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Distribution System Voltage Control by Using Distributed Energy Resource

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ABSTRACT

The voltage regulators mostly used in power systems (tap-changing transformers and capacitor banks) cannot controls the voltage continuously and they do not have dynamic capability to respond to rapid voltage variations and transients.

The main aim of this research is to show that distributed energy resources are used not only for local power demand but also for voltage control of a power distribution network with proper control mechanism. In this research, an adaptive voltage control technique is used to control volt/var level of a power distribution network using inverter based photovoltaic generator with a feed-back control action by a PI controllers. The photo voltaic generator is connected to the feeder having high loss sensitivity factor for supplying of energy to the inverter. The optimal or desired value of bus voltage is determined by genetic algorithm with the objective of the distributed energy resource has to inject a complex power that results less power loss and cumulative voltage deviation. The response of the proposed system for keeping the volt/var level of distribution network is verified by considering load variation as a means of creating transient. Three cases on system loading conditions are considered with all the programming and modeling of the study is performed by MATLAB 7.6 programming language. As proved by the result of the study, distributed energy resource injects/absorb reactive power to improve bus voltage profile whenever loading condition is varied.

***Key words**:- Adaptive voltage control, Genetic algorithm, Loss sensitivity factor, PI controller ,volt/var control*

1. INTRODUCTION

The electrical power system grid is composed of the generation, transmission, and distribution system. Conventionally, electrical power is generated centrally and transported over a long distance to the end users. However, since the last decade, there has been increasing interest in distributed energy resources (DE) which includes distributed generation (DG). [1][2].

As tested in this research, Distributed energy resources which can be powered by renewable fuel, such as wind energy, solar energy, and biomass are not only used for supporting the energy need of the customers but they are used for controlling the voltage level of the to control distribution system voltage level.

2. MATERIALS AND METHODS

2.1. PROBLEM FORMULATION

The solving of voltage control of distribution system by using Distributed Energy resource requires placement and sizing of DG unit’s for determination of the base case (reference) system voltage level with Distributed generation. From 2004 onwards power loss sensitivity and voltage sensitivity factors have been applied to optimal DG sitting as in [39] and [40]. The power loss sensitivity factor is derived from the "exact loss formula", PL, which is widely used in the capacitor allocation problem and gives the real power loss in a system [41]:

$$P_L = \sum_{i=1}^{N}\sum_{i=1}^{N}[\alpha_{ij}(p_i p_j + Q_j) + \beta_{ij}(Q_i P_j - P_i Q_j)$$

(1.1)

Where

$$\alpha_{ij} = \frac{r_{ij}}{v_i v_j}\cos(\delta_i - \delta_j) \quad (1.2)$$

$$\beta_{ij} = \frac{r_{ij}}{v_i v_j}\sin(\delta_i - \delta_j \quad (1.3)$$

The exact loss formula is then liberalized to give the sensitivity of power loss at a specific node after each load flow simulation. The nodes are then ranked in descending order of loss sensitivity to identify the most optimal location for DG to minimize power loss. The sensitivity factor, αi, is thus the partial derivative of the exact loss formula with respect to the injected power, given by [40] as:

$$\alpha_i = \frac{\partial P_L}{\partial Pi} = 2\sum_{i=1}^{N}(\alpha_{ij} P_j - \beta_{ij} Q_j) \quad (1.4)$$

Sizing of DG resource requires defining the Fitness Function that can be optimized in the presence of some constraints. The fitness function is selected for reducing power losses and increasing of voltage stability margin in the system or reducing cumulative voltage deviation.

GA starts the process by automatically proposing different DG sizes within the proposed DG size limits and internally executes the load flow program which is properly linked with Genetic Algorithm package till the minimum solution is obtained for the suggested location. After taking this DG size for determination of reference PCC voltage, the Distributed energy resource (compensator) regulates the system voltage/reactive power level by injecting or absorbing reactive power for different system conditions. In the proposed method, load variation is considered as a means of creating new system condition which can be occurred due to different occasions. The suggested algorithm is programmed under MATLAB software. The general procedure of the proposed system is shown belowin fig. 2.1

Objective Function

The main goal of the proposed algorithm is to determine the best locations and size for new Distributed Generation resources .Two main goals are taken into considerations to determine the Objective Formula that is used in point of start: Power Losses reduction and voltage profile improvement. The Fitness Function is determined as following

$$F=W_p*P_L+W_q*Q_L+W_v*CVD \quad (1.5)$$

Where:

P_L =Active power loss
Q_L= Reactive power loss
CVD = cumulative voltage deviation
F=fitness function

The active and reactive power losses are obtained from load flow program. The cumulative voltage deviation norm is defined as "the normalized sum of the deviations of the obtained value from the desired value at every node on thefeeder.

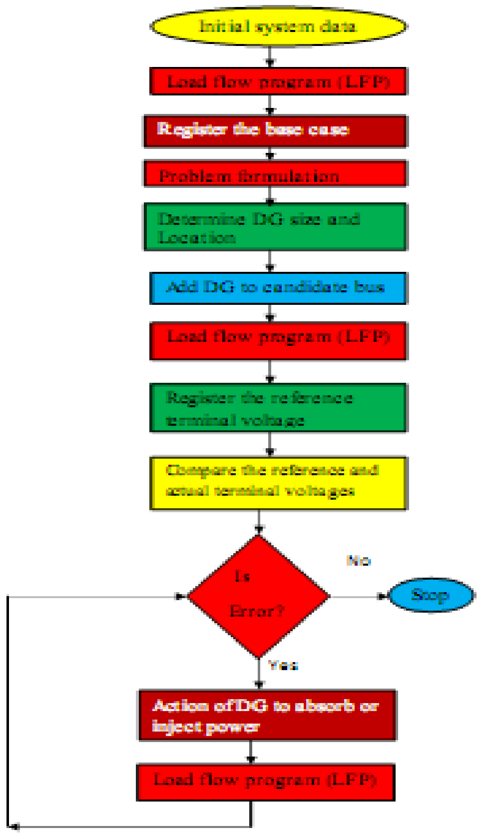

Figure.2.1. General flow chart diagram of the proposed system

The desired value being 1.0 PU and the obtained value being the value obtained from the three-phase distribution power flow [42]. In this work the CVD is determined the same way as following:

$$CVD = \left| \sum_{i}^{n} (1 - v_i) \right| \quad (1.6)$$

Where:

N: The total number of nodes

W_p, W_q , W_V: The Objective Function weights (Active, Reactive power losses and Cumulative Voltage Deviationweights), subjected to:

$$W_p + W_q + W_V = 1 \quad (1.7)$$

Constraints

The main constraints in the optimization process in the proposed methodology are:

1. Active and reactive power losses constraints
2. Voltage Constraints
3. DG size constraint

Active and reactive power losses constraint*:*

The losses after installing DG in power grid should be less than or equal losses before installing DGs.

PL with DG $\leq$ PL without DG

QL with DG $\leq$ QL without DG

Voltage constraint

To ensure the voltage of any bus should be within predefined limits the following constraint is considered:

$$V_{bus\text{-}min} \leq V_{bus} \leq V_{bus\text{-}max} \quad (1.8)$$

V_{bus} : Bus voltage

$V_{bus\text{-}min}$: Bus minimum voltage

$V_{bus\text{-}max}$: Bus minimum voltage

2.2. VOLTAGE REGULATION BY POWER ELECTRONIC INTERFACED DISTRIBUTED ENERGY RESOURCE

A DE with a PE interface can provide a wide range of ancillary services, including voltage regulation which has drawn much interest because of the reactive power shortage and transportation problems in power systems. A system configuration of Photo Voltaic with an inverter interface is shown in Fig. 1.4.The Photo Voltaic system is connected in parallel with the grid through a coupling inductor *Lc*. The PE interface includes the inverter, a DC side capacitance or V_{dc}, and a DE such as a fuel cell, solar panel, or energy storage supplying a DC current. Coupling inductors *Lc*are also inserted between the inverter and the rest of the system.

The PE interface is referred to as the compensator because voltage regulation using the DE is our primary concern. The compensator is connected, in parallel, with the load to the distribution system, which is simplified as an infinite voltage source (utility) with a system impedance of R_S+jωL_s. The parallel compensator is connected through the coupling inductors $L_C$at the point of common coupling (PCC). The PCC voltage is denoted as V_t. By generating or consuming a certain amount of reactive power, the compensator regulates the PCC voltage V_t.

A voltage regulation method is developed, based on the system configuration in Fig. 1.3, with a PI feedback controller. The control diagram is shown in Fig. 1.4.

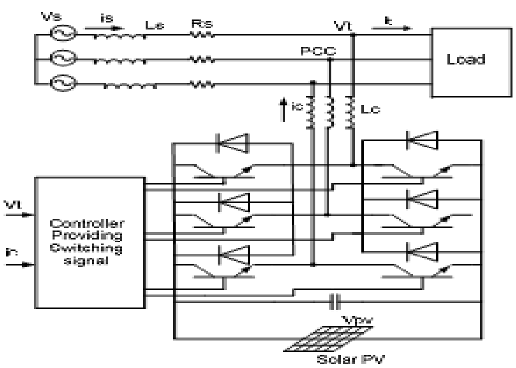

Figure 1.3 Parallel connection of a DE with PE converter.

The PCC voltage $V_t$is measured and its RMS ValueV_t is calculated. The RMS value is then compared to a voltage reference, V_t^*(which could be a utility specified voltage schedule and possibly subject to adjustment based on load patterns like daily, seasonally, and on-and-off peak).

The error between the actual and reference is fed back to adjust the reference compensator output voltage V_C^*, which is the reference for generating the pulse-width modulation (PWM) signals to drive the inverter. A sinusoidal PWM is applied here because of its simplicity for implementation. The Adaptive voltage control methods for single Distributed Energy solar Photovoltaic generators

If $k_P$or $k_I$is not chosen appropriately, the system response may be poor and at worst, create instability. So preventing a poor system response and optimizing the response speed are what is desired from the PI controller design. Thus the goal is to create an adaptive PI design that can dynamically adjust the PI controller in real-time based on the system's behavior and configuration. The proposed adaptive PI control method, inspired by the generic adaptive control method in [8] [9] [10], consists of three procedures:

Determine the DC source voltage of the DE;

Set the initial controller values, $k_P$and k_I; and

Adaptively adjust the controller parameters according to real-time system conditions. Compensator output voltage $V_C^*$is controlled to regulate $V_t$to the reference V_t^*. The control scheme can be specifically expressed as

$$V_C^* = V_t(t)\,[1 + K_p(V_t^*(t) - V_t(t)) + K_I\int_0^t (Vt^*(t) - Vt(t))dt\;] \quad (1.70)$$

Where $k_P$and k_I*are* the proportional and integral gain parameters of the PI controller

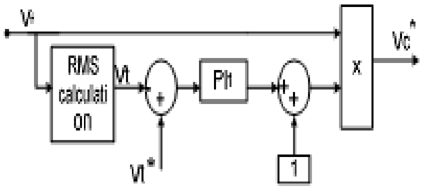

Figure 1.4. Control diagram for voltage regulation

2.3. ADAPTIVE VOLTAGE CONTROL METHODS FOR SINGLE DISTRIBUTED ENERGY SOLAR PHOTOVOLTAIC GENERATORS

If $k_P$or $k_I$is not chosen appropriately, the system response may be poor and at worst, create instability. So preventing a poor system response and optimizing the response speed are what is desired from the PI controller design. Thus the goal is to create an adaptive PI design that can dynamically adjust the PI controller in real-time based on the system's behavior and configuration. The proposed adaptive PI control method, inspired by the generic adaptive control method in [11] [12] [13], consists of three procedures:

A. Determine the DC source voltage of the DE;
B. Set the initial controller values, $k_P$and k_I; and
C. Adaptively adjust the controller parameters according to real-time system conditions.

A. Determine the DC Source Voltage

The DE's PE interface with the utility is a VSI and the PWM method is used to convert the DC source voltage to an AC supply.

Fig. 1.5 shows the relationship between $2v_c^p/V_{dc}$and the modulation index *m*a, where $V_c^p$is the peak voltage of the fundamental-frequency component of the compensator output voltage V_c and *V dc* is the voltage of the DC supply. As shown in Figure 1.5, for a given *V dc*V_c^pvaries linearly with the modulation index*ma* when it is 1.0 or less. It also shows that V_c^pshould be less than $\frac{4}{\Pi} * \frac{V_{dc}}{2}$ for any *ma*, even if itis under the saturated square-wave region. This means that *V dc* determines the DE's ability toprovide voltage regulation. To reduce the DE harmonic injection, *ma* is chosen to be nogreater than 1. Accordingly, we have:

$$V_{dc} \geq 2V_C^P = 2\sqrt{2} * V_c \quad (1.71)$$

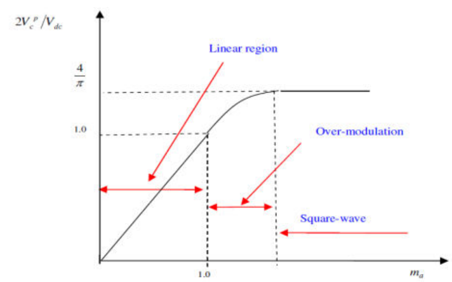

Figure 1.5 PWM voltage control by varying modulation index ma

B. Set the Initial PI Controller Gains

Lower gain parameters, $k_P$and/or k_I, are typically chosen initially and only increased after confirming that they do not cause any of the above mentioned poor response and instability problems. In the following discussion, a method to initialize the gains is proposed.

Set the Initial KP Value

At the initial time 0_+ (immediately after a voltage transient), the reference compensator output voltage V_c^* can be expressed as (1.72), since the contribution of the integral controller is 0:

$$V_c^* = V_t^0(t)\,[1 + K_p(V_t^*(t) - V_t^0(t))] \quad (1.72)$$

To keep the PWM modulation index, ma,no greater than 1, the peak value of V_C^*needs to be less than the peak value of the triangle carrier signal, which is 0.5×*V dc*. Hence, we have:

$$K_P \leq \frac{\frac{0.5Vdc}{V_t^{0,p}} - 1}{\nabla V_t^0} \quad (1.73)$$

Where $\nabla V_t^0 = V_t^*(t) - V_t^0(t)$ is the initial RMS voltage deviation at time 0+. This can be chosen as, and usually is, the maximum voltage deviation from the reference voltage at PCC.

Similarly, $V_t^{0,p}$ can be accordingly chosen as the peak value of the voltage, $V_t$at time 0+.Nevertheless, the initial value is only important for the initial transients and will be adjusted by the adaptive control when the system condition changes, as discussed next.

Setting the Initial KI Value

The voltage response time of the controller for a voltage transient is set to 0.5 seconds in order to not interfere with the conventional utility voltage control. In an ideal voltage control process, the response of the control system to a step change can be approximated as an exponential decay curve, i.e.

$$V(t) = \nabla Vt_0\, e^{\frac{-t}{\tau}} \quad (1.74)$$

Where τ is the time Constant. Here a period of 5 times the time constant, 5t , is chosen as the response time since this is normally the time needed to reach a new steady-state condition since *e-5* =0.007≈ 0.Hence, we have 5t » 0.5*s* for the controller. When reaching the new steady state, the proportional part of the controller provides relatively no assistance and therefore we have:

$$V_c^* = V_t^{steady}(t)\,[1+K_I \int_0^{5\tau} \Delta_t(t)dt \quad (1.75)$$

Since in this study, PWM works only in the linear area, the amplitude of the triangle carrier signal is 0.5×*Vdc,* so for the fundamental frequency component, the compensator output voltage V_c^*defined by Equation (1.71) should be equal to V_C .Replacing $\nabla V_t(t)$with $\nabla Vt_0\, e^{\frac{-t}{\tau}}$ and V_C^* with Vc we have:

$$K_I = \frac{\frac{V_C^{Steady}}{V_t^{seady}} - 1}{\int_0^{5\tau} \Delta V_{to} e \frac{-t}{\tau}} \quad (1.76)$$

Where $\frac{V_C^{Steady}}{V_t^{seady}}$ is the ratio of converter output voltage to the voltage at the PCC which equals V_t^*in the steady state.

C. Adaptively Adjusting the PI Controller Gain Parameters

The controller with a fixed $k_p$and K_I may not always reach the desired and acceptable response in power systems since system load and other conditions are constantly changing. Without a centralized communication and control system, the controller has to utilize a self-learning capability to adjust $k_p$and K_I dynamically. Using the case of local voltage requiring as an increase as an example, if the control logic shows that the voltage has increased too rapidly, then $k_p$and $K_I$will be adjusted to lower values. On the contrary for when it is too slow, $k_p$and $K_I$will be adjusted to higher values. Certainly, this needs additional logic to check the present voltage response with respect to the desired voltage response.Fig. 1.6 shows the overall logic of the adaptive control method. The key processes of this approach are:

In every step, the actual voltage deviation and desired voltage deviation are monitored and a scaling factor $R_{V,}$ which is equal to the ratio of Actual voltage deviation to ideal voltage deviation, is calculated. Here the actual voltage deviationis the voltage difference between the measured V_t and reference V_t^* and the ideal voltage deviationis the voltage deviation between the optimal terminal voltage which is determined by optimization and one per unit voltage (1 PU).

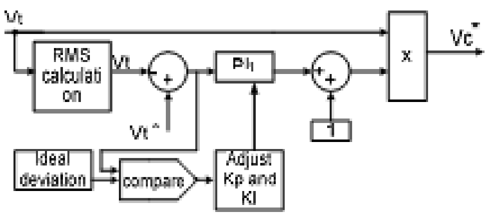

Figure 1.6.Adaptive Control of the Voltage Regulation.

Next, $k_p$and K_I are multiplied by the scaling factorR_v. When the actual deviation is greater than the desired ideal deviation, it will be slowed when $k_p$and K_I are multiplied by R_v<1.

Similarly, when the actual deviation is slower than the desired ideal deviation, it will speed up when $K_p$and $K_I$are multiplied by R_v>1. This approach avoids the possible issues of slow response, overshoot, oscillation, or instability.

2.4. POWER FLOW CONTROL METHODS FOR SOLAR PHOTO VOLTAIC GENERATORS

In this section, an active and reactive power (PQ) control algorithm is proposed in the case of solar Photo Voltaic generators to control the desired amount of active and reactive power as demanded by the local load.

2.4.1. ACTIVE AND REACTIVE POWER (PQ) CONTROL ALGORITHM

According to the instantaneous power definitions, for a balanced three-phase system, if $V_t(t)$ and $V_C(t)$ denote the instantaneous PCC voltage and the inverter output voltage (harmonics are neglected), respectively, then, the average power of the Photo Voltaic denoted as $P(t)$, the apparent power $S(t)$ and the average non-active/reactive power $Q(t)$ of the Photo voltaic are as given below:-

$$P\ (t) = \frac{2}{T}\int_{t}^{t}\frac{T}{2}V_t(\tau)i_c(\tau)d\tau = \frac{V_tV_c}{\omega L_C}\sin\alpha \quad (1.77)$$

$$Q\ (t) = V_t(t)I_{cn}(t) = \frac{V_tV_c}{\omega L_C}V_c\cos\alpha - V_t \quad (1.78)$$

Here, α is the phase angle of $V_C(t)$ relative to the PCC voltage . P (t) and Q (t) in (1.77) and (1.78) can be approximated by the first terms of the Taylor series if the angle α is small, as shown in (1.79) and (1.80):

$$P(t) \approx \frac{V_tV_c}{\omega L_C} \quad (1.79)$$

$$Q\ (t) \approx \frac{V_t}{\omega L_C}(V_t - V_C) \qquad (1.80)$$

This control method is based on a popularly used Proportional and Integral (PI) controller and hence, is a simple, however very effective measurement based method of controlling the power injections from the Photovoltaic generator. The three phase instantaneous active and reactive power from the Photovoltaic generator can be calculated directly from the measurement of the terminal voltage, V_t and the inverter current i_C. The PQ control problem can be considered to be the case in which Photo Voltaic generator is part of an islanded micro grid and it has to generate the power with the set point provided by the central controller so as to supply some local loads.

In (1.79) and (1.80), with the assumption that the variation of $V_t$can be neglected, that is, $V_t$is constant, then the averagenon-active/reactive power Q (t) is proportional to the magnitude of the inverter output voltage $V_C(t)$. However, the average active power $P(t)$ is dependent on both the amplitude $V_C$andthe phase angle α of $V_C(t)$.

A control scheme is developed accordingly with two feedback control loops as shown in Fig. 1.8 and based on this control scheme, simulink block model is developed . The inner loop 1 controls the reactive power $Q(t)$ by controlling the amplitude of $V_C(t)$ while the outer loop 2, controls the active power $P(t)$ by controlling the phase angle α of $V_C(t)$. The active power and reactive power are considered as the variables to be controlled. The instantaneous inverter output voltage $V_C(t)$ is controlled to be in phase with the PCC voltage $V_t(t)$. A PI controller PI_1 is used to control the magnitude of the inverter output voltage, $V_C(t)$ using equation (1.81)

$$V_{C1}^{*} = [1 + K_{p1}(Q_{ref} - Q_{act}) + K_{I1}\int_{0}^{t}(Q_{ref} - Q_{act})dt)]V_t(t)$$

(1.81)

The inverter active power control is realized by controlling the phase angle of the inverter output voltage. The active power control loop is described by (1.82). The phase angle of $V_C(t)$ is controlled by the PI controller PI_2 , where P_{ref} is the reference, andP_{act} *is* the actual value.

$$\alpha^{*} = K_{p2}(p_{ref} - p_{act}) + K_{I2}\int_{0}^{t}(p_{ref} - p_{act})dt)$$

(1.82)

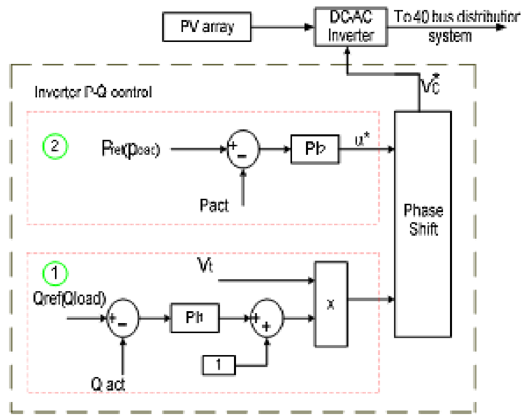

Figure 1.8 Active and reactive power control diagram

3. RESULT AND DISCUSSION

For this study one feeder frombahirdar-Ethiopia distribution system is selected. Bahirdar is the capital city of Amhara National regional state. The electric power is mainly supplied from TissAbayI, TissAbayII, Beles, Fincha, and 230 KV of Alamata substations. The loads manly supplied from three substations. These are 400/230 KV substation (substation III), 132/230/15 KV and 230/66/15KV substation (substation II) and 66/45/15 KV substation (substation I). Bahir Dar town distribution network consists of seven radial feeders, of these five(Airforce,Bata,Gion,Industry,andPapyrus)feeders are from substation II and the rest (sematate,Boiler)feeders are from substation I .For controlling the Volt/Var level of the system, Bata feeder is selected from substation II as a test feeder. The radial configuration of the Bata feeder in [48] consists of forty buses, of which node 1 is taken as reference node. From the rest thirty nine branches 30 nodes are connected to loads through step-down distribution transformer and the remaining 9 are common coupling nodes. The single line diagram of the

Bata feeder is shown in fig.2.1.The feeder is stranded conductor of type AAC-50 and AAC-95 with the total length of 16.544km.These overhead lines (feeders) are used to distribute medium voltage (15KV) power from Bahirdar Substation II to the distribution transformers. All the simulation is done using MATLAB 7.6.programming language.Before solving the Volt/Var control problem in distribution network by using distributed energy resource as a compensator, the base case load flow has to be analyzed for the selected feeder as shown in table 2.1, which is important to find the node voltages at each node of the distribution system.

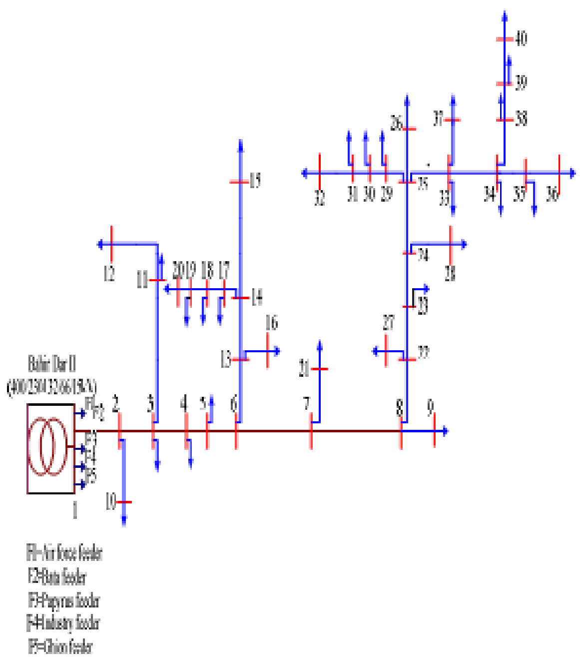

Figure 2.1 Single Line Diagram of 15kV, 40-Bus Bata Feeder

The node voltages are used to calculate the real and reactive power loss at each branch which is used to find the loss sensitivity factor of the system as shown in fig. 2.2 which is important to select the best position of the distributed energy resource connection to the system. After selecting the position of the DG (Distributed Generation), the optimal size of DG needed to be connected to the bus having high loss has to be determined. Then, based on the optimally injected DG capacity, the reference terminal voltage for controlling the volt/var level is determined.

TABLE2.1 Base case bus voltage without DG connection to the feeder

Bus No.	Bus Voltage	Bus No.	Bus Voltage	Bus No.	Bus Voltage	Bus No.	Bus Voltage
1	1	11	0.97	21	0.9678	31	0.95
2	0.9811	12	0.97	22	0.9634	32	0.95
3	0.977	13	0.97	23	0.9618	33	0.95
4	0.9748	14	0.96	24	0.9611	34	0.95
5	0.9739	15	0.96	25	0.9599	35	0.95
6	0.972	16	0.97	26	0.9599	36	0.95
7	0.9683	17	0.96	27	0.9631	37	0.95
8	0.9657	18	0.96	28	0.961	38	0.95
9	0.9657	19	0.96	29	0.9597	39	0.95
10	0.9807	20	0.96	30	0.9593	40	0.95

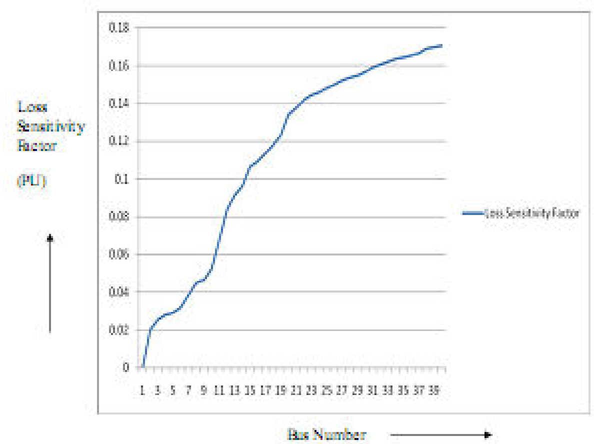

Figure 2.2 Loss Sensitivity Factor for each bus

Weight of real power loss, reactive power loss and cumulative voltage deviation for optimal sizing of DG is0.05, 0.2, 0.75 for real power loss, reactive power loss and cumulative voltage division respectively.By using genetic algorithm the optimal distributed Generation (DG) capacity is found to be 0.114707 and 0.121990 PU for active and reactive power injection respectively. Based on this, the optimal load flow solution is done and the reference bus voltage (V40) is determined. As shown in fig. 2.3 connecting distributed generation to the bus having high loss will improve system voltage.

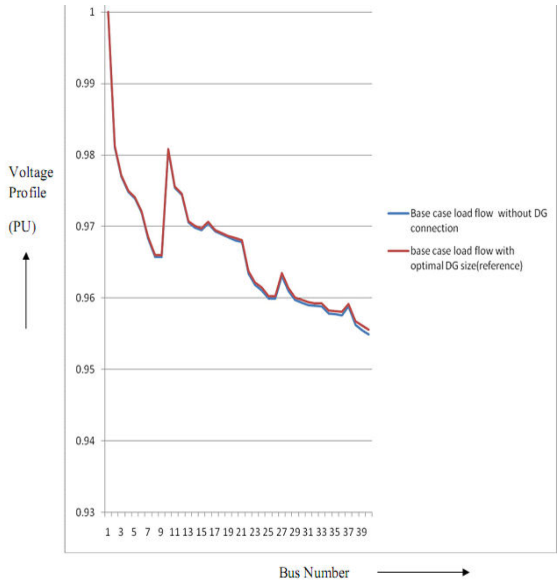

Figure 2.3 Impact of DG connections to system voltage

The reference bus voltage is to be 0.9556 PU .Therefore, for any change in system condition especially in case of transient, the bus voltage V40 should be near to the reference.

Determination of DC source voltage of the distributed generator, compensator output voltage Vc, and initial setting of $K_p$and K_I Parameter of the PI controller, ideal voltage deviation of the system is expressed in the following table

No	Parameters	Set values
1.	DC source voltage of the Distributed energy resource(solar Photo Voltaic generator)	16.56KV
2.	Compensator output voltage (V_C)	5.856KV
3.	Proportional Gain (K_p)	-0.007388
4.	Integral Gain (K_I)	-0.00716
5.	Ideal voltage deviation	0.443PU
6.	Angular frequency(ω)	314 Rad/sec
7.	Coupling inductance (L_C)	0.0033 H
8.	System frequency(f)	50 HZ
9.	Reference voltage(V_{ref})	0.9556 PU
10.	Reference Active load of the test bus (P_{ref})	1.5975PU
11.	Reference Reactive load of the test bus(Q_{ref})	1.5845PU

TABLE2.3 Initial parameter setting for the Simulink block

For the studied system, load variation is considered to be a means of creating transient to the system. Based on this, the distributed generation (DG) response with respect to system load change for compensating voltage profile is tested for three test conditions as shown in the following scenarios with the test point for load variation is bus 21(a bus having relatively large load).

Case 1:- when there is no change in system load condition

In this case the compensator (DG) will not have any effect to the system i.e. the active and reactive power response will be zero.

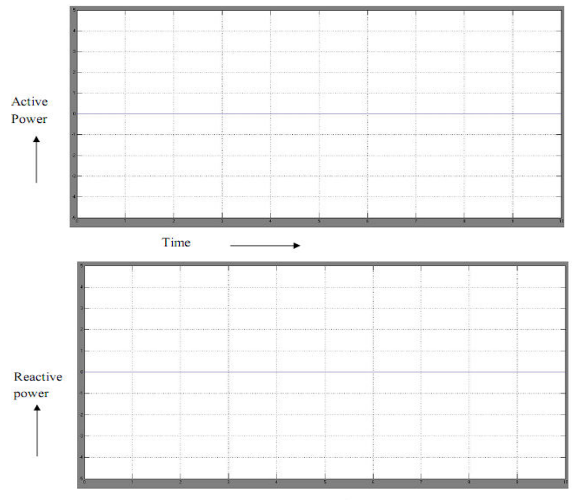

Figure 2.4 compensator active & reactive power response to no load change in system condition

Case 2:- When the system load condition increase

When load connected to bus 21 changed from 1.5975 to 2.0 and 1.5845 to 2.1 active and reactive powers respectively, the voltage profile of bus 40 decreases from 0.9556 to 0.9545 then, the DG (compensator) injects an active power of 0.45 and reactive power of 2.2 as shown in fig. 2.5and the voltage profile of the reference (V40) is improved to 0.9620 as indicated by the upper curve of fig. 2.6.

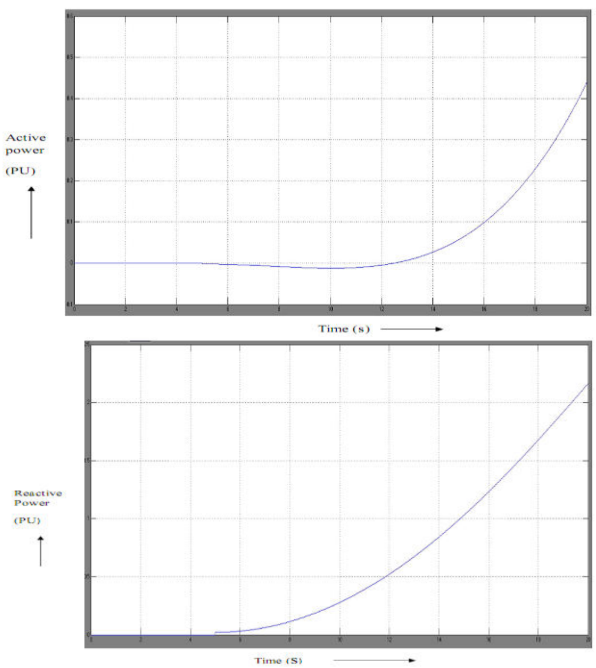

Figure 2.5 Active & reactive power response by Distributed Generation to a load change

In another case, when a large load increase occurs, from 1.59 to 8.00 and 1.58 to 9.00 active and reactive power respectively, the reference voltage (V40) changes from 0.9556 to 0.9390 PU. At this time the DG injects a reactive power of 15 and absorbs an active power of - 1.25 .The reference voltage changes from 0.9390 to 0.9890 as indicated in fig. 2.7.

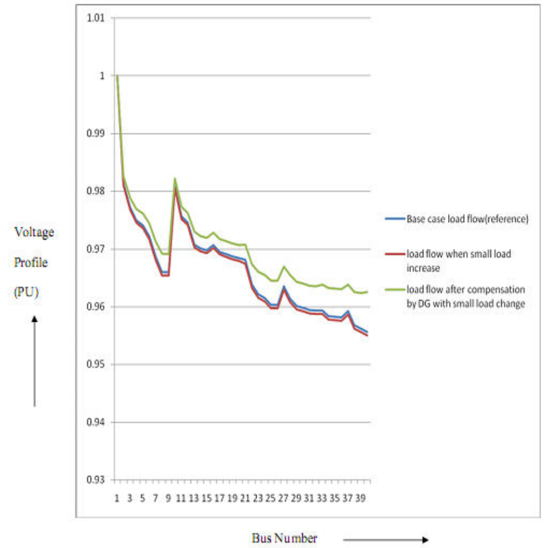

Figure 2.6. Effect DG response to a small load change (small increase) for compensating the system voltage

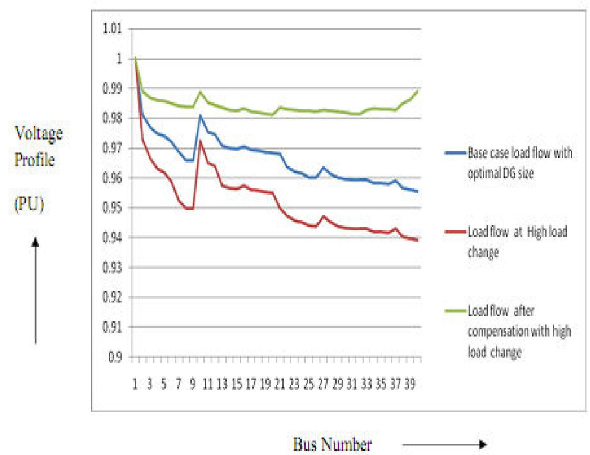

Figure 2.7 Effect of DG responses to highly increased load to compensate system voltage

Case 3:- when load outage occurs

The third considered case is when a large load outage occurs, i.e. when the load connected to bus 21 is zero. The reference voltage V40 changes from 0.9556 to 0.9593 PU which indicates the system is going to be over voltage. In this case, the compensator absorbs both active and reactive power of 1.3 and 2.5 respectively due to this, the reference voltage decreases to 0.9480 as shown in fig. 2.8. As observed from this figure, when

DG act to compensate the system voltage in case of large load outage, the system voltage decreases from reference and therefore the mechanism to control the DG response is that, the compensator should respond to the system condition when reference voltage (V40) is less than 0.9556 (in case of load increase) and greater than 1.05 (in case of load outage and when the system voltage becomes over). In the studied system, the system works based on this principle.

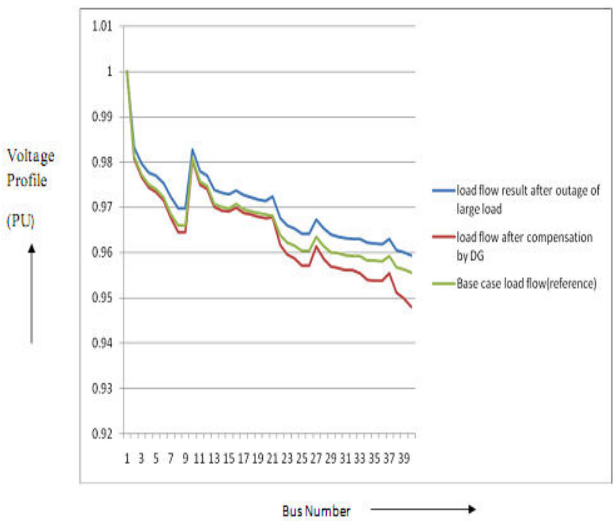

Figure 2.8Effect of DG responses to large load outage to compensate system voltage

4. CONCLUSION

The volt/var control is performed by using distributed energy resources as a compensator. The performance of the proposed system is verified by using load variation as a means of creating transient to the system. Three cases are considered to test the response of DG resource to a load change in the system by selecting bus 21 as a test bus. The result indicates that, the DG application is more effective when the load in the system is increased (in case of under voltage) and very often when load outage Occurs system voltage increases and the DG does not respond until the system voltage is greater than 1.05 PU but when it is greater than the upper limit, the compensator decreases the voltage level by absorbing reactive power from the system.

Therefore, we can conclude that distributed energy resources are used not only for system support by supplying power but also used to control the distribution system voltage level by injecting/ absorbing reactive power depending on system condition while this cannot be possible by local voltage control techniques.

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