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RESEARCH ARTICLE

MODELING AND ANALYSIS OF LOCATION AND SIZE OF CAPACITOR BANKS INSTALLED AT 132 KV GRID STATION QASIMABAD HYDERABAD, PAKISTAN

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ABSTRACT

In this paper the modeling and analysis of suitable locationand size of capacitor banks installed at 11 kV bus of 132 kV grid station have been carried out with an objective of improving the voltage profile and power loss reduction. At present capacitor bank of full size, i-e 1.21 Mvar is installed at 11 kV bus at grid station. The aim of this paper is to present small sized capacitor banks that would be installed at different feeders instead of one large size capacitor bank at 11 kV bus. The effects of large bank on 11 kV bus and small size capacitor banks at different feeders on the voltage profile of consumer and supply side are simulated through MATLAB Simulink Laboratory..

INTRODUCTION

For improving the voltage profile, power factor and reducing line power loss, capacitor banks are invariably installed at the substations, where they provide reactive power compensation. The major issue in the power distribution network is the voltage drop which is due to heavy reactive loads on the systems, rapid growth of load on the distribution network and geographic spread of distribution system [1, 2]

However if a big size capacitor bank configuration is chosen which is to be installed at 11 kV bus from where number of feeders are taken out, then if it fails then regulation for all the feeders would be out. So the provision is to choose the small sized capacitor banks, to be installed on individual feeders, whose size depends upon the reactive power demand on each feeder [3, 4]. With this arrangement not only high availability of capacitor banks can be achieved means if any of capacitor bank on any feeder fails then it would not affect the regulation of others but also correct regulation on each feeder be obtained [4.5]. Although the cost of replacing large size capacitor bank installed at 11 kV bus by small sized capacitor banks installed at individual feeders is more which is actually one disadvantage but the transient produced by small sized capacitor banks are less than that of large sized capacitor banks, so the power loss contributed by these small sized capacitor banks is also low and also mainly the correct voltage regulation is achieved by means of these smaller capacitor banks, so the money saved on these losses by small sized capacitor banks is approximately same as cumulative extra cost invested on these small sized capacitor banks [6,7]

Since most of the research has been carried to place the capacitor banks in the balanced distribution and utilization networks where the currents flowing through all the phases are equal so analysis can be done on the single phase basis [8]. The difficulty arises while placing capacitor bank in the unbalanced distribution and utilization networks because the currents flowing through all the phases are unequal and zero sequence components currents cause large distortions [9].

The techniques used to solve the problem of placing the capacitor banks in unbalanced network include the proper location of capacitor bank [10], power loss reduction by means of installing proper sized capacitor banks, by installing new feeders and balancing load among the feeders [11, 12].

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In this paper we have presented through analysis that if the location of capacitor is changed from bus with large capacitor bank to individual feeders with small sized capacitor banks then either the voltage profile of system is maintained or not. And also it has been analyzed that whether the system is balanced or unbalanced it would not affect the system regulation if individual small banks are being installed at different feeders. All the consequences are presented through MATLAB simulink Models

Network Representation

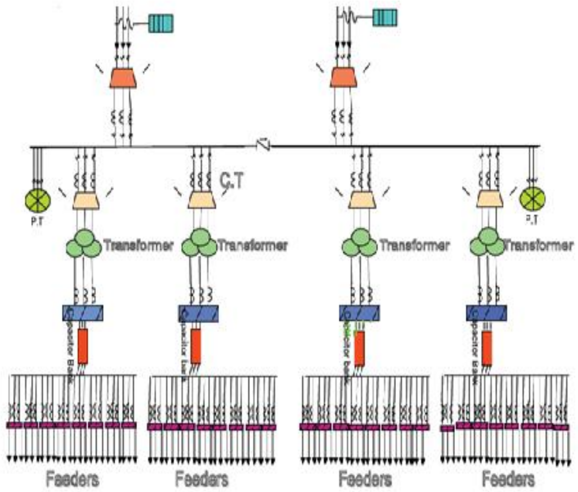

Fig 1 Graphical representation of 132 kV grid station Qasimabad, Hyderabad

Fig.01 represents the 132kV network of Qasimabad grid station Hyderabad which is consisting of two 132 kV lines, one coming from Halla and other from Jamshoro. The 132 kV voltages is stepped down to 11 kVvoltages atgrid station by means of Transformers and then distributed to Hyderabad cities through 25 feeders. When there is heavy load on feeders then a considerable drop of voltage is observed For improving the voltage of system Capacitor banks are installed at the buses before the feeders as shown in Fig.1.

Simulink Representation of System

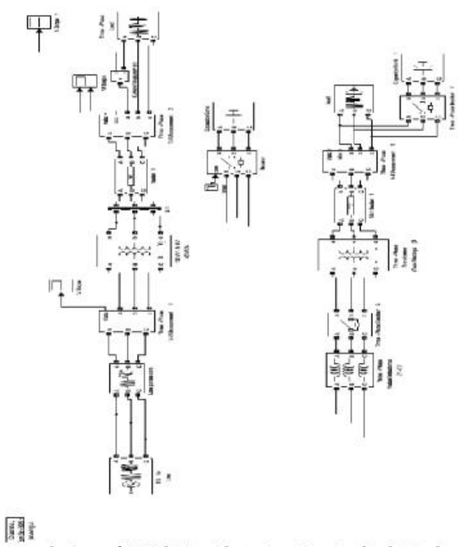

Fig.2 Simulation of 132 kV grid station Qasimabad, Hyderabad

Fig.2 represents the simulink model of 132 kV grid station Qasimabad Hyderabad. The system was simulated with load of 10 MVA at a 0.87 lagging power factor. These values were included in our MATLAB/SIMULINK model along with line inductances, capacitances, and resistances. The most important components connected to the buses at the grid station were the fixed capacitor banks of 1.21 Mvar

Location of Capacitor bank

The capacitors banks are normally installed at the buses on the grid station because thenumbers of feeders which carry the actual load are connected to buses. If we install a large capacitor bank at the bus to improve voltage profile then the feeders which have normal rated loads will get shoot up in voltage and may cause damage to equipments. Capacitors are designed for largest length of feeders to maintain voltage at the far end of feeder. Since the reactive power supplied by the capacitor is proportional to square of its voltage [11]. When the system voltage is down then reactive power supplied by capacitor will also down and it is not useful because whenwe need reactive power then it is not being supplied by the capacitor bank. It is convenient to install a separate capacitor bank of small size at each feeder, so that voltage profile is corrected to the condition of that feeder and unnecessary drop be avoided. With this configuration the reliability system increases because if any one bank is out of order then will have no influence of it.

Since the reactive power supplied by the capacitor is proportional to square of its voltage [11]. When the system voltage is down then reactive power supplied by capacitor will also down and it is not useful because when we need reactive power then it is not being supplied by the capacitor bank. It is convenient to install a separate capacitor bank of small size at each feeder, so that voltage profile is corrected to the condition of that feeder and unnecessary drop be avoided. With this configuration the reliability system increases because if any one bank is out of order then will have no influence of it.

Base Case

Initially when no capacitor bank is connected in the system at 132 kV grid station Qasimabad Hyderabad then system voltage is dropped below the reference voltage i-e 11 kV to 10 kV due to reactive power requirement as shown in Fig.3

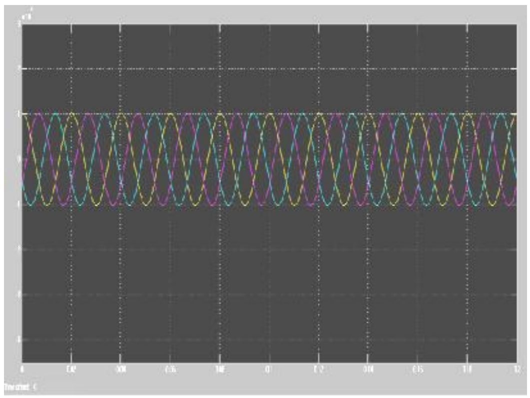

Fig.3 Voltage at Distribution network whenno Capacitor bank in service

Large Capacitor Bank in Service at Bus

When the capacitor banks of 1.21 Mvar are connected to 11 kV buses before the feeders due to which voltage has increased from 10 kV to 11.5 kV as shown on Fig.4. Since if any bank is out of order then, all the feeders connected to bus would not get voltage regulation. Since the reactive power supplied by capacitor bank is proportional to square of its voltage, so if bus voltage dips below natural line then power supplied by capacitor banks would also reduced when it is needed the most.

So we should install individual small sized capacitor banks on each individual feeders according to their own reactive power demands because load on all the feeders is not same, so different voltage regulation would be needed there.

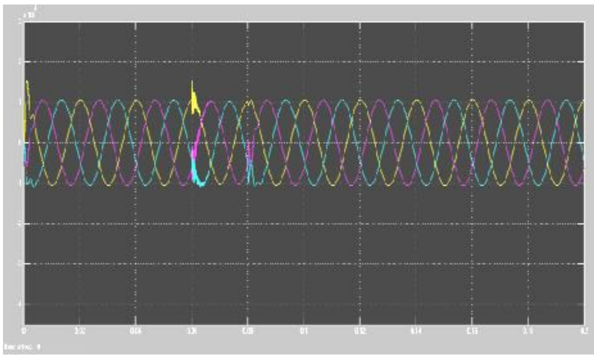

Fig.4 Voltage at Distribution network when Capacitors bank is in service

Small Capacitor Bank in service at feeder

since,
S_{Load}=3 MVA
$p.f_{load} = 0.87$
$p.f_{required} = 0.953$
$Q_{bank}= S_{load}(p.f_{required}- p.f_{load})$
$Q_{bank}= 3000\ (0.953-0.87)$
$Q_{bank}= 250$ kVAr

When capacitor bank of 250 kVAr is connected across thesachal feeder installed at 132 kV grid station Qasimabad, as in Fig.5 having load of 3MVA at power factor of 0.87 then voltage improves to exactly 11 *kV* and power factor would be corrected to 0.953 as shown in Fig.6.

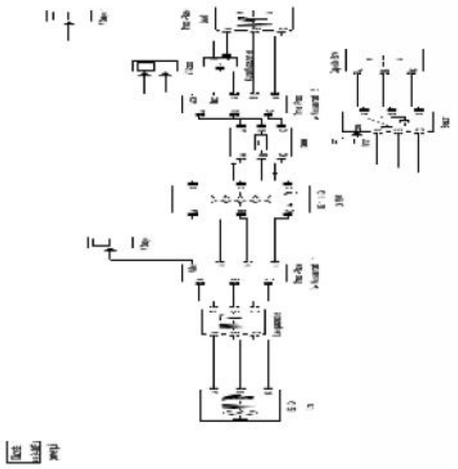

Fig.5 Simulation of 11 kV feeder of 132 kV grid station Qasimabad, Hyderabad

With this arrangementhigh availability of capacitor banks is achieved. If capacitor bank of any of the feeder got failed then it would not affect the service of other banks and hence voltage profile of other feeders circuits is maintained. Also with this arrangement only the voltage of that feeder be reduced which is heavily loaded and reactive power shortage would only occur in that section.

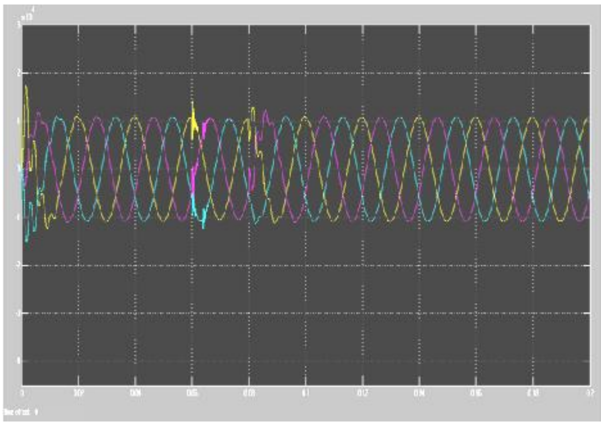

Fig.6 Voltage at Distribution network when small Capacitor banks are in service

Size of Capacitor bank [11]

A capacitor bank is grouping of several identical capacitors interconnected in parallel or in series with one another. These groups of capacitors are typically used to correct or counteract undesirable characteristics such as power factor lag or phase shifts inherent in alternating current (AC) in power supplies. It is installed in the grid station to improve power factor. With the improvement of power factor line current decreases hence line losses and voltage drop decreases and the system voltage improves automatically.

This gives boost to the efficiency of electrical equipment. There are four shunt capacitor banks (SCB) installed in grid station connected to each transformer. Each capacitor unit is rated at 1.21 Mvar. They are commonly used on the distribution networks to provide reactive power compensation which improves voltage profile, reduces line losses and provides power factor correction. With their the power transmitting capability of transmission is increased because their provide reactive at the user terminals where it is required, so no need to draw it from generators through the transmission line and the transmission line is mainly utilized for active power transfer. There use is extensively increased because they are cheap and flexible in installation and control anywhere in the network.

Simulinks with Full Capacitor Banks in Service

When the full sized capacitor banks i- e, 1.21 MVAr are installed at the 11 kV bus then with this large bank installed the voltage is shooted up to 11.5 kV which is favorable with +10% voltage regulation but it is not our requirement from economy, our requirement is that system voltage be maintained constant at 11 kV. So by reducing some of the size of Capacitor bank installed at 11 kV bus our requirement of maintaining 11 kV can be met with – 10 % voltage regulation as simulated in Fig.7

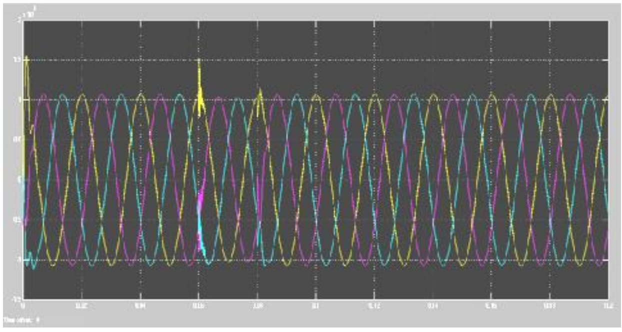

Fig.7 Voltage at Distribution network when Full Capacitor banks are in service

With this reduction of size of capacitor bank, a certain amount of money would be saved on each capacitor bank.

Simulinks when Capacitor bank of 1.21 MVA in service at 7 Km feeder

Since according to equation [12]

$$\text{Location} = \frac{2}{(2n+1)} * L$$

Since at 132 kV 1.21 MVAr capacitor banks are designed to be located at 5 Km distance, the maximum length of feeder would be;
5 = 2/ 2+1 * L
L= 7.5 Km

Table1 Different companies capacitor banks with their size and price

S.no	Name of brand	Rated voltage	Rated kvar	Price
1	TK	11kV	1.21 MVAR	US$ 4000/UNIT
2	Daelim	11kv	1.11 kVAR	US 7200/UNIT
3	High voltage shunt capacitor	1 kV~20kV	50 - 800 kVAR	US $ 5000-1800000/UNIT
4	HOMOR	11kV	100 – 10,000 kVAR	US$900/ UNIT
5	ZHIYUE	11kV	30 – 334 kVAR	US$50-450/UNIT
6	JCKN	11KV	250 kVAR	US $100-1000/ UNIT
7	ONLYSTAR	6.3 – 12 kV	50 – 500 kVAR	US $200-2000/ UNIT
8	WIRUN	300 V – 12000 V	100 – 500 kVAR	US $ 20-1500/ UNIT

Since the standard length of feeders is 5-8 Km andthe feeders installed at 132 kV grid station Qasimabad Hyderabad are not homogenous in the length i-e some are 6 Km and some are 7 Km. now by making the lengths of all feeders 7 Km then it is observed that system voltage is maintained at 11 kV approximately as simulated in Fig.09

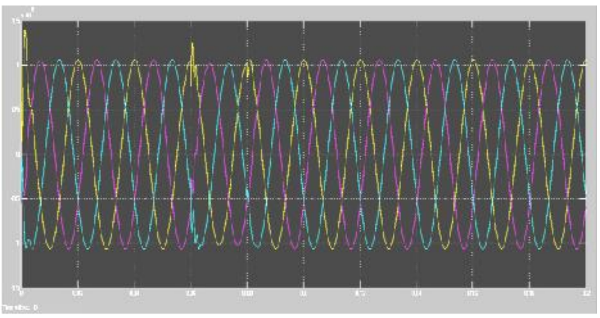

Fig.9 Voltage at Distribution network when Capacitor bank of 1.21 MVA is in service at 8 Km

Since from our above analysis it is proved that we can replace large sized capacitor bank installed at 11 kV bus of 132 kV grid station Qasimabad Hyderabad at Rs. US $ 8000/unit, by small sized capacitor banks installed at individual feeders with approximately same price as whole of Rs. US $ 900/unit and same performance. Yes the some what cost is high, like for six different feeders on single bus the cumulative cost of all small sized capacitor banks would be

Cost= 900 * 6= $5400

Which is greater than $4000 for single 1.21MVar. Since the price of replacing banks for small sized capacitor is surely greater but the amount of money saved on loss reduction is much more than to it, because this replacement expenditure is just for once, then after saving would be for whole life of capacitor banks. The biggest advantage is that high availability of capacitor bank can be achieved with this arrangement

CONCLUSION

It has been analyzed and calculated that the feeders installed at 132kV grid station are non-homogenous in lengths, but are of varying lengths i-e some are of 6 Km and some are of 7Km. By equalizing the feeders lengths' to 7Km for all, still the same voltage regulation can be obtained even at end user and with this increased length of feeders more consumers can be supplied with same feeders instead of installing new feeders, which also reduces complexity and meets the economy. Also it has been analyzed that capacitor banks of size 1.21 Mvar installed at 11 kV bus of 132 kV grid station Qasimabad Hyderabad can be replaced with small size of about 250 kVar calculated according to feeder load, which is different for different feeders, that is to be installed at individual feeders, so that regulation characteristics on each individual feeders can be obtained correctly according to its reactive power demand and also need of high availability of capacitor banks can be met during the peak load hours..

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