American Journal of Science, Engineering and Technology
2017; 2(4): 120-131
http://www.sciencepublishinggroup.com/j/ajset
doi: 10.11648/j.ajset.20170204.14

Application of Distribution System Automatic Capacitor Banks for Power Factor Improvement (132/66/33 kV, 90 MVA Aung Chan Thar (Monywa) Substation in Myanmar)

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To cite this article:
Soe Win Naing. Application of Distribution System Automatic Capacitor Banks for Power Factor Improvement (132/66/33 kV, 90 MVA Aung Chan Thar (Monywa) Substation in Myanmar). *American Journal of Science, Engineering and Technology*. Vol. 2, No. 4, 2017, pp. 120-131. doi: 10.11648/j.ajset.20170204.14

Received: November 4, 2017; **Accepted**: November 20, 2017; **Published**: December 14, 2017

Abstract: Various inductive loads used in all industries deals with the problem of power factor improvement. Capacitor bank connected in shunt helps in maintaining the power factor closer to unity. They improve the electrical supply quality and increase the efficiency of the system. Also the line losses are also reduced. Shunt capacitor banks are less costly and can be installed anywhere. This paper deals with shunt capacitor bank designing for power factor improvement considering overvoltage for substation installation. The main reason of installing a capacitor bank is to reduce electricity costs. This inappropriate installation without enough study gives rise to a great variety of technical problems. Therefore, the fact that capacitor banks are designed for long-term use should be considered. A capacitor consists of two conducting plates separated by a layer of insulating material called the dielectric. A capacitor may be thought of as a battery that stores and releases current to improve the power factor.

Keywords: Shunt Capacitor Bank, Overvoltage Consideration, Power Factor Improvement, Efficiency, Electricity Costs

1. Introduction

Most ac electric machines draw apparent power in terms of kilovolt-amperes (kVA) which is in excess of the useful power, measured in kilowatts (kW), required by the machine. The ratio of these quantities (kW/kVA) is called the power factor and is dependent on the type of machine in use. A large proportion of the electric machinery used in industry has an inherently low power factor, which means that the supply authorities have to generate much more current than is theoretically required. In addition, the transformers and cables have to carry this high current. When the overall power factor of a generating station's load is low, the system is inefficient and the cost of electricity corresponding high [2]. To overcome this, and at the same time ensure that the generators and cables are not loaded with the wattless current, the supply authorities often impulse penalties for low power factor [3] [4]. Some of the machinery or equipments with low power factor are listed below:

1. induction motors of all types
2. power thyristor installations
3. welding machines
4. electric arc and induction furnaces
5. choke coils and induction furnaces
6. neon signs and fluorescent lighting

The method employed to improve the power factor involves introducing reactive (kVAR) into the system in phase opposition to the wattless or reactive current. Standard practice is to connect power capacitors in the power system at appropriate places to compensate the inductive nature of the load.

2. Power Factor Improvement and Its Benefits

The apparent power (kVA) in a. c. circuit can be resolved into two components, the in-phase component which supplies the useful power (kW), and the wattless component (kVAR) which does no useful work. The phasor sum of the two is the kVA drawn from the supply. The cosine of the phase angle between the kVA and the kW represents the power factor of the load. This is shown by the phasor diagram in Figure 1. To improve the power factor, equipment drawing kVAR of approximately the same magnitude as the load kVAR, but in phase opposition (leading), is connected in parallel with the load.

The resultant kVA is now smaller and the new power factor is increased in Figure 1 and Figure 2, is controlled by the magnitude of the kVAR added. Thus any desired power factor can be obtained by varying the leading kVAR. A typical arrangement of shunt capacitor connected in parallel with a load is shown in Figure 3.

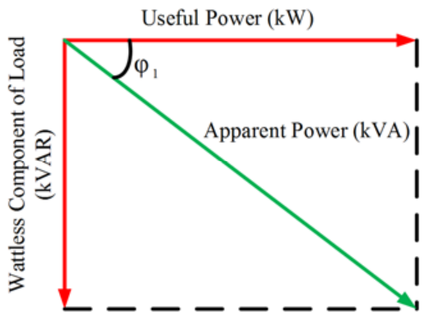


Figure 1. *Phasor Diagram of a Plant Operation at Lagging Power Factor.*

$$\text{Power factor}\ (\cos\varphi) = \frac{\text{Useful Power (kW)}}{\text{Apparent Power (kVA)}} \qquad (1)$$

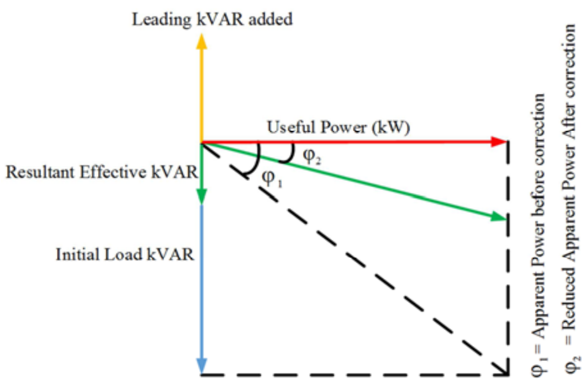


Figure 2. *Power Factor Correction by adding Leading kVAR.*

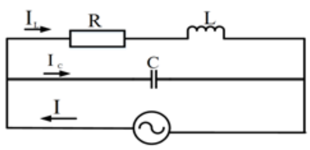


Figure 3. *Capacitor connected in parallel with load.*

The benefits that can be achieved by applying the correct power factor correction are:

1. reduction of power consumption due to improved energy efficiency. Reduced power consumption means less greenhouse gas emissions and fossil fuel depletion by power stations.
2. reduction of electricity bills
3. extra kVA available from the existing supply
4. reduction of I^2R losses in transformers and distribution equipment
5. reduction of voltage drops in long cables.
6. reduced electrical burden on cables and electrical components.

3. Methods of Capacitor Banks Installation

We need to choose the optimum type, size and number of capacitors for the substation. There are four methods of capacitor installations:

3.1. Method 1: Capacitor at Load

Installed a single capacitor at each sizeable motor and energize it whenever the motor is in operation. This method usually offer the greatest advantage of all and the capacitors could be connected either in location (A) as (B) in Figure 4 below.

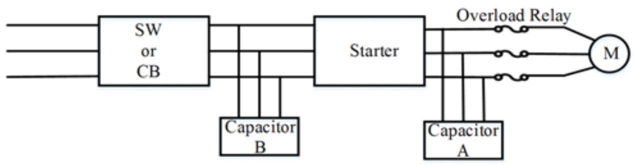


Figure 4. *Location of the capacitor connections.*

1. Location A - normally used for most motor applications.
2. Location B - used when motors are jogged, plugged, revered: for multi-speed motors, as reduced voltage start motors.

3.2. Method 2: Fixed Capacitor Bank

Installed a fixed quality of kVAR electrically connected at one or more locations in the plant's electrical distribution systems, and energized at all times. This method is often used when the facility has few motors of any sizeable horsepower to which capacitors can economically be added. When the system is lightly loaded, and the amount of kVAR energized is too large, the voltage can be so great that motors, lamps, and controls can burn out. It is a important fact to remember that kVAR equal to 20% of the transformer kVA is the maximum size of a fixed kVAR bank. Valued greater than this can result in a large resonant current, which is potentially harmful to the system.

3.3. Method 3: Automatic Capacitor Bank

It is installed at the motor control centre at the service entrance. This bank will closely maintain a preselected value of power factor. This is accomplished by taming a controller switch steps of kVAR on, as off, as needed. Automatic switching ensures exact amount of power factor correction, eliminates over capacitance and resulting over voltages.

3.4. Method 4: Combination of Methods

Since no two electrical distribution systems are identical, each must be carefully analyzed to arrive at the most cost-effective solution, using are or more of the method.

Table 1. *Summary of Advantages and Disadvantages.*

No	Method	Advantages	Disadvantages
1	Individual Capacitors	Most technically efficient, most flexible	Higher installation and Maintenance cost
2	Fixed Capacitor Bank	Most economical, fewer installations	Less flexible, requires switches and/or circuit breakers
3	Automatic Capacitor Bank	Best for variable loads, prevents over voltages, low installation cost	Higher equipment cost
4	Combination	Most practical for larger numbers of motors	Least flexible

4. Automatic Capacitor Bank Installation

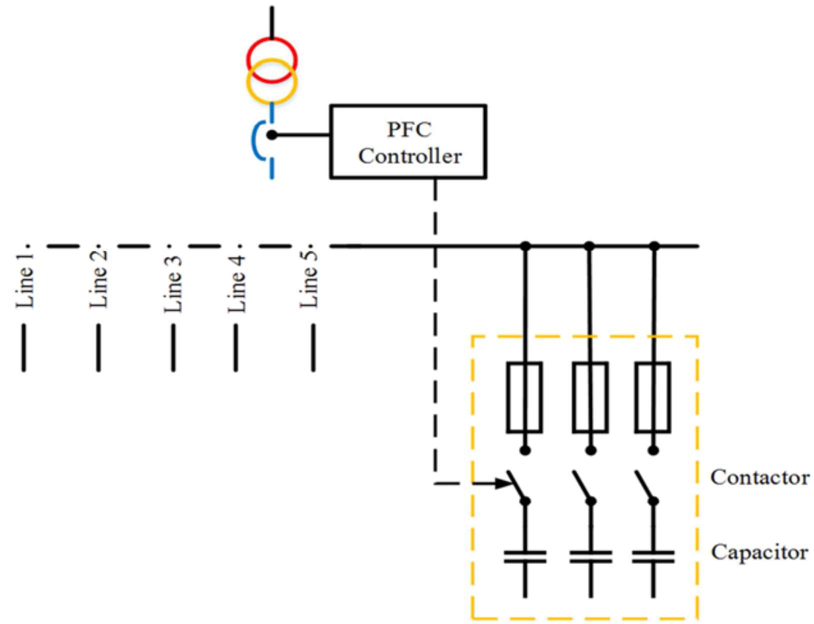


Figure 5. *Standard Power Factor Correction.*

It is installed at the control center at the service entrance. This bank will closely maintain a pre-selected value of power factor. This is accomplished by having a controller switch steps of kVAR on, or off, as needed. This type of bank eliminates the concern of having too much kVAR energized at light load periods. Automatic switching also ensures exact amount of power factor correction. Standard power factor correction using automatic capacitor bank is shown in Figure 5. This type would seem to have much appeal, but it also has a real disadvantage. Since it is usually located near the incoming service, like the fixed bank this automatic bank does nothing to reduce the conductor losses (and thus billed kilowatt-hours).

5. Load Data and Field Data

5.1. Analysis of Load Data with Power Factor Changes

Aung Chan Thar (Monywa) substation is connected 132 kV to the 66 kV distribution network which applied 45 MVA transformer from 132 kV step down to 66 kV and 132 kV to the 33 kV distribution network which applied 45 MVA transformer from 132 kV step down to 33 kV. These lines are radial lines system.

Table 2. *66 kV Main 45 MVA No (1) Log Sheet Data.*

Time	kV	A	MVA	MW	PF
1:00	67	50	5.8	5.2	0.8966
2:00	67	47	5.4	4.8	0.8889
3:00	66	46	5.3	4.7	0.8868
4:00	66	48	5.5	5.0	0.9091
5:00	64	62	6.9	6.2	0.8986
6:00	65.5	73	8.5	7.8	0.9176
7:00	65.5	75	8.5	7.7	0.9059
8:00	65.5	74	8.5	7.7	0.9059
9:00	63	78	8.5	7.6	0.8941
10:00	63	78	8.5	7.6	0.8941
11:00	63	78	8.5	7.6	0.8941
12:00	65	79	8.9	7.5	0.8427
13:00	64	85	9.4	8.5	0.9043
14:00	63	87	9.5	8.7	0.9158
15:00	63	87	9.5	8.7	0.9158
16:00	63	86	9.4	8.6	0.9149
17:00	63	90	9.8	9.0	0.9184
18:00	64	102	11.3	10.0	0.8850
19:00	64.4	87	9.7	8.9	0.9175
20:00	69.7	93.3	11.3	10.0	0.8850
21:00	65	96	10.8	9.6	0.8889
22:00	66	86	9.8	8.6	0.8776
23:00	67	80	9.3	8.0	0.8602
24:00	67	75	8.7	7.5	0.8621

If kW or Power Factor is not known, the three basic formulas required to calculate kVAR.

$$PF = \frac{kW}{kVA} \quad (2)$$

$$kVA = \frac{1.73 \times I \times E}{1000} \quad (3)$$

$$kW = \frac{1.73 \times I \times E \times PF}{1000} \text{ (or) } kW = \frac{HP \times 0.746}{\eta} \quad (4)$$

Where, I = Full load current
E = Voltage
PF = Power factor
HP = Rated horse power
η = Rated efficiency

Table 2 is to illustrate some variables obtained from power factor changes at 66 kV bus bar and Table 3 is to illustrate some variables obtained from power factor changes at 33 kV bus bar. Capacitor rating added to improve power factor can be determined. Capacitor rating is the difference between MVAR ratings of original power factor and desired power factor.

Table 3. *33 kV Main 45 MVA No (2) Log Sheet Data.*

Time	kV	A	MVA	MW	PF
1:00	33.0	340	19.4	18	0.9278
2:00	32.9	325	18.5	17.1	0.9243
3:00	32.9	323	18.4	16	0.8696
4:00	32.8	343	19.5	18	0.9231
5:00	31.5	466	25.4	23	0.9055
6:00	31.9	605	33.4	29	0.8683
7:00	31.2	512	27.6	25	0.9058
8:00	30.9	571	30.5	28	0.9180
9:00	30.7	539.3	28.6	26	0.9091
10:00	30.9	539.3	28.8	26	0.9028
11:00	30.9	501.4	26.8	24	0.8955
12:00	30.9	501.4	26.8	24	0.8955
13:00	31.3	483.0	26.2	23	0.8778
14:00	31.0	510.5	27.4	25	0.9124
15:00	31.2	498.6	26.9	24	0.8923
16:00	30.7	552.2	29.3	26	0.8873
17:00	30.8	553.6	29.5	27	0.9153
18:00	31.4	516	28.0	25	0.8929
19:00	31.4	535	29.1	26	0.8935
20:00	31.4	598	32.5	28	0.8615
21:00	31.8	566	31.1	28	0.9003
22:00	32.4	540	30.3	26	0.8581
23:00	32.9	426	24.3	21.3	0.8765
24:00	32.9	432	24.6	21.6	0.8781

5.2. Field Data of Aung Chan Thar (Monywa) Substation

The following data are obtained from Aung Chan Thar (Monywa) Substation to design capacitor bank for power factor correction.

5.2.1. 45 MVA Main Power Transformer No (1) at 66 kV Bus Bar

Table 4. *66 kV Main 45 MVA No (1).*

Parameters	Value	Units
Transformer rating	45	MVA
Transformer reactance	15	%
Voltage	66	kV
Present maximum load	10	MW
Present maximum MVA	11.3	MVA
Power factor (maximum load)	88.5	%
Desired power factor	95	%
Present minimum load	4.7	MW
Present minimum MVA	5.3	MVA
Power factor (minimum load)	88.68	%

5.2.2. 45 MVA Main Power Transformer No (2) at 33 kV Bus Bar

Table 5. *33 kV Main 45 MVA No (2).*

Parameters	Value	Units
Transformer rating	45	MVA
Transformer reactance	15	%
Voltage	33	kV
Present maximum load	29	MW
Present maximum MVA	33.4	MVA
Power factor (maximum load)	86.83	%
Desired power factor	95	%
Present minimum load	16	MW
Present minimum MVA	18.4	MVA
Power factor (minimum load)	86.96	%

6. Design Calculation of Capacitor Banks Size

6.1. For 45 MVA Main No (1) at 66 kV Bus Bar

Present load (maximum) = 10 MW

Present power factor (maximum) = 88.5%

$$\text{Present MVA Demand} = \frac{\text{Present load}}{\text{Present power factor}} \quad (5)$$

$$= \frac{10}{0.885} = 11.30\,\text{MVA}$$

If the power factor is raised to 95%,

$$\text{Desired MVA Demand} = \frac{\text{Present load}}{\text{Desired power factor}} \quad (6)$$

$$= \frac{10}{0.95} = 10.53\,\text{MVA}$$

The size of the capacitor required to accomplish this is determined from the MVAR at the two values of power factor as follows:

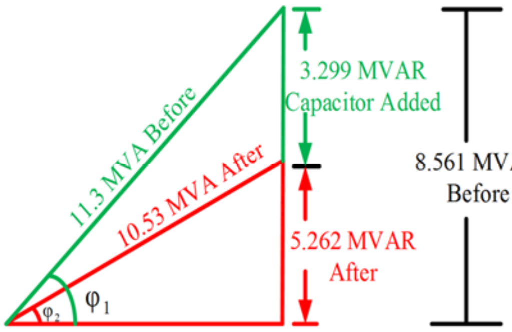
$$\text{MVAR} = \sqrt{\text{MVA}^2 - \text{MW}^2} \tag{7}$$

$$\text{MVAR}_1 \text{ at } 88.5\,\%\text{ PF} = \sqrt{11.3^2 - 10^2} = 5.262 \text{ MVAR}$$

$$\text{MVAR}_2 \text{ at } 95\%\text{ PF} = \sqrt{10.53^2 - 10^2} = 3.299 \text{ MVAR}$$

$$\text{Capacitor Rating} = \text{MVAR}_1 - \text{MVAR}_2 \tag{8}$$

$$= 5.262 - 3.299 = 1.963 \text{ MVAR}$$



(At 95% Power Factor)

Figure 6. *Required apparent power before and after adding capacitors.*

This power triangle shows apparent power demand on a system before and after adding capacitors. In Figure 6, by installing power capacitors and increasing power factor to 95%, apparent power is reduced from 11.3 MVA to 10.53 MVA (reduction of 6.81%). Theoretically, capacitors could provide 100% of needed reactive power. In practical usage, however, power factor correction to approximately 95% provides maximum benefit.

From Table A (Calculation table for capacitor selection) in Appendix,

$$\text{Multiplying factor} = \frac{\text{Value from the table}}{100} \tag{9}$$

$$= \frac{21}{100} = 0.21$$

$$\text{Capacitor Rating} = \text{ Mutiplying Factor} \times \text{MW Demand} \tag{10}$$

$$= 0.21 \times 10 = 2.1 \approx 3 \text{ MVAR}$$

95% is a good economic power factor for industrial purposes. In this paper, this power factor is corrected from 88.5%. Therefore the installation of 3 MVAR capacitor bank is determined for achieving power factor of 95% while providing the same productive power of 10 MW.

6.2. For 45 MVA Main No (2) at 33 kV Bus Bar

$$\text{Present load (maximum)} = 29 \text{ MW}$$

$$\text{Present power factor (maximum)} = 86.83\%$$

$$\text{Present MVA Demand} = \frac{\text{Present load}}{\text{Present PF}} = \frac{29}{0.8683} = 33.4 \text{ MVA}$$

If the power factor is raised to 95%,

$$\text{Desired MVA Demand} = \frac{\text{Present load}}{\text{Desired PF}} = \frac{29}{0.95} = 30.53 \text{ MVA}$$

The size of the capacitor required to accomplish this is determined from the MVAR at the two values of power factor as follows:

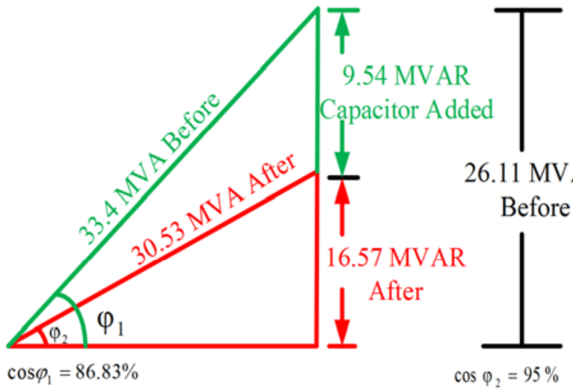
$$\text{MVAR} = \sqrt{\text{MVA}^2 - \text{MW}^2}$$

$$\text{MVAR}_1 \text{ at } 86.83\%\text{ PF} = \sqrt{33.4^2 - 29^2} = 16.57 \text{ MVAR}$$

$$\text{MVAR}_2 \text{ at } 95\%\text{ PF} = \sqrt{30.53^2 - 29^2} = 9.54 \text{ MVAR}$$

$$\text{Capacitor Rating} = \text{MVAR}_1 - \text{MVAR}_2$$

$$= 16.57 - 9.54 = 7.03 \text{ MVAR}$$



(At 95% Power Factor)

Figure 7. *Required apparent power before and after adding capacitors.*

In Figure 7, by installing power capacitors and increasing power factor to 95%, apparent power is reduced from 33.4 MVA to 30.53 MVA (reduction of 8.59%).

$$\text{Multiplying factor} = \frac{26}{100} = 0.26$$

$$\text{Capacitor Rating} = \text{ Mutiplying Factor} \times \text{MW Demand}$$

$$= 0.26 \times 29 = 7.54 \approx 8 \text{ MVAR}$$

95% is a good economic power factor for industrial purposes. In this paper, this power factor is corrected from 86.83%. Therefore the installation of 8 MVAR capacitor bank is determined for achieving power factor of 95% while providing the same productive power of 29 MW.

7. Check Calculation for After Installation of Capacitor Banks

7.1. For 45 MVA Main No (1) at 66 kV Bus Bar

1) For Minimum Load Condition

$$MVAR_1 = \sqrt{MVA^2 - MW^2} = \sqrt{5.3^2 - 4.7^2} = 2.45\ MVAR \quad MVAR_2 = MVAR_1 - Capacitor\ \ Rating = 2.45 - 3 = -0.55\ MVAR$$

$$MVA_2 = \sqrt{MVAR^2 + MW^2} = \sqrt{(-0.55)^2 + 4.7^2} = 4.7321\ MVAR$$

$$Power\ Factor = \frac{4.7}{4.7321} = 0.99$$

2) For Maximum Load Condition

$$MVAR_1 = \sqrt{MVA^2 - MW^2} = \sqrt{11.3^2 - 10^2} = 5.262\ MVAR$$

$$MVAR_2 = MVAR_1 - Capacitor\ \ Rating = 5.262 - 3 = 2.262\ MVAR$$

$$MVA_2 = \sqrt{MVAR^2 + MW^2} = \sqrt{2.262^2 + 10^2} = 10.253 MVAR$$

$$Power\ Factor = \frac{10}{10.253} = 0.98$$

7.2. For 45 MVA Main No (2) at 33 kV Bus Bar

1) For Minimum Load Condition

$$MVAR_1 = \sqrt{MVA^2 - MW^2} = \sqrt{18.4^2 - 16^2} = 9.09\ MVAR \quad MVAR_2 = MVAR_1 - Capacitor\ Rating = 9.09 - 8 = 1.09\ MVAR$$

$$MVA_2 = \sqrt{MVAR^2 + MW^2} = \sqrt{1.09^2 + 16^2} = 16.04\ MVAR \quad Power\ Factor = \frac{16}{16.04} = 0.99$$

2) For Maximum Load Condition

$$MVAR_1 = \sqrt{MVA^2 - MW^2} = \sqrt{33.4^2 - 29^2} = 16.57\ MVAR \quad MVAR_2 = MVAR_1 - Capacitor\ Rating = 16.57 - 8 = 8.57\ MVAR$$

$$MVA_2 = \sqrt{MVAR^2 + MW^2} = \sqrt{8.57^2 + 29^2} = 30.24\ MVAR \quad Power\ Factor = \frac{29}{30.24} = 0.959$$

8. Voltage Rise

8.1. For 45 MVA Main No (1) at 66 kV Bus Bar

The approximate voltage change due to capacitors at a transformer secondary bus is determined by using the following equation:

$$\%\ Voltage\ Rise = \frac{Capacitor\ MVAR \times \%\ Transformer\ Reactance}{Transformer\ MVA} \quad (11)$$

Capacitor Rating = 3 MVAR

Transformer Reactance = 15%

Transformer MVA = 45 MVA

$$\%\ Voltage\ Rise = \frac{3 \times 15}{45} = 1\%$$

8.2. For 45 MVA Main No (2) at 33 kV Bus Bar

Capacitor Rating = 8 MVAR

Transformer Reactance = 15%

Transformer MVA = 45 MVA

$$\%\ Voltage\ Rise = \frac{8 \times 15}{45} = 2.67\%$$

The voltage regulation of a system from no-load to full-load is practically unaffected by the amount of capacitors, unless the capacitors are switch. However, the addition of capacitors can raise the voltage level. The voltage rise due to capacitors in most industrial plants with modern power distribution system and a single transformation is rarely more than a few percent.

9. Line Current and Lower Losses

9.1. Line current Reduction

9.1.1. For 45 MVA Main No (1) at 66 kV Bus Bar

The percent line current reduction may be approximated from this equation.

$$\%\ Line\ Current\ Reduction = 100 \times \left[1 - \frac{Present\ PF}{Improved\ \ PF}\right] \quad (12)$$

$$= 100 \times \left[1 - \frac{0.885}{0.95}\right] = 6.84\%$$

9.1.2. For 45 MVA Main No (2) at 33 kV Bus Bar

$$\%\ \text{Line current reduction} = 100\times\left[1-\frac{0.8683}{0.95}\right] = 8.6\,\%$$

9.2. Lower Losses

An estimate of reduction of power losses can be made using following equations.

$$\%\ \text{Loss Reduction} = 100\times\left[1-\left(\frac{\text{Present Power Factor}}{\text{Improved Power Factor}}\right)^2\right] \quad (13)$$

9.2.1. For 45 MVA Main No (1) at 66 kV Bus Bar

$$\%\ \text{Loss Reduction} = 100\times\left[1-\left(\frac{0.885}{0.95}\right)^2\right] = 13.22\%$$

9.2.2. For 45 MVA Main No (2) at 33 kV Bus Bar

$$\%\ \text{Loss Reduction} = 100\times\left[1-\left(\frac{0.8683}{0.95}\right)^2\right] = 16.46\%$$

There is 13.22% reduction in power losses for No (1) and 16.46% reduction in power losses for No (2).

10. Result Data

After installing 3 MVAR and 8 MVAR capacitor banks for the entire substation power factor improvement, the following results are obtained. These results are benefits of this installation.

Table 6. *Result Data after Power factor Improvement.*

Load Data	Value	
	45 MVA Main No (1) at 66 kV Bus Bar	**45 MVA Main No (2) at 33 kV Bus Bar**
MW Demand	10 MW	29 MW
Power Factor	95%	95%
Voltage Rise	1%	2.67%
Line Current Reduction	6.84%	8.6%
Power Loss Reduction	13.22%	16.46%

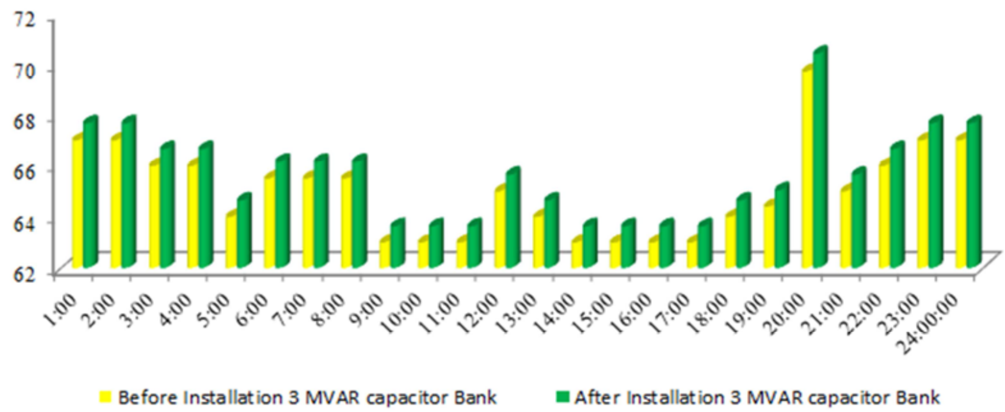


Figure 8. *Voltage chart before and after installation 3 MVAR capacitor bank at 66 kV bus.*

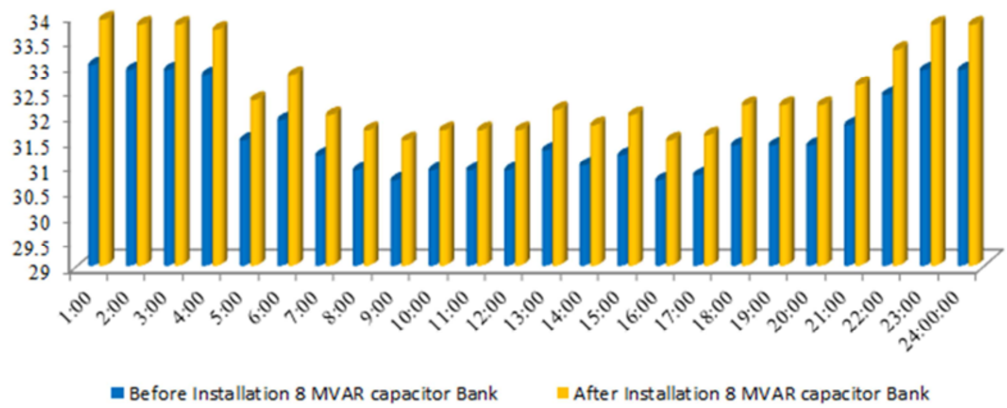


Figure 9. *Voltage chart before and after installation 8 MVAR capacitor bank at 33 kV bus bar.*

After installation 3 MVAR capacitor bank at 66 kV bus bar, the lowest power factor 0.8602% becomes 0.9302% and the highest power factor 0.9158% becomes 0.9886%. It is shown in Figure 10.

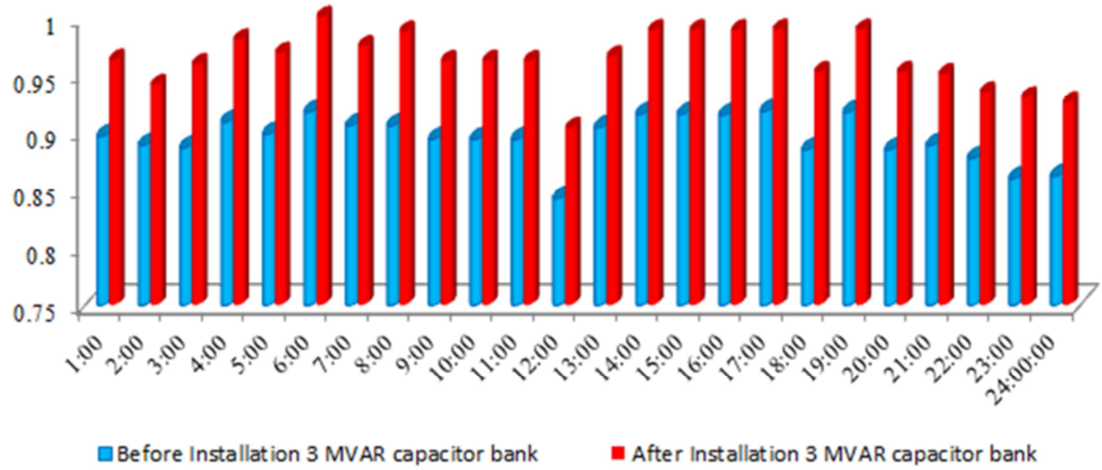


Figure 10. *Power factor chart before and after installation 3 MVAR capacitor bank at 66 kV bus bar.*

After installation 8 MVAR capacitor bank at 33 kV bus bar, the lowest power factor 0.8581% becomes 0.9386% and the highest power factor 0.9278% becomes unity power factor. It is shown in Figure 11.

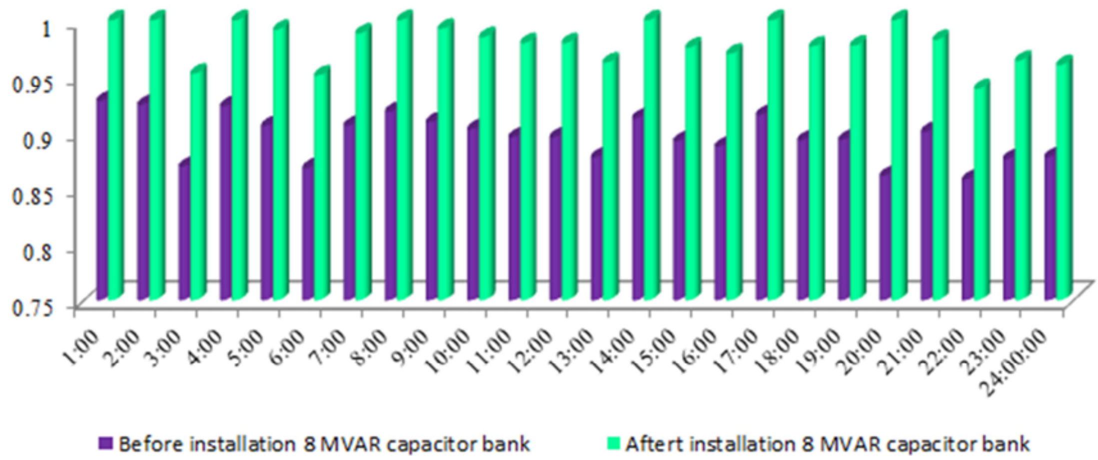


Figure 11. *Power factor chart before and after installation 3 MVAR capacitor bank at 33 kV bus bar.*

Acknowledgements

The author is grateful to express his gratitude to all persons who were directly or indirectly involved towards the successful completion of this paper.

Appendix

Table A. *Calculation Table for Capacitor Selection.*

Power Factor Value after Adjustment / Power Factor Value before Adjustment	1	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.9
0.5	173	159	153	148	144	140	137	134	131	128	125
0.51	169	154	148	144	139	136	132	129	126	123	120
0.52	164	150	144	139	135	131	128	125	122	119	116
0.53	160	146	140	135	131	127	124	120	117	114	112
0.54	156	142	136	131	127	123	120	116	113	110	107
0.55	152	138	132	127	123	119	116	112	109	106	103

Power Factor Value after Adjustment / Power Factor Value before Adjustment	1	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.9
0.56	148	134	128	123	119	115	112	108	105	102	100
0.57	144	130	124	119	115	111	108	105	102	99	96
0.58	140	126	120	115	111	108	104	101	98	95	92
0.59	137	123	117	112	108	104	101	97	94	91	88
0.6	133	119	113	108	104	100	97	94	91	88	85
0.61	130	116	110	105	101	97	94	90	87	84	81
0.62	127	112	106	101	97	94	90	87	84	81	78
0.63	123	109	103	98	94	90	87	84	81	78	75
0.64	120	106	100	95	91	87	84	81	77	74	72
0.65	117	103	97	92	88	84	81	77	74	71	68
0.66	114	100	94	89	85	81	78	74	71	68	65
0.67	111	97	90	86	82	78	75	71	68	65	62
0.68	108	94	88	83	79	75	72	68	65	62	59
0.69	105	91	85	80	76	72	69	65	62	59	56
0.7	102	88	82	77	73	69	66	62	59	56	54
0.71	99	85	79	74	70	66	63	60	57	54	51
0.72	96	82	76	71	67	64	60	57	54	51	48
0.73	94	79	73	69	64	61	57	54	51	48	45
0.74	91	77	71	66	62	58	55	51	48	45	42
0.75	88	74	68	63	59	55	52	49	46	43	40
0.76	86	71	65	60	56	53	49	46	43	40	37
0.77	83	69	63	58	54	50	47	43	40	37	34
0.78	80	66	60	55	51	47	44	41	38	35	32
0.79	78	63	57	53	48	45	41	38	35	32	29
0.8	75	61	55	50	46	42	39	35	32	29	27
0.81	72	58	52	47	43	40	36	33	30	27	24
0.82	70	56	49	45	41	37	34	30	27	24	21
0.83	67	53	47	42	38	34	31	28	25	22	19
0.84	65	50	44	40	35	32	28	25	22	19	16
0.85	62	48	42	37	33	29	26	22	19	16	14
0.86	59	45	39	34	30	26	23	20	17	14	11
0.87	57	42	36	32	28	24	20	17	14	11	8
0.88	54	40	34	29	25	21	18	14	11	8	6
0.89	51	37	31	26	22	18	15	12	9	6	2.8
0.9	48	34	28	23	19	16	12	9	6	2.9	
0.91	46	31	25	20	16	13	9	6	3		
0.92	43	28	22	18	13	10	6	3.1			
0.93	40	25	19	14	10	7	3.2				
0.94	36	22	16	11	7	3.4					
0.95	33	19	13	8	3.7						
0.96	29	15	9	4.1							
0.97	25	11	4.8								
0.98	20	6									
0.99	14										

Table A. *Continued.*

Power Factor Value after Adjustment. / Power Factor Value before Adjustment	**0.89**	**0.88**	**0.87**	**0.86**	**0.85**	**0.84**	**0.83**	**0.82**	**0.81**	**0.8**
0.5	122	119	117	114	111	109	106	103	101	98
0.51	117	115	112	109	107	104	101	99	96	94
0.52	113	110	108	105	102	100	97	94	92	89
0.53	109	106	103	101	98	95	93	90	88	85
0.54	105	102	99	97	94	91	89	86	83	81
0.55	101	98	95	93	90	87	85	82	79	77
0.56	97	94	91	89	86	83	81	78	76	73
0.57	93	90	87	85	82	80	77	74	72	69
0.58	89	86	84	81	78	76	73	71	68	65
0.59	86	83	80	78	75	72	70	67	64	62
0.6	82	79	77	74	71	69	66	64	61	58
0.61	79	76	73	71	68	65	63	60	58	55
0.62	75	73	70	67	65	62	59	57	54	52
0.63	72	69	67	64	61	59	56	53	51	48
0.64	69	66	63	61	58	55	53	50	48	45
0.65	66	63	60	58	55	52	50	47	45	42
0.66	63	60	57	55	52	49	47	44	41	39
0.67	60	57	54	52	49	46	44	41	38	36
0.68	57	54	51	49	46	43	41	38	35	33
0.69	54	51	48	46	43	40	38	35	33	30
0.7	51	48	45	43	40	37	35	32	30	27
0.71	48	45	43	40	37	35	32	29	27	24
0.72	45	42	40	37	34	32	29	27	24	21
0.73	42	40	37	34	32	29	26	24	21	19
0.74	40	37	34	32	29	26	24	21	18	16
0.75	37	34	32	29	26	24	21	18	16	13
0.76	34	32	29	26	24	21	18	16	13	11
0.77	32	29	26	24	21	18	16	13	10	8
0.78	29	26	24	21	18	16	13	10	8	5
0.79	26	24	21	18	16	13	10	8	5	2.6
0.8	24	21	18	16	13	10	8	5	2.6	
0.81	21	18	16	13	10	8	5	2.6		
0.82	19	16	13	10	8	5	2.6			
0.83	16	13	11	8	5	2.6				
0.84	13	11	8	5	2.6					
0.85	11	8	5	2.6						
0.86	8	5	2.7							
0.87	5	2.7								
0.88	2.7									
0.89										
0.9										
0.91										
0.92										
0.93										
0.94										
0.95										
0.96										
0.97										
0.98										
0.99										

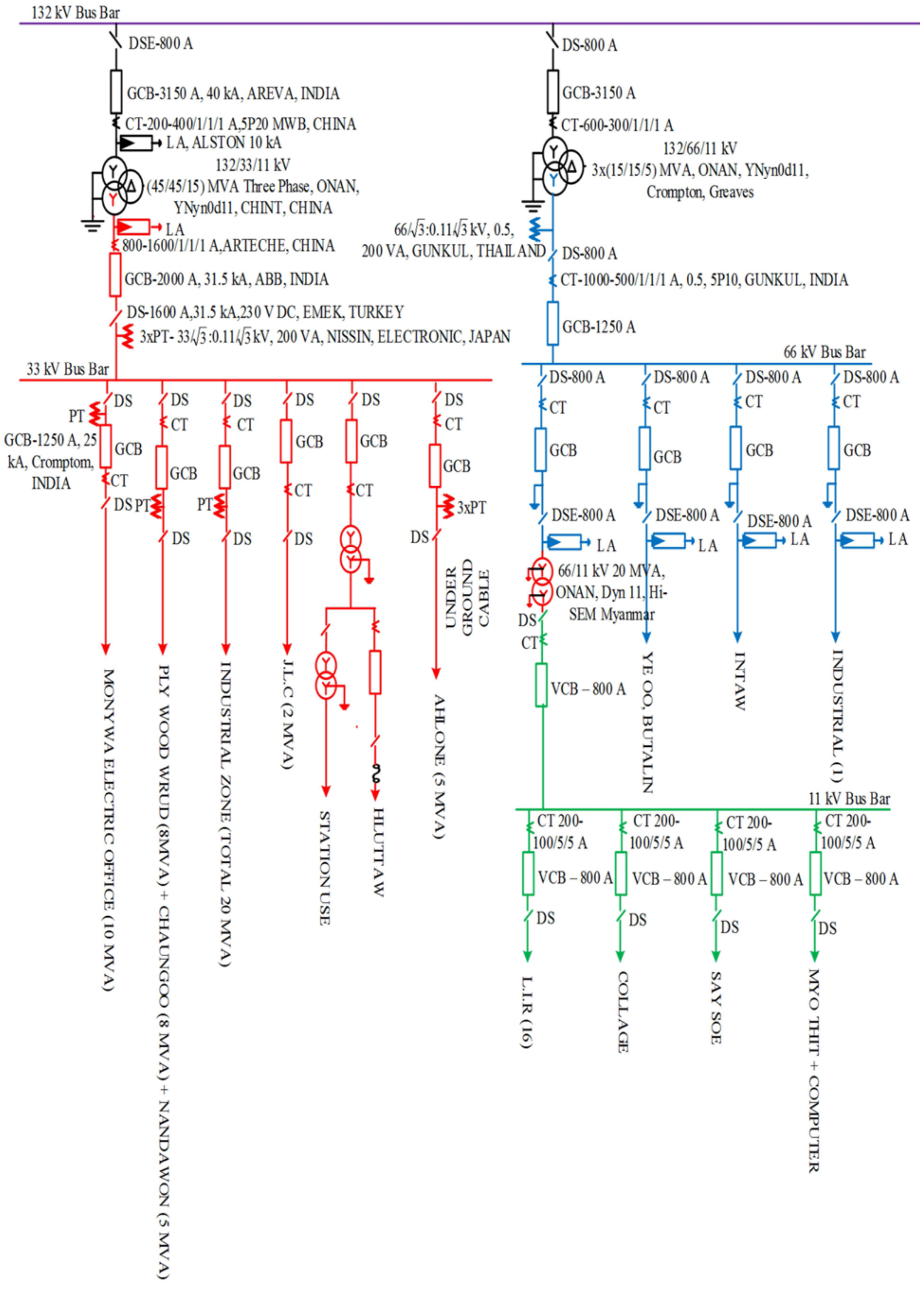


Figure 12. *Single Line Diagram of 132 kV Aung Chan Thar (Monywa) Substation.*

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