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Voltage stability enhancement by VAR management using SVC and STATCOM

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Abstract:- **Transmission lines need to be optimally utilised in order to have maximum utilisation of the installed transmission network. This results in heavily loaded lines whose operations are governed by thermal limits and voltage stability limits in case of long lines. The voltages are to be maintained within the acceptable limits in order to have a voltage stable power system. There are various methods of enhancing the voltage stability by VAR management. FACTS controllers proved to be quite helpful in enhancing the voltage stability margin of the entire system. In this paper the Voltage stability margin enhancement using SVC and STATCOM are investigated on an IEEE 14 bus system.**

Keywords*:- Voltage stability, load ability, voltage stability margin, PSAT,FACTS, SVC, STATCOM.*

Introduction:-

Transmission lines in a power system are loaded more heavily than ever before to avoid the capital cost of building new lines. For a short line, the loading capability may be restricted by thermal limit. However, for a long line, the loading capability may be dictated by the voltage stability rather than the thermal or transient stability limit. When a power system approaches the voltage stability limit, the voltage of some buses reduces rapidly for small increments in load and the controls or operators may not be able to prevent the voltage decay. In some cases the response of controls or operators may aggravate the situation and the ultimate result is voltage collapse.

There are various methods of VAR management techniques which include the reactive power control of synchronous generator, Shunt capacitor and series compensation techniques. FACTS devices also add a new dimension of rapid control and injection of active and reactive power to control the flow of power through the transmission lines. The voltage levels are improved as a result and the voltage stability margin is increased corresponding to given operating point.

Voltage stability

The voltage stability can be defined as the ability of the system to maintain the acceptable voltages at all the buses before and after being subjected to a disturbance [1]. Many times voltage stability is defined by absence of voltage instability. The voltage at any bus of the power system is dependent upon the reactive power injection at that particular bus. The main reason for voltage instability in a power system is inadequate reactive power support at some critical buses. [2].Voltage instability is a reactive power problem. Unlike active power, it is very difficult to estimate the reactive power margin required to achieve a certain degree of voltage security. Therefore the voltage stability margin is defined in terms of distance in MW from the point of collapse and the current operating point.

The voltage collapse analysis methods are classified as dynamic methods, employing nonlinear algebraic and differential equations in the power system model and steady state methods. The steady state methods consist of the load flow or steady state stability methods.[3]. In this paper only steady state analysis method is considered.

The PV curves are useful in determination of the voltage stability margin. The voltage stability margin is measured in terms of MW distance from the current operating point to point of collapse or critical point. The system has different solutions as the system loading is varied. As the loading is increased towards a point of maximum loadability, the numbers of solutions decrease until at some point only a single solution of type one and an operable solution remain. Maximum loadability occurs when these two solution coalesce at a point on the maximum loadability boundary in a saddle node bifurcation. System loadability can be monitored by tracking the distance between the operable solution and this type one solution [4].

The concept of extreme loading condition (XLC) of a power system was also introduced which is significant for the assessment of voltage stability. It relates the critical loading condition of the power system after which the system collapses. A method of calculation of XLC includes the increment in the load pattern in both the active and reactive powers such that a maximum is reached for any one of the loads. The method for the calculation for XLC based on increasing the load admittances keeping the generator voltage phasors constant and then adjusting these phasors for satisfying operational requirement with respect to the generation powers.[5]

Various indices have also been proposed to indicate the voltage stability margin from the current operating point. This paper utilises the voltage change index to find out weakest bus The voltage change index is derived from the voltage values at the given operating point and the same at the collapse point. This index gives the relative voltage stability such that the value of index near one indicates that the bus under consideration is the weakest bus[6].

Various researchers have suggested different methods like using shunt capacitors etc. A. Edris presented the effects of FACTS controllers like STATCOM, UPFC and CSC on the transmission line power transfer capability. [6].The present paper discusses the effect of VAR management technique using FACTS controllers. The SVC and STATCOM are used on the standard IEEE 14 bus system for the purpose of study.

The voltage change indicator is given by

$$VCI = (V_{init} - V_{lim})/V_{lim} \quad (1)$$

More the value of VCI is near to unity more the voltage unstable the bus is. V_{lim} is the voltage at the selected bus at the point of collapse and V_{init} is the bus voltage at the base load condition.[5]

A new indicator is proposed which is derived from VCI and can be used to indicate the voltage stability margin, it is given by

$$VCPI_{ch} = 1 - [(V_{init} - V_{lim})/V_{lim}] \quad (2)$$

The various values of $VCPI_{ch}$ without and with FACTS devices are investigated in this paper.

Methodology

The model of IEEE 14 bus system is made using power system analysis toolbox known as PSAT.[7] The model is solved by using continuous power flow method to produce the power flow solutions at different loadings. The weakest bus is identified using the voltage change indicator. The SVC and STATCOM are used to improve the voltage stability.[8]. These controllers are fixed at various load buses and the results are obtained in terms of the maximum loading parameter λ. The PSAT model with SVC fixed at bus no.9 is shown in Fig.1.

The voltage stability margin is also calculated using an indicator derived from voltage change indicators. The results for various locations of the devices are tabulated in table 2. to indicate the proximity from the voltage collapse point. The PV curves are also drawn with and without loading conditions

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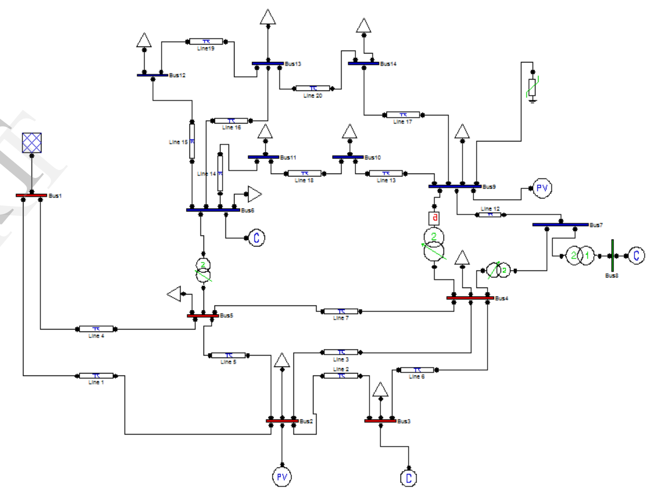

Fig.1 PSAT Model for IEEE 14 Bus system with SVC at Bus no.9

The standard IEEE 14bus model was selected for the purpose of analysis. The basic and other models were developed using PSAT toolbox with SVC and STATCOM installed at various buses. The continuous power flow method of load flow was used to find out maximum loading conditions. The conditions of maximum loading are measured in the terms of maximum loading parameter λ for all the models. The results obtained are tabulated in Table no.1.

Sr. No	Load bus No.	With SVC	With STATCOM
1	4	2.954286	1.640429
2	5	2.963071	1.749
3	7	2.969929	2.651571
4	9	3.034	2.486286
5	10	2.948714	2.748929
6	11	2.8635	2.866714
7	12	2.823929	2.824357
8	13	2.844	2.846214
9	14	2.901714	2.8908

Table 1. Loading Parameter λ with SVC and STATCOM

Sr. No.	Load bus No.	$VCPI_{ch}$ at Base Load	$VCPI_{ch}$ with SVC at Bus No. 9	$VCPI_{ch}$ with STATCOM at Bus No.14	$VCPI_{ch}$ with SVC at bus No.9 and STATCOM at Bus No.14
1	4	0.43984	0.52586	0.614631	0.457215
2	5	0.38513	0.45964	0.585509	0.367424
3	7	0.60837	0.8185	0.770798	0.815316
4	9	0.41301	0.85896	0.717682	0.875948
5	10	0.47313	0.8438	0.724314	0.858681
6	11	0.76289	0.90845	0.856969	0.915339
7	12	0.90137	0.92336	0.944685	0.943435
8	13	0.83901	0.89032	0.927734	0.9293
9	14	0.38714	0.74646	0.928818	0.939691

Table 2. Voltage stability margin index with various positioning of FACTS controllers

The voltages at various buses at the collapse conditions are recorded for all the models. This data was used to calculate the voltage stability margin index $VCPI_{ch}$ which is proposed here in this paper. The results are tabulated in table no. 2.

The different cases with the locations of FACTS controllers where the condition of the maximum value of loadability parameter are achieved are presented below.

1. **Case I: Conditions of Base Load without any FACT device**:- The Standard IEEE bus system is tested for maximum value of loadability conditions which is expressed in terms of loading parameter lambda. The system is loaded in such a way that all the buses are simultaneously loaded with incremental loads. The maximum value of the parameter recorded is λ=2.8327 pu.

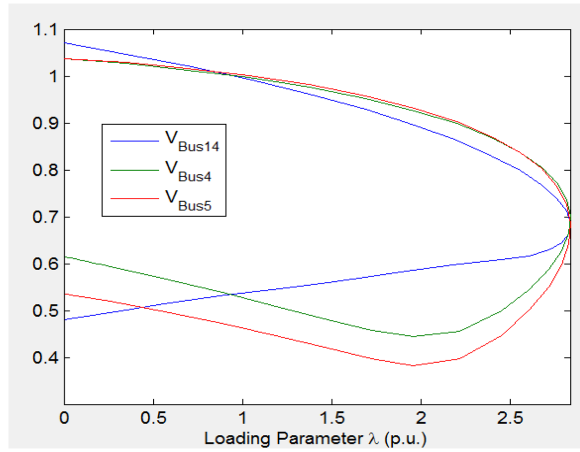

Fig. 2. PV curves for IEEE 14 Bus system without FACTS controllers

2. **Case II- With STATCOM at bus 14** The effects of FACTS devices to improve the loadability margin is analysed here with STATCOM fixed at various buses. It has been observed that the maximum value of loading parameter λ is increased to 2.8907 when STATCOM is placed at Bus No14.As a result of which the voltages of bus no. 14 have improved.

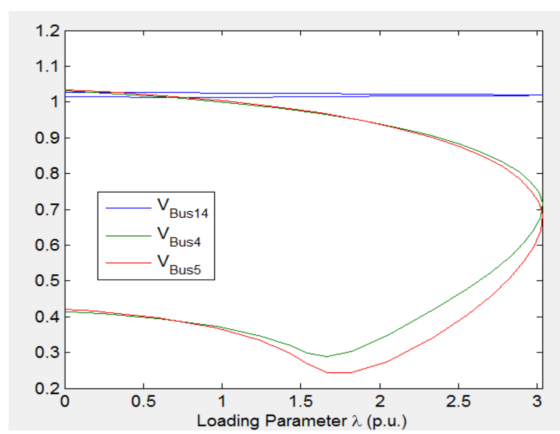

Fig. 3. PV curves for IEEE 14 Bus system with STATCOM at Bus no. 14

3. **Case III**: **With SVC at bus no.9**:- The effects of FACTS devices to improve the loadability margin is analysed here with SVC fixed at various buses. It has been observed that the maximum value of loading parameter λ is increased to 3.0346 when SVC is placed at Bus No. 9.As a result of which the voltages of bus no. 14 have improved.

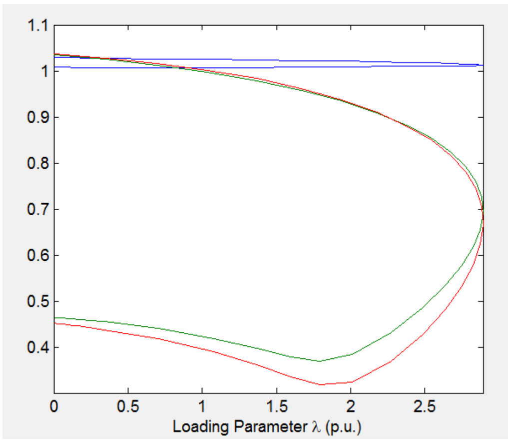

Fig. 4. PV curves for IEEE 14 Bus system with SVC at Bus no. 9.

4. **Case IV:-With Both STATCOM at bus 14 and SVC at bus 9.** The last case for study here is with STATCOM fixed at Bus 14 and SVC is fixed at Bus 9. This is considered to analyse the combined effect of STATCOM and SVC both. It is observed that the value of the loading parameter is increased to 3.0324.

The results shown considerable improvement in voltage levels and hence the loading conditions are achieved with improved voltage stability margin.

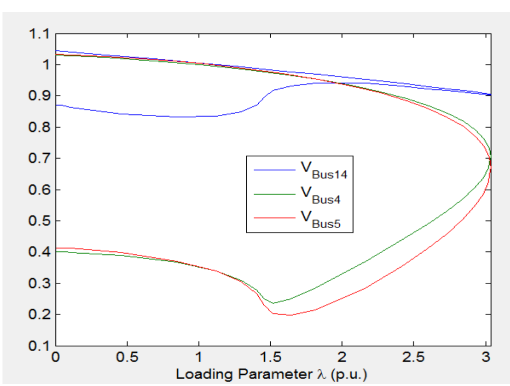

Fig. 5. PV curves for IEEE 14 Bus system with STATCOM at bus 14 and SVC at Bus no. 9.

Conclusion:-

It is observed that for IEEE bus no. 14 there is a considerable improvement of the voltage stability margin with FACTS devices like SVC and STATCOM fixed at various buses. It is also observed that the STATCOM fives the best results when fixed at bus no. 14 where as the SVC gives best results when fixed at bus no. 9. As an additional analysis the models with both the SVC and STATCOM placed together at bus no. 9 and STATCOM at bus no.14 was done. The results are also shown in terms of loading parameters and voltage stability margin index are also shown. The PV curves for the weakest bus no.14 and the next weakest buses are shown in case of maximum possible loading conditions which occurred in case of SVC at Bus no. 9 and STATCOM at bus no.14 separately and then taken together. When both devices are used the much improvement is not seen. Taking the costing effects in consideration the best approach is to use an SVC at bus no. 9. The above analysis only considers the static approach the results may vary if the dynamic effects are taken into consideration.

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