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Voltage Stability Analysis of a WSCC 9- Bus System using Power World Simulator

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Abstract: Voltage collapse event is identified as complex and localized in nature but its effect is extensive once occurred. The vital effect of voltage collapse would be the total system collapse or blackouts which would cost a large loss to utility companies. The voltage instability may occur either due to overloading of the load buses, sudden generator removal or a sudden loss of a transmission line.

Hence in this work, the effect of such disturbances on a WSCC 9-bus system is observed. The voltages at all the buses are obtained by running the Newton- Raphson (N-R) method.

The corrective measure to improve the voltage profile is done by providing compensation at the weakest bus through a shunt capacitor. The weakest bus is identified using Fast Voltage stability Index (FVSI). The simulation work is performed using Power World Simulator software.

Keywords: WSCC system, FVSI index, N-R method, Power world simulator

I. INTRODUCTION

Present day power systems are being operated closer to their stability limits due to economic and environmental constraints. Maintaining a stable and secure operation of a power system is therefore a very important and challenging issue. Voltage instability has been given much attention by power system researchers and planners in recent years, and is being regarded as one of the major sources of power system insecurity.

Voltage instability occurs when the receiving end voltage reduces below its nominal value due to a disturbance in the system. The time span of a disturbance in a power system, causing a potential voltage instability problem, can be classified into short-term and long-term.

The corresponding voltage stability dynamics is called short term and long-term dynamics respectively [2-5]. Long-term voltage instability may occur due to high power imports from remote generating stations, a sudden large disturbance, or a sudden load build up.

These disturbances if not controlled would lead to voltage collapse in the system. Hence timely application of reactive power compensation or load shedding may prevent this type of voltage instability. In this work the effect of such disturbances on the voltage at each bus of WSCC 9- bus is studied by running the Newton Raphson method of load flow analysis. The compensation is then provided to the weakest bus using a shunt capacitor. To find the weakest bus the voltage stability index called the Fast Voltage stability Index (FVSI) is used.

The simulations is carried our using power world simulator software.

II. FAST VOLTAGE STABILITY INDEX (FVSI)

Fast Voltage Stability Index, FVSI*:* This index is proposed by I. Musirin and it is calculated by [11]:

$$FVSI_{ij} = \frac{4Z^2Q_j}{V_i^2X_{ij}}$$

Z = line impedance

X_{ij}= reactive power at the receiving end

V_i= sending end voltage

The value of FVSI for a line closest to 1.00 will be taken as the most critical line corresponding to a bus that may lead to the whole system instability.

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III. TEST SYSTEM ANALYSIS AND RESULTS

The model of WSCC 9-bus system developed using the power world simulator software is shown in fig 1. The figure gives the details of the voltages and power flows at various buses after running the N-R load flow method.

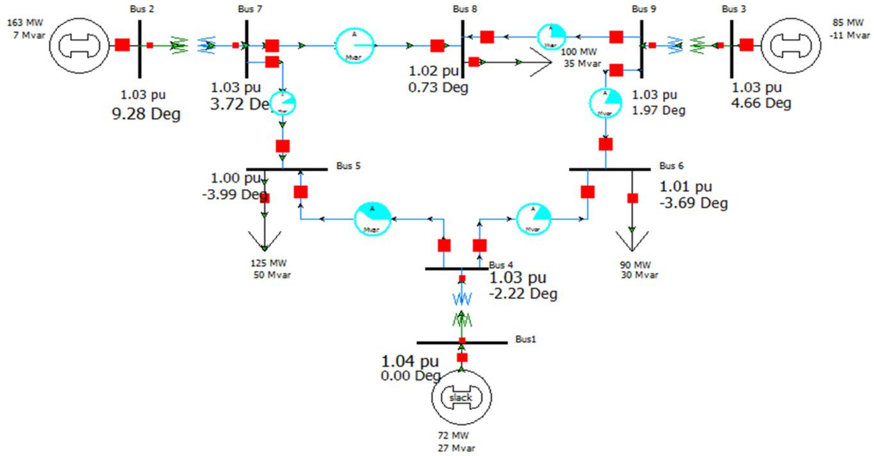

Fig 1: Model of WSCC 9-bus system

IV. SYSTEM UNDER OVER-LOADED CONDITION

All the Load buses are added with additional loads, which caused the system to get overloaded. This resulted in the dip of voltage at the buses which was found after running the load flow. A shunt capacitor was connected at the weakest bus to improve the voltage levels. The weakest bus was found from the results of the voltage stability index which are depicted in fig 2. The weakest bus was found to be bus 5. To decide on the rating of the capacitor, a temporary generator was added at bus 5 and the load flow was run. The reactive power of the temporary generator was the desired value of the capacitor needed. The improved voltage profile of the system after compensation is shown in fig 3.

```
The FVSI value of line 4-5 is    8.3616e-04

The FVSI value of line 4-6 is    6.5573e-04

The FVSI value of line 7-5 is     0.0016

The FVSI value of line 7-8 is    5.6110e-04

The FVSI value of line 9-8 is    7.6392e-04

The FVSI value of line 9-6 is     0.0012
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Fig 2. FVSI Results

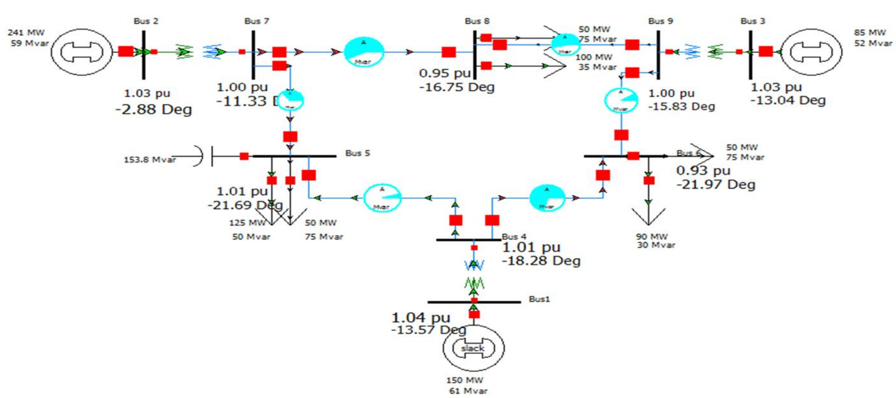

Fig 3 Compensated system for overloaded condition

V. ISOLATION OF A TRANSMISSION LINE

A transmission line will be isolated if either a disturbance like fault occurs on it or for maintenance purpose. With the removal of a transmission line the burden on the other lines increases and also the voltage at various buses gets affected. In the present work, the transmission line connected between buses 4 and 5 was removed and the load flow was run. The voltages across various buses reduced below their nominal value. So, to improve the voltage levels again a shunt capacitor was connected at the weakest bus. To detect the weakest bus the FVSI results were used which are depicted in fig 4. In this case the weakest was found to be bus 5. The system with the improved voltage levels is shown in fig 5.

```
The FVSI value of line 4-5 is    3.9436e-04
The FVSI value of line 4-6 is    1.0605e-04
The FVSI value of line 7-5 is     0.0045
The FVSI value of line 7-8 is    1.5614e-04
The FVSI value of line 9-8 is    2.0244e-04
The FVSI value of line 9-6 is    2.0296e-04
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Fig 4. FVSI Results

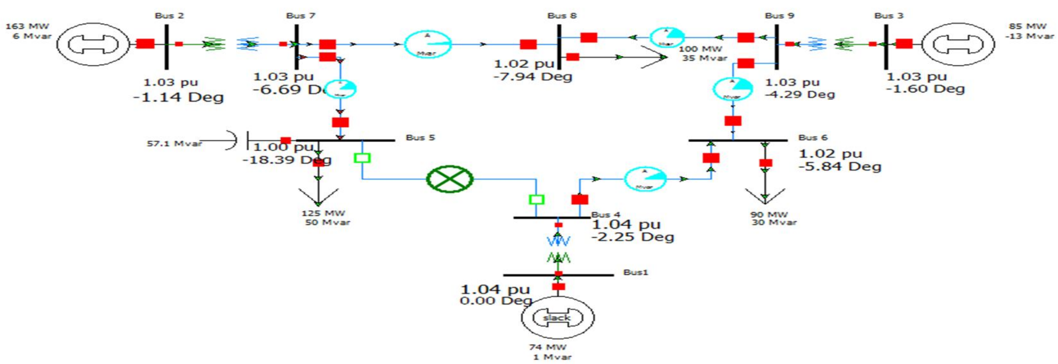

Fig 5. The compensated system post to the transmission line isolation

VI. CONCLUSION

This paper discusses the effect on the voltages at various buses of the WSCC 9-bus system under varying disturbance conditions that lead to voltage instability by running the load flow on the system. The corrective measures in the form of either load shedding or compensation should be provided to avoid voltage collapse of the system. Here the shunt compensation is provided for each case at the weakest bus found from the results of voltage stability index (FVSI).

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