Advantage of DG for improving voltage profile over facts devices

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Abstract :
These days DG(Distribution Generation) is going to be a credible alternative generation paradigm by overcoming significant economic, regulatory, technical and environmental hindrance. DG has unique advantages in supporting the power system reducing energy consumption, using new energy, enhancing reliability and flexibility. In this paper the advantages of DG for improving voltage profile and reliability of a system through a load flow based approach is discussed with Etap. Further it is compared to two other voltage profile improvement methods - Static Var Compensator and Fixed capacitor. In this paper two radial test distribution systems are considered with active load of 3.715 MW and 2.57 MW. The circuit is simulated with Etap 7.0 software by placing DG, Static Var Compensator(SVC) and Fixed Capacitor(FC) separately. The result with DG gives the pleasing improvement of voltage profile and reliability of the system.

Keywords : Distributed Generations, Static Var Compensator, Fixed Capacitor, Reactive Power compensation, ETAP software.

1.Introduction :

Distributed Generation(DG) occurs when power is generated locally and sometimes might be shared with or sold to neighbors(industry or residential) through the electrical grid. DG technology involves photovoltaic cell, fuel cell, micro turbine, wind turbine, combustion turbine etc. The advances in Distributed Generation have opened new dimensions in the field of distribution system modeling. The world is moving towards green energy and highly reliable systems. Obviously systems would have low maintenance cost. Hence DG is the best solution for this purpose. There will be substantial increase in Distribution Generation connected to distribution system utility over the next decade. According to Thomas, et al the distribution generations can be divided into four main categories[1]-

1. Micro DG(1 W to 5 KW)
2. Small DG(5 KW to 5 MW)
3. Medium DG(5MW to 50 MW)
4. Large DG(50 MW to 300 MW)

Many researches are going on DG placement and to determine the actual size of DG for the minimization of loss and to increase system reliability[2]. Some authors have also discussed about some good voltage control strategies[3,4,5]. Some combined process is also there[6,7] where DG and other element like SVC or Distribution-Facts are also applied, but here in this paper the approach is moved to Distribution Generation(DG) only, how using DG only a system can be elevated.
Now the contribution of FACTS is also irrefutable in the field of active and reactive power compensation. Here we are considering the SVC and FC, to see the effect of those on the line. SVC rapidly and continuously can compensate the reactive power, so increases power factor and hence improves the power quality. Fixed capacitorscan be connected to the line either in series or in parallel, but parallel connection is preferred because at any short circuit condition the series capacitors have to withstand a very high current and secondly resonance may occur in the circuit that will lead to very low impedance and very high current through the lines. Fixed Capacitors(FC) are also well known as the good absorber of leading vars(and thus generating lagging vars).

2. Why we prefer DG ?

Literature says the voltage profile of a Distribution Network with Distribution Generation depends on injected active and reactive power by the DG(or DGs) and the loads. It is seen that line losses increase if DG is not placed in the exact placed. The place where DG to be placed is may be of source side, midpoint of transmission line or at the customer meter side, but due to the following reasons if we place a DG at the midpoint of transmission line or at the customer side that will be more helpful.

(a) DG can continuously supply power at the time of power Islanding[8].
(b) DG can reduce the total network losses[9].
(c) It canimprove the system's voltage profile[9,10,].
(d) The current carrying capacity of the conductor also increase as these are placed near to the load[11].

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(e) For selling ancillary services(reactive power, stand by capacity) to the grid.

3. Compensation with SVC :

The SVC's are mainly two types- Fixed Capacitor Thyristor Controlled Reactors(FCTCR) and Thyristor Switched Capacitor Thyristor Controlled Reactors(TSCTCR). The SVCs are constructed with capacitor bank/filter banks and air core reactors connected in parallel. The air core reactors connected in series with the thyristors. In Fig. 1(a) basic structure of FCTCR is shown, where TS is the thyristor switch and "C" is the capacitor.

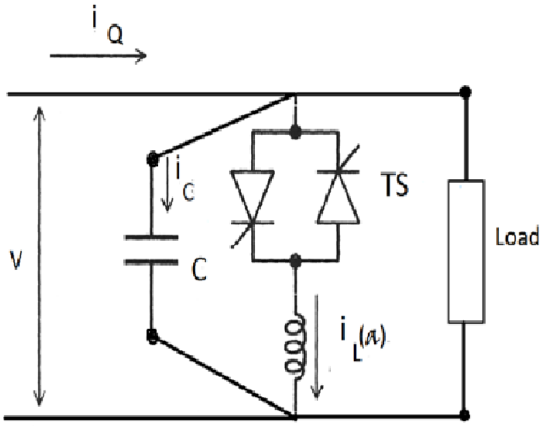

Fig.1(a) Fixed Capacitor Thyristor Controlled Reactors

The reactor is varied by controlling the firing angle of thyristor. The control mechanism of TSCTCR is almost similar to FCTCR, the only difference is that here capacitor is also controlled by Thyristor switches, Fig. 1(b) shows the basic diagram of TSCTCR. Both the SVCs are useful according to situations[12].

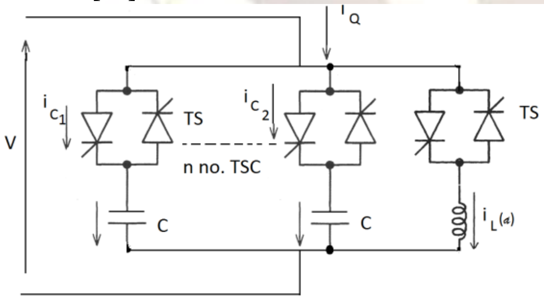

Fig.1(b) Thyristor Switched Capacitor Thyristor Controlled Reactors

5.Compensation With Fixed Capacitor :

As stated in art 1 that parallel connection is preferred when compensating with fixed capacitor, the typical diagram we can see in Fig. 2. Here saturated reactor is used that is basically a iron cored reactor, it does not need any control and automatically adjust its loading to that required by the system.

If active power transfer of a line, $P = \frac{EV}{X_L}\sin\delta$; Where E sending end voltage and V receiving end voltage.

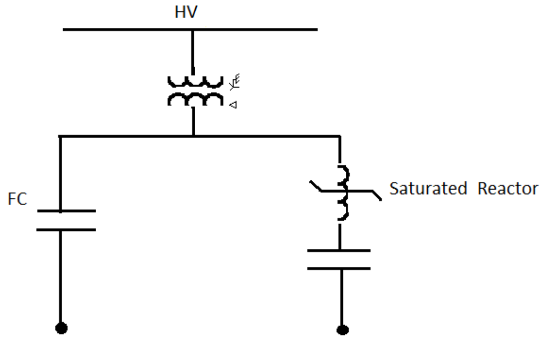

Fig. 2 Compensation with power capacitor

Then reactive power $Q = \frac{EV}{X}\cos\delta - \frac{V^2}{X} + V^2\omega C$, where $V^2\omega C$ is charging power.

Now if we search for the solution of the above two equations approach

Then,J=

$$\begin{bmatrix} EV\cos\delta & E\sin\delta \\ -EV\sin\delta & -2V + E\cos\delta + 2VX\omega C \end{bmatrix}$$

After solving the above equation the voltage value we get is

$V_{Critical} = \frac{E}{2\cos\delta(1-X\omega C)}$; So it is clear from the above discussion that injection of charging power(shunt capacitor) in the system improves the voltage profile and also improves the power factor.

6. The effect of DG, SVC and FC on the line :

6.1 Problem Formulation :

If a basic electrical distribution system is considered like Fig. 3 , the total power(P_T) generated will be

$P_T = P_G + P_{DG}$

Power demand $P_D = P_T - P_{Loss}$;

and $P_T = P_G + P_{DG}$,So we can write

$P_D = P_G + P_{DG} - P_{Loss}$;

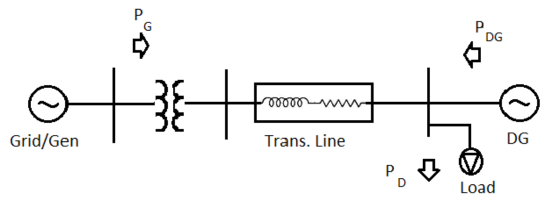

Fig.3 Basic electrical distribution with DG

Now if it is considered that some fixed loading condition(at a certain time) then the power demand is also a constant value and that is equal to power generated by generator(or grid) and DG. If line loss is reduced there will be increase in demand power, because power generated by generator(or grid) can't be increased, so by any means loss has to minimized. In this paper the approach is taken through DG and Facts.

6.2 Case study :

Here the method described is applied to a 33 bus, 32 branches and 32 load(static) radial distribution system[13]. The described system has active load of the 3.715 MW and reactive load of 2.3 MVar. Another test system of 85 buses with active and reactive power load of 2.57 MW and 2.622 MVar[15]. Both the circuits are simulated with ETAP 7.0 software through load flow approach(NR method). Four cases have been considered where system is without DG , with SVC , with FC and after placing the DG respectively.

6.3 Result and Analysis :

The power output of the DG is taken as 1 MW and placed in the system as [9]. Fig. 4 shows how the voltage(%) is varying bus to bus.

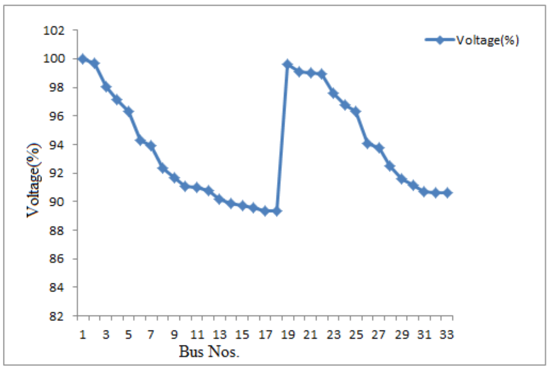

Fig. 4 Voltage magnitude at different buses

At buses 14,15,16,17,18 the magnitude of the voltage is too low(10% less than normal value). Next step is to place the SVC. As per[12] the best place for Facts to place in the system is mid-point for transmission line and at the load end for the radial distribution system. So SVC is connected to bus 18.

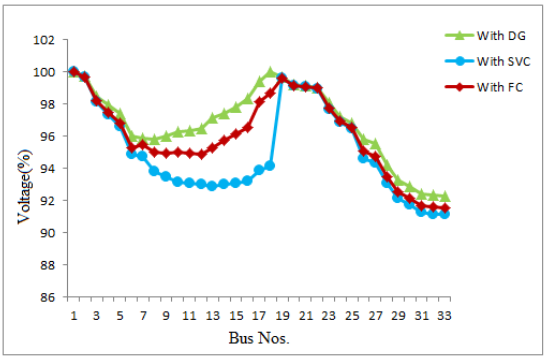

Fig. 5 System voltage with DG , SVC , FC

The voltage magnitude(Fig. 5) change in 14,15,16 buses are really to notice(3-4%) , but still violating the limit. Fig. 5 also shows the effect of fixed capacitor on the system. The rating of fixed capacitor is taken as 2/3rd rule[14]. It is slightly better than SVC , but the result is far better with DG(placed at bus 18).

For 85 bus system the DG size is taken as 2 MW and placed at bus no 51. Fig. 6 shows the voltage profile of the system.

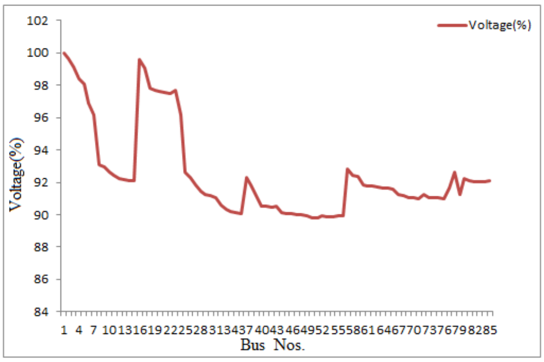

Fig. 6 Voltage magnitude at different buses

Bus nos. 51,52,53,54 are having voltage less than 0.8 pu. Now as [9] the DG is placed at bus no 51 , SVC and FC are also placed(as [12]). Fig. 7 shows the comparison between DG and FACTs. It is clear from Fig. 7 that DG alone can take care of voltage profile of the system and system is quite voltage stable other than systems with FACTs.

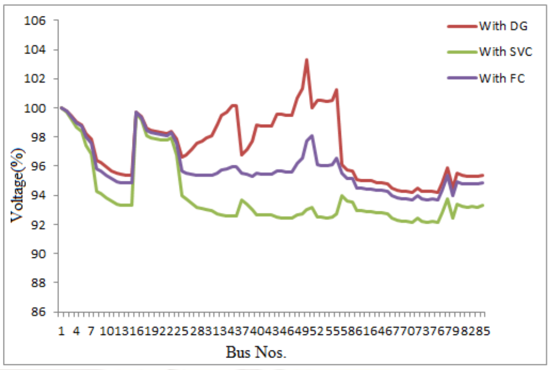

Fig.7 System voltage with DG , SVC , FC

7. Conclusion :

The comparison of using the DG, SVC and FC in the same system shows that in case of compensation or loss reduction of the system the choice of DG is better than the others, DG corrects the voltage profile, minimizes the losses, improves power quality and also increases the reliability. This approach also solves the problem of DG allocation to some extent. Small overview regarding Facts helps to understand the basic difference between DG, SVC and FC. Study says placement of SVC and FC can also save the system from huge losses and can be used according to system requirement.

In practice this may not be possible to arrange a DG at the weakest bus always due to some unavoidable circumstances, but this approach suggest how to take care of the losses arising in the system. This type of DG connection will be no-doubt helpful in Need Base Energy Management(NBEM) systems also.

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