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Influence of Static Var Compensator for Undervoltage Load Shedding To Avoid Voltage Instability

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ABSTRACT

In the recent years, operation of power systems at lower stability margins has increased the importance of system protection methods that protect the system stability against various disturbances. Among these methods, the load shedding serves as an effective and last-resort tool to prevent system frequency/voltage instability. For major combinational disturbances, the active power deficit is usually accompanied by reactive power deficit. Under frequency load shedding schemes have been widely used, to restore powersystem stability post major disturbances. However, the analysis of recent blackouts suggests that voltage collapse and voltage-related problems are also important concerns in maintaining system stability. For this reason, voltage also needs to be taken into account in load shedding schemes. This paper considers both parameters in designing a load shedding scheme to determine the amount of load to be shed and its appropriate location .The amount of load to be shed from each bus is decided using the fixed step size method and it's location has been identified by using voltage collapse proximity index method. Static VAR Compensator (SVC) is shunt connected FACTS device used to improve the voltage profile of the system. In this paper impact of SVC on load shedding for IEEE 14 bus system has been presented and analyzed.

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1. INTRODUCTION

The requirement for improved efficiency whilst maintaining system security necessitates the development of improved system analysis approaches and the development of advanced emergency control technologies. Load shedding is a type of emergency control that is designed to ensure system stability by curtailing system load to match generation supply. Here a new adaptive load shedding scheme that provides emergency protection against excess voltage decline, whilst minimizing the risk of line overloading. When a sudden loss of generation is occurred, there will be a mismatch between energy supplied and energy demanded which will lead to system frequency drop or voltage drop .If governor action cannot activate the available spinning reserve from generating units quickly enough to restore the system to its normal operating value the system will collapse, which will lead to a large scale loss of load. So, a suitable corrective control action should be applied to restore the system to a new steady-state operating condition .Load shedding is an effective corrective control action in which a part of the system loads are disconnected according to certain priority in order to steer the power system from the existing potential dangers with the least probability of disconnecting the important loads. Load shedding is considered as the last resort tool for use in that extreme situation and usually the less preferred action to be adopted, but in this kind of problem it is vital to prevent the system from collapsing [1]. Therefore, load shedding becomes a common practice for electric utilities proposed load shedding scheme uses the local voltage rate information to adapt the load shedding behaviour to suit the size and location of the experienced disturbance. In a power system disturbance, the deviation of frequency and voltage quantities are related to each other. Hence, it is more logical to consider combinational load shedding methods, which are dependent on both frequency and voltage, instead of designing two independent under-frequency and under-voltage load shed schemes [2]. In proposed combinational methods, load shedding decisions are based on the combination of measured frequency and voltage at relay locations [3]. In these methods, load shedding is selected as a function of the disturbance location, either directly or indirectly. Since the load shedding decision is made locally based on local measured quantities, no communication link is required for implementing these methods. It should be noted that this paper's objective is not focused on selecting the most economical location for load shedding amounts. The objective is to rescue the system during severe combinational events.A power system can experience blackout for various reasonssuch as frequency instability, voltage instability[4].The FACTS device performance depends upon its location and parameter setting.The power electronic based flexible AC transmission systems introduced in 1980's,provided a highly efficient and economical means to control the power transfer in interconnected AC transmission systems.A FACTS device in a power system improves voltage stability,reduces the power losses and also improves the security of the system[5].Flexible AC transmission system is akin to high voltage dc and related thyristors developed designed to overcome the limitations of the present mechanically controlled ac power transmission system.

The SVC is most commonly used FACT devices which is shunt connected providing simultaneous control of voltage magnitude and reactive power flows.StaticVar Compensator (SVC) The SVC uses conventional thyristors to achieve fast control of shunt-connected capacitors and reactors. Among the FACTS devices, the Static VAR compensator is a versatile device that controls the reactive power injection at a bus using power electronic switching components [6]. The reactive source is usually a combination of reactors and capacitors. SVC state variables are combined with the nodal voltage magnitudes and angles of the network in a single frame of reference for unified, iterative solutions using the Newton-Raphson method [7].

In this paper Voltage Collapse Proximity Indicator has been used to identify the best location for load shedding. SVC incorporated in Newton Raphson Power flow to observe the impact of SVC on load shedding. Amount of load to shed at a particular location is based on fixed step size method.This paper proposes a new use of SVC to reduce load shedding. IEEE 14 bus system results are presented and analyzed.

2. VOLTAGE COLLAPSE PROXIMITY INDICATOR FOR OPTIMAL LOCATION FOR LOAD SHEDDING

Here we look at a method based on the sensitivity of the total change in generator reactive power for a change in real power demand at particular bus is one method. It is called voltage collapse proximity indicator (V C P I). The voltage collapse proximity indicator for each load bus, considering reactive power only, is:

$$VCPI_{Pi} = \left(\sum \Delta Q_g\right) / \Delta P_i \qquad (1)$$

Where ΔQg is the change in reactive power output at generators for a change in real load at bus i.

The bus with the highest value of $VCPI_{Pi}$is the most suitable location for Load shedding. In this study 10% of the real load increased in respective load buses and compute the $VCPI_{Pi}$. The Table I indicates the $VCPI_{Pi}$ calculated the bus number and its index for IEEE 14 bus system. From this table it is also observed that the bus no 14 has highest $VCPI_{Pi}$ compared to all other load buses. So the bus no 14 is the most suitable location for Load shedding.

Table I. Weak Buses Ordering In IEEE 14 Bus Systems

Rank	$VCPI_{Pi}$ Bus	Index $VCPI_{Pi}$
1	14	39.2751
2	10	33.5
3	13	33.133
4	9	33.040

5	12	31.786
6	11	31
7	4	24.548
8	5	20.052

3. STATIC VAR COMPENSATOR

Static VAR Compensator (SVC) is a shunt connected FACTS controller used to regulate the voltage at a given bus by modulating its equivalent reactance. SVC normally includes a combination of mechanically controlled and thyristor controlled shunt capacitors and reactors. The most popular configuration for continuously controlled SVC is the combination of fixed capacitor and thyristor controlled reactor. The SVC is taken to be a continuous, variable susceptance, which is adjusted in order to achieve a specified voltage magnitude while satisfying constraint conditions. SVC total susceptance model represents a changing susceptance [8, 9]. The SVC (Static Var Compensator) may have inductive or capacitive, respectively to absorb or provide reactive power. It may take values characterized by the reactive power Q_{svc} injected or absorbed at the voltage of 1 p.u. The variable susceptance model and its equivalent circuit is shown in Fig 1. SVC can be represented as an adjustable reactance [10].

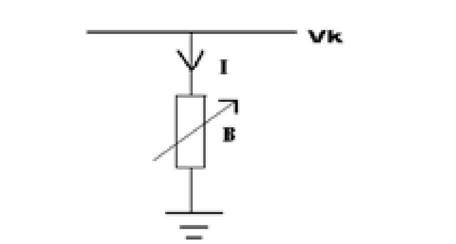

Figure 1. Variable shunt Susceptance

In general, the transfer admittance equation for the variable shunt compensator is

$$I = jBV_k \tag{2}$$

And the reactive power equation is,

$$Q_k = -V_k^2 B \tag{3}$$

The current drawn by the SVC is

$$I_{svc} = jB_{svc}V_k \tag{4}$$

Reactive power drawn by the SVC, which is also reactive power injected at bus k, is

$$Q_{svc} = -V_k^2 B_{SVC} \tag{5}$$

The linearised equation of the SVC is given by the following equation where the total susceptanceBsvc is taken to be the state variable.

$$\begin{bmatrix} \Delta P_k \\ \Delta Q_k \end{bmatrix}^i = \begin{bmatrix} 0 & 0 \\ 0 & Q_k \end{bmatrix}^i \begin{bmatrix} \Delta \theta_k \\ \Delta B_{svc} / B_{svc} \end{bmatrix}^i \qquad (6)$$

At the end of iteration i, the variable shunt susceptanceBsvc updated according to the equation given below;

$$B^{i}{}_{SVC} = B^{(i-1)}{}_{SVC} + \left(\frac{\Delta B_{SVC}}{B_{SVC}} \right)^{i} B^{(i-1)}{}_{SVC} \qquad (7)$$

The changing susceptance represents the total SVC susceptance necessary to maintain the nodal voltage magnitude at the specified value that is 1.0pu.

4. RESULTS AND ANALYSIS

In IEEE 14 bus system bus no 1 is considered as a slack bus and bus no’s 2,3,6,8 are considered as a PV buses all other buses are considered as load buses.This system has 20 interconnected lines. A MATLAB program is coded for the test system and results have been presented and analyzed.Table II represents the voltage profiles without the placement of SVCat 14-bus. Table-III indicates the initial and final losses without SVC and the amount of load to be shed is 0.0840.Table-IV indicates the voltage profiles with the placement of SVC at bus 13. Table-V shows the SVC at different bus locations and the minimum amount of load to be shedded is found at bus no-9. The voltage profiles have been improved and brought in to limits.

Table 2. Comparision of Voltage Profiles Before, After Load Shedding Without SVC

Before Load Shedding		After Load Shedding	
V	VA	V	VA
1.06	0	1.06	0
1.0450	-3.6948	1.0450	-0.0610
1.0100	-9.0156	1.0100	-0.1515
1.0120	-6.3917	1.0142	-0.1044
1.0198	-5.3960	1.0216	-0.0874
1.0	-7.6116	1.0	-0.1156
0.9889	-5.9851	0.9928	-0.0914
1.0	-1.8991	1.0	0.0203
0.9722	-8.3857	0.9794	-0.1296
0.9690	-8.5755	0.9751	-0.1328
0.9805	-8.2361	0.9836	-0.1268
0.9831	-8.5997	0.9861	-0.1315
0.9770	-8.6772	0.9834	-0.1327
0.9548	-9.6838	0.9815	-0.1438

Table 3. Initial and Final Losses With out SVC

Before Load Shedding		After Load Shedding		
Total Real Power Generation	Initial Losses	Total Real Power Generation	Final Losses	Amount of load shed at bus no 14
265.9654	6.9654	256.6988	6.0988	0.0840

Table 4. Comparision of Voltage Profiles before, after load shedding with SVC at Bus No-13

Before Load Shedding		After Load Shedding	
V	VA	V	VA
1.06	0	1.0600	0
1.0450	-3.6955	1.0450	-0.0627
1.0100	-9.0156	1.0100	-0.1543
1.0126	-6.4066	1.0136	-0.1080
1.0202	-5.4020	1.0211	-0.0907
1.00	-7.584	1.000	-0.1235
0.9909	-6.0235	0.9927	-0.0983
1.0	-1.9459	1.0000	-0.0272
0.9763	-8.4213	0.9794	-0.1382
0.9724	-8.6004	0.9750	-0.1413
0.9822	-8.2376	0.9836	-0.1350
0.9956	-8.7763	0.9953	-0.1431
1.00	-9.3408	1.0000	-0.1517
0.9673	-9.9635	0.9793	-0.1602

Table 5. Amount of Load Shedding By Placing SVC at Different Bus Locations

Before Load Shedding			After Load Shedding		
SVC location	Total Real Power Generation	Initial Losses	Total Real Power Generation	Final Losses	Amount of load shed at bus no 14
13	266.0092	7.0092	261.2278	6.5278	0.0430
12	266.0205	7.0205	257.8252	6.2252	0.0740
11	265.9552	6.9552	260.2896	.3896	0.0510
10	265.8758	6.8758	262.8703	6.5703	0.0270
9	265.8120	6.8120	264.7004	6.7004	0.0100
8	265.9654	6.9654	256.6988	6.0988	0.0840

4. CONCLUSION

The load-shedding system has undoubtedly benefited in terms of reliability and minimizing production losses.By finding out the VCPI at each bus location we came to know the suitable location for the load shedding and by placing the static var compensator the voltage profiles have been improved and thereby reducing the real power losses by shedding minimum percentage of loads at that particular bus.The results show that incoperating the svc in the IEEE 14 bus system can reduce the real powerlosses,improves the voltage profiles and enhances the system stability.

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