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Voltage Stability Enhancement for Unbalanced Multiphase Distribution Networks

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Abstract: Voltage instability problems have become important issues in unbalanced multiphase distribution networks. This paper expands the well-known voltage index V/V0 and defines an improved positive sequence voltage index of Vcollapse/Vno-load to identify the weakest single-, two- and three-phase buses in unbalanced multiphase distribution networks. First, the ranking index is validated based on grid losses and PV curves without and with compensation devices. Then, the index is utilized to place single-phase shunt capacitors, three-phase DG without and with SVC devices at the most appropriate buses of the IEEE unbalanced multiphase 13 node test feeder using the MATLAB/SIMULINK software. Finally, simulation results are presented to show the application of the proposed approach in improving voltage stability under unbalanced loading and/or network conditions.

Keywords: Voltage stability, weakest bus and unbalanced distribution network.

I. INTRODUCTION

Voltage instability is becoming a challenging problem in distribution networks. The application of Distributed Generator systems is growing to reduce costs and power losses. The connection of Distributed Generator to the grid might improve the voltage profile and enhance the voltage stability of a distribution system while reducing active and reactive power losses [1]-[4]. The improvements will mainly depend on the configuration of the distribution network, type of distributed generation systems and load characteristics.

When the network is balanced, there are different methods to detect the weakest bus for Distributed Generator placement such as modal analysis [5,6], sensitivity analysis [7], V/Vo index [8], [9], bus voltage change index [10], and integrated bus voltage change index with reactive power margin [11]. All these techniques have the capability to identify which node is the weakest bus of a balanced system. Moreover, providing enough reactive power support at the suitable location (the weakest bus) to resolve the voltage instability problems in different situations [12]. However, the problem becomes very difficult in multiphase and unbalanced operating conditions.

To find the weakest bus the bus ranking method is done where we will come to know which is the weakest bus to place the compensating devices to improve the voltage .Here we already come to know which is the weakest bus of single phase, two phase, and three phase in IEEE 13 bus test feeder.

To solve the voltage stability problem in unbalanced multiphase distribution network, IEEE 13 bus test feeder is used in MATLAB SIMULATION software for different cases. The voltage is stabilized by using different compensator like voltage regulator, single phase shunt compensator, static VAR compensator, distribution generator. The respective simulation models and results are discussed further.

II. VOLTAGE STABILITY

Voltage collapses usually occur on power system which are heavily loaded or faulted or have shortage of reactive power. Voltage collapse is a system instability involving many power system components. In fact, a voltage collapse may involve an entire power system. Voltage collapse is typically associated with reactive power demand of load not being met due to shortage in reactive power production and transmission. Voltage collapse is a manifestation of voltage instability in the system. The definition of voltage stability as proposed by IEEE/CIGRE task force is as follows:

Voltage stability refer to the ability of power system to maintain steady voltages at all buses in the system after being subjected to a disturbance from a given initial operating point. The system state enters the voltage instability region when a disturbance or an increase in load demand or alteration in system state results in an uncontrollable and continuous drop in system voltage. A system is said to be in voltage stable state if at a given operating condition, for every bus in the system, the bus voltage magnitude increases as the reactive power injection at the same bus is increased. A system is voltage unstable if for at least one bus in the system, the bus voltage magnitude decreases as the reactive power injection at the same bus is increased. It implies that if, V-Q sensitivity is positive for every bus the

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system is voltage stable and if V-Q sensitivity is negative for at least one bus, the system is voltage unstable. The term voltage collapse is also often used for voltage instability conditions. It is the process, by which, the sequence of events following voltage instability leads to abnormally low voltages or even a black out in a large part of the system. The driving force for voltage instability is usually the loads and load characteristics, hence voltage stability is sometimes also called load stability. In response to a disturbance, the power consumed by the loads tends to be restored by load dynamics. This in turn increases the stress on the high voltage network by increasing the reactive power consumption and further reducing the voltage.
A major factor contributing to voltage instability is the voltage drop in the line impedances when active and reactive powers flow through it. As a result, the capability of the transmission network for power transfer and voltage support reduces. Voltage stability of a system is endangered when a disturbance increases the reactive power demand beyond the sustainable capacity of the available reactive power resources. The voltage stability has been further classified into four categories: Large disturbance voltage stability, small disturbance voltage stability, short term voltage satiability and long term voltage stability.

III. PROPOSED METHODOLOGY

The IEEE unbalanced multiphase 13 node test feeder shown in Fig.1 [18] has been simulated using MATLAB SIMULATION software. This Unbalanced multiphase feeder consists of three-phase (buses 650, RG60, 632, 634, 634, 671, 692 and 675), two-phase (buses 645, 646 and 684) and single-phase (buses 611 and 652) sections with overhead lines, two underground lines (through buses 684, 652 and 692, 675), unbalanced spot loads (Y-PQ, D-PQ, Y-I, D-I, Y-Z, D-Z), distributed loads (Y-PQ) between buses 632 and 671, a single-phase shunt capacitor (at buses 611), a three-phase shunt capacitor (at buses 675), and an in-line transformer (between buses 633 and 634). There is also a three-phase voltage regulator connected between buses 650 and RG60.

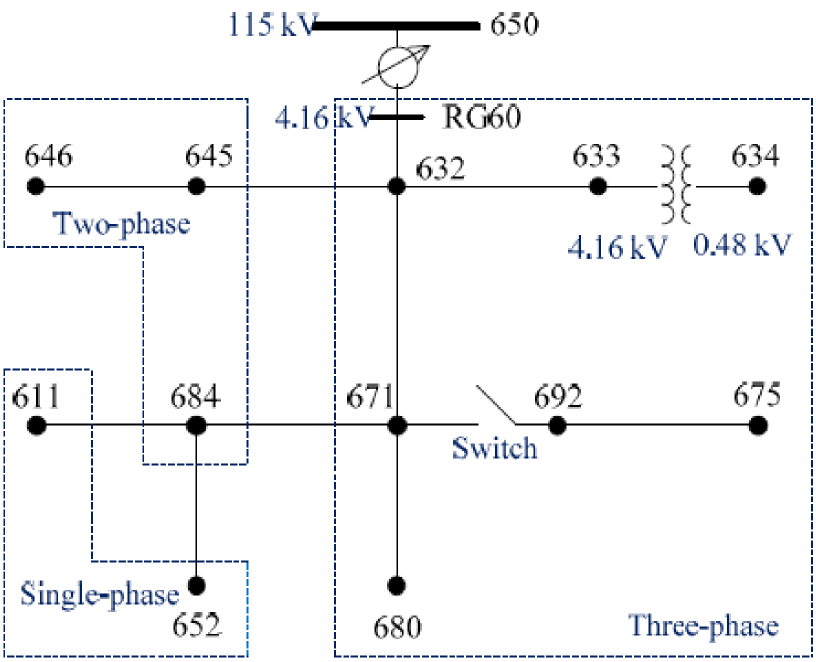

Fig 1: IEEE unbalanced multiphase 13 bus test feeder

Following are the different cases for simulation
Case 1: without a voltage regulator (fixed transformer tap ratio set to 1.0).
Case 2: with a voltage regulator and a single-phase shunt capacitor (0.1MVar) at bus 652.
Case 3: with a voltage regulator and one DG (358 kW) and one SVC (0.36MVar, acting as an unbalanced voltage controller) installed at the weakest three-phase node (bus 675), and bus 680.

Simulink model for case 1
The below fig 2 is the simulation model of IEEE 13 bus unbalanced test feeder where all components are selected from library and placed on model page. Here near bus 650 the step down transformer is connected where 115Kv is stepped down to 4.16Kv and transferred to all the components of 4.16Kv.

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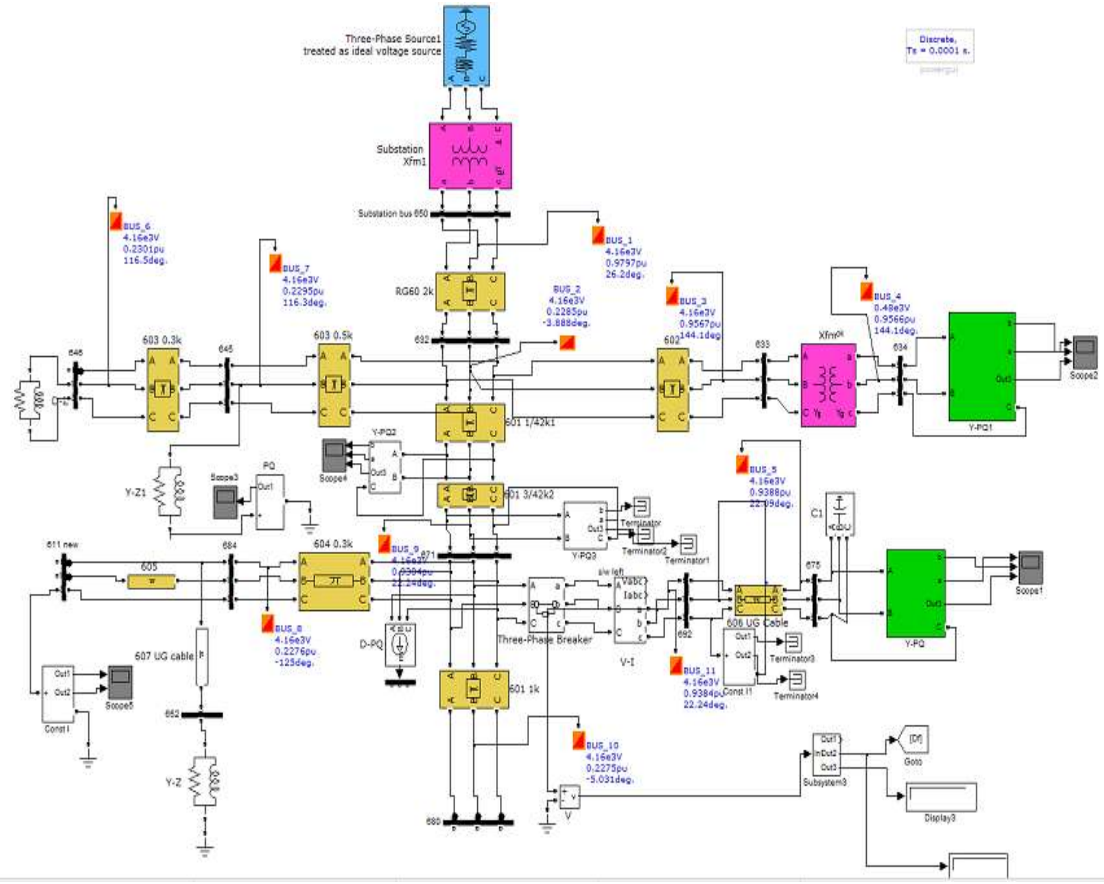

Fig 2: Simulation model of case 1

Simulink model for case 2

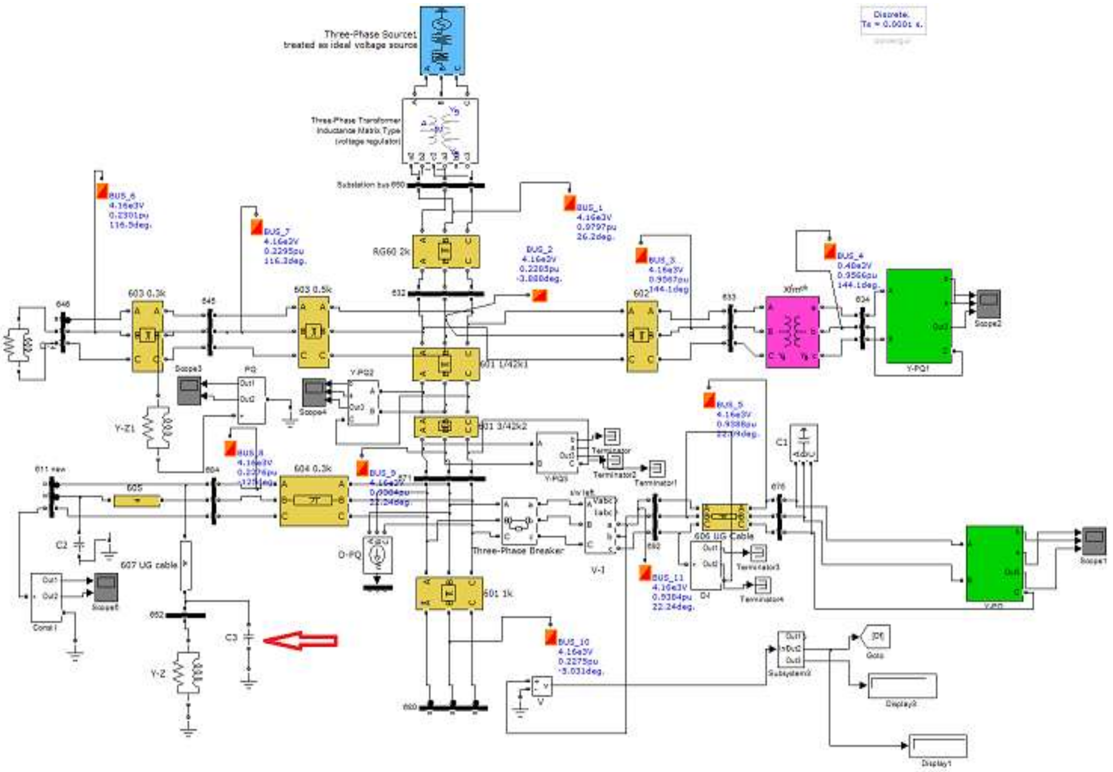

Fig 3: Simulation model of case 2

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The above fig 3 gives details of case 2 where single phase shunt capacitor of 100KVAr is connected near bus 652 bus and other components like voltage regulator and single phase shunt capacitor near bus 611 is added for further compensation.

Simulink model for case 3

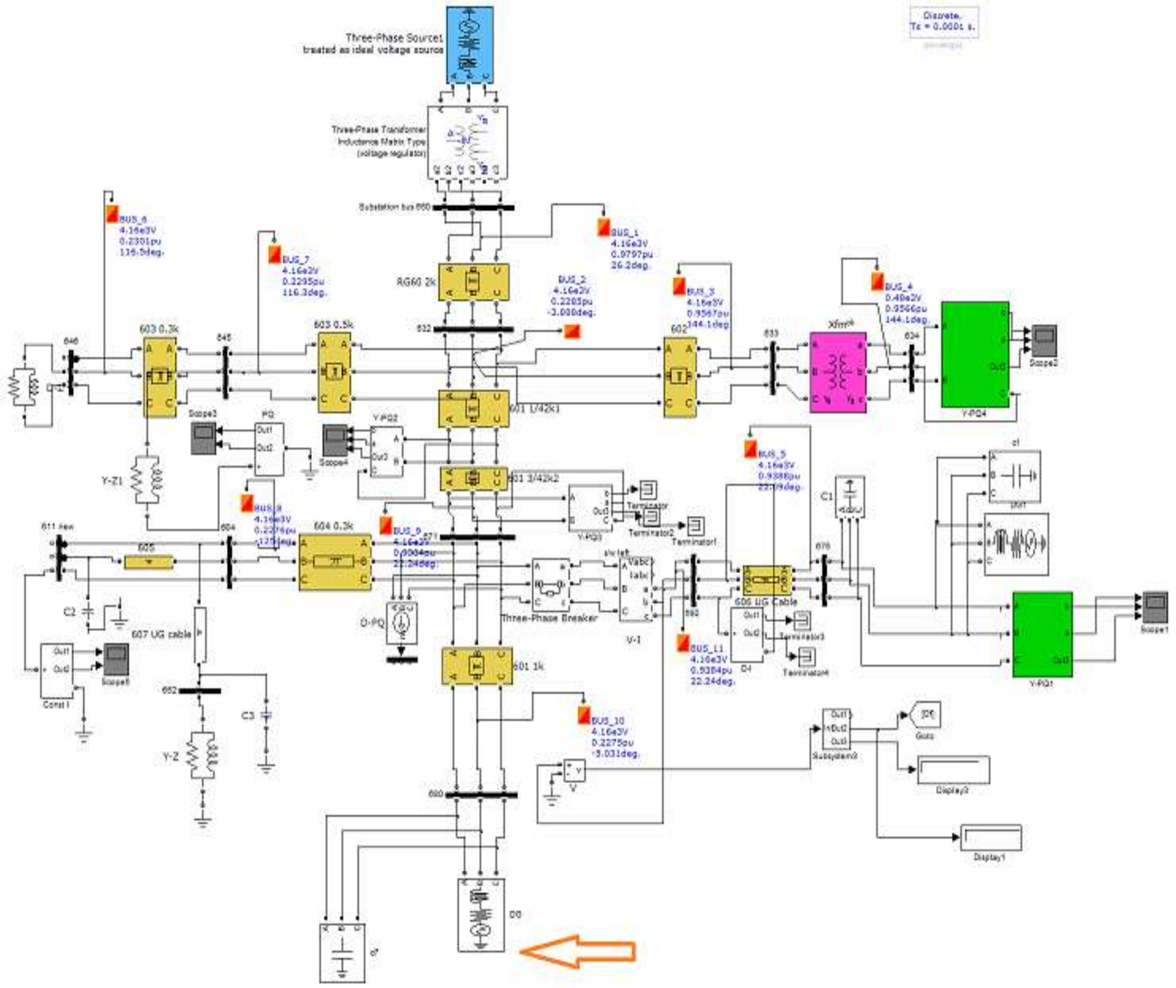

Fig 4: Simulation model of case 3

The above fig 4 gives details of case 3 with one Distributed Generator and one Static VAR Compensator near bus no 680 as shown in red arrow mark and rating of distributed generator is 358KW and SVC of 360 KVAr

IV. SIMULATION RESULTS

Case 1: Without voltage regulator

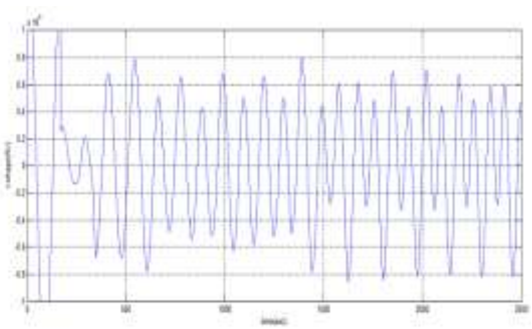

Fig5(a): Waveform of phase A near bus 675(scope1)

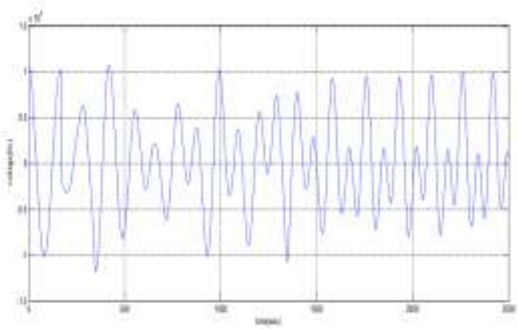

Fig 5(b): Waveform of phase B near bus 675(scope1)

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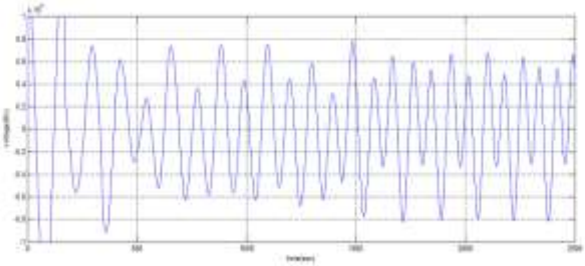

Fig 5(c): Waveform of phase C near bus 675(scope 1)

From above fig 5(a), 5(b) and 5(c) shows details of phase A,B,C near bus 675 scope 1 where the voltage is increased or unstable during case 1 and voltage is increased to 8 Kv. Y-axis is voltage(Kv) and X-axis for time(sec).

Case 2: With single phase shunt capacitor near bus 652

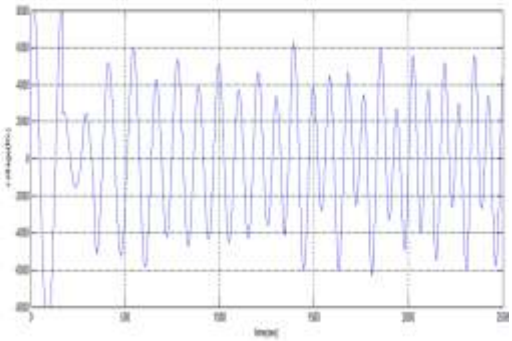

Fig 5(d) : Waveform of phase A near bus 675(scope1)

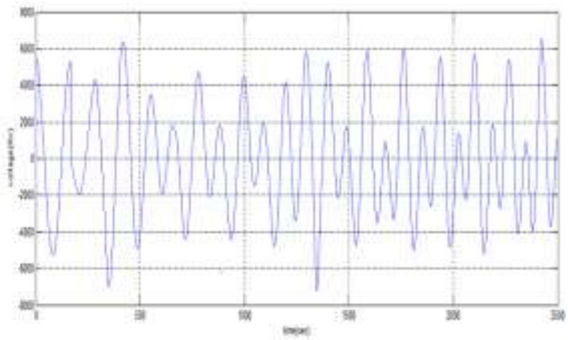

Fig 5(e): Waveform of phase B near bus 675(scope1)

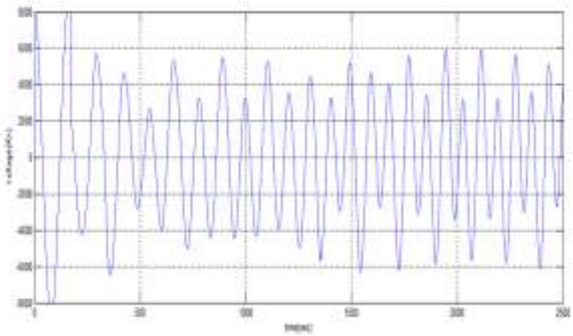

Fig 5(f) : Waveform of phase C near bus 675(scope1)

The above fig 5(d) ,5(e),5(f) shows waveform of case 2 with single phase shunt capacitor near bus 652 and voltage is stabilized from 6.5Kv to 6Kv

Case 3: With one Distributed Generator and one SVC near bus 680

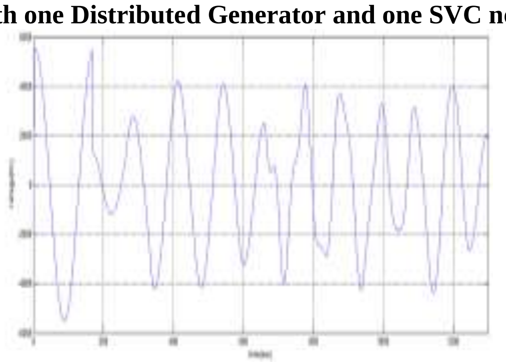

Fig 5(g): Waveform of phase A near bus 675(scope1)

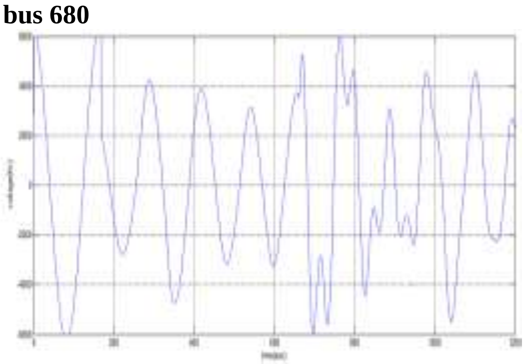

Fig 5(h): Waveform of phase B near bus 675(scope 1)

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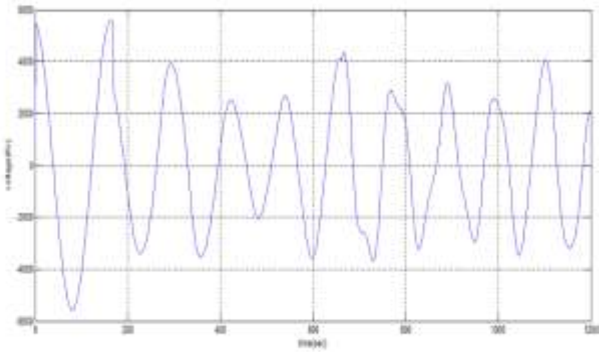

Fig 5(i): Waveform of phase B near bus 675(scope 1)

Finally, for case 3 fig (g), 5(h), 5(i) extra distributed generator and SVC is used and voltage is stabilized around 4.5Kv .So, the voltage is stable in the entire buses IEEE 13 bus test feeder.

IV. CONCLUSION

The above information will tell about voltage stability , simulink model of IEEE unbalanced multiphase 13 bus test feeder and outputs obtained from the simulink model is observed .From this the voltage will be unstable in IEEE unbalanced multiphase 13 bus test feeder. By using different compensating devices like single phase shunt capacitor, distributed generator and static VAR compensator near different weakest bus mention in [18] for single phase, two phase and three phase system the unstable voltage is maintained constant in all the buses in the system after being subjected to a disturbance from a given initial operating point. And in future not only voltage stability the maximum loading factor and grid losses can be analysed.

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