

Reactive Power Compensation using 12 MVA Capacitor Bank in 132/33 KV Distribution Substation

Yogesh U Sabale¹, Vishal U Mundavare², Pravin g Pisote³, Mr. Vishal K Vaidya⁴

^{1,2,3,4}Electrical Engineering Department,

^{1,2,3,4}SVIT, Chincholi Sinner, Nashik

Abstract- Shunt capacitor bank improves the power factor, increases voltage level on the load and reduces current flow through the transmission lines. The main reason of installing a capacitor bank is to increase power factor voltage level. This inappropriate installation without enough study gives rise to a reduce our technical problem. Therefore, the capacitor banks are designed for long-term use should be considered. Capacitor have fixed parts, initial cost is low, up keep costs are minimal, and they are compact, reliable, and highly efficient and can be installed basically three possibilities to correct loads individually, in groups or centrally. In this paper, model of 12 MVAR rating of shunt capacitor bank is designed installation for 33 kV busbar is Mhasrul 132/33 KV substation in Nasik.

Keywords- Power Factor Improvement, Reactive Power Stability, Shunt Capacitor Bank, Voltage Control..Reduce Voltage drop.

I. INTRODUCTION

An electrical power system consists mainly of the components are generators, transformers and transmission lines. The transmission system consists of all the equipment from the generating-end, switchyard lines, switching stations, equipment at the receiving-end till the entrance to sub-transmission networks, and distribution networks. A large number of distribution systems have run into problems such as low voltage regulation, low power factor, large amount of losses and less efficiency, overloading and discontinuity of supply. It is necessary to improve the working of the power distribution systems to reduce losses, improve voltage regulation, improve power factor etc. On a power line, besides the active power, the reactive power must also be available for inductive loads. An Generator can produce the reactive power for the line, but the reactive power can be supplied from any source that can be either an generator or capacitor groups connected near the load. The reactive power source must be very close to the load for efficient operation of the system. If the reactive power of any load is supplied from a synchronous motor or a group of capacitors rather than the power line, this system is called reactive power compensation. So, the power factor of the system can be kept at a required value. The

voltage control is achieved by regulating the reactive output of the generating plants, tap changing on the transformers and switching on or out reactors or capacitors to achieve target system voltages.

The system improvement has to be planned properly with the four objectives:

1. to reduce losses in the sub transmission system,
2. to improve the voltage regulation
3. to improve the continuity of supply,
4. to improve the power factor in the sub-transmission and distribution system
5. to compensate reactive power in substation.

Therefore, the used OF CAPACITOR BANK in transmission and distribution system to improve the power factor and voltage regulation.

II. SPECIFICATIONS OF POWER CAPACITOR USED IN 33 KV LINE

When applied on a power system for the reduction of inductive current, capacitors can be grouped into either transmission. In either case, they should be installed electrically as near to the load as possible for maximum effectiveness. When applied properly, capacitors balance out most of the inductive component of current to the load. The result is a reduce in size of the conductor required to serve a given load and reduction in I²R losses. Static capacitors may be used at any voltage, but practical considerations impose an upper limit of a few kilovolts per unit, therefore, high-voltage banks must be composed of many units connects in series and parallel. Small distribution capacitor may be vault or pole-top-mounted and protected by fuses. In this substation, at 33 kV bus, capacitors are grouped into the distribution classes. As industrial loads occasionally require very large amounts of power factor correction, varying with time and industrial process cycle. The capacitor bank continues in service; however, successive failures of elements will lead to the removal of the bank.

Table 1. data for proposed power capacitor at 33 kv bus

Line Voltage	33 KV
Rated Voltage	9.5 KV
Rated Current	87.3 A
Weight	6030 lb
No. of Phase	Single Phase
Frequency	50 Hz
Rated Capacity	834 Kvar
Insulation Level	No.30

III. SHUNT CAPACITOR FOR VOLTAGE REGULATION

The capacitors used in the transmission systems for the purpose of voltage regulation, act to improve power factor. In these installations, reactive output rating of a unit capacitor is chosen at kVAR and two groups are connected in series, and three of these groups in star connection with floating neutral make a three phase bank. The series reactor is connected in series with capacitors at neutral side of the bank. Once the list of additional reactive power requirements is finalized, determinations are made about the placement of each bank. The value of the kVAR connected to kVA per feeder, the position on the feeder of existing capacitor banks, and any concentration of present or future load are all considered in determining the position of the new capacitor banks. The single phase discharge coil is connected so as to bridge each phase leg of a capacitor bank. The secondary windings of the discharge coil are used for protecting relay system. Mahasrul substation is connected 132 kV to the 33 kV distribution network which applied 50 MVA transformer from 132 kV step down to 33 kV.

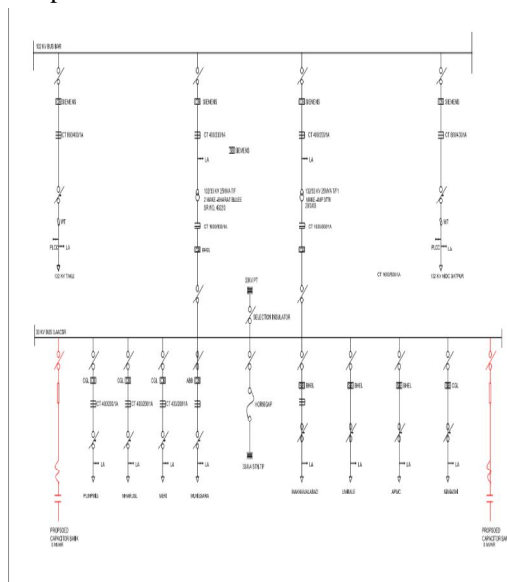


Figure 1.

IV. ANALYSIS OF LOAD DATA WITH RESPECT TO POWER FACTOR CHANGES

Table II is to illustrate some variables obtained from power factor changes. 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 (fig.2).

From Table II, 6 MVAR capacitor bank would be needed for 25 MVA power transformer to improve power factor.

Table 2. 33 kv mains 25mva log sheet data

TIME	KV	A	MVA	MW	PF
1.00	34.5	232	14.52	13.64	0.94
2.00	34.7	204	12.88	18.79	0.92
3.00	34.8	206	13.14	12.06	0.92
4.00	35.0	204	13.10	11.98	0.91
5.00	35.1	209	13.53	12.33	0.91
6.00	35.0	225	14.33	13.19	0.92
7.00	34.6	214	13.97	12.97	0.93
8.00	34.7	295	18.63	17.50	0.94
9.00	32.9	337	20.64	19.22	0.93
10.00	34.2	239	15.03	14.08	0.94
11.00	34.0	220	13.83	12.87	0.93
12.00	32.3	266	17.23	15.04	0.94
13.00	33.0	301	18.17	16.49	0.91
14.00	33.1	310	19.21	17.20	0.89
15.00	33.1	277	17.11	15.21	0.89
16.00	32.2	311	19.12	17.11	0.89
17.00	33.0	314	19.20	17.16	0.89
18.00	32.0	336	20.64	18.46	0.89
19.00	33.0	333	20.58	18.50	0.90
20.00	33.2	360	22.07	20.40	0.92
21.00	33.7	299	18.68	17.50	0.94
22.00	34.0	279	17.29	16.25	0.94
23.00	34.3	253	15.86	14.92	0.94
24.00	34.8	238	15.10	14.21	0.94

V. DESIGN & CALCULATION OF CAPACITOR BANK SIZE

The following data are obtained from Mashrul Substation to design capacitor bank for power factor correction.

1. Transformer rating = 25 MVA
2. Transformer reactance = 9.65 %
3. Voltage = 33 Kv
4. Maximum load = 20.40 MW
5. Maximum MVA = 22.07 MVA
6. Power factor = 0.92
7. Improved up to power factor = 0.99 .

If the power factor is raised UP to 99 %,

$$\text{Desire MVA Demand} = \frac{\text{Present Load}}{\text{Desire Power Factor}} = \frac{20.40}{0.99} = 20.60 \text{ MVA}$$

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

$$\text{MVAR1} = \sqrt{\text{MVA}^2 - \text{MW}^2} = \sqrt{22.07^2 - 20.40^2} = 8.42 \text{ MVAR}$$

MVAR1 at 92 % power factor = 8.42

$$\text{MVAR2} = \sqrt{\text{MVA}^2 - \text{MW}^2} = \sqrt{20.60^2 - 20.40^2} = 2.86 \text{ MVAR}$$

MVAR2 at 99 % power factor = 2.86

$$\frac{\text{Capacitor rating}}{\text{rating}} = \text{MVAR1 (Uncorrect)} - \text{MVAR2 (Corrected)} = 8.42 - 2.86 = 5.56 \text{ MVAR}$$

By installing power capacitors and increasing power factor to 99 %, apparent power is reduced from 22.07 MVA to 20.60 MVA (reduction of 13.64 %). Theoretically, capacitors could provide 100 % of needed reactive power. In practical usage, however, power factor correction to approximately 99 % provides maximum benefit.

Multiplying factor = 0.283

$$\begin{aligned} \text{Capacitor Rating} &= \text{Multiplying Factor} \times \text{MW Demand} \\ &= 0.283 \times 20.40 \\ &= 5.77 \\ &\approx 6 \text{ MVAR.} \end{aligned}$$

99 % is a good economic power factor for industrial purposes. In this thesis, this power factor is corrected from 92 %. Therefore the installation of 12 MVAR capacitor bank is determined for achieving power factor of 99 % while providing the same productive power of 20.40 MW.

VI. CHECK CALCULATION FOR AFTER INSTALLATION OF 6 MVAR CAPACITOR BANK ON ONE TRANSFORMER SIDE

For maximum load condition,

$$\begin{aligned} \text{MVAR2 (Corrected)} &= \text{MVAR1 (Uncorrect)} - \text{Capacitor rating} \\ &= 8.42 - 6 \\ &= 2.42 \text{ MVAR.} \end{aligned}$$

$$\begin{aligned} \text{MVA2} &= \sqrt{(\text{MVAR2})^2 + \text{MW}^2} = \sqrt{2.42^2 + 20.40^2} \\ &= 20.54 \text{ MVA} \end{aligned}$$

$$1. \text{ Power Factor} = \frac{\text{MVA Demand}}{\text{Present Load}} = \frac{20.40}{20.54} = 0.997$$

Table 3. power factor data after installing capacitor bank

TIME	POWER FACTOR	TIME	POWER FACTOR
1.00	0.98	13.00	0.98
2.00	0.98	14.00	0.97
3.00	0.98	15.00	0.98
4.00	0.98	16.00	0.98
5.00	0.99	17.00	0.97
6.00	0.99	18.00	0.98
7.00	0.98	19.00	0.98
8.00	0.99	20.00	0.99
9.00	0.99	21.00	0.99
10.00	0.99	22.00	0.99
11.00	0.99	23.00	0.99
12.00	0.97	24.00	0.99

VII. VOLTAGE RISE

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

Capacitor Rating = 6 MVAR (on one side transformer).
Transformer Reactance = 9.65 %

Transformer MVA = 25 MVA

$$\% \text{ Voltage Rise} = \frac{\text{Capacitor Mvar} \times \text{Transformer Reactance}}{\text{Transformer MVA}}$$

$$= \frac{6 \times 9.65\%}{25} = 2.316\%$$

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.

Table 4. voltage data after installing capacitor bank

Time	Voltage (KV)	Time	Voltage (KV)
1.00	35.03	13.00	33.63
2.00	35.09	14.00	33.75
3.00	35.02	15.00	33.76
4.00	35.53	16.00	33.84
5.00	35.64	17.00	32.82
6.00	35.53	18.00	32.68
7.00	34.99	19.00	33.70
8.00	35.23	20.00	34.99
9.00	33.65	21.00	34.35
10.00	33.72	22.00	34.65
11.00	34.52	23.00	34.96
12.00	32.92	24.00	35.33

For maximum load condition,
Present voltage = 33.2 KV
Voltage rise = 2.316 %

Therefore,

$$\text{Improved voltage} = 33.2 + \frac{33.2 \times 2.316}{100}$$

$$= 33.2 + 0.99$$

$$= 34.99 \text{ kV}$$

VIII. LINE CURRENT REDUCTION IN SYSTEM

THE PERCENT LINE CURRENT REDUCTION MAY BE APPROXIMATED FROM THIS EQUATION.

$$\% \text{ Line Current Reduction} = 100 \left[1 - \frac{\text{Present Power Factor}}{\text{Improve Power Factor}} \right]$$

$$\% \text{ Line Current Reduction} = 100 \left[1 - \frac{0.92}{0.99} \right]$$

$$= 7.07\%$$

For maximum load condition,
Maximum current = 360 A
Present power factor = 0.92
Improved power factor = 0.99

$$\% \text{ Line Current Reduction} = 100 \left[1 - \frac{\text{Present Power Factor}}{\text{Improve Power Factor}} \right]$$

$$\% \text{ Line Current Reduction} = 100 \left[1 - \frac{\text{Present Power Factor}}{\text{Improve Power Factor}} \right]$$

$$\text{Reduced Current} = 360 - \frac{360 \times 7.06}{100}$$

$$= 333.50 \text{ A.}$$

Table 5. line current data after installing capacitor

Time	Line Current	Time	Line Current
1.00	223	13.00	280
2.00	192	14.00	285
3.00	194	15.00	252
4.00	190	16.00	282
5.00	193	17.00	288
6.00	209	18.00	305
7.00	203	19.00	306
8.00	280	20.00	334
9.00	316	21.00	284
10.00	227	22.00	265
11.00	207	23.00	240
12.00	258	24.00	226

IX. CONCLUSION

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

$$\% \text{ Power Losses} = 100 \left[\frac{\text{Present Power Factor}}{\text{Improve Power Factor}} \right]^2$$

$$\% \text{ Power Losses} = 100 \left[\frac{0.92^2}{0.99} \right]^2$$

$$= 86.35\%$$

$$\% \text{ Losses Reduction} = 100 \left[1 - \left[\frac{\text{Present Power Factor}}{\text{Improve Power Factor}} \right]^2 \right]$$

$$= 100 \left[1 - \left[\frac{0.92^2}{0.99} \right]^2 \right]$$

$$= 13.64\%$$

There is 13.64 % reduction in power losses.

X. CONCLUSION

Having low power factor does not cause a piece of machinery to shut down, but high power factor is important for the overall health of the power system. Operating in a high power factor environment ensures that the power system is functioning efficiently. It also makes economic sense. As the demand for electrical energy continues to grow and the resources for producing the energy become less and less available, the idea of not using more than what we need takes on more relevance.

In this paper 12 MVAR shunt capacitor bank is installed at 33 kV bus for reactive power compensation in Mhasrul 132/33 kV substation. In this substation have 8-outgoing lines of 33 kV bus for available loads. Distribution line voltage 33 kV has decrease to 33.2 kV at present maximum load 20.4 MW and decrease to 34.99 kV at present minimum load 8.42 MW.

This voltage 34.99 kV is out of -5% range. So, a shunt capacitor bank (12 MVAR) has proposed installed for better voltage regulation, reduce transformer loading and improve the power factors of various loads.

XI. ACKNOWLEDGEMENT

The author wishes to express her deepest gratitude to her teachers, Department of Electrical Power Engineering,. The author also wishes to extend special thanks to her parent, her friends for their supports and help. Similar thanks to all for their instructions and willingness to share their ideas throughout all those years of study.

REFERENCES

- [1] Ramasamy Natarajan, "Power System Capacitors", CRC Press, Taylor & Francis group, LLC., New York, USA, (2005).
- [2] Technical Information, "Power Factor Correction", Emerson Climate Technologies, Copeland, Application Engineering Europe, April (2004).
- [3] G. Brunello, B. Kasztenny, C. Wester, "Shunt Capacitor Bank Fundamentals and Protection" Conference for Protective Relay Engineers -Texas A&M University, (2003).

- [4] Nagrath I. J., "Power System Engineering", Tata McGraw-Hill Publishing Company Limited, (2000)

About Authors

Mr. Yogesh U Sabale¹, students of BE Electrical Engineering from Sir Visvesvaraya Institute of Technology, Chincholi., Nashik.

Mr. Vishal U Mundavare², students of BE Electrical Engineering from Sir Visvesvaraya Institute of Technology, Chincholi., Nashik.

Mr. Pravin G Pisote³, students of BE Electrical Engineering from Sir Visvesvaraya Institute of Technology, Chincholi., Nashik.

Mr. Vishal K Vaidya, Received M.E from SPPU, and currently working as Asst. Prof. in Electrical Engineering Department, Sir Visvesvaraya Institute of Technology, Chincholi., Nashik.