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Voltage Control Scheme For Distribution System Network

[1]Rashid El-feres
[1]Gaser Ben Gashire High institute
Of Science and Technology
[1]Rashidelfares@gmail.com

[2]Abubaker O. Zawam
[2] Gaser Ben Gashire High institute
of Science and Technology
[2]Zawam67@gmail.com

Abstract-This work focuses on the development of the proposed voltage control scheme for distribution system network. This scheme comprises of distribution state estimator (DSE), Automatic Voltage Reference Setting (AVRS) and an Automatic Voltage Controller (AVC). The DSE and AVRS scheme have been formulated and implemented in C which with Real Time Digital Simulator (RTDS) used for power system modelling and Micro-Tapp as a voltage reference setting to form close loop system to model automatic voltage regulator for electric distribution network.

Keyword— Real Time Digital Simulator (RTDS), Distributed State Estimator (DSE), Micro

I. Introduction

To maintain satisfactory voltage in distribution system, there are number of methods which can be used. Some of these methods such as incorporating voltage regulating equipment into voltage feeder, building more substations, increasing feeder size transferring of loads to new substation or new feeder, installation of capacitor or increasing of primary feeder voltage level. The first three solution appear to be very costly and some of them environmentally unacceptable. Regarding moving load to another feeder is considered to be very costly .also, to apply capacitor to neutral lagging reactive power in distribution system is not beneficial because X / R ratio is considered to be low in the distribution.

Through the past years there are a number of regulation method which have been developed. Most the method which will be presented depends on OLTC associated with automatic voltage controller with few methods is incorporating capacitors as well. The voltage control methods are categorized on distribution with and without Distributed Generation.

1*)* Coordination between local voltage controllers using OLTCs transformer associated with AVC in power system which include Series OLTC Transformer Controls and Coordination [1] and Pre-Emptive Tap Changing Using the Duty of Responsibility[2]

2) Voltage control methods in distribution without DG which include Conventional Voltage Control in Distribution Systems [3], and Automatic Voltage Control using Regulating Transformer with line-drop Compensation

And Automatic Local Controller of (OLTC) in Distribution System [4], Optimal Voltage Control Using Active and Reactive Power as Bus constraint [5], Optimal Alteration method of Voltage Reference for an AVC relay Optimal Reactive Power and Voltage Control for Radial Distribution System [6], Supervisory Voltage Control in Distribution Substation [7]

3) Voltage control methods in distribution system with DG which include Voltage Control on Distribution Generation [8], Optimal Setting for Distribution Voltage Control Considering Interconnection of Distributed Generation [9], Optimization Voltage Control technique based on Line Drop Compensator with DG, Method of Determining the introduction limit of Distribution Generation in Distribution System [10]

Almost all the voltage control methods are located locally i.e at the main substation interconnecting distribution system to transmission system. Therefore, for enlarged distribution system with increase introduction of DGs resources communication channels are needed to bring remote measurements information to calculate voltage for control system. To use communication channels prove to be expense especially with distribution system privation and competitiveness of the market to beat the electricity price. Most of voltage control methods; they directly or indirectly depend on real time information such as load consumption to calculate customer voltage and to provide the right voltage. Currently, load flow method is used in distribution system to calculate customer voltage. Voltage calculation using load flow methods needs large number of real time measurements which is difficult to obtain. The other voltage control method which requires less real time measurements is line drop function (LDC). However, these method due to DGs introduction and it is difficult to locate load centre this prove to be unpractical.

II. **Automatic voltage controller scheme Architecture**

The arrangement of adaptive voltage reference setting controller architecture is shown in Fig. 1. The inputs to the state estimator consist of real time measurements, pseudo measurements and network topology data. Each measurement has an associated measurement standard deviation that weighs it to the state estimator. The real-time measurements are supplied from remote and local substations within the area where the Adaptive controller is managing the network in this scheme real time measurement were taken from power system device called RTDS (Real Time Digital Simulator). Pseudo-measurements are the estimation of load consumptions at the network substation transformers based on load model.

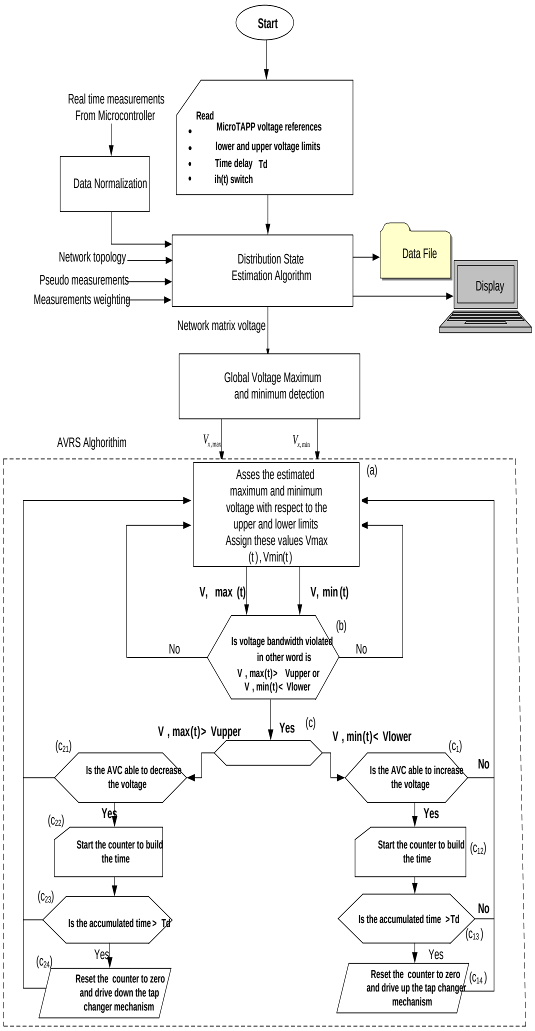

Fig. 1. Flow chart of the voltage controller scheme system

The DSE estimates the state of a distribution network. If an abnormal state occurs, the voltage reference setting will carry out the proper control actions, such as changing transformer tap position or changing generator load reference set point to ensure the level of the distribution network security. One of main objectives of the voltage reference setting controller for active distribution network management is to allow for maximum generation penetration into a distribution network without exceeding voltage limit anywhere in the network.

III. **System Validation**

To validate the developed advance voltage reference setting a number of implementation has been carried out on a network. The representation of network simplified 21 nodes; the data of the network which was given to state estimator is changed to line parameters (resistance and reactance) for network topology and pseudo measurements of load centre to resistance and reactance. Fig.2 show the 21 nodes used for this study. The main supply of the network is the 5 MVA 33 /11 kV OLTC step down transformer model with 8.5 % and 15 tap change interval at a step of 1.43 % with distributed generator connected on node 6).

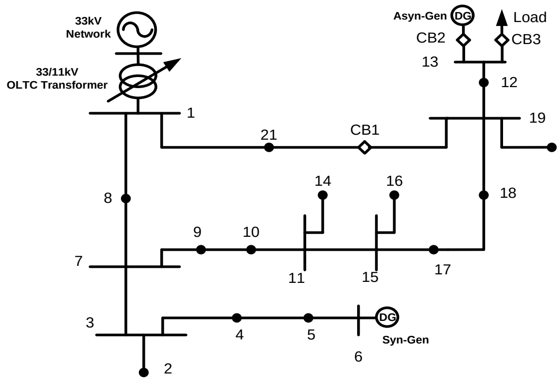

Fig.2. 21 node network topology

A number of scenarios to validate the scheme including connecting deferent type distributed generation and connection of loads.

The DG synchronous type used is working on leading power factor which will cause influence on the network voltage which can make the voltage high at point of connection and also effective load to make voltage to go low at point of connection. In order to verify adaptive voltage controller scheme a number of cases of study has been carried out. These cases were arranged in such way is to violate upper and lower limit of network regulation voltage using DGs and switching heavy load. The DG is connected to boost the voltage at busbar 6, from that bus active and reactive power with high accuracy to represent DG injected power. Also, another two of active and reactive power consumed were presented. Changing the DG torque at node (6) will disturb the power values at that bus; step change of variable load is used to disturb power at bus 13. Through state estimation power flow calculation the four power values from DG bus and variable load were introduced to state estimator algorithm.

To achieve similar to power flow program the real time measurement was given 1 % accuracy, injected power (active and reactive) and consumed power (active and reactive) were both given 3% accuracy. The pseudo measurements were given 25% accuracy.

Case 1: Effect of DG Synchronous Type on Distribution Network:

This case study is studying the effect of distribution generation on distribution network and the response of the adopted voltage controller. Fig.3. shows voltage traces at critical location on the network and DG power trace against the time on a number of critical location on the network.. Fig.4 shows all event of sate estimate result as a response for DG action and AVRS action. A number of snapshots marked in pricket in top of fig.5 were taken to see network ***voltage*** state estimation result at important location of real time simulation. The voltage state estimation snapshots were displayed in such a way to observe the affect of DG power on the system voltage and AVRS action to select AVC relay reference to tap up or down main OLTC transformer.

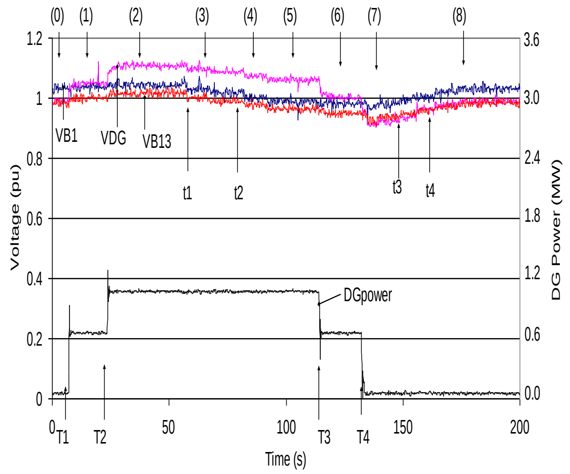

Fig. 3. Voltage traces at bus1, DG bus and load bus and DG power

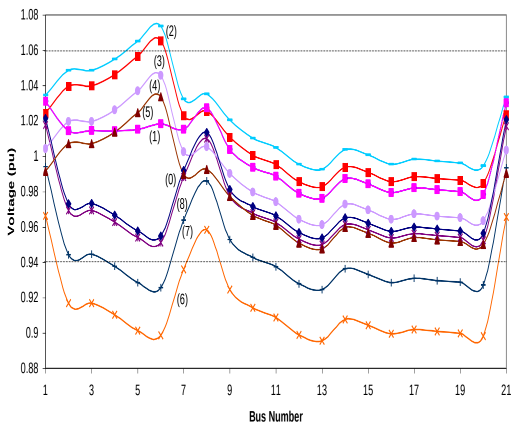

Fig. 4. DSE results for synchronous generator and AVRS action

Fig.3 shows at T1=7 s the power from DG has increased to 600 kW as result voltage at DG bus has risen to 11.45 kV. The state estimators update these changes and calculated the network voltage profile as shown in snapshot (0) of figure 5. From the state estimation the voltage still within the limit thus more DG power can be injected. At T2=20 s more DG power (500 kW) was injected this time state estimation calculation shows voltage at DG bus violated the upper limit, see again in fig.5 snapshot (2). As a result AVRS has to react, after 20s of preset time at t1=40s a signal has been send to AVC to select lower reference (10.89 kV). Another voltage update has taking place by state estimator, as shown in fig.5 snapshot (2), voltage at DG bus still violated thus, AVRS waits another 20 s of preset time at t2=60 s AVRS algorithm selects another reference (10.65 kV) to bring DG bus voltage to the limit. After a number of inter⁄taps by AVC relay DG bus voltage has return to the acceptable limits see snapshot (4) at fig.6.

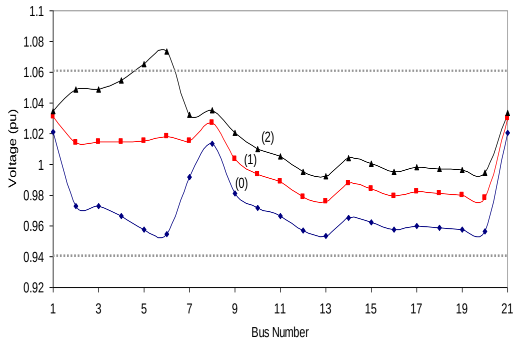

Fig. 5. Estimated snapshots (0), (1) and (2)

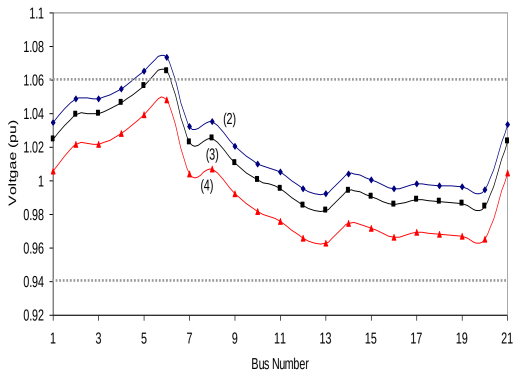

Fig. 6. Estimated voltage snapshots at (2) , (3) and (4)

After some time i.e when the system has stabilize, gradually DG torque has been reduced twice as shown in fig.3, at T3=120 s DG power reduced from 1100 kW to 500 kW and another reduction at T4=140 s. According to state estimation calculation of network voltage shown in snapshots (6) and (7) of fig.7 that lower voltage has been violated on the system. As a consequence the AVRS algorithm waits 20 s at t3=160 s then select 10.89 kV reference in the AVC relay, immediately the AVC relay found the voltage is outside this voltage reference bandwidth and send signal to OLTC to tap up. Again with new reference state estimation calculation shows lower limit still violated, the AVRS algorithm wait 20 s at t4=170s then selects 11.1 kV reference in the AVC relay, see fig.7 snapshots (7) and (8). Immediately the AVC relay send signal to OLTC to tap up, bringing the local voltage to 11.1 kV, state estimation calculates that voltage in all network bus brought to voltage limits as shown in fig.8. Finally no more AVRS reference has been selected and the system is working normally see fig.8 snapshot (8).

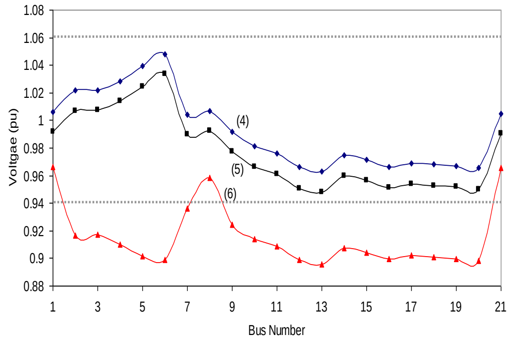

Fig. 7. Estimated voltage snapshot (4), (5) and (6)

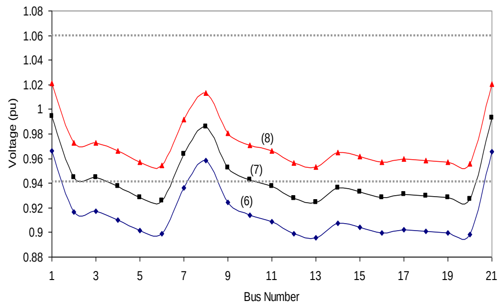

Fig. 8. Estimated voltage snapshots at (7),(8) and (9)

Case 2: Loss of Synchronous Generator and Switching load:

This case is studying the response of the adopted voltage controller to loss of distribution generation and switching of heavy load on distribution network. Results are shown in Fig.9. This figure represents the voltage traces of local voltage, DG bus voltage and variable load bus voltage as well as DG power traces against the time as taken from RTDS. Fig.10 shows the response of the estimator throughout the real time action. Numbers of snapshots figures were taken showing estimated voltage results during certain events of real time simulation of heavy loaded network. The events include DG disconnection and load increase.

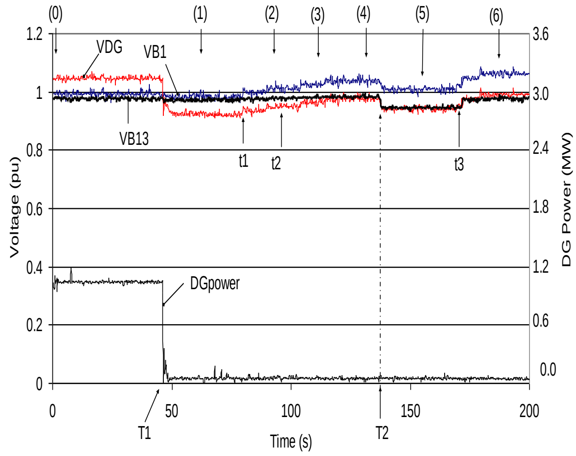

Fig. 9. Voltage traces of source bus, DG bus, variable load bus and DG power

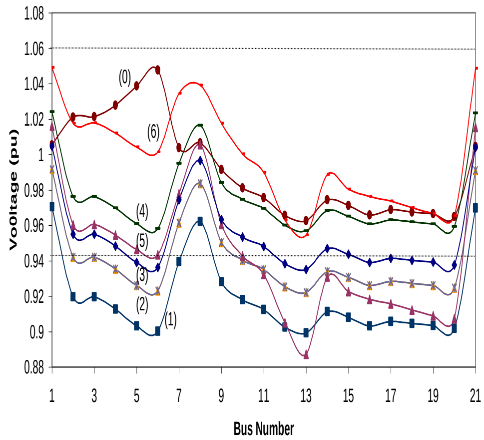

Fig.10 State estimation of all events of case two

At the beginning of the simulation the network voltage reference was at 10.6 kV and DG power was 1100 kW. According to state estimation result of network voltage all node voltages are within the limit as shown in fig.11 snapshot (0) so the AVRS algorithm stay idle. At T1=40 s DG power has reduced to null. As a result estimated network voltage shows network voltage is below lower limit, see snapshot (1) in fig.11. After approximately 20s s of preset time delay the AVRS algorithm has select another reference (10.89 kV) in the AVC relay. Immediately, at t2= 75 s the AVC relay send signal to main OLTC transformer to tap up. The update of estimated voltage results found that lower limit still violated as shown in snapshot (2) of fig 11. After 20 s of preset time delay AVRS select another reference (11.1 kV) in AVC relay. Because voltage is outside the bandwidth of that reference the AVC relay send signal to main transformer to tap up. After number of inter/tap network voltage has risen to acceptable limit as shown in fig.12 snapshot (4).

At T2= 142 s heavy reactive load of 700 kW and 300 kVAr was switched on at node 13. As a result system voltage has drop dramatically as shown in fig.9. The estimated voltage profile shows lower voltage violation has occurred see fig.13 snapshot (5). From estimated result the AVRS algorithm detect lower voltage violation, after 25 s of preset time at t4= 165s the AVRS algorithm select another reference (11.4 kV). Immediately the AVC relay found voltage is outside the reference bandwidth, it send signal to main OLTC transformer to tap up. After of number of inter/tap the voltage raise to reference AVC reference voltage bandwidth and the system voltage also raise to working limit as shown in the estimated voltage results snapshot (6) in fig 13. As system brought to working limit no more action is needed.

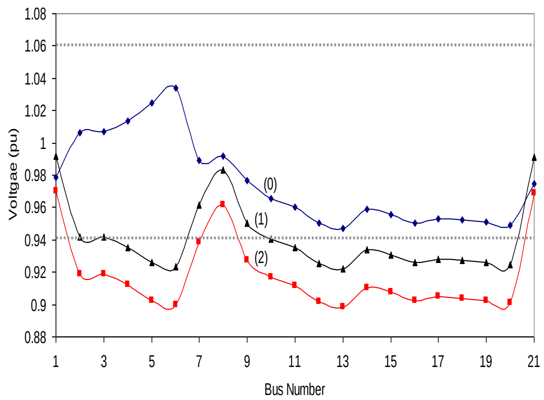

Fig. 11. Estimated voltages snapshots (0), (1) and (2)

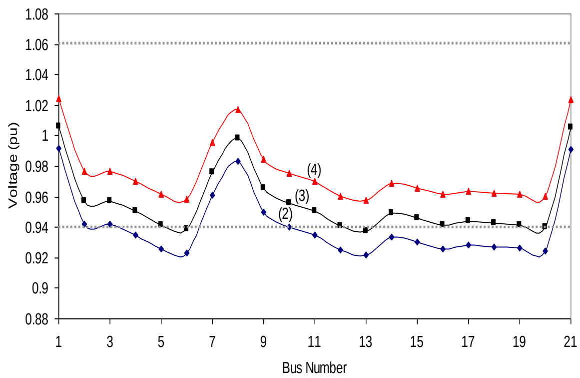

Fig.12 Estimated voltages snapshots at (2), (3) and (4).

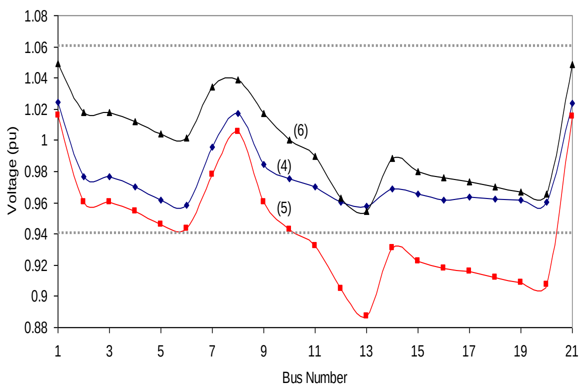

Fig.13 Estimated voltages snapshots at (4), (5) and (6).

IV. Conclusion

In this work setup of an automatic voltage reference setting controller has been developed to control voltage on distribution network. Conventional AVRS controller usually depends on real time measurements which are very difficult to acquire in distribution system. This work adopts distribution state estimation to estimate network voltages for AVRS controller. The integration of state estimation and AVRS algorithm can build the automatic AVRS voltage controller. AVRS algorithm will operate according to estimated maximum and minimum voltage. The study shows that the distribution generation has a tendency to increase the voltage at its terminal. Thus, by implementing the automatic voltage reference setting (AVRS) much of DG capacity can be harnessed.

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