A Case Study of Power Loss Analysis and Reactive Power Compensation in Distribution System at a 33KV Substation

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Abstract: This article gives the total data about the Reactive Power compensation given to the distribution framework for decreasing the Power Losses. In this article, a contextual investigation of 33KV Substation, Sector-6 Rohtak, Haryana is taken with shunt capacitor bank and without shunt capacitor bank at top hours is consider. It is seen from load bend that with the switch in of shunt capacitor bank, current of around 10-12 Ampere is dropped in 11 kV line. This drop of current decreases the weight on the gadgets of the 11 kV feeder. Additionally, flow saved is utilized for different clients for giving Electrical Power.Further MATLAB simulation is done to show the current drop in 11 kV feeder line with the consideration of shunt capacitor bank. Likewise, Annuity is utilized for Economic investigation for comprehension the lifecyclecost saving with the incorporation of shunt capacitor bank is determined. Regardless, this strategy can be utilized for any setup knowing the real saving with the incorporation of shunt capacitor in the distribution framework.

Keywords: Power Distribution, Shunt Capacitor Bank, Reactive Power, Compensation, MATLAB Simulation

I. INTRODUCTION

With the partial liberation of distribution framework in non-industrial nation, there is rivalry among various utilities to get effective or as such to decrease their general costs. This decrease of expenses considers decrease of tax. It is seen that the reactive power is identified with the attractive field energy needed in transformer, power lines engines, different burdens and so on Reactive power energies the Magnetic field. The working power from distribution framework is made out of both dynamic and reactive components. From the distinctive burden bend information, MW/MVAr shifts from 3 to multiple times [1]. It especially increments in top hours. Likewise, age and control of reactive power is imperative to keep up with entire framework dependability and decrease of losses [2]. The framework voltage breakdown because of absence of worldwide control of reactive power stream [4] during vital possibilities is arising as an extraordinary issue. The arrangement of northern framework has fallen ordinarily dunging most recent couple of years because of absence of reactive power in the district.

The distribution lines devour reactive power (I2R) contingent upon the series reactance and burden current. The series reactance of line is corresponding to the conductor self-inductance, which diminishes as the separating between conductor diminishes. Helpless power factor brought about by absence of appropriate compensation costs our local area in expanded power charges and pointless impact in the framework and helpless power quality. In this article, altogether investigation of reactive power compensation is done on distribution framework with the assistance ofcontextual analysis. Capacitor Bank and Reactors gadgets with mechanical time control switch can be associated in corresponding to the distribution organization to supply the sort of reactive power or current expected to check the out of stage segment of current needed by the inductive burden to kill or diminish to a satisfactory breaking point the voltage guideline [5].

Further, Economic examination is accomplished for lifecycle cost saving by giving reactive power compensation to the distribution framework. Regardless, this strategy can be applied to any distribution framework to decrease the general costs of whole framework [6].

II. ECONOMIC ADVANTAGES OF POWER FACTOR CORRECTION

Power factor correction in non-linear loads [7,8]:

Passive PFC: The least difficult approach to control the consonant current is to utilize a channel: it isfeasible to plan a channel that passes current just at line recurrence (50 Hz if there should arise an occurrence of India). This channel decreases the symphonious current, which implies that the non-straight gadget presently resembles a direct burden. Now the power factor can be brought to approach solidarity, utilizing capacitors or inductors as required. This channel requires huge worth high-current inductors, in any case, which are massive and costly. An inactive PFC requires an inductor bigger than the inductor in a functioning PFC, yet costs less. This is a basic method of rectifying the nonlinearity of a heap by utilizing capacitor banks. It's anything but as compelling as dynamic PFC. Uninvolved PFCs are regularly more power effective than dynamic PFCs. Effectiveness isn't to be mistaken for the PFC, however numerous PC equipment surveys conflate them. A latent PFC on an exchanging PC PSU has a normal power proficiency of around 96%, while a functioning PFC has an ordinary effectiveness of about 94% [9].

Dynamic PFC: An "functioning power factor corrector" (dynamic PFC) is a power electronic framework that changes the wave state of current attracted by a heap to further develop the power factor. The design is to make the heap hardware that is power factor adjusted show up simply resistive (clear power equivalent to genuine power). For this situation, the voltage and current are in stage and the reactive power utilization is zero. This empowers the most proficient conveyance of electrical power from the power organization to the purchaser. A few kinds of dynamic PFC are [10]: I. Lift, ii. Buck, iii. Buck-help.

Answers for further develop power factor issues and decrease music contortion [11]:

To accomplish further develop power factor is to utilize power factor revision switch associated at the closeto stack terminals [12].

Significance of power factor in distribution framework:

Power factors beneath 1.0 require a utility to create more than the base volt-amperes needed to supply the genuine power (watts). This builds age and transmission costs. For instance, if the heap power factor were pretty much as low as 0.7, the obvious power would be 1.4 occasions the genuine power utilized by the heap. Line current in the circuit would likewise be 1.4 occasions the current needed at 1.0 power factor, sothe losses in the circuit would be multiplied (since they are relative to the square of the current). On theother hand all parts of the framework like generators, conductors, transformers, and switchgear would be expanded in size (and cost) to convey the additional current. Utilities regularly charge extra expenses for clients who have a power factor beneath some cutoff, which is normally 0.9 to 0.95. Designers are regularly keen on the power factor of a heap as one of the factors that influence the proficiency of power transmission. With the increasing expense of energy and worries over the effective conveyance of power, dynamic PFC has gotten more normal in purchaser hardware [13].

Specialized benefits of power factor remedy:

By adjusting the power factor of an establishment providing locally the essential reactive power, at a similar degree of required yield power, it is feasible to lessen the flow esteem and subsequently the complete power consumed on the heap side; this suggests various benefits, among which a superior usage of electricalmachines (generators and transformers) and of electrical lines (transmission and distribution lines) [14].

Better use of electrical machines:

Generators and transformers are estimated by the obvious power S. At a similar dynamic power P, the more modest the reactive power Q to be conveyed, the more modest the clear power. In this way, by further developing the power factor of the establishment, these machines can be estimated for a lower evident power, yet convey a similar dynamic power [15].

Better use of electrical lines:

Power factor remedy permits getting benefits likewise for link measuring. Truth be told, as recently said, at a similar yield power, by expanding the power factor the current lessens. This decrease in current can be, for example, to permit the selection of conductors with lower cross sectional region [16].

Decrease of losses:

The power losses of an electric conveyor rely upon the obstruction of the actual conduit and on the square of the flow coursing through it; since, with a similar worth of communicated dynamic power, the higher the power factor the lower the flow, it follows that when the power factor rises, the losses in the transmitter on the stockpile side of where the power factor adjustment has been completed will diminish. Power supply specialists apply a duty framework which forces punishments on the drawing of energy with a month-to-month normal power factor lower than 0.9. The agreements applied are not the same as country to country and can change additionally as per the typologyof costumer: as an outcome, the accompanying comments are to be considered as a simple instructional and demonstrative data pointed toward showing the financial saving which can be gotten on account of the power factor revision [17]. As a rule, the power supply authoritative conditions require the installment of the consumed reactive energy when the power factor is remembered for the reach from 0.7 and 0.9, while nothing is expected in the event that it is higher than 0.9. For power factor is under 0.7 power supply specialists can oblige. Purchasers to do power factor revision. It is to be noticed that having a month-to-month normal power factor higher than or equivalent to 0.9 methods mentioning from the organization a reactive energy lower than or equivalent to half of the dynamic energy: Therefore, no punishments are applied if the prerequisites for reactive energy don't surpass half of the dynamic one. The expense that the buyer bears on a yearly base when drawing a reactive energy surpassing that relating to a power factor equivalentto 0.9 [18].

General Advantage of Power Factor [19]:

I. Diminished month to month energy costs,
ii. Effective electrical framework,
iii. Decreased stacking on transformers,
iv. Decreased stacking on distribution lines,
v. Decreased voltage drops,
vi. Decreased mileage on electrical hardware,
vii. Expanded burden taking care of ability of the plant's electrical framework.

Weakness of Low Power Factor [20]:

I. Expanded energy costs,
ii. Over-burden transformers,
iii. Over-burden distribution lines,
iv. Bringing about voltage drops and unnecessary mileage on electrical hardware,
v. Diminished burden taking care of capacity of the plant's electrical framework.

III. REACTIVE POWER CONTROL WITH SWITCHED SHUNT CAPACITORS

Shunt capacitors inject reactive power to the system according to [9]

$$Q_c = Q_{rat}\, U_c$$

Where, Q is the reactive power injected by the capacitor in MVar, Q_{rat} is the MVar rating of the capacitor, U_c is the voltage in pu (relative to the capacitor voltage rating). The reactive power injected by the capacitor will compensate the reactive power demand and thereby boost the voltage. For example, consider that in Figure 1 a shunt capacitor injecting reactive power Q is connected to the load bus. The voltage drop on the feeder can then be approximated as [21]:

$$\Delta U \approx \frac{R_{LN} P_L + X_{LN}(Q_L - Q_c)}{U_2}$$

Which indicates that the capacitor reduces the voltage drop. Further, when the capacitor properly compensates the reactive power demand, the capacitor will decrease the feeder current. These will in turn decrease the feeder losses P_{Loss}.

$$I = \frac{\sqrt{P_L^2 + (Q_L - Q_c)^2}}{U_2}$$

$$P_{Loss} = I^2 R_{LN}$$

In order to properly compensate the reactive power demand that changes from minimum to maximum and to be switched off at the load minimum. When the load varies during the day, the switched capacitors should be properly controlled. Different conventional controls can be used to control switched capacitors, such as time, voltage and reactive power [22]. Time controlled capacitors are especially applicable on feeders with typical daily load profiles in a long term, where the time of the switching-on and off of the shunt capacitor can be predicted. The main disadvantage of this control is that the control has no flexibility to respond toload fluctuation caused by weather, holidays, etc. voltage-controlled capacitors are most appropriate when the primary role of the capacitor is for voltage support and regulation [23]. Reactive power- c o n t r o l l e d capacitors are effective when the capacitor is intended to minimize the reactive power flow.

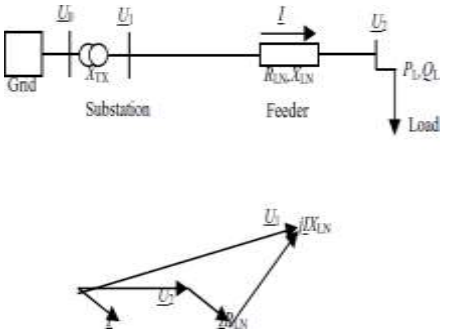

Fig. 1 One- l i n e diagram and corresponding phasor diagram of voltage drop in a distribution system

Calculation of the size of capacitor banks.

The source is Y connected and the line Voltage is 11kv,

Phase Voltage, $V_{ph} = \frac{11kV}{\sqrt{3}} = 6.35\,V$

Capacitor bank rating $Q_c = 600$ kvar.

Capacitor bank rating per phase $Q_{cph} = \frac{600\,kvar}{3} = 200kvar$.

Impedance of capacitance per Phase,

$X_{Cph} = \frac{V^2_{ph}}{Q_{cph}} = \frac{(6.35kv)^2}{200kvar} = 201.61\Omega$

$Xcph = \frac{1}{2\pi \times f \times C} \Rightarrow C = 15.78\,\mu F$,

Where f= 50 Hz, is the power system frequency.

Assuming severest conditions of switching the value of L in Henry is given by

$L = \frac{1}{(2\pi \times f)^2 \times C} = 0.64\,H$.

$\text{Inrush Current} = \sqrt{2} \times 6.35 \times 10^3 \times \sqrt{\frac{15.78 \times 10^{-6}}{0.64}} = 44.59\,\text{amps}$.

Line X_L: Aerial line with Conductor of size $100mm^2$

Length of line = 5m.

Line $X_L = 0.5\,\Omega$ / km.

Total Line X_L is $0.005 \times 0.5 = 0.0025\,\Omega$.

IV. CASE STUDY

A. Matlab Simulation of Feeder

The power factor remedy got by utilizing power factor revision switches banks (shunt capacitor) to create locally the reactive energy essential for the exchange of electrical helpful power, permits a superior and more levelheaded specialized prudent administration of the plants. The framework is equipped for remedying power factor up to solidarity or changing it as indicated by client want [24]. The proposed framework is describedby, no age of music, and decrease of distribution losses. Simulation results are accounted for and end up being in acceptable concurrence with the applicable test results. Beneath show the contextual analysis of distribution feeder of 11 kV line where capacitor is exchanged in and give the reactive power compensation. Transformer of the 3 stage, 8 MVA, 33/11 kV of essential distribution is utilized. Fig. 2 shows the simulation of 11kV feeder line in which capacitor is associated with the assistance of Circuit breaker. Fig. 3 shows the simulation with compensation [25].

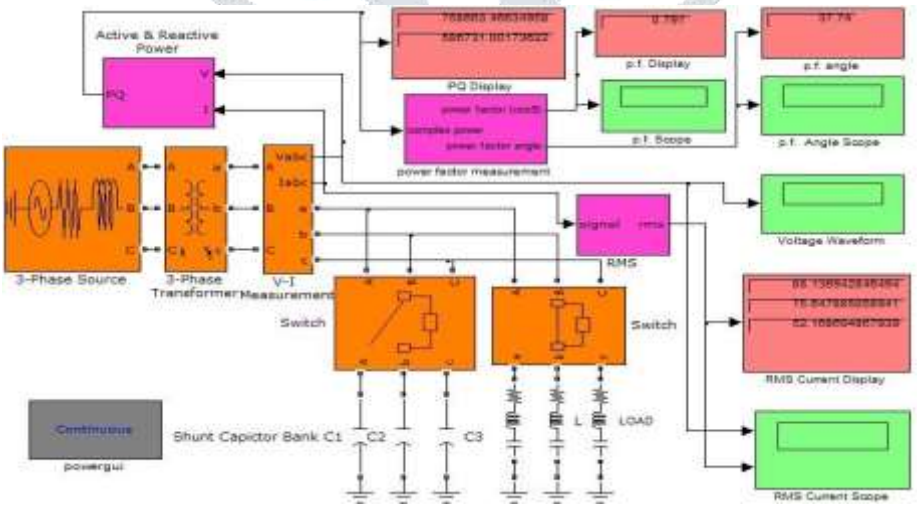

Fig. 2 shows the Uncompensated Feeder of 11 kV line.

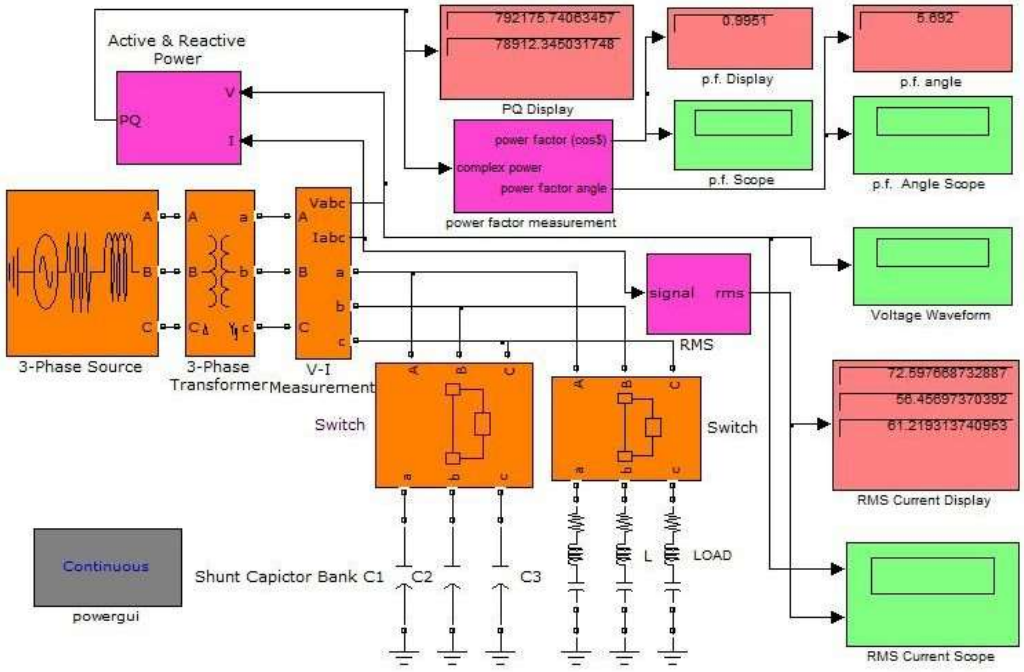

Fig. 3 shows the Shunt Capacitance Compensated Feeder of 11 kV line.

B. Economic Analysis of Power Losses

The economical assessment of the power losses assumes a huge part in the general expense assessment during the functional existence of a distribution line [26]. Cash is the most fluid financial asset and it has procuring limit whenever. The expense of cash or cost of cash is loan fee. Because of the financing cost the worth of an amount of cash is diverse at various time which is called time worth of cash [27]. A rupee close by today is worth in excess of a rupee to be gotten in the future since on the off chance that you have it now, you can contribute it and acquire the interest [28]. The time worth of cash is the main mathof money and it is utilized in various spaces of business. Time worth of cash idea is utilized to make diverse monetary, financial and bookkeeping choices of the business. The principal factors of time worth of cash are the amount of cash, financing cost and time span. Time worth of cash is partitioned into present worth and future worth. The amount of cash might be cost of resource, measure of credit, compensations, lease, charge, etc. The loan fee might be pace of return, cost of capital, opportunity cost, etc. [29]. Timemight be day, month, quarter, half year, year, etc. Present worth is otherwise called limited worth or current worth or starting worth. Present worth is the current or limited worth of future money flow(s) addressed by Double round section all through in this Article. Income might be single or singular amount, even (every year) lopsided (arbitrary and developing). Right now is indicated by nothing and the future occasions aremeant by 1,2,3, 4,… ⋯ ..∞. The income proclamation alongside time-frame is known as income timetables. Income timetables are utilized to assist with picturing what's going on in time worth of cash issues [30].

Lifecycle = 40 (a long time); Real pace of revenue (rebate rate) = 5%; energy saving expense = Rs3.20.

TABLE I. Power Saving of Distribution Feeder of 11 kV

11 kV Feeder	Power Losses Saving (KW)	Annual EnergySaving Cost (KW)	Annual EnergySaving in Rupees in Million (AESC)
Phase 1	184.61	1,617,183.6	5.17
Phase 2	230.34	2,017,778.4	6.45
Phase 3 (Without Shunt Compensation)	-165.94	(-)1,453,634.4	(-) 4.65

Therefore, Annual Energy Saving Cost (AESC) = actual loss (KiloWatt) × 365 × 24 & discounted values (Ordinary Annuity) are given by:

$$((E)) = \frac{(1+i)^n-1}{i(1+i)^n} \text{ (AESC) [7].}$$

Where i = 5% & n = 40 years therefore calculating, we have ((E)) = **88.70, 110.66, and (-) 79.77** million rupees for three different phases of 11 kV feeder. It is seen from calculation that around Rs. 10 Crore is saved from entire service life of substation by using shunt capacitor bank. Also, it is seen that device used in the substation have low power rating because of lower value of current. One another benefit of usingshunt capacitor bank is extra current which is lost without using of capacitor, can be used to provide the electricity to another consumer [31].

TABLE II: Power Saving of Distribution Feeder in Million Rupees (discounted)

11 kV Feeder	Power Saving in Million Rupees ((E))
Phase 1	88.70
Phase 2	110.66
Phase 3 (Without Shunt Compensation)	(-) 79.77

CONCLUSION

In this paper shunt capacitors are connected to prevent low power factor during peak load conditions. The capacitors Banks are typically exchanged during top power stream periods and decrease the consistent power move ability to the line during this period. High velocity mechanical switches equipped for interfacing the capacitor banks to the organization are accessible for administrator coordinated consistent state voltage control. The decrease in max load during Peak loading period suggests limit discharge on the organization, this implies extra income for the service organization and more homes will be furnished with power. Besides the evacuation of the running expense of these generators from the creation line of the enterprises will decrease the creation cost of the merchandise delivered; the resultant impact will be a decrease in the creation cost of such products, and the duplicating impact on the decreases of cost of labor and products given by such ventures. It is seen from estimation that around Rs. 10 Crore (present worth) is saved from whole help lifeof substation by utilizing shunt capacitor bank. This is huge measure of saving, use of Decision- M a k i n g hypothesis unmistakably demonstrate association of shunt capacitor bank to substation where power factor is low because of quality of inductive load. Another part of consideration of shunt capacitor is decrease of weight on the devices of substation.

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