

$$\text{SAIDI} = \frac{\sum \text{Customer Interruption Durations}}{\text{Total Number of Customers Served}} \tag{2}$$

Customer average interruption duration (CAIDI) index,

$$\text{CAIDI} = \frac{\sum \text{Customer Interruption Durations}}{\text{Total Number of Customer Interruptions}} \tag{3}$$

Total energy not supplied (ENS),

$$\text{ENS} = \sum L_{a(i)} U_i \tag{4}$$

Annual energy not supplied (AENS)

$$\text{AENS} = \frac{\text{Total energy not suplied}}{\text{Total number at customers served}} \tag{5}$$

(5)

Where $L_{a(i)}$ and U_i respectively are the average connected load and the average annual outage time at load point i.

6. RELIABILIYT AND MAINTENANCE

The customer interruption costs or outage costs per year is the majority contribute of disturbances in the electrical distribution system. The duration of the customer outages can be reduced by increasing the reliability and reserve capacity within distribution network. By increasing maintenance of components is the main point of high reliability and reduce in probability of failure. The reserve capacity for the supply of electricity and adding redundancy cause the reduction of customer outages duration. Maintenance of components in the system can be classified as coordinated maintenance, uncoordinated maintenance, preventive maintenance and corrective maintenance. Coordinated maintenance is when a component is taken out of operation for maintenance along with the other components in the same branch. Uncoordinated maintenance is when a component is taken out of operation and maintained independently of the other components in the same branch. Preventive maintenance is scheduled maintenance with the objective of reducing the failure rate and prolonging the lifetime of the component. Corrective maintenance is maintenance carried out after the fault and has the objective of returning the component into a functioning state

7. RELIABILITY IMPROVEMENT BY PROTECTION SYSTEM

Using protective device on radial system has a great effect on reliability of the system. By using protective devices, reliability improvement scheme can be tested according to effect of without protection device, effect of lateral protection, effect of disconnection switches and effect of protection failure. Finally, it can be chosen the economic cost.The reliability evaluation of No (1) Pakokku distribution substation is focused on all cases. According to data sheet of substation, the number of customers and connected loads are shown in Table 1 and annual data of outage time designated by u (h/yr) and failure rate designated by λ (f/yr) and repaired time designated by r (hr) is shown in Table 2.

Table 1.Research Data of NO (1) Pakokku Substation

Components	λ(f/yr)	r(hr)	load point	No.of customers	Average load conneced (kW)
Section 1	0.38	4	A	1389	1300
2	0.49	4			
3	0.23	4			
4	0.53	4			
Distributor (A)	3.7	4.8	B	7422	3800
(B)	3.75	5.5	C	1985	1830
(C)	3.95	5	D	4823	3200
(D)	3.9	5.5			

The distributor of Yat Kyae feeder is designated by A (1300kW). Buddha Gone feeder is referred to B(3800 kW). Zelifar plant and industrial zone feeder is designated by C (1830 kW)and eastern part of the town feeder is referred to D (3200 kW). Radial distribution network of No (1) Pakokku substation is shown in Fig 2.

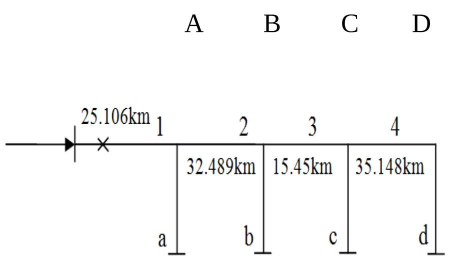

Fig 2. Radial distribution network of No(1) Pakokku substation

Table 2. Annual Data of Outage Time and Failure Rate of No (1) Pakokku Substation

Month	Feeder Name							
	Buddha Gone		Yat Kyae		Zaliphar		Ashae Myoe Dwin	
	λ(f/yr)	r(hr)	λ(f/yr)	r(hr)	λ(f/yr)	r(hr)	λ(f/yr)	r(hr)
May	-	-	1	1:40	1	1:40	2	2:10
June	5	3:24	4	2:08	5	2:54	5	6:34
July	7	8:08	7	9:26	9	12:18	9	11:10
August	8	17:40	7	16:45	8	18:03	10	22:22
September	9	8:10	8	8:00	7	6:25	8	7:12
October	2	0:40	4	2:15	3	1:05	3	1:00
November	1	0:46	1	0:32	3	1:33	1	0:23
December	3	1:03	2	0:40	2	0:40	2	0:40
January	3	3:30	3	3:30	3	3:30	3	3:30
February	2	6:13	2	6:12	1	5:43	1	5:43
March	2	2:45	2	2:45	3	3:50	2	2:45
April	2	2:05	3	2:55	2	2:10	1	1:55

By using fuse shown in Fig . 3 in lateral line ,the total failure rate λ(f/yr) and outage time u(h/yr) are different.The result data is shown in Table 3. According to IEEE standard, the repaired time for 11 kV line is 4 hours.

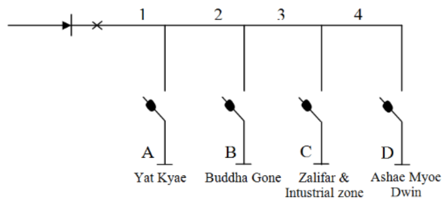

Fig 3. Schematic diagram of substation by using fuse in lateral line

Table 3.Result Data of Substation with Impact of Fuse

components	A			B			C			D		
	γ(f/yr)	r(h)	u(h/yr)	γ(f/ yr)	r(h)	u(h/yr)	γ(f/ yr)	r(h)	u(h/yr)	γ(f/ yr)	r(h)	u(h/yr)
1	0.38	4	1.52	0.38	4	1.25	0.38	4	1.25	0.38	4	1.25
2	0.49	4	1.96	0.49	4	1.96	0.49	4	1.96	0.49	4	1.96
3	0.23	4	0.92	0.23	4	0.92	0.23	4	0.92	0.23	4	0.92
4	0.53	4	2.12	0.53	4	2.12	0.53	4	2.12	0.53	4	2.12
a	3.7	4.8	17.76									
b				3.75	5.5	20.63						
c							3.9	5.5	19.5			
d										3.9	5.5	21.45
Total	5.33	4.56	24.28	5.38	5.05	27.15	5.53	4.71	26.03	5.53	5.06	27.97

8 FEEDER PROTECTION WITH DISCONNECTING SWITCHES

The provision of disconnecting switches at appropriate points along the switches and therefore any short circuit on a feeder still causes the main breaker to operate. A second of alternative reinforcement of improvement scheme is the provision of disconnects at judicious points along the main feeder. Schematic Diagram and result data sheet of No (1) Pakokku Substation by using Disconnecting Switches is shown in Fig. 4 and Table 4.

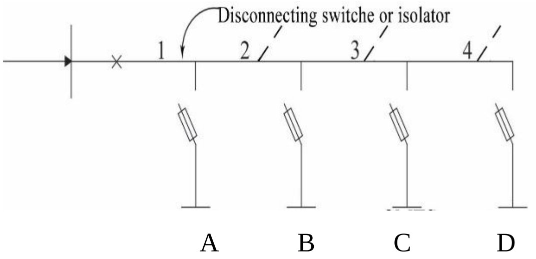

Fig 4. Schematic diagram od Substation by using disconnecting switches

Table 4.Result Data of Substation with Disconnecting Switches

components	A			B			C			D		
	γ(f/yr)	r(h)	u(h/yr)	γ(f/ yr)	r(h)	u(h/yr)	γ(f/ yr)	r(h)	u(h/yr)	γ(f/ yr)	r(h)	u(h/yr)
1	0.38	4	1.52	0.38	4	1.52	0.38	4	1.52	0.38	4	1.52
2	0.49	0.5	0.25	0.49	4	1.96	0.49	4	1.96	0.49	4	1.96
3	0.23	0.5	0.12	0.23	0.5	0.12	0.23	4	0.92	0.23	4	0.92
4	0.53	0.5	0.27	0.53	0.5	0.27	0.53	0.5	0.27	0.53	4	2.12
a	3.7	4.8	17.76									
b				3.75	5.5	20.63						
c							3.9	5.5	19.5			
d										3.9	5.5	21.45
Total	5.33	3.74	19.92	5.38	4.55	24.5	5.53	4.37	24.17	5.53	5.06	27.97

9. EFFECT OF PROTECTION FAILURE

Assume that the fuse gear operate with a probability of 0.9, i,e. the fuses operate successfully 9 time-out of 10 when required. The contribution to the failure rate can be evaluated using the concept of expectation. To calculate the effect of protection failure with 90% reliability of fuse, the equation (6) can be used. In this research, 90% reliable fuse is used and result data is shown in Table 5 and result data of without protective devices is shown in Table 6.

Failure rate= (failure rate / fuse operates) x P (fuse operates) + (failure rate / fuse fails) x P (fuse fails) (6)

Table 5. Result Data of Substation with Effect of Protection Failure with 90 % Reliable Fuse

components	**A**			**B**			**C**			**D**		
	γ(f/yr)	r(hr)	u(hr/y)	γ(f/yr)	r(hr)	u(hr/y)	γ(f/yr)	r(hr)	u(hr/y)	γ(f/yr)	r(hr)	u(hr/y)
1	0.38	4	1.25	0.38	4	1.25	0.38	4	1.25	0.38	4	1.25
2	0.49	0.54	1.96	0.49	4	1.96	0.49	4	1.96	0.49	4	1.96
3	0.23	0.5	0.92	0.23	0.5	0.92	0.23	4	0.92	0.23	4	0.92
4	0.53	0.5	2.12	0.53	0.5	2,12	0.53	0.5	2.12	0.53	4	2.12
a	3.7	4.8	17.76	0.37	0.5	0.18	0.37	0.5	0.18	0.27	0.5	0.18
b	0.37	0.5	0.18	3.75	5.5	20.63	0.37	0.5	0.18	0.37	0.5	0.18
c	0.39	0.5	0.19	0.39	0.5	0.19	3.9	5	19.5	0.39	0.5	0.19
d	0.39	0.5	0.19	0.39	0.5	0.19	0.39	0.5	0.19	3.9	5.5	21.45
Total	6.49	3.16	20.50	6.53	3.84	25.07	6.67	3.71	24.74	6.67	4.28	28.54

Table 6. Result Data of Substation without Protective Devices

components	**A**			**B**			**C**			**D**		
	γ(f/yr)	r(hr)	u(hr/y)	γ(f/yr)	r(hr)	u(hr/y)	γ(f/yr)	r(hr)	u(hr/y)	γ(f/yr)	r(hr)	u(hr/y)
1	0.38	4	1.25	0.38	4	1.25	0.38	4	1.25	0.38	4	1.25
2	0.49	4	1.96	0.49	4	1.96	0.49	4	1.96	0.49	4	1.96
3	0.23	4	0.92	0.23	4	0.92	0.23	4	0.92	0.23	4	0.92
4	0.53	4	2.12	0.53	4	2,12	0.53	4	2.12	0.53	4	2.12
a	3.7	4.8	17.76	3.7	4.8	17.76	3.7	4.8	17.76	3.7	4.8	17.7
b	3.75	5.5	20.63	3.75	5.5	20.63	3.75	5.5	20.63	3.75	5.5	20.63
c	3.9	5	19.5	3.9	5	19.5	3.9	5	19.5	3.9	5	19.5
d	3.9	5.5	21.45	3.9	5.5	21.45	3.9	5.5	21.45	3.9	5.5	21.45
Total	16.88	5.09	85.86	16.88	5.09	85.86	16.88	5.09	85.86	16.88	5.09	85.86

By using equations 1, 2,3,4,5 and 6, the values of reliability indices (SAIFI, SAIDI, CAIDI, ENS and AENS) are calculated and shown in Table 7.

Table 7. Result Data of Substation with Various Protective Devices

Customer oriented indices	Effect of without Protection device	Effect of disconnec -ting switches	Effect of lateral Protection (impact of fuse)	Effect of (fuse) protection failure with 90%
SAIFI (interrupt-ion/ customer /yr)	16.88	5.39	5.44	6.59
SAIDI (h/customer/ yr)	85.86	24.14	26.36	27.71
CAIDI (h/customr intrruption)	5.09	4.48	4.85	3.72
ENS (MWh/yr)	869.76	244.54	267.03	250.32
AENS (kWh/cust-omer/yr)	55.69	15.66	17.09	16.03

10. COMPARISON OF CALCULATED RESULT

Finally, according to calculated result, the comparison of SAIFI, SAIDI, CAIDI, ENS and AENS are shown in followings figure (5), (6), (7), (8) and (9). These comparisons are the most important factor to evaluate the reliability cost and worth.

SAIFI (interruption/ customer/ yr)

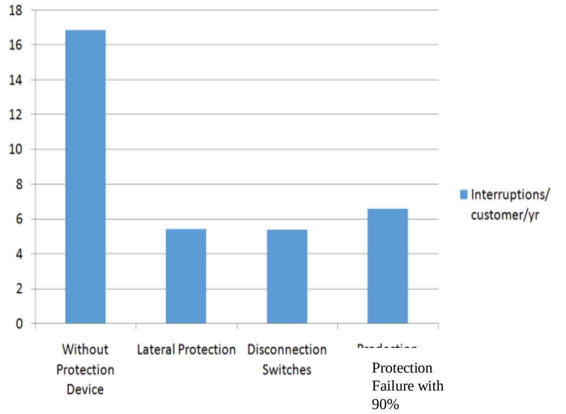

Fig 5. SAIFI with various protective devices

SAIDI (h/ customer/ yr)

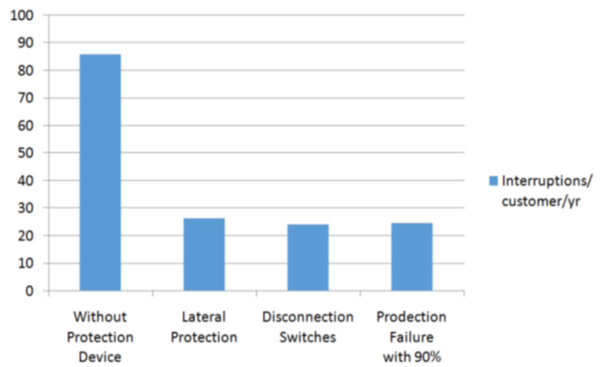

Fig 6. SAIDI with various protective devices

CAIDI (h/ customer interruption)

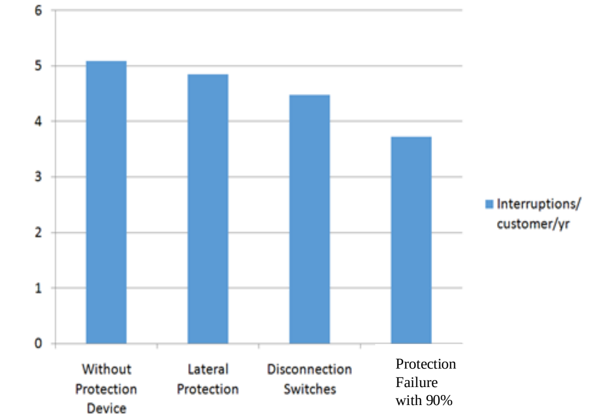

Fig 7. CAIDI with various protective devices

ENS (MWh/yr)

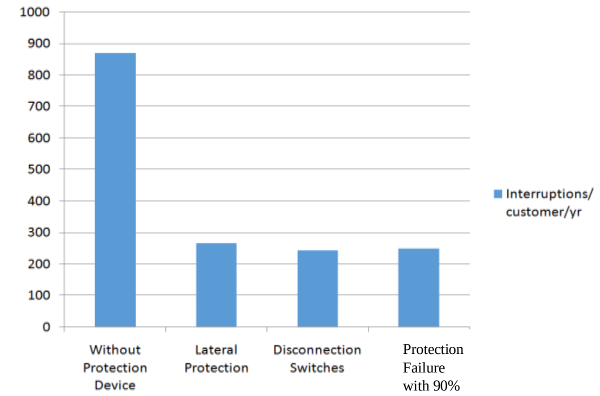

Fig 8. ENS with various protective devices

AENS(kWh/customer/yr)

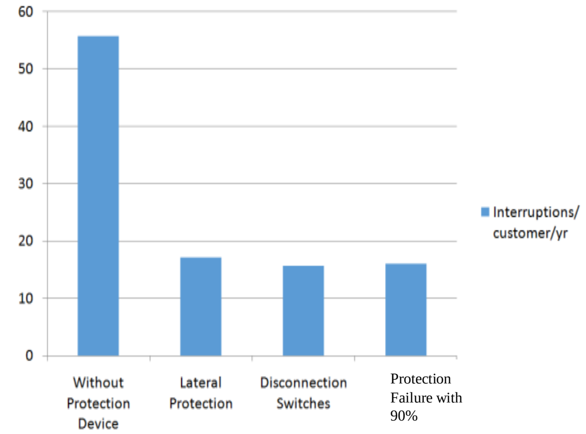

Fig 9. AENS with various protective devices

11. UNIT PRICES OF ELECTRICITY SUPPLY ENTRTPERISE

Today prices of electricity in Myanmar are started to change in first July 2019. In electricity supply enterprise, 1 kWh is defined as 1 unit. The earlier price of 1 unit is 35 kyats for all consumption but the prices are different according to load today. The new prices for each unit are shown in Table 8.

Table 8. Prices of Unit for Residual Customer

No	Unit Prices	
	number of units	Cost (Kyats)
1	1-30	35
2	31-50	50
3	51-75	70
4	76-100	90
5	101-150	100
6	151-200	120
7	500	125
8	4500	135
9	5000	145
10	10000	155
11	30000	165
12	50000	175
13	Over 50000	185

By calculated results, the ENS values are 811.82 MWh/yr for without protection device, 208.5 MWh/yr for lateral protection, 206.35 MWh/yr for disconnecting switches and 212.163 MWh/yr for protection failure. The total customer interruption costs are calculated according to Table 7. The sending end unit is preordained in MWh and receiving end unit is preordained in kWh and it is used to calculate the costs. The total customer interruption costs are calculated below and shown in Table 9.

Unit	**Prices (kyats)**	**Total Prices (kyats)**
500	125	= 62500
4500	135	= 607500
5000	145	= 725000
10000	155	= 1550000
30000	165	= 4950000
50000	175	= 8750000
100,000 units		= 16,645,000
811820 units – 100000 units		= 711820 units
711820 units ×185 kyats		= 131,686,700 kyats
Total costs of 811820 units		= 140,436,700 kyats

Similarly calculated the interruption costs of other feeders, the result is shown in Table 9.

Table 9. Interruption Cost of All Feeders with Various Protective Devices

Sending End Unit (MWh)	Receiving End Unit (kWh)	Protective Devices	Total Interruption Cost(Kyats)
811.82	811820	Without Protective Devices	140,436,700
208.5	208200	Lateral Protection	36,662,000
206.35	206350	Disconnecting Switches	36,319,750
212.163	212163	90 % Protective Fuse	37,395,155

In this research, the interruption costs without protective devices is 140,436,700 kyats, 36,662,000 kyats with lateral protection, 36,319,750 kyats with disconnecting switches and 37,395,155 kyats with 90% protection failure. According to results, the customer interruption cost using disconnecting switches is the least as compared to other protective devices. Therefore, using disconnecting switches is the most effective for No (1) Pakokku substation. By using MATLAB software, it can be proved that the more the losses, the higher the interruption cost, and result is shown in Fig 10.

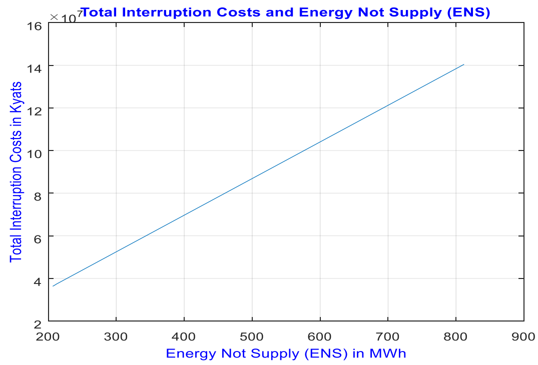

Fig 10. Total Interruption costs and energy not supply (ENS)

The fuse, disconnecting switches and lateral protection can be used to reduce the failure rate and outages time. According to this research, the interruption costs or outages costs caused by failure rate and outage time is least by using the disconnecting switches. The main medium voltage fuse type include the E rated fuse, the R rated fuse and potential transformer or PT rated fuse. E rated medium voltage fuses are general purpose fuses that are primarly used to protect transformers and provide both current overload, and short circuit protestion. R rated medium voltage power fuses require they operate within 15-35 seconds when subjected to an rms current 100 times the R rating. E rated fuses have time current characterist designed to provide current limited protection for power transformer, potential transformer, power centers, feeder centers, and unit substations. This research is about feeder centers and unit substation. Therefore, E rated fuses are more suitable in this research. The 11 kV disconnecting switch is shown in Fig 10 and 11 kV fuse is shown in Fig 11. The disconnecting switches are more expansive than fuse in market. But to have higher reliability, expensive materials are required.

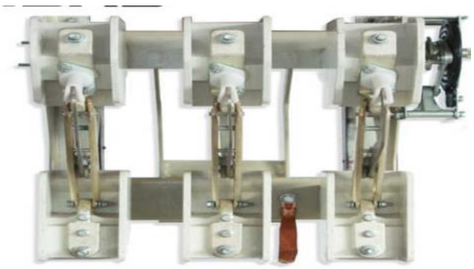

Fig 11. 11 kV AC Medium Voltage Disconnecting Switch

Fig 12. 11 kV Drop Out Fuse

12. CONCLUSIONS

For a better reliability condition of power distribution system, it is required to calculate the reliability indices because the reliability condition can be guessed according to it. Analytical method and simulation method can be used to calculate the reliability indices. These techniques are highly developed and have been used in practical applications for many years. In this research, analytical method is used and calculates only the normal weather condition. The interruption cost of without protection system on feeders is highest in this research. Therefore, it is required to install the protective devices on feeders anyway. By calculated result, the customer interruption costs using with disconnecting switches is the least among all other protective devices. The more interruption, the higher cost the customers have. Therefore, this protective device is effective for substation to get the most reliability cost and worth. Distribution system reliability indices can be evaluated by using analytical methods or Monte Carlo simulation method. This research focuses only on the analytical method. The others can be calculated the reliability cost and worth by using the simulation method. In the reliability evaluation, the sequential simulation technique makes it possible to incorporate the time varying and random nature of load and cost models. This simulation technique can also provide a wide range of indices and their probability distributions. A time sequential simulation approach is also developed and used to evaluate the basic distribution system reliability indices and their distributions.

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Design and Construction of Automatic Irrigation System by using PLC

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ABSTRACT*:* This paper is about automatic irrigation system by using PLC. PLC has implemented sensors which detect the humidity in the soil and supply water to the field which has water requirement. In this paper describe the water filling system design and irrigation system design. Both section contain pump size calculation and control design. The paper is over all controlled by 7 days timer which controls the pump. There are sensors presented in each field which are not activated till water is present on the field. If the field gets dry, sensors will sense the requirement of water in the field and send a signal to the PLC microcontroller. PLC controller is controlled by programmable 7 days timer. PLC microcontroller then supply water by the solenoid valve to that particular field which has water requirement till the 7 days timer is deactivated again. The agriculture fields watering system such as sprinkler or drip water are fitted to feed the plants to reduce human load sprinkler system operate with respect to time.The aim of this system making is for the plants which do not need large amount of water. So, the watering time is set onMonday, Wednesday and Friday.

KEYWORDS: *PLC, pump and control design, sprinkler irrigation, water filling, and 7 day timer,*

1. INTRODUCTION

As part of the development community's fascination with the field of appropriate technologies, a range of technologies, techniques and practices have been developed over the years on behalf of smallholders. However, many, if not most technologies have not been successful in their performance, application dissemination or adoption. Development agencies have tried to encourage farmers to adopt bush pumps, rope-and-washer pumps, rower pumps, treadle pumps, pitcher pot systems, drag-hose sprinklers, hydraulic ram pumps, micro-irrigation systems, windmills, water harvesting techniques and a host of other technologies with mixed success. While it may be that some of the technologies simply did not perform up to the expectations, there is a natural tendency to over-emphasize the technology itself rather than pay attention to the process by which it is identified, modified, and disseminated.

A reliable and suitable irrigation water supply can result in vast improvements in agricultural production and assure the economic vitality of the region. Many civilizations have been dependent on irrigated agriculture to provide the basis of their society and enhance the security of their people. Some have estimated that as little as 15-20 percent of the worldwide total cultivated area is irrigated. Judging from irrigated and non-irrigated yields in some areas, this relatively small fraction of agriculture may be contributing as much as 30-40 percent of gross agricultural output [Walker, W.R (1989)].

Besides management problems of large-scale irrigations, most existing modern irrigation devices do not fit the plots of smallholders, and are far too expensive (in terms of capital or running costs) to be affordable. One key, then, to increasing the agricultural productivity of small farmers is access to affordable and efficient irrigation technologies.

In present days, in the field of agriculture farmers are facing major problems in watering their crops. It's because they do not have proper idea about the availability of the power. Even if it is available, they need to pump water and wait until the field is properly watered, which compels them to stop doing other activities – which are also important for them, and thus they loss their precious time and efforts. But, there is a solution – "An Automatic Irrigation System" not only helps farmers but also others for watering their gardens as well.

2. TYPES OF IRRIGATION

2.1Drip Irrigation

Drip irrigation is one of the commonest localized irrigation systems. It is a synonym to trickle or micro irrigation. This irrigation system consists of a network of pipelines and valves. These valves facilitate dripping water directly to the plant root zone. Unnecessary places in the cultivation are not wetted by this method, and ultimately it reduces the water loss by evaporation and leaking. The valve size, pipe diameter, and flow rate are determined by considering the water requirement at the specific time. In addition, it depends on the cultivation too.

Fig 1. Drip Irrigation. [Brent Row (2015)]

There are several advantages in drip irrigation compared to the other methods of irrigation such as flood and sprinkler systems. Not only water is supplied through this arrangement but also the soluble fertilizer and chemicals (pesticides, cleaning agents) can be applied to the crop by dissolving in irrigated water.

Needed amount of water and fertilizer can be pre estimated. Therefore, the loss can be minimized. This method prevents the spreading of diseases caused by contact of water. Drip irrigation is widely used in areas where water scarcity is a huge problem. In addition, it is very much useful in commercial agricultural systems such as green houses, containerized plants, coconut cultivation, and landscape purposes. Figure 1 show the drip irrigation [Brent Row (2015)].

2.2 Sprinkler Irrigation

The origin of the lawn sprinkler goes back to the earliest attempts to irrigate fields and raise crops in areas where there was not enough water. Sprinkler irrigation system is also a localized method of supplying water for agricultural crops and landscaping plants. It is also used as a cooling system or prevention method of airborne dust. Sprinkler system consists of pipelines, spray guns and spray nozzles. The gun will rotate as a circle by using the power of the spraying water. As it is a localized irrigation method, it has a lot of advantages compared to surface irrigation. Although the water loss is very much less than surface irrigation, it is somewhat higher than drip irrigation. Also, spraying water all over the field may cause to spread some plant diseases and favors to increase the pest population.

Fig 2. Sprinkler Irrigation [Lionel Rolland (1982)]

The most advantages of applied automatic sprinkler is the labor and time efficiency, and cost savings. So, This paper use the sprinkler irrigation. Figure 2 shows sprinkler irrigation [Lionel Rolland (1982)].

3. DESIGN METHODOLOGY

In this paper, two major field are needed to calculate and operate, which are water filling field and irrigation field. Although water filling field is not main content of paper, this field is also important for irrigation system.

3.1 Water Filling System

In water filling system, the followings are needed to design:

- Pump size calculation
- Control design.

3.1.1 Pump size calculation

The pump output power for water filling system is shown in following equation

$$P = \rho \times Q \times g \times H \quad (1)$$

Where,

P = pump output power (kW)
ρ = density of water (1000kg/m^3)
Q = flow rate (m^3/s)
g = acceleration due to gravity (9.81m/s^2)
H = total water head loss (m)

$$Q = \frac{\text{storage water tank } (m^3)}{\text{operating time (s)}} \quad (2)$$

Hazen Williams equation for pipe flow,

$$H = 10.65 \times \frac{Q^{1.85}}{C^{1.85}} \times \frac{l}{d^{4.87}} \quad (3)$$

Where,

l = length of pipe (m)
d = diameter of pipe (m)
C = Hazen William's coefficient

Table 1. Hazen William's coefficient (C)

Pipe Material	Design (C)
PVC	150
Asbestos cement	140
Copper or Brass	130
Welded Steel	100
Concrete	100
Cast Iron	100
Vitrified Clay	100
Corrvgated Steel	60

$$\text{Total Pipe Length} = \text{Actual Pipe Length} + \text{Equivalent Pipe Length for } 90^\circ \text{ Elbow} \quad (4)$$

$$\text{Equivalent pipe length For} 90^\circ \text{elbows} = \text{number of elbow} \times \text{loss of head} \quad (5)$$

Table2. Equivalent Pipe Lengths

diameter of pipe (mm)	Copper PVC	
	Elbow (m)	Tee (m)
15	0.5	0.8
20	0.8	1.0
25	1.0	1.5
32	1.4	2.0

Loss of head is choose based on diameter of pipe.

3.1.2 Control design

In this design, auto-manual operation can be chosen by selector switch. In auto operation, magnetic contactor is controlled by floatless relay switch to run pump motor according to the water level. And the manual operation is that the motor can be run anytime without floatless relay switch. Thermal relay is just only for motor protection and it breaks down the motor when motor increases heat, then if heat decreases, motor will run again. Figure 3 show water filling system design.

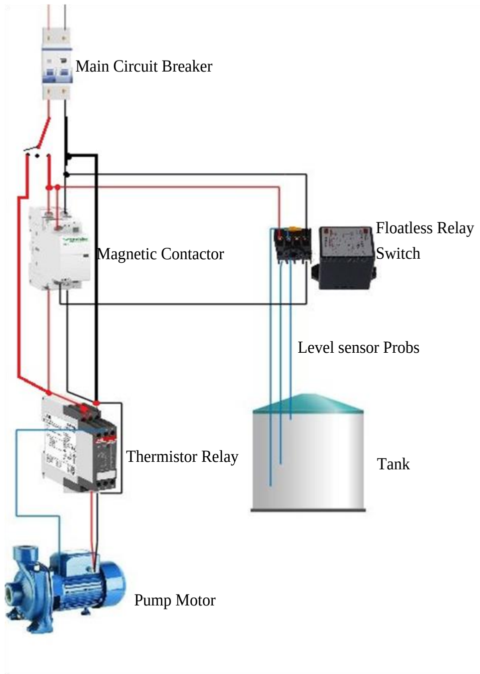

Fig 3 Water Filling System Design

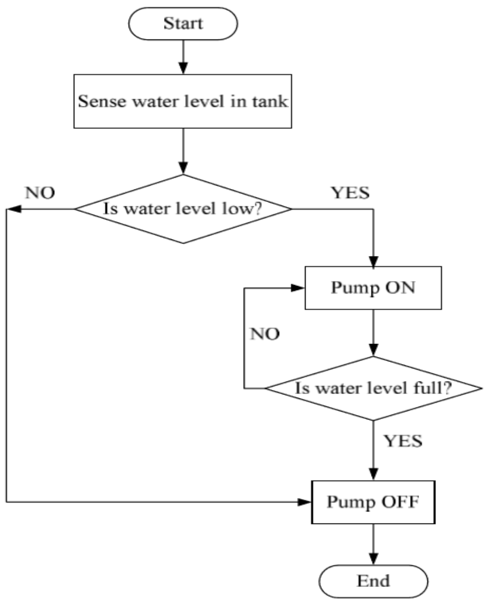

Fig.4 Flow Chart of Water Filling System

Figure(4) show the flow chat of water filling system. In this system, water level in tank is sensed by using floatless relay. If the water level in tank is low, the water pump is ON. If the water level in tank is full, the water pump is OFF.

3.2 Irrigation System

In irrigation system, the followings are needed to calculate:

- Pump size calculation
- Control design

3.2.1 Pump size calculation

Horsepower is a measurement of the amount of energy necessary to do work. In determining the horse power to pump water, the following units must be known:[Guy Fipps (1947)]

$$hp = \frac{whp}{\eta} \quad (6)$$

$$whp = \frac{gpm \times TDH \times SG}{3960} \quad (7)$$

TDH = total distance + fraction head loss (8)

Where,

hp = motor horse power
whp = water horse power
η = pump efficiency (0.5~0.85)
SG = Specific gravity(SG of water is 1.)
TDH = Total dynamic head (ft)
gpm = gallon per minute

Table 3. One Inch PVC Pipe Friction Losses

1 inches				
Volume Flow (gal/min)	**Volume Flow (gal/hr)**	**Velocity (ft/sec)**	**Friction Head (ft/100 ft)**	**Friction Loss (psi/100ft)**
2	120	0.8	0.6	0.2
5	300	1.9	1.7	0.8
7	420	2.7	3.2	1.4
10	600	3.9	6.0	2.6
15	900	5.8	12.8	5.5
20	1200	7.7	21.8	9.4
25	1500	9.7	32.9	14.2
30	1800	11.6	46.1	20.0

Table 4.Inches PVC Pipe Friction Losses

2 inches				
Volume Flow (gal/min)	**Volume Flow (gal/hr)**	**Velocity (ft/sec)**	**Friction Head (ft/100ft)**	**Friction Loss (psi/100ft)**
5	300	0.5	0.07	0.03
7	420	0.7	0.1	0.05
10	600	1.0	0.2	0.09
15	900	1.5	0.5	0.2
20	1200	2.0	0.8	0.3
25	1500	2.4	1.2	0.5
30	1800	2.9	1.6	0.7
35	2100	3.4	2.2	0.9
40	2400	3.9	2.8	1.2

Friction head losses are choose based on inches of PVC pipes and volume flow.

$$gpm = \frac{1 \times ft^3}{449} \quad (9)$$

Volume of pipe (ft^3) = Area x pipe length (10)

$$Area = 3.14 \times \pi r^2 \quad (11)$$

Where,

r = radius of pipe

$$\text{Total Pipe Length} = \text{Actual Pipe Length} + \text{Equivalent Pipe Length for } 90^{\circ} \text{ Elbow} \quad (12)$$

$$\text{Equivalent pipe length for } 90^{\circ}\text{elbows} = \text{number of elbow} \times \text{loss of head} \quad (13)$$

Pump size is depended on the farms. If the farm is wide, pump size should be used the large size.

3.2.2 Control design

In automatic irrigation system, it is difficult to use selector switch as the design has two control systems which are pump control and valve control. To build up selector switch in this design, it is needed to directly connect the pump and valve. Valve used with PLC are 12/24V supply and it is needed 220V supply type valve for directly connecting with selector switch. Figure 5 show automatic irrigation system design.

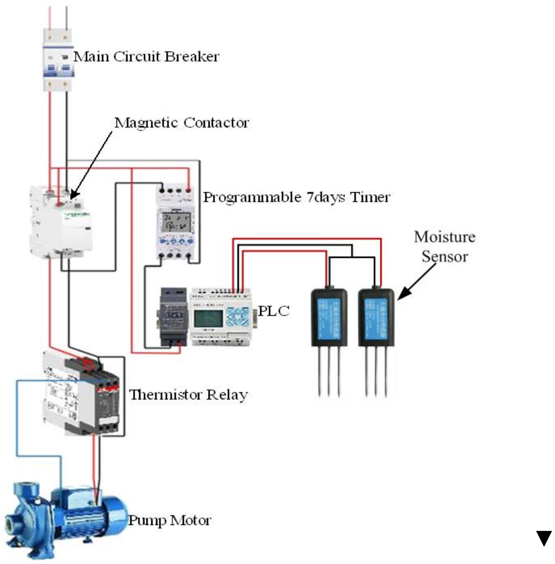

Fig5. Automatic Irrigation System Design

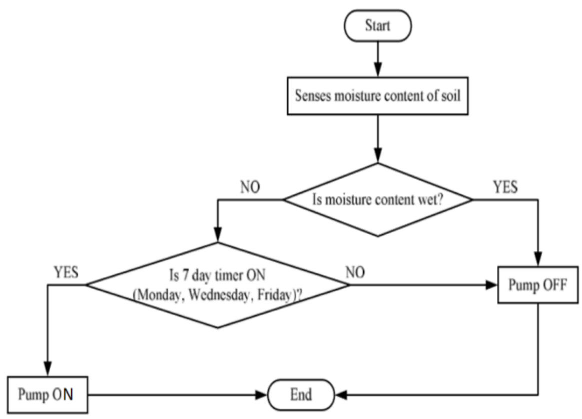

Fig 6. Flow Chat of Irrigation System

Figure (6) show the flow chat of irrigation system. In the flow chat, moisture content of soil is sensed by using moisture sensor as the first step. If the moisture content is wet, the pump is OFF. If the moisture content is dry and 7 days timer is ON, the pump is ON. Although the moisture content is dry and 7 days timer is OFF, the pump is still OFF.

4. TEST AND RESULT

In this system, moisture sensor and 7 days timer are used to control automatic irrigation. 7 days timer setting is turned ON on Monday, Wednesday and Friday. Although the moisture is dry on the other days(Tuesday, Thursday, Saturday, Sunday), the pump is OFF because the 7 days timer setting is turned OFF.Both of pump and PLC controller are controlled by programmable 7 days timer.

To close pump, programmable 7 days timer will operate by the schedule setting. Figure 7 shows PLC ladder diagram of irrigation system. When 7days timer runs and set-up time is reached, PLC controller and motor will run. It needs a 220/24V transformer to supply PLC controller and a 220/12V transformer to supply valves and motor in this paper.Figure 8 shows prototype of automatic irrigation system.

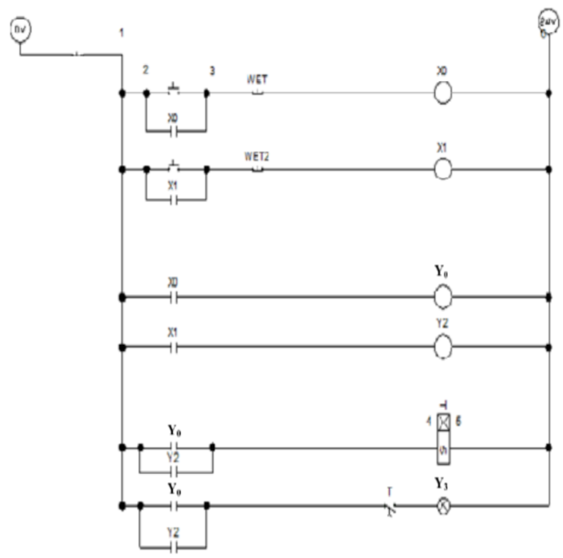

Fig 7. PLC Ladder Diagram of Irrigation System

Fig 8. Prototype of Automatic Irrigation System

PLC controller has two major input from two moisture sensors. X_0 and X_1 are input modules of PLC controller from Moisture Sensor where X_0 is moisture sensor of farm 1 and X_1 is from farm 2. If X_0 is active, valve (Y_0) will open. This means that valve Y_0 will open in farm 1 which does not have enough moisture level. In farm 2, valve Y_2 also will operate like in farm 1. Push buttons are used for dry condition.

As shown in PLC ladder diagram, if valve 2(Y_2) or valve 1(Y_0) just closes because one farm gets enough moisture content, the motor (Y_3) still run. If the two farms get enough moisture content, the motor will also stop.

5. CONCLUSIONS

This research can be constructed for good irrigation method, and it must be effective for Burma-farmers and reduce water usage that is unnecessary.

The research is designed to replace the back-breaking and time-consuming work of irrigating water from the well to the fields. The amount of suitable water (based on range of its soil moisture) needed to deliver for the plants is being controlled so there is no excess water, which mainly contributes to conservation of water. This system will improve overall use of water resources. And it will also improve quality of the crop. It will be helpful to save water at the same time the system consumes minimum power. PLC is controlled by 7 days timer switch. So it can be programmed according to the user's requirements.

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Design and Construction of Remote Control Spray Robot for COVID-19

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ABSTRACT*:* This paper describes the evolving role of robotics in healthcare and allied areas with special concerns relating to the management and control of the spread of the novel coronavirus disease 2019 (COVID-19). Recently, in hospitals, doctors and nurses, family members, and even receptionists are using robots to interact in real-time with patients from a safe distance. Also, outside of the hospitals, public works, and public safety departments are using robots. These robots will result in minimizing the life threat to medical staff and doctors taking an active role in the management of the COVID-19 pandemic. So, in this research paper, an automatic spraying robot for COVID-19 is designed and constructed, such as hospitals and public areas or quarantine center. This research is purposed to spray disinfecting rooms for patients and healthcare fields. Its function is to mix the pesticide with water in a prerequisite amount and spray it in three directions namely 15 feet height ceiling, wall, and floor, as per the set dosage. And then, its motions are four directions namely forward, reverse, right and left evenly.

KEYWORDS: *Spraying Robot, COVID-19, Healthcare, Design and Construction, Remote Control*

1. INTRODUCTION

The World Health Organization (WHO) on January 30, 2020, publicly declared the COVID-19 pandemic as a “global emergency” because of the rapidity at which it had spread worldwide [5]. COVID-19, the disease caused by the novel coronavirus, has been created a global lockdown, the likes of which hasn’t been seen in over a century. Responses in hot spots have varied from recommended social distancing to mandated self-isolation. While the public does its best to heed these directives, critical workers such as first responders, nurses and doctors, transit employees, grocery store employees and others remain at their jobs. To reduce human contact in these affected indoor and outdoor areas, disinfecting robots and machines are being developed. Instead of manual disinfection, which requires workforce mobilization and increases exposure risk to cleaning personnel, autonomous or remote-controlled disinfection robots could lead to cost-effective, fast, and effective disinfection [5].

Robots and machines can significantly help in the fight against the corona virus disease that is spreading across the globe. Now, robots and machines are playing a major role in this fight, improving the health and safety of individuals and patients. Never before, scientists say, have so many of the world researchers focused so urgently on a single topic. Nearly all other research has ground to a halt [1]. Many technological universities from all over the world do the machines and robots such as automatic mask machines, ventilators and spray machines. Chinese starts doing robots spray disinfectant to fight spread of COVID-19. This invented robot by Chinese scientists is manipulated using a remote control [3]. Spray robot is a useful resource during the COVID-19 public health emergency. This robot is the process in which spraying is done by the machine to reduce the human effort and to increase accuracy. It can use to disinfect hospitals, shops, schools, airports, markets, sports halls and religious sites etc which can mitigate the spread of the virus. Cleaning interior space is often more critical because the novel coronavirus lingers on some surfaces for days.

2. LITERITURE REVIEW

The applications of robotics and automation in healthcare and allied areas is increasing day by day, Iqbal, J.; Khan, Z.; Khalid, A, 2017 and Khan, Z.H.; Khalid, A.; Iqbal, J, 2018. [9,10]. The International Federation of Robots (IFR) predicts an ever-increasing trend in the demand of medical robots within the coming years with an estimation of 9.1 billion USD market by 2022 as shown in Fig 1. Robots not only help physicians and medical staff to carry out complex and precise tasks but also lower their workload thus improving the efficiency of the overall healthcare facilities [11]. Robots designed for use in healthcare and medicine have stringent cleaning requirements as they must be free of germs and microbes which can spread communicable and contagious diseases to other patients [7]. Most of the surgical end effectors are designed for single use only. Service robots must be sterilized from time to time so that they do not become infective carriers [8].

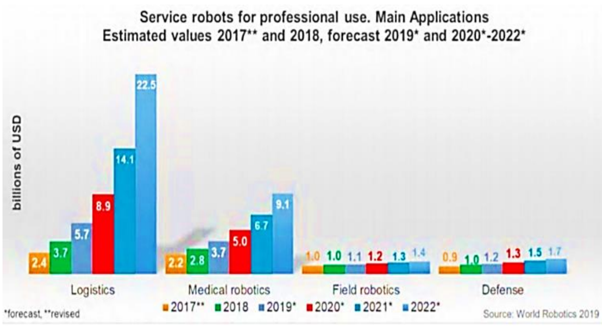


Fig 1. Increasing demand for medical robots in the world market [6]

Robots are mainly classified with various applications in healthcare and related fields. These classifications are broadly designated such as receptionist robot area, nurse robots in hospital area, ambulance robot area, telemedicine robot area, hospital serving robot area, cleaning robot area, spraying/disinfestation robot area, surgical robot area, radiologist robot area, rehabilitation robot area, food robot area, and outdoor delivery robot area. In this paper, the remote control spray robot for COVID-19 is mainly designed and constructed.

2.1. Spraying/Disinfestation Robots

Such robots are widely used in spraying antiseptic mixtures over large outdoor areas e.g., residential centers of the city. These robots are remotely controlled to avoid hazardous contact with the disinfectant spray [2]. Fig 2 shows such scenarios where sanitary workers on scooters control the robot in order to disinfect the surroundings. Autonomously guided hand sanitizer dispensing robots are designed to alleviate infections on human hands and faces. Such alcohol-based sanitizers remove bacteria, viruses, and other microbes to prevent the spread of contagious diseases among large populations as shown in Fig 2.

Fig 2. Spraying and sanitizing robots in residential areas of China [2]

3. COMPONENTS LIST

In this research paper, the main components of spray robot are: DC Gear Motor, Battery, BTS 7960 motor driver, 5V DC Relay, Limit Switch, Water Pump, Nozzle, Arduino Mega, Rubber Wheel and Castor Wheel,

3.1 DC motor

A DC motor is any of a class of rotary electrical motors that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. In this research, two DC motor is used to rotate the wheel which is used to move the machine from one place to another and one DC motor is used to lift up and down for steel rod as shown in Fig 3. Following are the specification of DC motor: 60 rpm, DC Motor Current: 0.7 A, Voltage: 12 V.

Fig 3. 12 V DC Gear motor

3.2 Lithium-ion Battery

In this research, 12V,40Ah Lithium ion battery is used and as shown in Fig 4. It's one of the most popular types of rechargeable batteries. It has found in different portable appliances including mobile phones, smart devices and several other battery appliances used at home. It is also found applications in aerospace and military applications due to their lightweight nature

Fig 4. Lithium ion battery

3.3 BTS 7960 Motor Driver

To drive a dc motor, we need a dc motor driver. So, we used full-bridge driver with twe BTS7960 motor drive as shown in Fig 5 and it is used to control speed and route of motors.

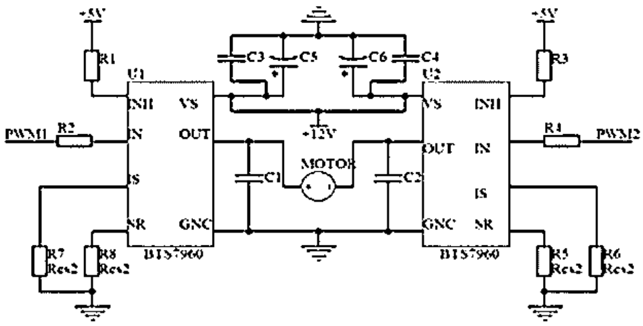


Fig 5. BTS 7960 Motor Driver

3.4 DC Relay

Direct current (DC) is steady and never reverses. A DC relay uses a single coil of wire wound around the iron core to make the electromagnet. Once the current is turned off and the iron core is no longer magnetized, the spring-loaded lever returns to a relaxed position and the electrical contacts are switched back. Fig 6 is as shown in 5 V DC relay.

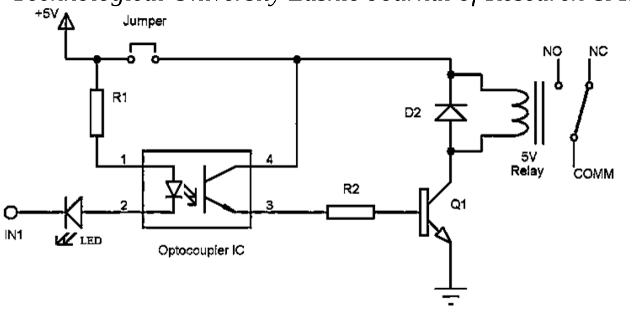


Fig 6. 5V DC Relay

3.5 Limit Switch

Limit switch as shown in Fig 7 is used in a variety of applications and environments because of their ruggedness, ease of installation, and reliability of operation. In this research, limit switch is used for lift up and down.

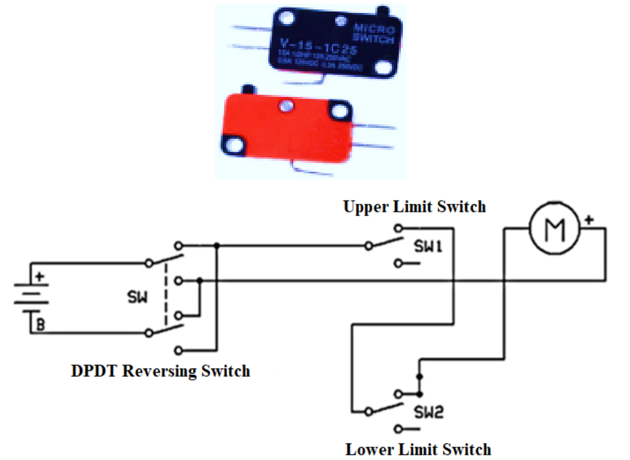


Fig 7. Limit Switch

3.6 Water Pump

The water pump is a pump which uses the principles like mechanical as well as hydraulic throughout a piping system and to make sufficient force for its future use. At present these pumps are used to transport mixture of water and pesticides from tank to the delivery nozzle as shown in Fig 8. These are the DC water Pump of specification. Pressure = 6.2 bar = 80 Psi, Current = 2.1 A and 6.7 A, Voltage = 12 V.

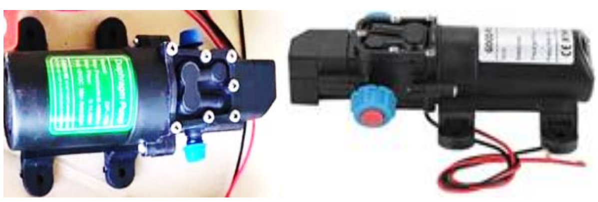


Fig 8. DC Water Pump

3.7 Arduino Mega

The Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields designed for the Uno and the former boards Duemilanove or Diecimila. In this research the Arduino Mega 2560 is supports a large variety of sensors, actuators, and motors. Fig 9 is shown in Arduino Mega 2560.

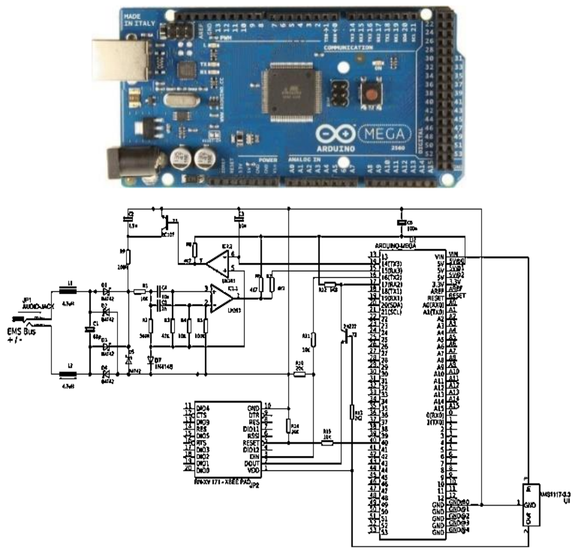


Fig 9. Arduino Mega 2560

3.8 Nozzle

A nozzle is often a pipe or tube of varying cross-sectional area, and it can be used to direct or modify the flow of a fluid. In this research, used in nozzle specification: Nozzle Type: Cone Nozzle, Nozzle Angle: 90-degree, Nozzle radius: 0.1 mm. Fig 10 is shown in nozzle.

Fig 10. Nozzle

3.9 Rubber Wheel and Castor Wheel

Wheels reduce friction. Wheels are used to transfer machine from one place to another by rotary motion of it. Castor has four types rigid, swivel, industrial, and braking and locking. In this research, 2 rubber wheels and swivel types of 2 castor wheels are used as shown in Fig 11. Swivel casters rotate 360°. Specifications of wheels are as follows: Radius: 8 ft and 4 ft, Wheel materials: rubber and plastic.

Fig 11. Rubber and Plastic Castor Wheel

3.10 Plastic Tank

Tank is the unit where we can store the mixture of water and pesticides. To protect it from corrosion and for log life and to reduce weight so, it is made up of plastic. In this research water tank capacity is 23 lit as shown in Fig 12.

Fig 12. Plastic Tank

3.11 Frame

Frame is made up of steel and use in body of this robot as shown in Fig 13. The other components are getting assembled on the frame by means of Bolts, Nut, Chain and Chain sprocket. These specifications are width = 2 ft, length = 3 ft and height = 3 ft. The main frame is covered from all the sides with Formica sheets. Frame is nothing but the chassis for a machine or vehicle.

Fig 13. Robot Frame

3.12 Pipe

Pipe is the unit used to carry water from pump or tank to DC Pump and from DC Pump to nozzles. To reduce cart weight and to eliminate corrosion effect it is made up of plastic. In this research, plastic pipe length is used 40 ft as shown in Fig 14.

Fig 14. Pipe

4. CONSTRUCTION AND WORKING PRINCIPLE

4.1 Chassis

Firstly, the body frame of spray robot was designed which length is 2 feet, breadth 1.5 feet, height 3 feet, the whole body was constructed by steel as shown in Fig 15. And then the two 10-inch-diameter rubber wheels and two 2-inch-diameter caster wheels are fixed to the body frame and another two castor wheels are constructed in front of the frame as manual wheels for better movement. Last, but not least, the composite was covered to the whole-body frame for waterproof. The total weight of the spray robot is about 70kg including 20kg of water weight and 40 Ahr battery weight.

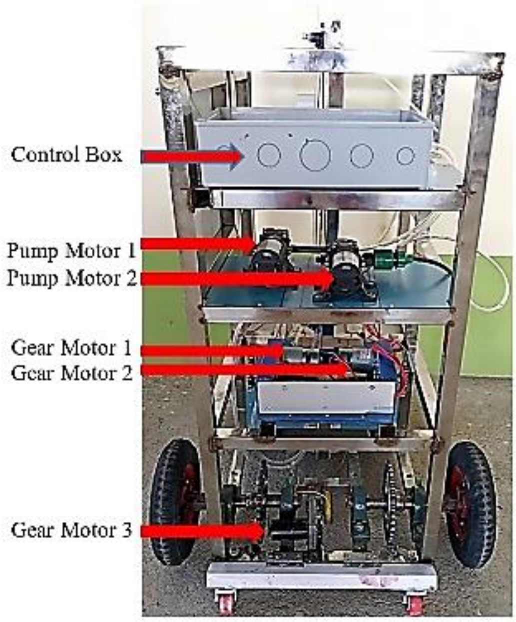


Fig 15. Chassis

4.2 Motors

In this research, two pump motors (PM-1, PM-2) and three gear motors (GM-1, GM-2 and GM-3) were used. Two pump motors, which current rating is PM-1 = 6.7A and PM-2 = 2.5A for spraying. Then, three gear motor types are 555 gear motor (GM-3) and 775 gear motors (GM-1 and GM-2) for movement and lifting. From the body frame, 5 feet height lift was also designed which can extend about 10 feet by using 555 gear motor (GM-3) together with 5-yard nylon string to lift up, the lift for spraying the ceiling. The two set of chain and chain sprocket are linked-up between 775 gear motors (GM-1 and GM-2) and 10-inch-diameter rubber wheels. The first pump motor (PM-1) was used to spray the ceiling by using 2 nozzles which are at the top of the lift, then for the ground floor, 5 nozzles which are in front and beside of the body frame are used. The second pump motor (PM-2) was used to spray the wall by using three nozzles. Water tank capacity is 23 liters. Fig 16 shows in water tank and pumps motor.

Fig 16. Water Tank and Pumps Motor

5. CIRCUIT OPERATIONS

The operation procedure is shown step by step. Power bank supply connects with Arduino Mega. It gives 5V power supply to control signals such as 5V relays, receiver and H-Bridge driver and then the ground pin of Arduino Mega connects to 5V relays, receiver and H-Bridge driver. The pins of receiver connect with the pins of Arduino are N0.8, 9, 10, 11, 12, 14 and 15. In spray robot, there are two H-Bridge drivers for two motors.

Fig 17. Installed of Control Circuit

One of the H-Bridge drivers for motor No.1 use the pins such as IN 1, 2, VCC, GND and EN to connect Arduino Mega. The pin No.1, 2 and EN of H-Bridge driver connect respectively with the pins of Arduino Mega No.2, 4 and 3. The second H-Bridge driver is used for motor No.2 and the pin number of IN 1 connect to the pin No. 7 of Arduino. The remaining pins number IN 2 and EN connect to the pin No.6 and No.5. The other pins of H-Bridge driver are used for 12V battery and two motors. Fig 17 is shown in the installed of control circuit.

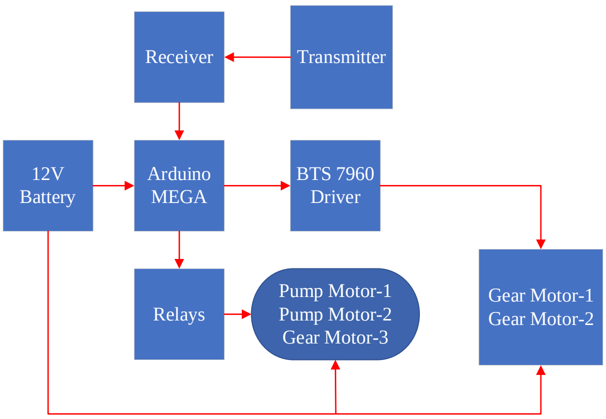


Fig 18. Control Environment of the Developed System

There are 5V four relays that used for spray robot circuit. Relay no.1 and no.2 are used for two pumps and relay no.3 and no.4 are used for lifting motor which purpose are to lift the steel rod up and down. Relay no.1 is for pump motor 1 which connects to the pin No. 13 and relay no.2 is for pump motor 2 which connects to pin No.19 of Arduino. The pins No.17 and 16 are connected to the remaining relay no.3 and 4 which purpose is used for lifting motor. The control environment of the developed system is shown in Fig 18, Fig 19 shows the pin connection diagram of Spray Robot and the complete control circuit diagram of spray robot is shown in Fig 20. The receiver out means signal output that is ON/OFF signal.

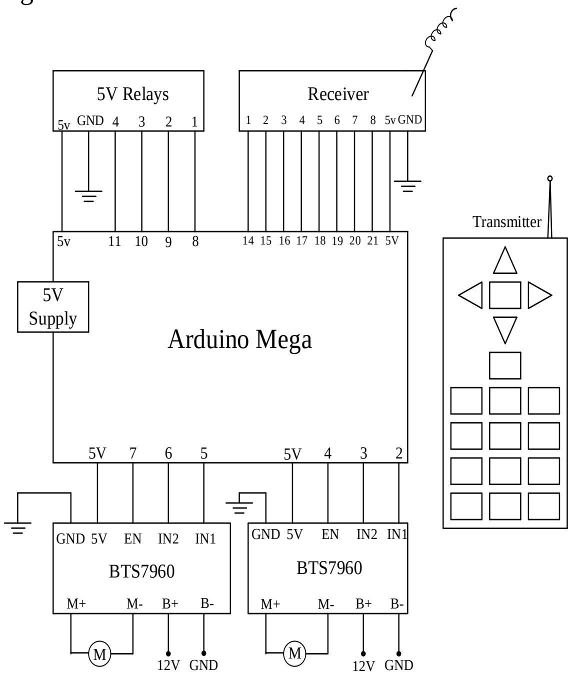


Fig 19. Pin Connection Diagram of Spray Robot

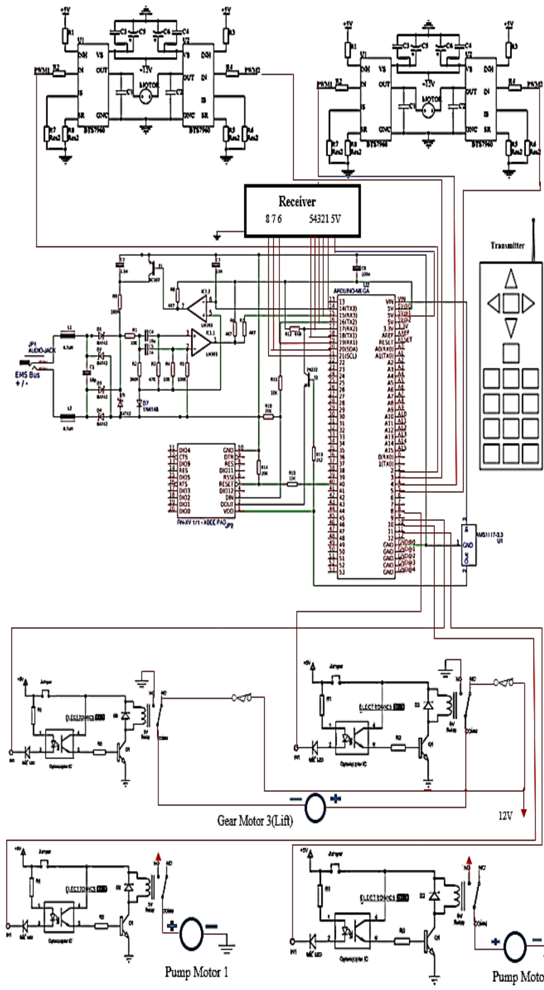


Fig 20. Complete Control Circuit Diagram of Spray Robot

The procedure for using the Remote-Control Spray Robot for Covid-19 must firstly be powered a breaker. Next, turn on the power button on the remote control. Once the power is on, press the Number 1 button on the remote control to move forward. To move backwards, press the Number 2 button. To turn, press the Number 3 button. To turn right again, press the Number 4 button. The Number 5 button is used to lift the lift. Press the Number 6 key to lower the lift which is at the top. To spray the ceiling and floor, press the Number 7 button and so, 7 steps can do couple. To spray on a wall, press the Number 8 button. The 8-channel digital remote controller is shown in Fig 21. The duration of each step is around 5sec to 10sec. All step or any step can transfer as we like. If the upper or top spray, dual direction will go which is forward and backward.

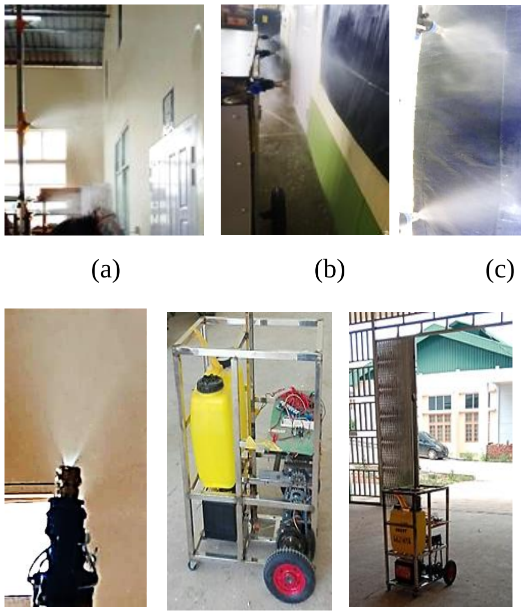
Fig 21. 8 Channel Digital Remote Controller

6.TEST AND RESULT

The robot can drive on rough concrete floors as well as on smooth concrete floors, as well as on 30-degree slopes. Spray test in the room, the pesticide spray nozzle of the spray water can get good results. The nozzle is producing fog. It can be evenly sprayed on the 15 feet height ceiling, wall, and floor as shown in Fig 22(a)(b)(c)(d). Measuring the distance of the farthest injection is 2 ft, the spray angle can be controlled at 30-150 degrees as shown in Fig 22(d). The spray angle area is 0.88m^2 takes about 5 minutes to spray pesticides in a room around 10 feet, and also 3 liters of disinfectant is reduced. So, 35-40 minutes to spray on time for 7 room around 10 feet and 23 liters are reduced. Fig 22(e) and (f) are shown in testing of rough floor. Table 1 is shown in test and result for Spray Robot and Table 2 shows the operating conditions of Spray Robot.

Table 1. Test and Result for Spray Robot

Descriptions	**Test and Result**
Nozzle	Producing Fog (nozzle radius 0.1 mm)
Nozzle injection	2 ft
Nozzle spray angle	30 -150 degree
Robot can drive	Rough and Smooth Street
Robot drive slope	30 degree
Sprayed on height ceiling	15 ft
Pesticides spray on time for a room around 10 ft	5 min
Reduced Pesticides for a room around 10 ft	3 liters
Pesticides sprayed on time for Spray Robot	35 - 40 min
Sprayed Pesticides 23 liters (water tank) for spray robot	7 room around 10 ft



(a) (b) (c)

(d) (e) (f)

Fig 22. Testing of Spray Robot

(a) Testing Wall
(b)Testing Floor
(c) Testing Wall
(d) Testing 15 height celling
(e) and (f) Testing rough floor

Table 2. Operating Conditions of Spray Robot

Digital Channel	ON (or) OFF	Operating Condition
1	ON	Go Forward
	OFF	OFF
2	ON	Go Backward
	OFF	OFF
3	ON	Turn Left
	OFF	OFF
4	ON	Turn Right
	OFF	OFF
5	ON	Rise the Lift
	OFF	OFF
6	ON	Fall the Lift
	OFF	OFF
7	ON	Pump-1
	OFF	OFF
8	ON	Pump-2
	OFF	OFF

7. CONCLUSIONS

We are seeing the devastating effects of the virus, and we must all support public health authorities and health care workers. Pesticide spray robots are very useful for our health care. That's why we developed spray robots primarily to prevent and control the spread of the Covid-19 virus. These spray robots may be used on 15 feet high ceilings, remote control of pesticides can be applied to any room, such as walls or floors, reducing contact between pesticides and the human body. And then two caster wheels are mounted on the front of the frame for manual use, making it easy to carry.

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ANALYSIS AND CALCULATION OF CAPACITOR BANK IN SUBSTATION (LASHIO)

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ABSTRACT*:* In power electric systems capacitors and capacitors banks which must be in accordance with are used to compensate reactive energy (power factor correction) due to consumers and the inductive effect of long overhead lines and underground cables and provide voltage regulation. A shunt capacitor bank (or simply capacitor bank) is a set of capacitor units, arranged parallel/series associated with a steel enclosure. Capacitors banks may have built-in discharge resistors to dissipate stored energy to safe level within a few seconds after power is removed. They shall be stored with the terminals shorted, as protection from potentially dangerous due to dielectric absorption. HV capacitor banks are installed outdoors, surrounded by a fence, and LV capacitor banks are installed indoors, in metallic enclosures (switchboards). The more power consuming will increase the resistive load and inductive load. Installation capacitor bank in substation is not only good for industrials but also reducing waste energy. This paper represents a real distribution system 66/33 kV from Substation (Lashio) in 2018 and using MATLAB software in this paper.

KEYWORDS*: Power System***,** *Sub-station, Capacitor bank, MATLAB software.*

1. INTRODUCTION

Power system consists of several components such are generations, transmission lines, distributions and loads. Each part consists of components that might encounter losses during their operations which can be divided into technical losses and non-technical losses. The main focus of this paper is the technical losses that caused by the physical properties of components at transmission lines especially the MW loss and the MVAR loss.

Several studies have been conducted for the system which can be shown before and after installing capacitor mounting which is increased to twice the value of the original setting. The purpose is to decrease greater value of power losses. This paper is mainly concentrated to reduce the unnecessary MVAR losses and to modify the capacitor bank installed in 66/33 kV substation (Lashio).

The study will concentrate on the MW and MVAR power losses created at transmission lines. Basically, power losses are caused by several effects such as copper losses, reactive loss and dielectric loss. In this paper, such losses can only be minimized by power factor correction and by installing the capacitor bank at various size and location to the power grid system.

2. POWER QUALITY

Power Quality (PQ) related issues are of most concern nowadays. The increased sensitivity of the vast majority of processes (industrial, services and even residential) to PQ problems turns the availability of electric power with quality a crucial factor for competitiveness in every activity sector. Some consumers require a level of PQ higher than the level provided by modern electric networks. This implies that some measures must be taken in order to achieve higher levels of Power Quality. There are two types of PQ problem, (i) transient overvoltage and (ii) harmonics distortion of the voltage and current.

The PQ can be classified in real power, reactive power, and apparent power as shown in Fig 1.

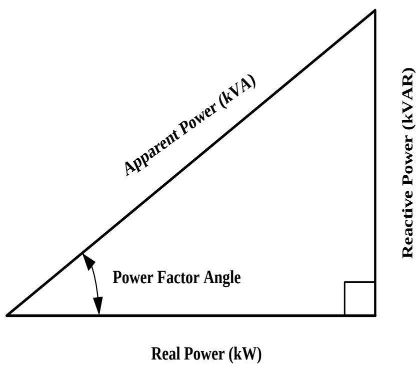

Fig 1.Power Triangle

2.1 Power Factor

For inductive loads to operate requires real and reactive power. Reactive power is required to provide the electromagnetic field necessary to operate an induction motor.

Power factor is related to power flow in electrical systems and measures how effectively an electrical power system is being used. In order to efficiently use a power system be as close to 1.0 as possible, which implies that the flow of reactive power should be as kept to a minimum. Maintaining a high power factor is a key to obtaining the best possible economic advantage for both utilities and industrial end users.

Operating the power system at a higher power factor allows the system to maximize the capacity of the system by maximizing the delivery of real power.

Commercial and industrial customers avoid utility charges by operating at an acceptable power factor.

2.2 Capacitor Banks

Capacitor banks are very economical and generally trouble free. Installing capacitors will decrease the magnitude of reactive power supplied to the inductive loads by the utility distribution system thereby improving the power factor of the electrical system. Supply of reactive power from the utility power system is now reduced.

Installation of capacitor banks close to the load center will reduce the magnitude of reactive power drawn by the load from the utility distribution system. The most common method in practice today for improving power factor (correct to near unity) is the installation of capacitor banks.

Capacitors are intended to operate at or below their rated voltage and frequency and are suited for continuous operation at 135% of rated reactive power. Capacitors can operate continuously only when the following limitations are not exceeded. They are(i) 110% of rated rms voltage (ii) 120% of rated crest voltage(iii) 135% of nominal rms current based on rated voltage and rated KVAR, including fundamental currents and harmonic currents. (iv) 135% of rated KVA [1].

2.3 Reduction of losses in MV lines

Capacitor banks can be installed to decrease the level of losses in a MV distribution line. In fact, the installation of the capacitor will produce a direct reduction of the reactive energy (Q network) and apparent energy requested from the system.

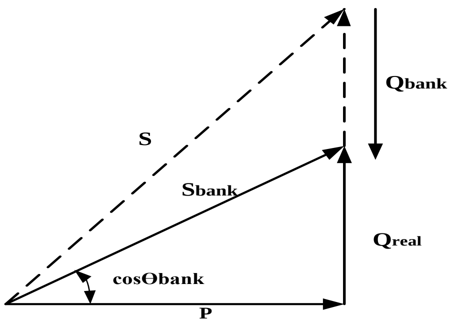

Fig 2. Reduction of losses in MV lines

Fig 2 shows the expressions required for the calculation of MVAR losses, increase of voltage and line voltage drop when a capacitor bank is connected [2].

Apparent Power (S) = $\sqrt{3} \times VI$ (1)

Real Power $P = \sqrt{3} \times VI \times Cos\theta$ (2)

Reactive Power $Q = \sqrt{3} \times VI \times Sin\theta$ (3)

Reactance $X = 2\pi \times f \times L$ (4)

$$\Delta U(\%) = \frac{Q_{bank} \times 100}{S_{cc}} \quad (5)$$

$$V(\%) = \frac{P \times L}{10 \times V^2}(R_1 + X_1 \tan \phi) \quad (6)$$

$$C_{per\ phase}(F) = \frac{Q_{var}(total)}{2\pi \times f \times (V_{L-L})^2} \quad (7)$$

The rise of voltage after the installation of capacitor bank is the ratio of the product of the capacitor MVAR and transformer reactance to transformer MVA.

The percentage of line current reducing after the installation of capacitor bank is the ratio of the product of the present current and reducing current.

3. CALCULATION OF CAPACITOR BNANK

Lashio 66/33 kV distribution substation is located in Thein Ni Road, Namachol Village Lashio. Incoming line is from Mansan 230 kV substation. This incoming Line is distributed to 4 branches in Lashio, Mine-yeal Township and Cornerstone Resources (Myanmar) Zinc purification factory. In this branch, there are number of two 20MVA and one 30 MVA. There have already installed 8MVAR capacitor bank. This paper expresses analysis and calculation of this capacitor bank. In Fig 3. shows layout plan of Substation (Lashio).

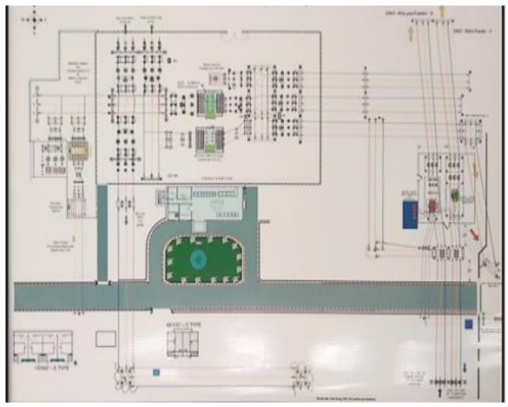

Fig 3. Layout plan of Substation (Lashio)

3.1 Calculation of MVAR

At first, some of the data is the average value of the year 2018 and to improve the power factor($\cos\theta$) of 66 kV, 50Hz, 30MVA transformer in substation from 0.8 to 0.95.

For 30MVA transformer, V = 66 kV

At 0.8 power factor,

$\cos\theta = 0.8$, $\sin\theta = 0.6$,

Apparent power, $S = \sqrt{3} \times VI$

$$I = \frac{S}{\sqrt{3} \times V}$$

$$= \frac{3\times10^6}{\sqrt{3}\times66\times10^3}$$

= 262.43 A

Real Power $P_1 = \sqrt{3} \times VI \times Cos\theta$

= 23999.823 kW

Reactive Power $Q_1 = \sqrt{3} \times VI \times Sin\theta$

=17.995 MVAR

At 0.95 power factor,

cosθ = 0.95, sinθ= 0.312,

Apparent power $S = \sqrt{3} \times VI$

$$I = \frac{S}{\sqrt{3} \times V}$$

$$= \frac{3\times10^6}{\sqrt{3}\times66\times10^3}$$

= 262.43 A

Real Power $P_2 = \sqrt{3} \times VI \times Cos\theta$

= 23999.823 kW

Reactive Power $Q_2 = \sqrt{3} \times VI \times Sin\theta$

=9.365 MVAR

Reactive power required to compensate for 30 MVA transformers.

Required MVAR for capacitor bank Q = $Q_1 - Q_2$

= 8.63 MVAR

To improve the power factor of (20 MVA + 20 MVA+ 30 MVA) total of 70 MVA transformers in substation to 0.95, its power factor is 0.8 at 66 kV, 50 Hz.

For total 70 MVA transformer, V = 66 kV

Before power factor improvement,

cosθ= 0.8, sinθ = 0.6,

Apparent power, $S = \sqrt{3} \times VI$

$$I = \frac{S}{\sqrt{3} \times V}$$

$$= \frac{70\times10^6}{\sqrt{3}\times66\times10^3}$$

= 612.34 A

Real Power $P_1 = \sqrt{3} \times VI \times Cos\theta$

= 55999.89 kW

Reactive Power $Q_1 = \sqrt{3} \times VI \times Sin\theta$

=41.99 MVAR

To improve power factor 0.8 to 0.95,

cosθ = 0.95, sinθ= 0.312,

Apparent power, $S = \sqrt{3} \times VI$

$$I = \frac{S}{\sqrt{3} \times V}$$

$$= \frac{70\times10^6}{\sqrt{3}\times66\times10^3}$$

= 612.34 A

Real Power $P_1 = \sqrt{3} \times VI \times Cos\theta$

= 66499.87 kW

Reactive Power $Q_1 = \sqrt{3} \times VI \times Sin\theta$

=21.85 MVAR

Reactive power required to compensate for 30 MVA transformers.

Required MVAR for capacitor bank Q = $Q_1 - Q_2$

= 20.14 MVAR

= 25 MVAR

(Selected Rating)

3.2 Calculation of capacitor for required capacitor bank

Calculate capacitor, for 8.63 MVAR,

$$C_{\text{per phase}}(F) = \frac{Q_{\text{var}}(total)}{2\pi \times f \times (V_{L-L})^2}$$

$$C_{\text{per phase}}(F) = \frac{8.63\times10^6}{2\pi \times f \times (66\times10^6)^2}$$

= 6.3 μF

For 25 MVAR,

$$C_{\text{per phase}}(F) = \frac{Q_{\text{var}}(total)}{2\pi \times f \times (V_{L-L})^2}$$

$$C_{\text{per phase}}(F) = \frac{25\times10^6}{2\pi \times f \times (66\times10^6)^2}$$

= 14.72 μF

Table (1) Comparison of the required ratings for each capacitor bank

Transformer rating(MVA)	Power factor (cosØ	Current(A)	Active power (MW)	Reactive power (MVAR)	Required MVAR(Q_1-Q_2)	Required Capacitance per phase
30	0.8	262.43	23.99	17.99		
	0.95	262.43	28.499	9.365	8.63	6.3 μF
70	0.8	612.34	55.99	41.99		
	0.95	612.34	66.49	21.85	25	18 μF

In Table-2, the comparison of power factor before and after installation in each hour in substation. This data is collected from Substation (Lashio) which is the average value of annual data.

Table (2) Power factor before and after installation

Time	Power factor before installation	Power factor after installation
01:00 am	0.8	0.96
02:00 am	0.8	0.94
03:00 am	0.8	0.96
04:00 am	0.8	0.95
05:00 am	0.8	0.97
06:00 am	0.8	0.99
07:00 am	0.8	0.99
08:00 am	0.8	0.98
09:00 am	0.8	0.98
10:00 am	0.8	0.98
11:00 am	0.8	0.99
12:00 pm	0.8	0.90
13:00 pm	0.8	0.90
14:00 pm	0.8	0.98
15:00 pm	0.8	0.98
16:00 pm	0.8	0.98
17:00 pm	0.8	0.98
18:00 pm	0.8	0.90
19:00 pm	0.8	0.98
20:00 pm	0.8	0.99
21:00 pm	0.8	0.90
22:00 pm	0.8	0.99
23:00 pm	0.8	0.98
24:00 am	0.8	0.99

3.3. Calculation of Increase Voltage Due to the Effect of Capacitor Bank

Total short circuit

current of transformers,I = 10.93+ 9.77+ 9.77 = 30.47 A

Short circuit power transformers,

$$S_{cc} = I \times P_{base} \times 100\%$$

$$= 30.47\times70\times 100\%$$

$$=213.29 \text{ MVAR}$$

Increase of voltage when 70 MVAR capacitor bank is connected,

$$\Delta U(\%) = \frac{Q_{bank} \times 100}{S_{cc}}$$

$$= \frac{25\times100}{213.29}$$

$$= 11.72\%$$

$$= 12\ \%$$

Increase of voltage to incoming line = 66 kV + (12 % of 66kV) = 78 kV

Table (3) Resistance and reactance of Substation (Lashio)

Feeder and Line length (km)	Cond-uctor size (mm^2)	Resist-ance (Ω/km)	Reacta -nce (mH/km)
Lashio-Thein ni(66 kV) 34miles (54.718km)	397.5	0.1417	0.2808
Mine Yeal (66 kV) 48.18 miles (77.538km)	397.5	0.1417	0.2808
Baho Feeder(33 kV) 6.155 miles (9.906 km)	120	0.253	0.625
Kha Yae (33kV) 13.357miles(21.496km)	120	0.253	0.625
Tha Pyae (33 kV) 1.2 miles(20.719 km)	150	0.206	0.191
Computer (33 kV) 1.2 miles(1.93km)	120	0.253	0.625
Cornerstone (33 kV) 11.5 miles (18.51km)	397.5	0.1417	0.2808

Table (3) shows the feeder number, name and its line length in (miles) km and resistance, reactance of each line. Calculating the voltage drop of each line depends on the resistance and reactance of type of feeder and length.

Calculate Line voltage drop,

$V(\%) = \frac{P \times L}{10 \times V^2}(R + X\, tan\theta)$

Table (4) Voltage drop in Substation (Lashio)

Feeder and Line length (km)	R (Ω)	X(Ω)	Voltage drop (%)
Lashio-Thein ni(66 kV) 34miles (54.718km)	7.75	4.8	3.4
Mine Yeal (66 kV) 48.18 miles (77.538km)	10.98	6.8	4.8
Baho Feeder(33 kV) 6.155 miles (9.906 km)	4.3	1.94	1.256
Kha Yae (33kV) 13.357miles(21.496km)	5.4	4.2	4.0
Tha Pyae (33 kV) 1.2 miles(20.719 km)	4.2	3.95	2.179
Computer (33 kV) 1.2 miles(1.93km)	0.49	0.37	0.22
Cornerstone (33 kV) 11.5 miles (18.51km)	2.62	1.62	1.04

Table (4) expresses the real components of R, X and voltage drop of each line. The line length of each feeder is less than 11 miles. And then the limitation of voltage drop is ± 5% of sending voltage. Voltage drop in Substation (Lashio) is good in condition.

3.4 Result of line current, voltage and power after the installation of capacitor bank

The result of installation of capacitor bank reduces line current and rises voltage.

For line current,

$$\%I_{(Reducing)} = 100 \times \left[1 - \frac{\text{Present pf}}{\text{Improved pf}}\right]$$

$$I_{(Reduced)} = I_{(Present)} - \frac{I_{(Present)} \times I_{(Reduced)}}{100}$$

For voltage,

$$\%V_{(Rise)} = \frac{\text{Capacitor MVAR} \times \text{X'erX}}{\text{X'erMVA}}$$

$$V_{(Improved)} = V_{(Present)} + \frac{V_{(Present)} \times V_{(Rise)}}{100}$$

Table (5) shows the reduced current comparison between before and after installation of capacitor bank in substation. Before condition, the least current at maximum load demand stands fair condition.

Table (5) Result of current condition in Substation (Lashio)

Time	Line current (A) before installation	Line current (A) after installation
01:00 am	189	187.86
02:00 am	187	184.382
03:00 am	167	165.99
04:00 am	157	156.2
05:00 am	161	159.8
06:00 am	195	193.2
07:00 am	310	304.11
08:00 am	357	354.14
09:00 am	345	342.24
10:00 am	307.4	304.94
11:00 am	312.8	309.98
12:00 pm	306.8	300.97
13:00 pm	267.9	262.81
14:00 pm	248.4	243.93
15:00 pm	255	252.71
16:00 pm	268.1	265.96
17:00 pm	287.1	281.93
18:00 pm	328.5	322.26
19:00 pm	327.1	324.16
20:00 pm	353	350.18
21:00 pm	348.3	341.68
22:00 pm	299.6	296.9
23:00 pm	201.6	199.98

24:00 am	173.8	173.6

Table (6) Result of voltage condition in Substation (Lashio)

Time	Voltage(kV) before installation	Voltage (kV) after installation
01:00 am	64.81	66.677
02:00 am	64.32	66.172
03:00 am	64.32	66.286
04:00 am	64.38	66.234
05:00 am	63.91	65.751
06:00 am	62.44	64.238
07:00 am	60.38	62.119
08:00 am	60.09	61.821
09:00 am	60.79	62.541
10:00 am	60.03	61.759
11:00 am	60.51	62.253
12:00 pm	62.66	64.465
13:00 pm	63.16	64.979
14:00 pm	62.64	64.444
15:00 pm	62.82	64.629
16:00 pm	60.03	61.759
17:00 pm	60.21	61.944
18:00 pm	60.82	62.572
19:00 pm	60.18	61.913
20:00 pm	60.84	62.592
21:00 pm	62.89	64.701
22:00 pm	63.55	65.38
23:00 pm	63.52	65.349
24:00 am	64.29	66.142

Table (6) shows the rise voltage comparison between before and after installation of capacitor bank in substation. Before condition, the maximum voltage at maximum load demand stands 61.759 kV. After installation the values of voltages stand good in condition.

The voltage analysis between the two differences is clearly seen in Fig-4.The voltage is important role in calculation capacitor bank. The installation of capacitor bank is not only easily mounted but also good result in distribution.

And also, power distribution is rise in good condition as shown in Fig-5.

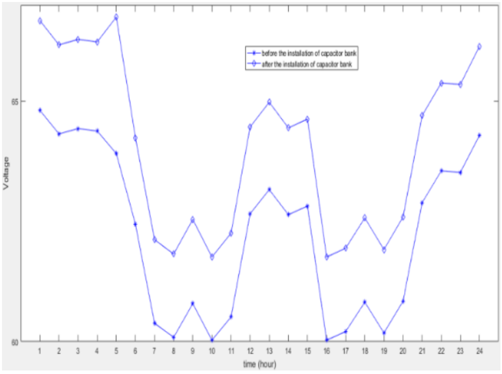

Fig 4. Analysis Model of Voltage rise due to Capacitor Bank

To reduce the inductance effect, capacitor bank should be used or installed and can be controlled. To get good power factor condition, the real and apparent power should adjust. Therefore, the rise of electrical demand increases strongly day by day. The installations of capacitor banks are more and more instead of changing conductor sizes.

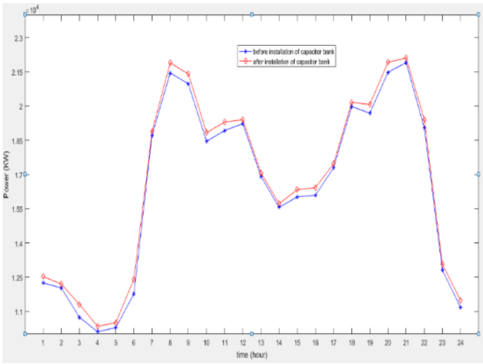

Fig 5. Analysis Model of Comparing Power for Capacitor Bank

4. CONCLUSIONS

Electrical equipment consumes both active and reactive power, and the reactive power requirement is generated in the same way that active power is generated and has to be transmitted to the consumers. Both active and reactive power flows cause energy losses in power systems. Therefore, to minimize the losses in transmission, it is always advisable to compensate reactive power locally at the distribution end. This can be achieved by installing reactive power compensation devices such as Capacitor banks installed at distribution level or transmission level.

This paper is mainly focus on the capacitor bank installed in 66/33kV Substation (Lashio) . In this substation, there are 8MVAR capacitor bank is installed. This substation is supplied to six feeders with three of two 20MVA transformers and one 20MVA transformer. Due to the result in calculation, there must be installed 21MVAR and 8MVAR capacitor bank is not sufficient for improving the power factor for all of the feeders. There are another ways to improve power factor such as Synchronous Condenser and Phase Advancer. This paper is focus on capacitor to improve power factor. There are another way to upgrade this thesis with shunt reactor and static var compensator etc.

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NOVEL ELECTRICAL ENERGY HARVESING METHOD BY USING PIEZOELECTRIC TRANSDUCER

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ABSTRACT: Piezoelectric materials (PZT) can be used as mechanisms to transfer ambient vibrations into electrical energy can be stored and used to power devices. In this paper, the dynamics of piezoelectric materials for the use of power generation devices has been experimentally investigated. The objectives of this work are to estimate the amount of power that piezoelectric (PZT) can generate, and to identify the feasibility of the devices for real - world applications. A great deal of this experiment has repeatedly demonstrated that Piezoelectric energy harvesters hold the promise of providing and alterative power source that can enhance or replace conventional batteries and power wireless devices. Also, ambient vibrations have been the focus as a source due to the amount of energy available. By using energy harvesting devices to extract energy from their environments, the sensors that the power can be self-reliant and maintenance time and cost can be reduced. In addition, piezoelectric materials are of primary concern in the field of advanced lightweight structures, where the smart structure technology is now emerging.

KEYWORDS: ***crystal, dc motor, devices, piezoelectric, power generation***

1. INTRODUCTION

Piezoelectric materials have the ability to be used as mechanisms to transform mechanical energy, usually ambient vibration into electrical energy that can be used to power other devices. The practice of harnessing energy around a system and converting it into usable power is termed power harvesting. By implementing these power harvesting devices, portable systems can be developed that do not depend on the traditional methods for providing power, such as the battery, which has a limited operating life. However since these devices require their own power supply, which is in most cases finite; they must be regularly retrieved and the power supply replaced. This process can become tedious and even costly in many circumstances. The electronic systems described , are ideal applications for the power harvesting devices. However, the energy generated through the piezoelectric effect is not sufficient for directly powering most electronic circuits. Thus, for the power harvesting technology to make its way into the commercial market, methods of accumulating and storing the harvested energy until a sufficient amount can be recovered to power the portable electronics.

The energy produced by the PZT is stored using two different methods. The first method tested will be the capacitor, and the second method is to charge a nickel metal hydride battery. The electrical energy from a piezoelectric device has a high voltage component and a very low current; however, a high current is needed to recharge a battery. Therefore, the ability to use this energy from the piezoelectric to charge a discharged battery must be shown before other studies into this technology can be performed.

2.PIEZOELECTRICS MATERIALS

Piezoelectric materials create a positive and a negative end when work is done to deform their original shape. The International Harvest Tribune claims that “energy harvesting”, more commonly referred to as “crowd farming”, has been in existence for as long as 10 years. An electrical charge flows across the material once pressure is relieved from them. While they usually provide very low currents, they can generate extremely high voltages. Harvesting energy from piezoelectric flooring is said to be impractical in residential applications due to the high cost of implementation and small amount of electricity generated in these settings. Common piezoelectric materials include quartz, and some ceramics. The New York Times also claims that harvesting energy from piezoelectric materials is inefficient, converting only a small amount of kinetic energy into electricity. [1]The piezoelectric effect occurs in several crystaline substances, such as barium titanate and tourmaline. The effect is explained by the displacement of ions in crystals that have a nonsymmetrical unit cell. When the crystal is compressed, the ions in each unit cell are displaced, causing the electric polarization of the unit cell. When an external electric field is applied to the crystal, the ions in each unit cell are displaced by electrostatic forces, resulting in the mechanical deformation of the whole crystal. [2]

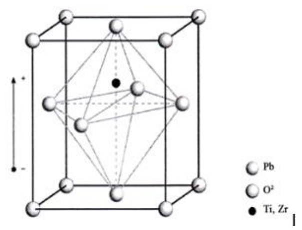

Fig.1 Atomic structure of PZT at MPB.

3. COMPONENTS OF A POWER HARVESTING SYSTEM

Piezoelectric technology are employed in variety of applications. Power harvesting block diagram is shown in fig.2. The operation of the overall block diagram is influenced by the following sub-block. They are;

(1) Speed controller
(2) Power drive circuit
(3) Vibration unit
(4) PZT plates
(5) Rectifier circuit
(6) Storage and Regulator circuit

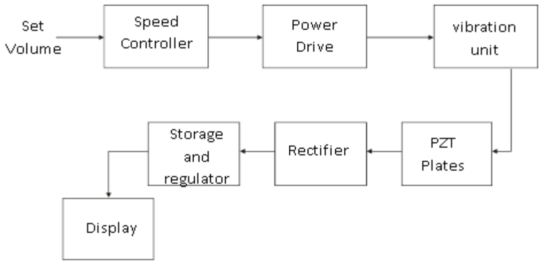

Fig.2 Main components of power harvesting system

3.1. Speed Controller

The heart of the speed controller is 555 timer integrated circuit (IC). The 555 timer circuit is a versatile and widely used device because it can be configured in two different modes as either a monostable multivibrator or a astable multivibrator. In this circuit to generate the PWM square wave is used the astable circuit of 555 timer IC. The 555 timer circuit is shown in Fig.3.

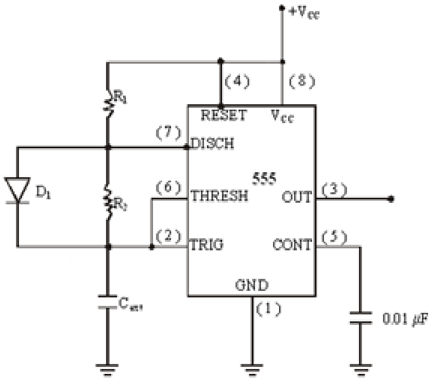

Fig.3.The 555 timer connected as an astable multivibrator

The motor speed depends on duty cycle of the speed controller. The duty cycle formula is,

Duty cycle $D= R_1+R_2/R_1+2R_2$ (1)

Where,R_1 , R_2=the value of external resistance

3.2. Power Drive Circuit

Below the fig.4 is shown the power drive circuit. The input of the power drive circuit is square wave. The ON pulse width of the square wave is effected to the overage power of the DC motor. In this case, the frequency of the square wave is constant. The more ON time of the square wave, the motor is received more power. So, the speed of the motor is increased. Simulation result of the power drive are developing.

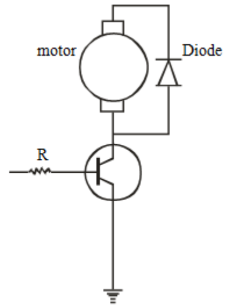

Fig.4.Power drive circuit

3.3 Vibration Unit

There are so many type of vibration system such as engine, motor and other. In this circuit, motor is the main device of vibration unit. The motor have brushes, commutator contacts, and windings.[4]

Fig.5.DC Motor for Vibration Unit

When the motor winding is applied with the specified DC voltage it start to work due to magnetic field. When the rotor windings is applied with more DC voltage, the magnetic field is more appear around the rotor windings. This process is increase of the motor speed and also gain more vibration.

3.4. PZT Plates

The circuit PZT plates are used for energy harvesting system. In this paper,this dimension of the PZT plates are,

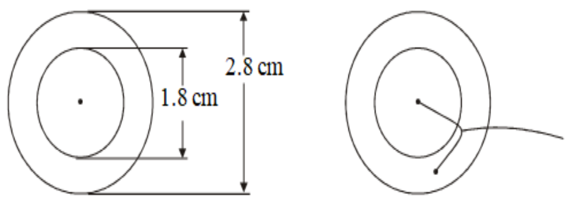

Fig.6. Dimensions and Layout of aluminium disks with PZT

3.5. Storage and Rectangular Circuit

There are two type of PZT power harvesting system. They are on-line and off-line made. In this system, the off-line mode is used. The method of collecting the energy generated by the piezoelectric allows the energy to be used almost instantaneously, whereas other methods storing energy, completed before the power can be used. The method of energy storage used a capacitor to accumulate the energy generated by the piezoelectric material. The other piezoelectric device is capable of charging a nickel metal hydride battery. The battery can also be used instead of the capacitor. A schematic of the complete circuit used for this study is shown in Fig 7. To prevent the capacitor's over charge, zener diode is used. The ability to keep the voltage across its terminals essentially constant is the key feature of the voltage charging preventer.[6]

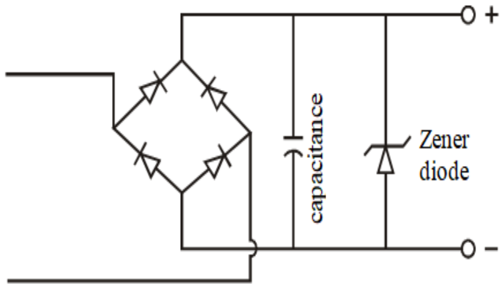

Fig.7. Storage and regulator circuit

3.6. Rectifier Circuit

When the piezo plates is vibrated with run the dc motor, the micro AC voltage is generated. So, it is needed to transfer DC voltage for other system to gain DC voltage from micro AC voltage. Rectifier circuit is done the micro AC voltage to transfer the DC voltage. The diode bridge rectifier circuit is used for rectifier process. The bridge rectifier uses four diodes.

4. SYSTEM DESCRIPTION

Fig.8 is shown the operation of power harvesting circuit. The DC voltage is supplied to operate the control circuit and motor. In this case,the 555 timer used for speed control circuit and 5V motor for the vibration system. To obtain the DC 5V supply, the home AC line is used. So, the home AC 220V is decreased to obtain 5VDC. The step down transformer is used to convert the 220V AC. Then, the supply DC voltage is obtained from 220V AC voltage by using the Bridge rectifier circuit.

The 555 timer is designed to operate as astable mode. To get astable mode, the 555 timer's pins are connected. The 555 timer's pins generates the square wave with the constant frequency. The motor drive circuit use the pulse width modulate (PWM) pulses from 555 timer to control the speed of motor.

The percentage of PWM pulse is varied by changing the resistance of the variable resistor connected to the 555 timer. Also the percentage of PWM pulse is change the switching speed of motor drive circuit. The average power gained form the switching operation of the power drive is applied to the DC motor. When the PZT plates are applied with vibration they generate the micro AC voltage. In this paper, the more the DC the motor runs the more micro voltage the PZT plates generates The micro voltage from PZT plate is AC so the AC voltage is converted to DC voltage. The Bridge diode rectifier circuit is used to convert DC. The converted DC is variable micro level. It is needed to accumulated in a capacitor. The micro DC voltage increase due to capacitance effect. In this circuit, the increased capacitor voltage is displayed on a digital multimeter.

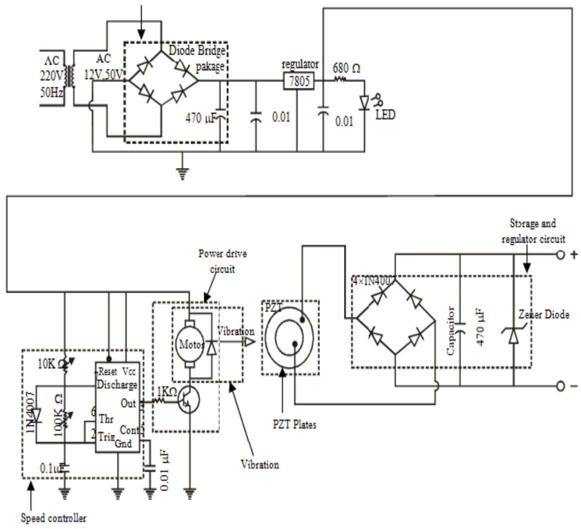

Fig 8. Overall system description

5. RESULTS

The charging voltage accumulated in capacitor is measured with a digital multimeter. After the motor operates with specific for one hour, the measured capacitor voltages are gained. The measured voltages are shown in Table 1. And the motor's current, voltage and power are also displayed. The motor's power is calculated using the following relation,

There are so many types of vibrating sources. They are wind, human body, engine, railway. In this paper, the 5 V DC motor that purchases easily in local market is used as a simple vibrator. The motor vibrating pressure is directly proportional to motor speed. The motor speed are described in terms of motor power. Their relationship is described in the following Table 1.

Table1.Test result of power harvesting system

Voltage (motor)(V)	Current (motor)(A)	Power (motor)(W)	Voltage produced byPZT combine plates(for one hour)
0.6	10mA	6mW	0.02 V
1	40mA	40mW	0.012V
1.8	42.5mA	76.5mW	0.034V
2.4	45mA	108mW	0.063V
3.2	47mA	150.4mW	0.091V
4.8	50mA	240mW	0.12V

In table1, m=$10^{-3.}$

Using data in table 1, the motor power and storage voltage relationship graph is shown in Fig 10.

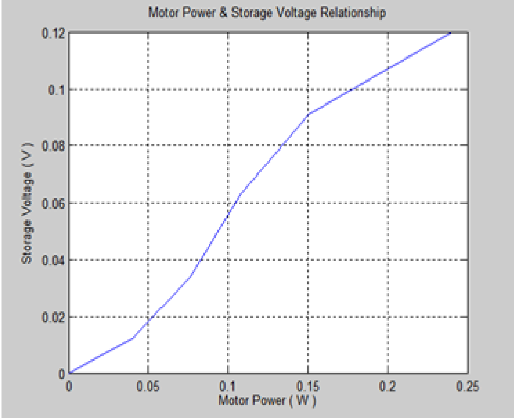

Fig 10. Motor power and storage voltage relationship

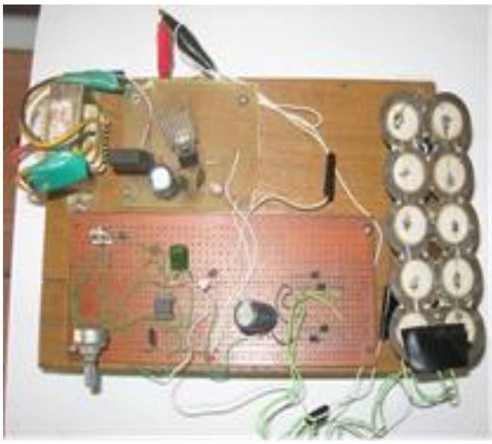

Fig.11Complete diagram of power harvesting system

6.CONCLUSION

Piezoelectric materials are capable of converting mechanical energy into electrical energy. Possible circuit configurations are highly dependent on the output characteristics of the harvester device: vibration frequency, output power, and output voltage. Resonance behaviour of the harvester device restricts possible configuration options. A brief history of piezoelectric materials was given, followed by fundamentals of piezoelectric sensors and actuators. A review of this paper done in the energy harvesting area was performed. The concept was utilized on a multilayer beam with a harvesting layer, tuning layer, and substrate layer. This paper presents a theoretical analysis of piezoelectric power generation that is verified with experimental results.

ACKNOWLEDGMENT

The authors would like to express her gratitude and appreciation to the teachers who taught her everything from childhood till now and all the person who assisted directly or indirectly in her research. Thanks are also extended to her dear parents and friends for their support.

RECOMMENDATIONS

A brief history of piezoelectric materials was given, followed by fundamentals of piezoelectric sensors and actuators. A review of this paper done in the energy harvesting area was performed. The concept was utilized on a multilayer beam with a harvesting layer, tuning layer, and substrate layer. This paper presents a theoretical analysis of piezoelectric power generation that is verified with experimental results. Furthermore study is needed to compute the function of the equipment in power harvesting system.

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Modeling and Analysis on Current Limiting Performances of Current Limiting Reactor and Solid State Fault Current Limiter

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ABSTRACT*:* In modern power system, an increase in the growth of electrical energy demand is inevitable resulting in a corresponding increase in the short circuit current level in the power system. This paper presents Current Limiting Reactor (CLR) in power systems offer the opportunity to reduce short-circuit stresses to the system in the case of faults. But as electrical power systems are normally operated without faults most of the time, CLRs must not have negative effects during these periods of normal operation. Current Limiting Reactors offers a possible solution to the electrical network. For this, Current Limiting Reactor (CLR) became best option to reduce circuit breakers rated capacity and may limit the electromagnetic stress in associated equipment's. With the development in technology, Solid State Current Limiting Reactors (SSFCL) takes in place of CLR since these devices can provide better current limiting performance during fault conditions. In this paper, modeling of Current Limiting Reactor (CLR) and SSFCL under various fault conditions are carried out and their fault current limiting performance are observed. The detail study is implemented on 10 miles substations comprising five numbers of 6.6 kV feeders. The performance of proposed CLR and SSFCL are evaluated in terms of fault currents and short circuit levels. The simulation results reveal the applicability of CLR and SSFCL to reduce maximum fault currents. The modeling and simulation are done by MATLAB/Simulink.

KEYWORDS: *Short Circuit Level, Limiting of Fault Current, Current Limiting Reactor, Solid State Fault Current Limiter, Different Fault Types*

1. INTRODUCTION

The main function of a distribution system is to receive electric power from large power source and to distribute electric power to consumers at various levels with acceptable degrees of reliability .In the power distribution, the short circuit faults cause the most damaging conditions among the numerous faults occurring. In electrical network, the excessive fault current usually lead to thermal or mechanical stress for the affected equipment. At these instants, the normal power flow is interrupted by the protection relay. Then the serious problem occurs due to these high level of short circuit current. The main problems are damages of the electric devices or undesired effect on machine operation. The fault current of all short circuit condition has frequently exceeded the withstand capacity of existing power system equipment`s. As consequence to this matter, security, stability and reliability of power system may be affected. Therefore limiting the fault current of to a safe level can significantly reduce the risk of failure of the power system equipment`s due to high fault current flowing through the system. Science, this technology may limit the fault current to a lower level; it has grabbed a concern of research in recent past [06VKS].

In this paper, the fault current limiting performances by Fault Limiting Reactor (FLR) and Solid State Fault Current limiter (SSFCL) are observed. The detail study is carried out for a distribution system consisting of a transformer and five feeders. The modeling is executed by using Matlab/Simulink software.

2. SHORT CIRCUIT LEVEL OF PROTECTIVE DEVICES

Three main ratings of circuit breakers are making capacity, breaking capacity and short time capacity. The breaking capacity of a circuit breaker is defined as the RMS current that a circuit breaker is capable of breaking at recovery voltage and under specified condition. The normal frequency root mean square voltage that appears at the contacts of the circuit breaker after final arc extinction is the recovery voltage of that circuit breaker. The breaking capacity of a circuit breaker is defined as the RMS value of fault current at the instant of contact separation. It is expressed in units of MVA.

Making capacity is defined as the maximum current during the first value of current wave after the circuit breaker closing. The making capacity is determined by the ability to withstand and close successfully against the effects of electromagnetic forces. These electromagnetic forces are directly proportional to the square of maximum immediate current on closing. It is expressed in terms of kA.

Short time rating is the duration for which the circuit breaker is able to convey fault current while remaining the contacts are closed. This rating is determined by its ability to withstand the temperature rise and the electromagnetic force effects. When the ratio of symmetrical breaking current to the rated normal current does not exceed 40, the circuit breakers have a specified limit of 3 seconds. However, if this ratio is more than 40, then specified limit is 1 second.

The calculation of circuit breaker rating is based on the symmetrical fault or three phase fault. In short circuit fault analysis, three phase fault or symmetrical fault is defined as a fault which causes equal fault current magnitudes in the lines with 120 degree displacement. Faults could happen when a phase establishes a connection with another phase, lighting, insulation deterioration, wind damage, trees falling across lines, etc.

The effects of fault on power system are:

1. Due to overheating and mechanical forces developed by faults, electrical equipment such as bus-bars, generators and transformers may be damaged.
2. As a result of fault, the system voltage may be decreased to a value which is much lower than the voltage regulation limits.
3. A frequency drop may lead to instability.

These ratings are used by the engineering to determine the ability of the circuit breaker to protect it and other devices and to coordinate with other circuit breakers so the system will trip selectively [06VKS].

3. FAULT CURRENT LIMITING TECHNIQUES

Current Limiting Reactor (CLR) is a variable-impedance device connected in series with a circuit to limit the current under fault conditions. The impedances of fault limiting devices should have very low value during regular condition and high value under faulted condition. Based on these characteristic, different types of fault limiting devices have been developed. Some of these devices are based on superconductor technology, others are based on power electronic switches and tuned circuit impedance.

In power system protection research, the technologies of fault current limiting devices are essential and interested by many researchers. Most of these researches are based on superconducting technologies and power electronics. These devices are also known as fault current limiters (FCLs). FCL is a device which can reduce fault current levels during short circuit conditions. They can reduce short circuit levels on the power system equipment and may ultimately lead to lower rating of components being used or to increased capacity on existing systems. Power system protection is very attracted in such devices, providing that fault current limiter offer them fulfillment in economics aspect as well as technical constraints [17Kar].

The fault current limiters can be classified as three main categories as Current Limiting Reactors, Solid State Fault Current Limiter and Superconducting Fault Current Limiter.

3.1. Current Limiting Reactor

Current limiting reactor is a variable-impedance device. This device is connected in series with a circuit and limits the current when fault occurs. The impedances of fault limiting reactors are very low under normal operating condition and become very high impedance during fault conditions [14JPS].

3.2. Solid State Fault Current Limiters

SSFCLs apply power electronic switches. These devices are commonly used to reduce fault currents at distribution levels. Moreover, they are complicated and expensive. Some types of SSFCLs apply resonance or parallel resonance circuits.

In the construction of Solid State Fault Current Limiter (SSFCL), two parallel connected circuit branches are included. One branch is connected to the solid state switch comprising of only two antiparallel connected thyristor. The other branch consists of two thyristor connected in antiparallel but with current limiting impedance (reactor) connected in series with it. The first branch (with thyristor switch only) is used as a main circuit breaker and clears the fault when it occurs. It is normally closed and conducts current during normal operation.

When the current magnitude exceeds a preset value, the switches one will open the circuit immediately and interrupts the current flow. The switches from the next branches (with thyristor and current limiting reactor in series) are normally open and have no current flow during normal condition. Its function is to conduct fault current to enable operation of the conventional protective device on the load side of the SSFCL [03HA].

3.3. Superconducting Fault Current Limiters

Superconducting Fault Current Limiters (SFCL) can be applied as current limiting reactor. During normal operation of power system, its resistance is negligible. When fault occurs, the current magnitude increased. At that time, SFCL quenches and consequently its resistance increases significantly. There are three main types of SFCL as Resistive, inductive and transformer type. This limiter can provide the good current limiting performance. But, it is still too expensive for practical application due to the cost of its complicated cryogenic system [95And].

4. STUDY ON EXISTING DISTRIBUTION SYSTEM

In this study, the performance analysis of fault current limiter for distribution system by using solid state device is carried out in 10-Mile Substation. This distribution system is under the authority of Yangon Electricity Supply Board (YESB). This substation is operated with 66/33/11/6.6 kV voltage levels.

The distribution is carried out with 66/33 kV, 30 MVA No.1 Transformer, 66/11-6.6 kV 30 MVA No.2 Transformer and 33/11-6.6 kV, 10 MVA Transformer. Among them, the system under study consist of one 10MVA, 33/11/6.6 kV transformer and five numbers of feeders at 6.6kV bus in this research. The single line diagram is shown in Figure 1. The line length and maximum load of five feeders are shown in Table 1.

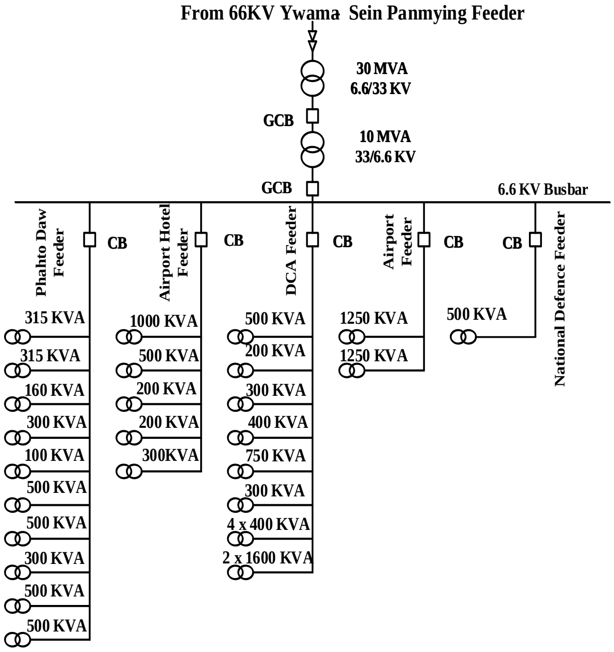

Figure 1.Single Line Diagram Showing 66/33kV Feeders under 10-Mile Substation

Table 1. Line Parameters for Five Feeders

No	Feeder Name	Conductor Size (mm^2)	Line Length (km)	Maximum Load (MW)
1.	Phahto Daw	150	2.5	1.83
2.	Airport Hotel	70	1.3	1.2
3.	DCA	150	1.5	0.914
4.	Airport	95	1.7	1.74
5.	National Defense	70	1	3.017

5. DESIGN CALCULATION OF SHORT CIRCUIT LEVEL AND REACTOR REQUIREMENT

Calculation of the short-circuit current involves the representation of the entire power system impedances from the point of the short-circuit back to and including the source(s) of the short-circuit current. The value of the impedance depends on the short-circuit ratings for the devices or equipment under consideration.

After all the components in the fault loop is represented with their corresponding impedance, the actual short-circuit computation is very simple. The standards propose a number of methods.

1. The Impedance Method
2. The Composition Method
3. The Conventional Method

For the purpose of this study only the first Method is considered [14Md].

5.1. Fundamental Concept of the Per Unit Method

$$\text{Per Unit Value} = \frac{\text{Actual Values}}{\text{Base Values}} \quad (1)$$

Base current in amperes,

$$= \frac{\text{base kVA}}{\sqrt{3}\times[\text{base kV(line–to–line)}]} \quad (2)$$

$$\text{Base impedance in ohm} = \frac{\left(\text{Base KV (line to line)}^2\right)}{\text{Base MVA}} \quad (3)$$

Per Unit Impedance,

$$= \frac{\text{Actual impedance in ohm} \times \text{MVA}}{\left[\text{Base kV (Line to Line)}^2\right]} \quad (4)$$

$$\text{Fault MVA} = \frac{\text{Base MVA}}{\text{Total Impedance}}$$

(5)

$$\text{Fault Current} = \frac{\text{Fault MVA}}{\sqrt{3}\times(\text{Line to Line voltage})} \quad (6)$$

Base MVA = 10MVA (assume)
Base V = 6.6kV
X'_{mer} impedance = 7.1% = 0.071pu
Source Short circuit MVA = 10000 MVA (assume)

$$Z_{source}(pu) = \frac{(\text{Base V})^2}{\text{Short circuit MVA}}$$

$$= \frac{(33k)^2}{10000}$$

$$= 0.1089\text{pu}$$

Z_{source}+ $Z_{X'mer}$ = 0.1089+0.07

= 0.1799 pu

From conductor size and line length, the per unit impedances of each feeder are obtained as follow:

Z_{pu} of Phahto Daw Feeder = 5.67 pu
Z_{pu} of Airport Hotel Feeder = 8.552 pu
Z_{pu} of DCA Feeder = 11.059 pu
Z_{pu} of Airport Feeder = 5.961 pu
Z_{pu} of National Defence Feeder = 3.485 pu

In this study, short circuit level is assumed as 10000 MVA because it is based on data taken from substation. The per unit values of feeder impedance are large because some feeders are long and some are small conductor sizes.

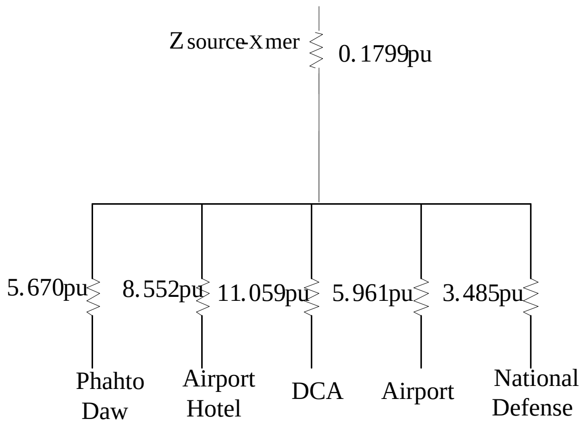

Figure 2. Single Line Diagram of Feeders under 10 Mile Substation with CB only

By impedance combination, total feeder impedance is obtained as 1.1927 pu. By parallel combination with this $Z_{Total\ Feeder}$ to $Z_{Source\ +\ X'mer}$, total system impedance is obtained as follow

$$\text{Total Impedance} = \frac{(Z_{source} + Z_{x'er}) \times Z_{Total\ Feeder}}{(Z_{source} + Z_{x'er}) + Z_{Total\ Feeder}}$$

$$= \frac{(0.1089 + 0.071) \times 1.1927}{(0.1089 + 0.071) + 1.1927}$$

$$= 0.1563 \text{ pu}$$

Then fault MVA and fault current for existing condition are obtained as follow:

$$\text{Fault MVA} = \frac{\text{Base MVA}}{\text{Total Impedance}}$$

$$= \frac{10}{0.1563}$$

$$= 63.979\text{MVA}$$

$$\text{Fault Current} = \frac{\text{Fault MVA}}{\sqrt{3} \times (\text{Line to Line voltage})}$$

$$= 5.5967 \text{ kA}$$

For the calculation of fault limiting reactor, the limited MVA is taken as half of the fault MVA under the existing condition,

Limited MVA $\approx$ 30 MVA

$$Z_{eq\ (new)} = \frac{\text{Base MVA}}{\text{Limited MVA}} = \frac{10}{30} = 0.3333 \text{ pu}$$

$$\frac{1}{Z_{eq(new)}} = \frac{1}{Z_{source} + Z_{x'er} + X_{reactor}} + \frac{1}{Z_{total\ feeder}}$$

$$\frac{1}{0.333} = \frac{1}{0.1799 + X_{reactor}} + \frac{1}{1.192}$$

$$X_{reactor} = 0.282\text{pu}$$

$$L = \frac{x}{2\pi f} = \frac{0.282}{2\pi \times 50} = 0.9 \text{ mH}$$

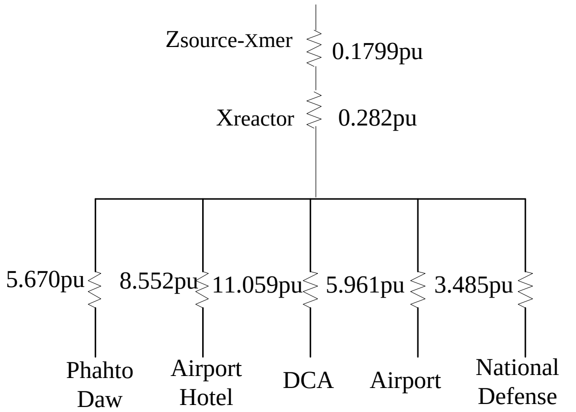

Figure 3. Single Line Diagram of Feeders under 10 Mile Substation with CB and Reactor

Then fault MVA and fault current with current limiting reactor are obtained as follow:

$$\frac{1}{Z_{total}} = \frac{1}{Z_{source} + Z_{x`er} + X_{reactor}} + \frac{1}{Z_{total\ feeder}}$$

$$\frac{1}{Z_{total}} = \frac{1}{0.1799 + 0.282} + \frac{1}{1.192}$$

$$Z_{total} = 0.3333 \text{ pu}$$

$$\text{Fault MVA} = \frac{\text{Base MVA}}{\text{Total impedance}} = \frac{10}{0.3333} = 30 \text{ MVA}$$

$$\text{Fault Current} = \frac{\text{Fault MVA}}{\sqrt{3} \times V_L} = \frac{30 \text{ M}}{\sqrt{3} \times 6.6\text{K}} = 2.624\text{kA}$$

6. MODELING OF SYSTEM

Modeling is carried out for three different system as with CB, i.e. existing system, with fault current limiter. For modeling of system, theorectical explanation is described in Section 3. Figure 3 and Figure 4 shows Simulink model of the system with CB and with fault current limiter respectively.

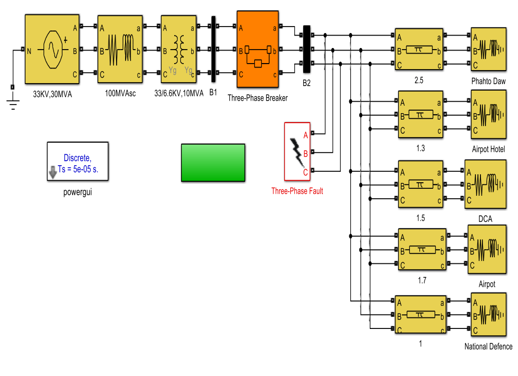

Figure 4. Simulink Model of the System with CB only

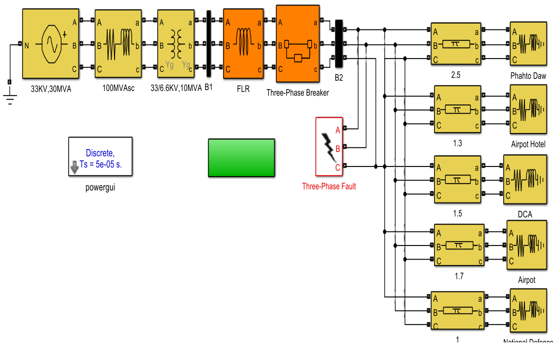

Figure 5. Simulink Model of the System with Fault Current Limiter

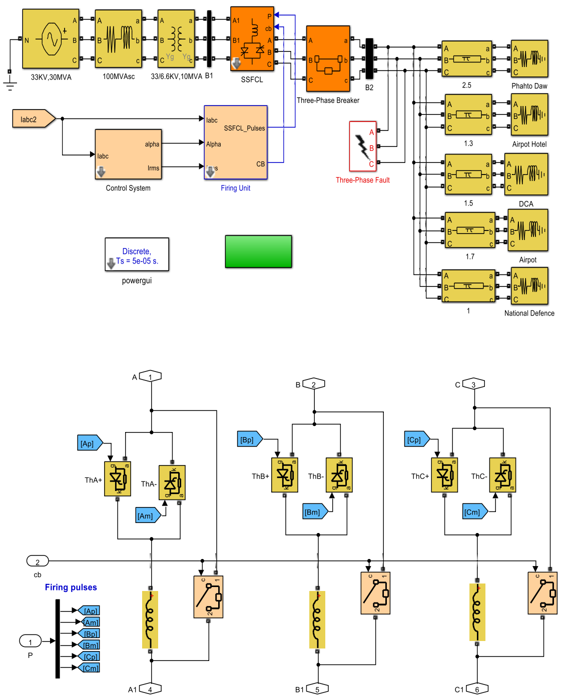

Figure 6. Simulation Model of Thyristor Switches and Reactors

The control of SSFCL consists of control system and firing unit. The control system calculates the RMS values of fault currents and firing angle (alpha) values. From these values and bus 2 currents, firing unit gives SSFCL pulses and circuit breaker signal to SSFCL. The simulation model of SSFCL is constructed by combing the simulation models for control system and firing unit of SSFCL as shown in Figure 5.

Under normal condition i.e. with no fault condition, firing unit gives circuit breaker ON signal and then no current passes reactor and CB works as bypass switch. When the fault occurs, firing unit gives corresponding alpha value which can limit the fault current to the limited value. The effective value of fault limiting reactor depends upon the values of alpha. Under this condition, circuit breaker is open condition.

7. SIMULATION WITH VARIOUS FAULTS

The simulation model for CB only, CB with FLR and CB with SSFCL for distribution network in 10 Mile Substation is executed with MATLAB/Simulink. To prove the performances of fault limiting reactor and solid state fault current limiter under various fault conditions, the analysis is carried out.

To evaluate the performance of fault limiting reactor and SSFCL, the fault is applied at load terminal. The fault starting time is set as 1.0 second and simulation time is set as 2 secomd.There are four types of fault to test as single line to ground fault, line to line fault, double line to ground fault and three phase fault. After applying each fault under each case, fault currents are measured and compared.

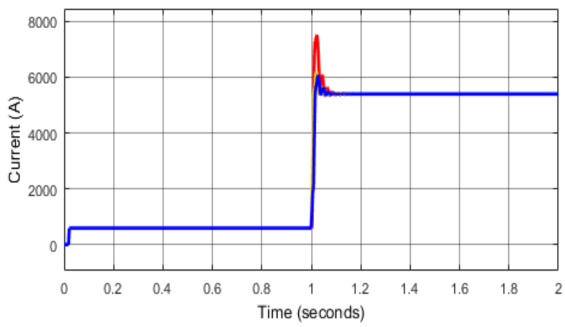

Figure 7.Line current for three phase fault with CB only

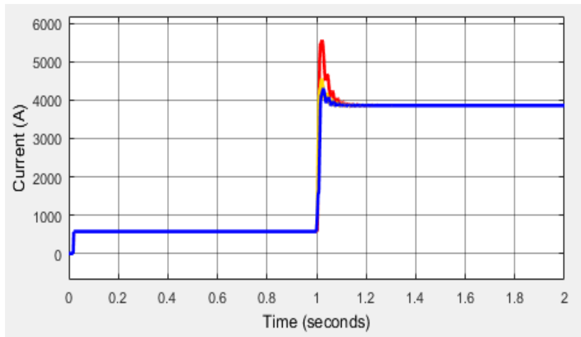

Figure 8.Line current for three phase fault with current limiting reactor

Three phase fault or balance fault is the most severe fault that occurs in the power systems. The RMS current waveform of the distribution system with CB only is shown in Figure 7. The 5.396 kA peak current as the fault phase current. The system with CLR is shown in Figure 8. The system with SSFCL is shown in Figure 9. These figures were subjected to three phase fault. The SSFCL is able to reduce 5.396 kA peak fault current to 1.672 kA.

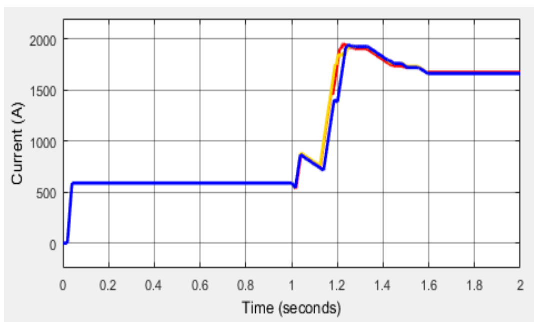

Figure 9.Line current for three phase fault with SSFCL

The simulations are also carried out for other types of faults. The maximum fault currents for different fault types with various current limiters are compared and shown in Figure 10. Fault current of double line to ground is higher than three phase due to simulation results. SSFCL is modeled and its simulation results are recorded. SSFCL is implemented using Matlab/Simulink. SSFCL can limit the fault current lower than that of reactor because thyristor switches are used to control effective reactance.

Table 2. Maximum fault currents for Different fault types with Various Current Limiters

	With CB only	With CB and Reactor	With CB and SSFCL
Pre-Fault	588.7A	588.7A	588.7A
Single Line to Ground(AG)	5387A	3858A	1680A
Line to Line(BC)	4882A	3551A	1673A
Double Line to Ground(BCG)	5456A	3893A	1673A
Three Phase	5396A	3862A	1672A

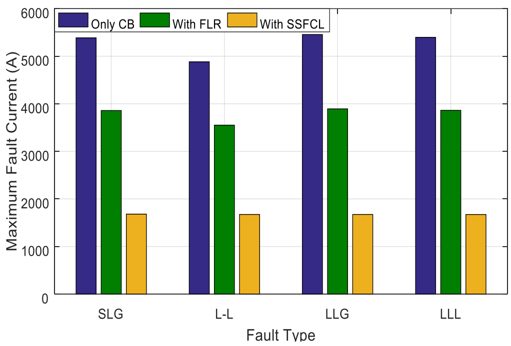

Figure10. Fault Current Comparison for with CB only, With Current Limiting Reactor and With SSFCL

As shown in Figure 10, the maximum fault currents of line to line fault are smaller compared to other types of faults. The use of CLR can reduce maximum fault significantly. But the application of SSFCL provide minimum fault current as shown in Figure 10.

8. DISCUSSION AND CONCLUSION

This paper presents the modeling and analysis of Fault current limiters using MATLAB SIMULINK. The function of SSFCL in power system is to work as circuit breaking element as well as limiting the fault current to a safe level. SSFCL is considered as the solution to the increment of short circuit level in power system. It may limit the fault current, SSFCL offer advantages to the electricity supply industry, technically and economically. The detailed study is carried out at 10 miles substation. The effects of short circuit level by CB and SSFCL are studied in detail with the models. This modelled is tested on 6.6kV Distribution feeder fed from a single source. Simulink results show that the SSFCL detects the fault current and activates the control circuit. Comparison of current has been made between the system without reactor,with reactor and with SSFCL for various types of fault. Simulation results show that SSFCL effectively limits the fault current and hence short circuit level during fault incident. In further study, superconducting fault current limiters should be oberserved and the performances shound be compared.

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Design and Power Factor Improvement of Edible Oil Store

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ABSTRACT: The main aim of this paper is to install the capacitor bank control panel for 60kW load edible oil store. Poor power factor in AC power needs to be minimized. The motor used in edible oil store is inductive load, which causes an inductance effect, and minimize the inductance effect by using capacitors bank to reduce unwanted overcurrent. Capacitor bank improves the power factor, increases voltage level, reduce the current and power losses. In medium and large industries, the power factor is improved by installing a capacitor bank. This paper describes how to install a capacitor bank control panel and its components.

KEYWORDS: *Capacitor Bank, Power Factor, Power Factor Improvement, Reactive Power Compensation Controller*

1. INTRODUCTION

Most plant loads are inductive and require a magnetic field to operate motors transformers and florescent lighting. The magnetic field is necessary, but produces no useful work. The utility must supply the power to produce the useful work. These two types of current are active and reactive. Shunt capacitor banks are mainly installed to provide capacitive reactive compensation/power factor correction. The use of SCBs has increased because they are relatively inexpensive, easy and quick to install. Its installation has other beneficial effects on the system such as: improvement of the voltage at the load, better voltage regulation, reduction of losses and reduction or postponement of investment in transmission. Power factor capacitors are static equipment without any rotating parts and require less maintenance. Therefore, shunt capacitors are widely used in power factor correction applications. [1]

Capacitor banks are used to compensate for reactive energy absorbed by electrical system loads, and sometimes to make at filters to reduce harmonics voltage. The resulting bank is then used to counteract or correct a power factor lag or phase shift in an alternating current (AC) power supply. Capacitor bank role is to improve the quality of the electrical system. A capacitor comes in the form of a case with insulating terminals on top. It comprises individual capacitances which have limited maximum permissible voltages and are series-mounted in groups to obtain the required voltage withstand and parallel-mounted to obtained the desired power rating. [2]

2. THEORETICAL BACKGROUND

2.1 Power Factor

Power Factor is the ratio between the active power (kW) to the total apparent power (kVA) consumed by and AC electrical equipment or complete electrical installation. It is a measure of how efficiently electrical power is converted into useful work output. The ideal power factor is unity, or one. The power factor can also be leading or lagging depending in whether the load is usually capacitive or inductive in nature. 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 current waveform. A poor power factor due to an inductive load can be improved by the addition of power factor correction. Power factor is the relation between current and voltage. So, power factor is also defined as the cosine of the phase difference between current and voltage. It can be mathematically expressed as cosφ, where ø is the phase difference between current and voltage.

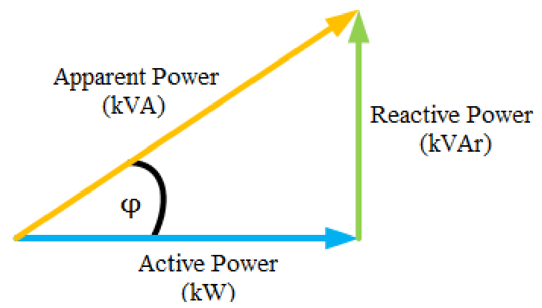

Fig 1. Power Triangle

$$\text{Power Factor}=\frac{\text{Actual Power (kW)}}{\text{Apparent Power (kVA)}} \quad (1)$$

Actual Power (or) Active Power (P,kW) – Active power is the electrical energy that makes a work. It can power electronic devices and do useful things.

Reactive Power (Q, kVAR) – Reactive power is a reactive electric field. It is the electric field that generates the required magnetic field flow for devices that generate inductive loads such as transformers, motors and electric furnace, etc. The higher the reactive power, the lower the power factor.

Apparent Power (S, kVA) – The combination of the active power and reactive power is called the apparent power. Power factor is the relation between current and voltage. So, power factor is also defined as the cosine of the phase difference between current and voltage.

It can be mathematically expressed as cosφ, where φ is the phase difference between current and voltage. Basically, AC power circuits, have resistive loads (like heaters) or inductive loads (like motors) or capacitive loads (like power supplies). Depending upon the loads the current phasor can be in-phase with voltage, lagging the voltage or leading the voltage.

2.2 Power Factor Improvement

Power factor improvement is the process of adjusting the characteristics of electrical loads in order to improve power factor so that it is closer to unity (1). Power factor improvement may be applied either by an electrical power transmission utility to improve the stability and efficiency of the transmission network; or correction may be installed by individual electrical customers to reduce the costs charged to them by their electricity supplier. A high-power factor is generally desirable in a transmission system to reduce transmission losses and improve voltage regulation at the load.

The low power factor mainly due to the fact that most of the power loads are inductive and, therefore, take lagging currents, in order to improve the power factor, some devices taking leading power should be connected in parallel with the load. One of such devices can be a capacitor. The capacitor draws a leading current and partly or completely neutralizes the lagging reactive component of load current. This raises the power factor of the load.

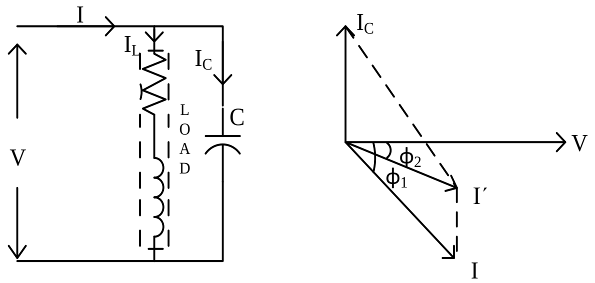

Fig 2. Power Factor Improvement Circuit and Phasor Diagram

Fig 2. shows the power factor improvement by a capacitor. It is considering a single-phase load taking lagging current I at a power factor $\cos\varphi_1$ as shown in Fig 2. The capacitor C is connected in parallel with the load. The capacitor draws current I_C which leads the supply voltage by 90. The resulting line current I´ is phasor sum of I and I_C and its angle of lags is φ_2 as shown in figure.5. It is clear that φ_2 is less than φ_1, so that $\cos\varphi_2$ greater than φ_1. Hence the power factor of the load is increased.

2.3 Cause of Low Power Factor

Low Power factor is caused by inductive loads. Inductive loads require the current to create a magnetic field that produces the desired work. The result is an increase in reactive and apparent power and a decrease in the power factor, or efficiency, of a system. Since the power factor is defined as the ratio of kW to kVA, we see that low power factor results when KW is small in relation to kVA. An inductive load includes transformers, induction motors, and induction generators, high intensity discharge lighting

The higher the reactive power, the lower the power factor. The disadvantage is that more current will flow through the power line, leading to more power loss, and a larger cable size will be used to reduce power loss. It makes the bomb less expensive, but it is more expensive and less effective. The lower the power factor, the greater the current flow. As the amount of current increase, the amount of losses become doubles. According to the graph below, when the power factor drops to 0.9, the current increased by 11 percent and the losses by 12,5 percent. When the power factor drops to 0.85, the current increased by 18% and the losses by 38.4%. When the power factor drops to 0.8, the current increased by 25% and the losses by 56.3%. When the power factor drops to 0.75, the current increased by 33% and the losses by 77.8%. When the power factor drops to 0.7, the current increased by 43% and the losses by 104%.

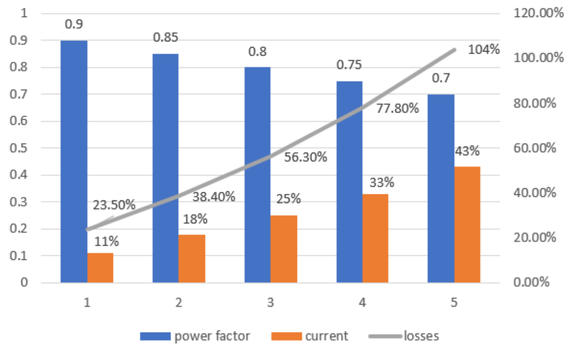

Fig 3. Power Factor, Current and Losses Graph

3. EXPERIMENT

3.1 Experiment apparatus

Main apparatus used in this scheme for three phase capacitor bank includes following components.

i. Reactive power auto compensation controller

Reactive power auto compensation controller that calculates capacitor values and automatically the required capacitors to eliminate unnecessary inductive loads. HJKL2C Reactive Power Factor Auto-compensation Controller is a special auxiliary product for low voltage electronics energy conservation systems; it can be equipped with different modes of capacitor distributing system.

Fig 4. Reactive Power Auto Compensation Controller

It concentrates the latest techniques in the world on one body, with the excellent advantages of light, delicacy, and good appearance as well as its complete range of functions, rather strong anti-interference ability, stable & reliable operation and accurate compensation, so it is the preferred products of electronics energy conservation systems. Things to include in the controller are power factor of load device, the power factor that want to change, capacitor value, current transformer ratio and delay time.

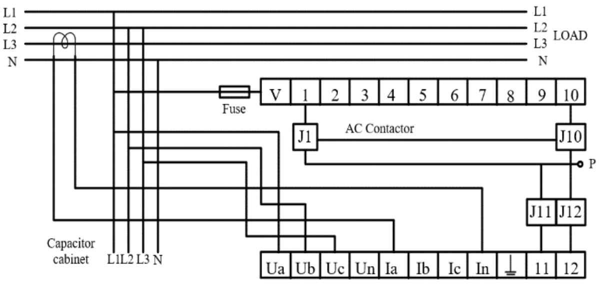

Fig 5. Pin Diagram of Reactive Power Auto Compensation Controller

In the pin diagram of reactive power auto compensation controller, Ua, Ub and Uc are input of voltage signals and Ia and In are input of current signals. V is the common terminal of common output. If the voltage is 380V, point p is connected to line 1 or line 3. If the voltage is 220V, Point P is connected to line neutral.

ii. Miniature circuit breaker

Circuit breaker is a protective device that protect overcurrent is specified when the current is exceed by an undetermined current. Overcurrent is a value that can be caused by either a short circuit or a bit more than the specified value. Circuit breaker deducted the overcurrent by a specified time. Whenever continuous overcurrent flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bimetallic strip releases a mechanical latch. As this mechanical latch is attached with the operating mechanism, it causes to open the miniature circuit breaker contacts, and the MCB turns off thereby stopping the current to flow in the circuit. Nowadays we use miniature circuit breaker (MCB) in

Fig 6. Miniature Circuit Breaker

low voltage electrical network instead of a fuse. The fuse may not sense it but the miniature circuit breaker does it in a more reliable way. MCB is much more sensitive to overcurrent than fuse.

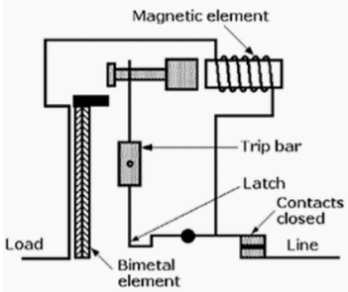

Fig 7. Circuit Diagram of Miniature Circuit Breaker

iii. Capacitor Contactor

The magnetic contactors used for the motor are only about four to four times the speed of the inrush current, which occurs suddenly during the motor cycle. The capacitor bank is more than 20 times the inrush current. When the capacitive load contactor is installed, if the capacitive load amperes are 10 amperes whereas inrush current above 20 times the current, the contactor will pass through 200 amperes.

Fig 8. Capacitor Contactor

The inner plates in the contactor are not durable. This can be destroyed within a short period of time. Therefore, when the capacitive load capacitor is used, the rising amperes must first be reduced using auxiliary contact dumping resistor.

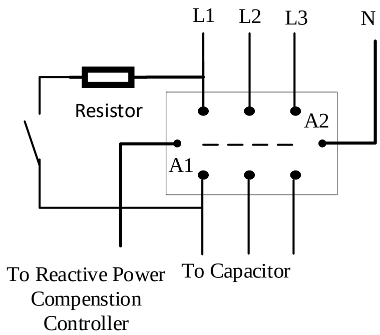

Fig 9. Circuit Diagram of Capacitor Contactor

The capacitor contactor works in the first resistor auxiliary contact before main contactor is activated. At this time the high inrush current was blocked by the resistor. Then the auxiliary contact is separated and the main contact is energized. Thus, the main contact plate can no longer feel the high inrush current and can work comfortably.

iv. Current Transformer

The work of the current transformer changes the required current level. The current level of the transformer will also be proportional to the current measured in the primary measuring line. At the primary current level, every secondary current output uses either 5A or 1A. This is because the current meter used to indicate the measured ampere uses only the 5A or 1A standards

Fig 10. Current Transformer

First, select the ampere of all loads that actually used, and select the current transformer ampere that is larger than the load ampere using. If the 200/5 ratio is used, the output will be 5 amperes when the measurement is 200 amperes. One of the features that needs to be added 40 that is 200 divided by 5 to the controller.

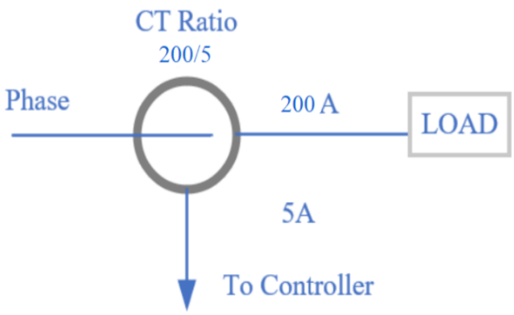

Fig 11. Circuit Diagram of Current Transformer

v. Shunt Capacitor

The shunt capacitors are primarily used to improve the power factor in the network, improve the voltage quality of transmission and distribution network, and compensate the reactive power. Poor electrical power factor causes poor voltage regulation. So, to avoid these difficulties, the electrical power factor of the system to be improved. As a capacitor causes current to lead the voltage and capacitance reactance can be used to cancel the inductive reactance of the system. The capacitor reactance can be used to cancel the inductive reactance of the system. The capacitor reactance is generally applied to the system by using static capacitor in shut or series with system. Instead of using a single unit of capacitor per phase of the system, it is quite effective to use a bank of capacitor units, in the view of maintenance and erection. This group or bank 3of capacitor units is known as **capacitor bank.**

Fig 12. Shunt Capacitor

3.2 Calculation of Required Capacitance

The current load is 60kW and the power factor is 0.85. In this case, the capacitor value required to obtain a power factor of 0.98 can be calculated as follows. The required value by changing the target power factor from the initial power factor can be obtained from the table**.**

Present Load, P = 60kW

Initial power factor $\cos\varphi_1 = 0.85$,

Target power factor $\cos\varphi_2 = 0.98$,

$$Q_C = \tan\varphi 1 - \tan\varphi 2 = K.P \qquad (2)$$

where, Q_C = Capacitive Reactance

K = Factor

P = Active Power

K = 0.417 (from Table 1)

$Q_C = 0.417 \times 60k = 25.020$kVAR

Table 1. The Value of Factor K

	Target Power Factor			
Initial Power Factor	0.95	0.96	0.97	0.98
0.79				0.573
0.80				0.547
0.81				0.521
0.82				0.495
0.83				0.469
0.84				0.443
0.85	0.291	0.328	0.369	0.417

The calculated capacitance value is 25.020 kVAR. So six 5 kVAR capacitors should be installed for this system. The required magnetic contactor (capacitor contactor) and MCB depends on the capacitor amperes. So, capacitor amperes need to be calculated.

$$\text{Capacitor Current, } I = \frac{\text{Capacitor kVAR}}{\sqrt{3} \times \text{Capacitor Rated Voltage}} \qquad (3)$$

$$I = \frac{25.020}{\sqrt{3} \times 400} = 36.1A$$

The required magnetic contactor current value is 1.5 times higher of capacitor current. So, when selecting the magnetic contactor (capacitor contactor) and MCB current must select the value of not less than 1.5 times of capacitor current.

4. ANALYSIS

4.1 Working Principle of Capacitor Bank Panel

Firstly, line1, line2 and line 3 of molded case circuit breaker (main circuit breaker) connects line1, line2 and line 3 of six miniature circuit breakers. The miniature circuit breaker will connect to six capacitor contactors. The capacitor contactors will connect six capacitors**.** The output of the circuit breaker must be connected to the controller U_a, U_b and U_c pin. Current transformer must be connected to the controller I_a and I_b pin. Grounding is required when installing the capacitor bank. The reactive power compensation controller will determine which contactors to operate according to the value of the capacitor. At the discretion of the reactive power compensation controller, the required capacitor will be activated. It is need to enter the required parameters into the reactive power controller.

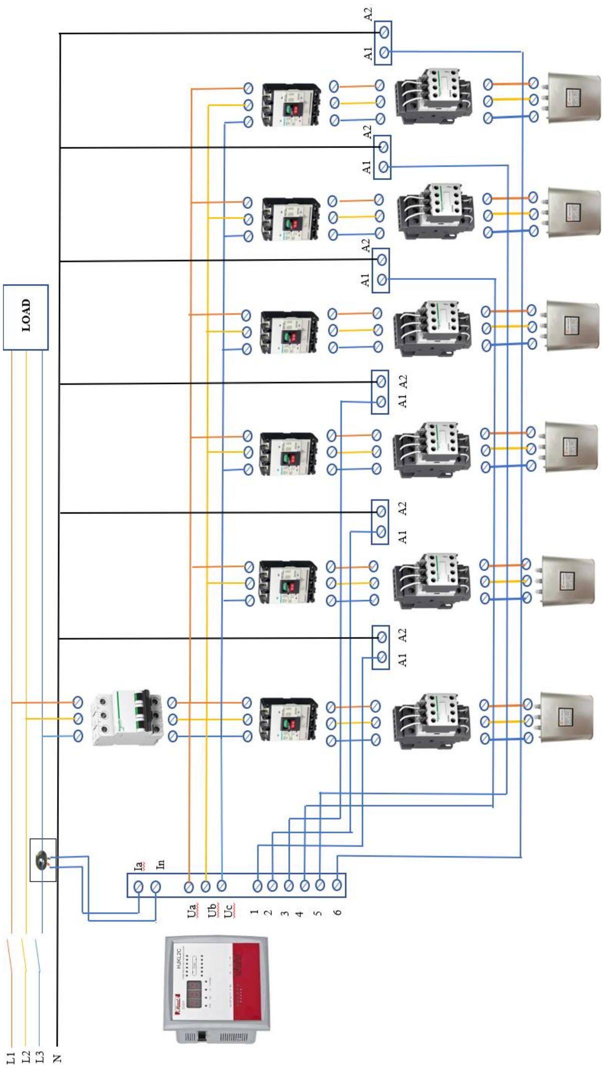

Fig 13. Connection Diagram of Capacitor Bank Control Panel

To enter the parameters into the controller, it is needed to press and hold the menu key on the controller for 3 seconds. The first thing to add is the target power factor. Then add 5-10 times the delay time. Adding a delay time means waiting for a while without adjusting the power immediately. Enter 400 volts of overvoltage value called voltage threshold. Then add the current transformer ratio. Since the current transformer ratio 200/5 is used, and add 40 which is the value of 200 divided by 5 to the reactive power auto compensation controller. And then enter each of the required calculated capacitor values. Six numbers of 5 kVAR capacitor are used in this capacitor bank. The controller can control three to six capacitors.

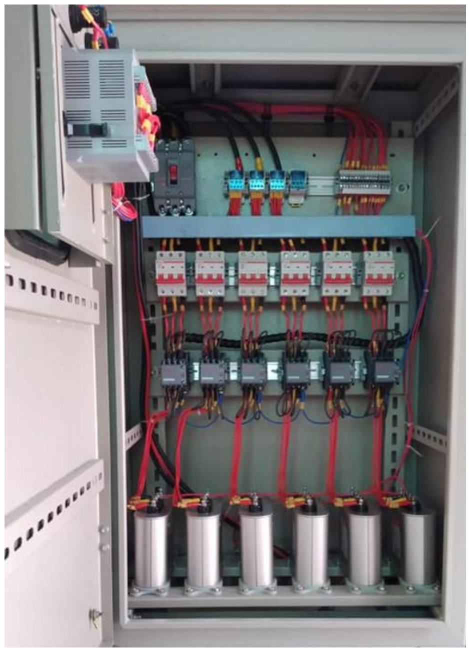

Fig 14. Capacitor Bank Control Panel

The installation of capacitor bank is as shown in Fig.9 and it can be used the rating of 60kW. Reactive power compensation controller shows the conditions of power factor. Power factor value shows the minus sign this means that the power factor is lagging power factor.

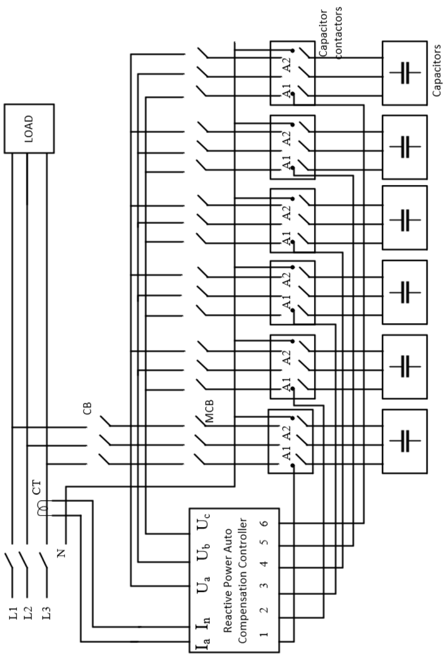

Fig 15. Overall Circuit Diagram of Capacitor bank Panel

Fig 16. Initial Power Factor Value in Reactive Power Compensation Controller

When the main circuit breaker opens in the incoming line, the load draws from the line and power factor will reduce. At that time, the reactive power compensation controller will compensate to reach the target power factor.

Fig 17. Target Power Factor Value in Reactive Power Compensation Controller

4.1 Design Calculation of Capacitor Bank

The following data are obtained from 60kW edible oil store to design capacitor bank control panel for power factor improvement. In this design calculation, the suitable size of capacitors for different power factor are calculated and illustrated by power triangle.

Power, P = 60 kW

Apparent Power, S = 70.588 kVA

Reactive Power, Q = 37.2 kVAR

Initial PF = 0.85

Target PF = 0.98

If power factor is raised to 0.9

Desired kVA Demand = Present Load/ Desired PF

= 60 kW/0.9

= 66.67 kVA

kVAR = $\sqrt{(kVA)^2-(kW)^2}$

$kVAR_1$ at 85% power factor = $\sqrt{(kVA)^2\text{-}(kW)^2}$

= $\sqrt{(70.588)^2\text{-}(60)^2}$

= 37.184 kVAR

If power factor is raised to 90 %

$kVAR_2$ at 90% power factor = $\sqrt{(kVA)^2-(kW)^2}$

= $\sqrt{(66.67)^2\text{-}(60)^2}$

= 29.067 kVAR

Capacitor Rating = $kVAR_1 - kVAR_2$

= 37.184−29.067

= 8.117 kVAR

Percentage of Line Current Reduction = 100[1- (Present PF/improved PF)]

= 100[1-(0.85/0.9)]= 5.56 %

% Loss Reduction= 100$\left[1\text{-(Present PF/improved PF)}^2\right]$

= $100[1-(0.85/0.9)^2]$

= 10 %

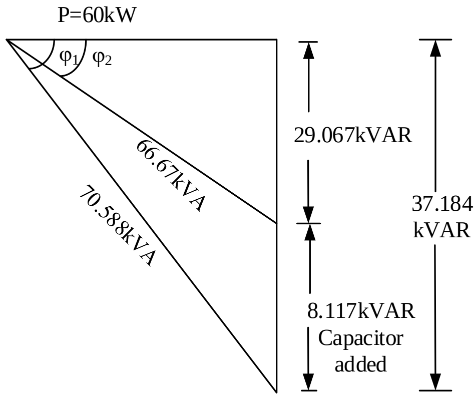

Fig 18. Required Reactive Power before and after Adding Capacitor (at 0.9 Power Factor)

If power factor is raised to 95 %

Desired kVA Demand = Present Load/ Desired PF

= 60kW/0.95

= 63.158 kVA

$kVAR_2$ at 95 % power factor = $\sqrt{(kVA)^2\text{-}(kW)^2}$

= $\sqrt{(63.158)^2\text{-}(60)^2}$

= 19.721 kVAR

Capacitor Rating = kVAR1− kVAR2

= 37.184−19.721

= 17.463 kVAR

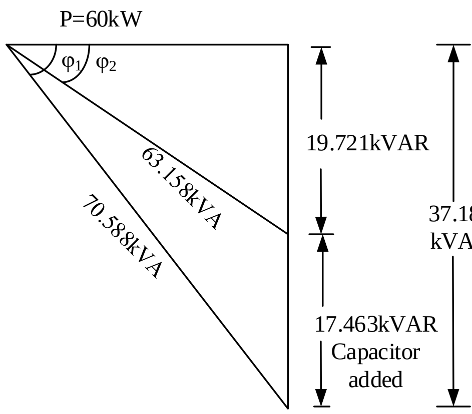

Fig 19. Required Reactive Power before and after Adding Capacitor (at 0.95 Power Factor)

Percentage of Line Current Reduction = 100[1-(Present PF/improved PF)]

= 1[1-(0.85/0.95)]00

= 10.526 %

% Loss Reduction= 100$\left[1\text{-(Present PF/improved PF)}^2\right]$

= $100[1-(0.85/0.95)^2]$

= 19.945 %

If PF is raised to 98 %

Desired kVA Demand = Present Load/Desired PF

= 60kW/0.98

= 61.224 kVA

$kVAR_2$ at 98 % power factor = $\sqrt{(kVA)^2\text{-}(kW)^2}$

= $\sqrt{(61.224)^2\text{-}(60)^2}$

= 12.181 kVAR

Capacitor Rating = $kVAR_1 - kVAR_2$

= 37.184−12.181

= 25.003 kVAR

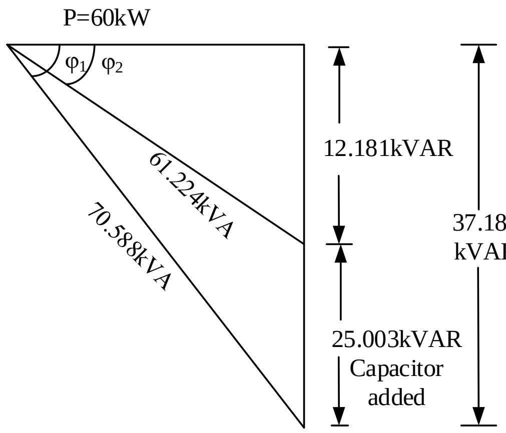

Fig 20. Required Reactive Power before and after Adding Capacitor (at 0.98 Power Factor)

Percentage of Line current Reduction = 100[1-(Present PF/improved PF)]

= 100[1-(0.85/0.98)]

= 13.265 %

% Loss Reduction= $100\left[1\text{-}(\text{Present PF/improved PF})^2\right]$

= $100\left[1\text{-}(0.85/0.98)^2\right]$

= 24.771 %

5. CONCLUSIONS

The useful output depends upon kW output. kW = kVA × cos ϕ, therefore, number of units supplied by it depends upon the power factor. The greater the power factor of the generating station, the higher the kWh delivers to the system. This led to the improved power factor increase the earning capacity of the power station. A delay time of 3 seconds is incorporated into the reactive power compensation controller, which speeds up the power factor and reduces noise**.** In summary, by installing suitably sized power capacitors into the circuit the power factor is improves and the value becomes nearer to 0.9 to 0.98. Thus, capacitor banks used for power factor correction reduce loses and increases the efficiency of the power system and also increases stability. Good power factor stabilization also improves product quality. Capacitor banks are good devices for improving the network.

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