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Dynamic Droop Load Sharing Scheme and its Stability Analysis in Islanded Microgrids

P. Vinay Kumar[1], K. Jithendra Gowd[2]

[1]PG Student, Department of EEE, JNTUA College of Engineering, Ananthapuram, Andhra Pradesh, India

[2]Assistant Professor, Department of EEE, JNTUA College of Engineering, Ananthapuram, Andhra Pradesh, India

ABSTRACT

This paper represents a dynamic droop load sharing plan in view of the accessible generation limit of the Distributed Generators (DG) units. Since ordinary droop plans share loads relative to units' ratings, they experience the ill effects of the failure to keep up a efficient operating point that their information sustainable power differs; without forcing their new working point on other associated DGs in the microgrid. This issue is essentially because of the lack of care of the droop plan to the varying nature of the sustainable assets utilized including wind and sun powered photovoltaic. A control technique is proposed for PV systems; be that as it may, it is appropriate for a wide range of droop controlled inexhaustible DG utilizing FUZZY logic controller. A stability analysis of the proposed conspire on DG units is additionally introduced to recognize theoretical and practical points of confinement. The proposed conspire distinguishes the DC working zone of the inverter-based source as irradiance level systems and conditions the droop parameters suitably for a efficient load sharing in light of available generation while the rating of every unit is likewise considered. The proposed plot gives energy saving; since energy demand from a neighborhood distribution generator is lessened. The proposed method is validated using MATLAB/SIMULINK simulations.

Keywords : Droop control, Distributed Generation, Stability analysis, Photovoltaic, Microgrids

I. INTRODUCTION

Distributed Generation (DG) is a term generally used to depict little inexhaustible power generators and storage that are situated as close as conceivable to clients. DG keeps on increasing various applications in cutting edge control system designing - it prospers from the way that progression in conveyed energy innovations upgrades the further execution of distributed generation systems (DGS) on the Grid/microgrid systems [1]-[3]. Quickly developing advances and improved infiltration of DGs helps their capability to give nearby energy and in addition further developed subordinate administrations to the National Grid (NG) including working stores, turning store, frequency and voltage control [4].

One of the principle challenges confronting the utilization of sustainable power sources all around is the means by which they can be effectively interfaced with the current NG

The NG was designed for a centralized distribution model characterized by large fossil-fuelled thermal power plants at the centre and a one way directional flow of electrical energy from high to low voltage at the point of use. at the purpose of utilization. Inexhaustible generation requires a conveyed generation display where the grid can acknowledge generation from any point in the transmission or dissemination arrange without causing specialized issues for the hardware used to control it or cause supply issues because of the expansive measure of discontinuous generation experienced with wind and sun powered [5]. An intermediate solution to the problem highlighted above is the concept of the microgrid - an interactive customer friendly cluster of distributed energy resources, loads and energy storage. It can work in matrix associated mode or islanded mode (without NG) to enhance control quality and system dependability. Present day ways to deal with microgrids advance self-sufficient control in a shared and attachment and-play operation show for every DG on the microgrid [3], [6]-[7]. The concept of peer-to-peer ensures there is no master controller or central storage unit that is critical for the operation of the microgrid; hence the microgrid will continue to operate with loss of any DG [1], [6]. Plug-and-play implies that the DG can seamlessly operate when placed or mounted at any point in the microgrid network without re-engineering the control scheme [8].

In Grid-associated mode, control measures are moderately simple to be actualized since voltage and frequency are managed by the utility grid for loads inside the microgrid; while in islanded-mode voltage and frequency must be effectively controlled for the persistent and stable execution of the system [7], [9]. Keeping in mind the end goal to adjust produced energy with demand in a microgrid, sustainable power source generation are regularly supplemented with dispatchable assets, for example, energy storage system and neighborhood auxiliary generation (AG) [7] ; absence of such resources can result in the possibility of stressing the inverter-based sources leading to excessive voltage rise due to over-modulation, yielding poor power sharing and circulating current among the inverters that can harm the switching components and result in overloading and excessive total harmonic distortion (THD) on the AC-side [6], [10]-[12].
In islanded network, DGs and in addition petroleum product sources must have the capacity to work self-rulingly in adjusting generation and demand, voltage and frequency control, cost minimization, while guaranteeing system stability [13]-. The droop sharing plan is normally utilized in a microgrid for voltage and frequency control between the accessible DGs, this plan embraces a self-governing burden sharing methodology, where each associated DG utilizes their nearby parameters for precise load sharing. In this way droop strategy gives higher adaptability and reliability quality when contrasted with master slave systems [2], - .

It is noticed that in a microgrid, most line can be for the most part resistive. In these cases, two primary techniques are proposed in writing: (1) it is appeared in - that in resistive lines, droops are dynamic power-voltage and reactive power-frequency inclines. (2) References - proposed a technique called "Virtual Impedance" to diminish the coupling amongst active and reactive power stream in low-voltage dissemination arrange due to non-insignificant feeder impedances. Both methodologies are pertinent to the strategy proposed in this paper. Be that as it may, this paper considers the great dynamic power-frequency droop to accentuate that the strategy is not restricted to resistive microgrids. Additionally; inductive microgrid is considered in numerous written works, for example, [10], [12], , - .

Distinctive parts of droop control have been examined in various references, for example, [1], [6], [13], [14], , to check the disadvantages with droop based control i.e. shakiness issues because of sudden load bother, poor transient reaction, mistaken load sharing, consistent state blunder of voltage and frequency . Reference [13] proposed the rakish droop strategy to perform load offering to least frequency variety; active power droop coefficient would thus be able to be picked relying upon the most extreme/least estimation of load demand and load sharing proportion [13]. Various inquires about have likewise been conveyed to enhanced droop sharing plan while keeping up a generally enduring frequency and voltage [13], - . For instance features the droop control and normal power control through two autonomous control factors on every DG for precise sharing of dynamic and reactive power-thus disposing of the affectability of the droop technique to estimation blunder and wire bungles. Reference proposed a three phase commonly intuitive droop plot in light of DC interface voltage variety, for control linearion between the DG and the AC transport. The plan works by the acquaintance of a power balance with the computed control from the traditional droop plot, keeping in mind the end goal to alter voltage reference to the inverter. The plan was tried to indicate control adjust in view of variety in load without thought for situation when demand surpasses generation.

Current approach towards enhancing the adaptability and dependability of the microgrid favors a half breed DG systems (trading off of inexhaustible sources, energy storage systems (ESS) and fossil-fuelled AG), with versatile order controller plans utilized for control molding and administration [3], , . In any case, the systems examined in these literary works do exclude a auxiliary generator while in any viable microgrid a fossil-fuelled AG is important to supply the basic loads if there should arise an occurrence of deficiency of energy. It is noticed that the part of the AG is not like that of an ace unit (in an ace slave worldview) since not at all like in an ace slave control, the operation of different units are not reliant on the AG. The ESS frequently gives control shortfall pay when all associated DG are completely used, with droop methods utilized for precise load sharing. For instance, in reference the frequency droop was controlled utilizing power reference from the ESS. The approach introduced in depends for the most part on appropriate comprehension of the province of Charge (SOC) of the battery in characterizing working conditions for charging the battery and for load sharing. In any case, the present paper considers systems without battery storage (to consent to current UK linearions on circulated PV systems). Also, dissimilar to in past literary works, the control of an distribution generator (AG) is displayed and the droop pick up is legitimately tuned to limit the energy required from the AG. Reference proposed a complex multi-arrange streamlining plan to limit fuel utilization in microgrids. Next to the reality the proposed technique in is extremely mind boggling, it doesn't consider the irregular idea of inexhaustible bases DG units which is a typical issue with these examinations. This downside is shown in Fig.1:

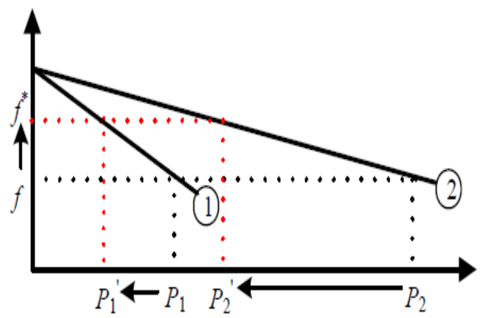


Fig. 1: Steady-state characteristic of traditional droop

The traditional static dynamic power-frequency (P-f) and reactive power-voltage (Q-V) droop sharing plan (appeared in Fig. 1) sets a settled frequency/voltage droop increase regardless of the accessible energy from the inexhaustible source. The frequency hence just systems because of load system; it is obliged inside the suitable frequency droop pick up [14]. In such cases, a drop in the accessible energy of one of the DG from P1 to P'1 (e.g. because of a lessening in sun based light) will move its frequency (f) to another working point (f*). Since the other DG must agree to the new working frequency (f*), its energy decreases from P2 to P'2 (despite the fact that it may have the ability to produce more power).

With a specific end goal to moderate this issue references [7] and , proposed a droop conspire for wind turbine era to control nearby demand. Other than the way that the technique was proposed just for wind generation, the stability examination of the plan was not exhibited while the creators conceded that the strategy may influence the system security.

The present paper proposes a dynamic droop plot for Photovoltaic (PV) systems. The proposed conspire utilizes the PV cluster's present versus voltage attributes in characterizing a working reach for the inverter-based source to guarantee a proficient load imparting cooperation to different DG(s); as the DC connect voltages systems because of fluctuating irradiance of sun based energy. The down to earth and hypothetical security of the proposed technique is additionally researched for one DG unit. This examination will be founded on PV sources yet it is vital for all sustainable power sources i.e. wind, tidal, and so on.

To the best of our insight, there is no earlier work that decisively concentrates on the discontinuous idea of the inexhaustible source(s) in designing the droop conspire i.e. droop increase touchy to source variety, with a specific end goal to limit the energy required from an distribution generator. This is particularly valuable in situations where ESS is not permitted, subsequently energy bolster is frequently given from utility side or a unified distribution generator inside the microgrid.

II. MICROGRID NETWORK UNDER STUDY

Fig. 2 demonstrates a microgrid arrange in islanded association with 3-phase inverter-based DGs (DG1, DG2). The power electronic controller (PEC) is utilized to control the stream of energy from neighborhood distribution generator (AG) utilizing nearby data from the DGs. This examination intends to break down the load sharing communication between these DG sources in the islanded microgrid arrange.

Without greatest power following, the PV working point is normally dictated by the AC-side load demand; thus the DC connect voltage (V_{DC}) will be annoyed persistently from the base working voltage ($V_{DC\text{-}min}$) to the PV exhibit's open circuit voltage (V_{OC}) as the irradiance level or load differs.

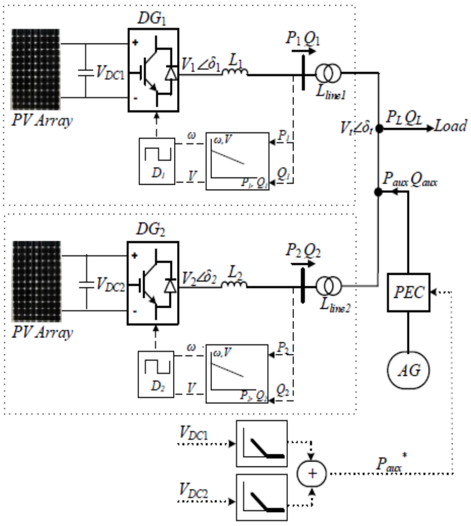


Fig. 2: MicroGrid Network Under study

The three phase inverter-based sources above are PWM controlled with PQ, voltage and current controllers. The customary PQ controller utilizes the droop conspire (f versus P and V versus Q) to self-governingly react to systems in associated loads.

The proposed dynamic droop plot utilizes the variety in irradiance (i.e. V_{DC}) in molding the traditional droop plot for a proficient load sharing while at the same time obliging V_{DC} inside V_{DC}-min to V_{OC} (since inverter yield voltage, Vinv ≈ $0.5DV_{DC}$ for a three phase system, where D is the adjustment list [6]). This will include a linear estimate of the PV most extreme power point trademark curve and the resulting droop pick up following of irradiance variety inside the DG's working zone.

The current study does not consider reactive power sharing; hence reactive power compensation control is not considered in the AG control scheme.

A. Inverter Operating Zone in DG Application

The mathematical model of a PV array is described in with P-V characteristic shown in Fig. 3. It was also shown in [10], [34] that a three-phase inverter (with sinusoidal PWM) can averagely be modeled using d-q frame transformation techniques:

$$V_{dc} = \frac{1}{2} D_{dq} V_{DC} \qquad (1)$$

Where Vdq is the d-q frame park transform of the AC bus voltage, Ddq is the modulating index (in d-q frame) and VDC is the DC link voltage. When there is a reduction in solar irradiance level (hence decreasing VDC), D must increase to maintain (1). At D =1; a constant Vdq depends solely on VDC. Further reduction in VDC due to irradiance perturbation will reduce Vdq. Generally VDC perturbs in response to irradiance level and demanded load. Hence, in order to accurately control AC bus voltage (Vdq), minimum DC voltage VDC-min must ensure (1) while D = 1; e.g. for a nominal RMS 240V DG(s) system explained in section II, VDC ≥ 678.8-V (i.e. operating point limit with modulating index, D = 1). Thus, the PV array must be designed such that the DC voltage of the maximum power at a small irradiation (say 0.05 pu) = VDC-min= 678.8 V (see Fig. 3).

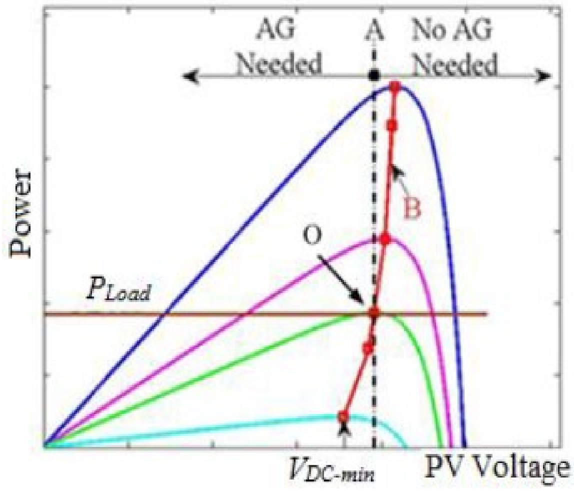


Fig. 3 : PV curve for varying irradiance level. (Curve B): Maximum point curve; (PLoad): Constant Load demand curve

B. Conventional Static Droop Load Sharing Scheme

Utilizing droop control, at least two parallel wired DGs can be controlled to convey the required active and reactive power. In distributed droop plans, two systems autonomous parameters are controlled to accomplish load imparting to insignificant correspondence between the sources [6], [13], The active and reactive forces infused from the DG to the microgrid are detected and arrived at the midpoint of; the subsequent signs are utilized to modify the frequency and voltage abundancy of the DG [6], [14].

The averaged real and reactive power (P and Q) of the DG(s) (deduced in [6]) shown in Fig. 2 is given below:

$$P = \frac{VV_t}{X} \sin\emptyset \approx \frac{VV_t}{X} \emptyset \qquad (2)$$

$$Q = \frac{V^2 - VV_t \cos\emptyset}{X} \approx \frac{V}{X}(V - V_t) \qquad (3)$$

Equation (2) and (3) shows P varies with the phase angle difference (ϕ) between the inverter output voltage

(V) and the common AC bus voltage (Vt) while Q varies with the amplitude difference (V - Vt). Where X is the output reactance of the inverter.

The P-ω and Q-V droop are entirely figured to guarantee that precise load sharing is conceivable without a critical enduring state frequency and voltage drop over the general system [14].

The droop square (characterized by ((4) and (5)) is utilized for corresponding sharing of P and Q; where P shifts with system frequency and Q with system voltage..

$$\omega = \omega_{ref} - m_p(P - P_{ref});\ m_p = \frac{\Delta\omega}{P_{rating}} \quad (4)$$

$$V_d = V_{ref} - n_q(Q - Q_{ref});\ n_q = \frac{\Delta V}{Q_{rating}} \quad (5)$$

Where ω, Vd, P and Q are the DG's angular frequency, terminal voltage, active and reactive power; ωref and Vref are the rated angular frequency and voltage of the DG. Δω and ΔV are the allowed frequency and voltage deviation. mp and nq are the droop coefficients (i.e. the gradient of droop lines in Fig. 4) – which ensures the desired proportional power sharing based on the DG's rating (i.e. Prating and Qrating) [13], , .

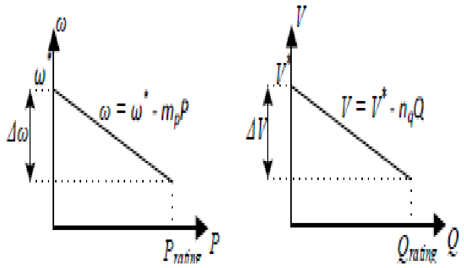


Fig. 4: Steady-state characteristic of traditional droop

Using (4) and (5), it was shown in [6, 13]:

$$\frac{P_1}{P_2} \approx \frac{m_{p2}}{m_{p1}} \approx \frac{P_{rating1}}{P_{rating2}} \quad (6)$$

An issue emerges if the accessible energy of one DG is insufficient to meet the demanded load. Another frequency working point will surface, which powers all other DG on the system to its new working point independent of the creating limit of alternate DG(s) as appeared in Fig. 1 and Fig. 3. As it were, a drop in generation of one unit (because of a decrease in illumination) causes diminishments in the various units' generation (see reenactment brings about Fig. 8). The deficiency of supply is repaid by the energy put away in the DC-connections' capacitors (or a nearby energy stockpiling) which causes a drop in the DC interface voltage. Subsequently, the DC-connect voltage (or the energy level of the energy energy storage) can be utilized to trigger an distribution generator (AG) by means of a Power Electronic Converter (PEC) to adjust for the deficiency of energy. It is noticed that since alternate DGs are compelled to lessen their generation, the energy demanded from the AG won't be optimized. This is because of the lack of care of a static droop control to the info sun oriented energy (Fig. 8).

C. Proposed Dynamic Droop Scheme

This area proposes a dynamic droop control in which the droop coefficient varies as sun based light systems without the need to measure the illumination. The strategy likewise guarantees that the most extreme power from every unit is created if required by the load. Fig. 3 portrays the PV curve of a DG as irradiance level differs. At the point when accessible sunlight based power is more than the load control, the system works typically inside its working zone (right hand side of curve B). As sun oriented illumination (S) drops, the DG will keep on supplying the load, until the point that the accessible sun oriented power is insufficient to take care of the demand (point O); AG is in this way activated on (when VDC turns out to be not as much as a limit) to make up for the deficiency in control.

The maximum power of a PV system varies according to S. In order to increase the efficiency of droop controlled PV systems and ensure proportional load sharing, the maximum power curve for various level of S can be used to define a reference for the droop gain. The maximum power points curve (curve B in Fig. 3) of the PV array can be accurately approximated by (7) [10] (shown in Fig. 5):

$$P_{DC-max} = aV_{DC}^3 + bV_{DC}^2 + cV_{DC} + d \quad (7)$$

Where a, b, c, and d were deduced using the Matlab "polyfit" command, VDC is calculated from the Ppv - Vpv characteristics of the array (as given by the PV manufacturer).

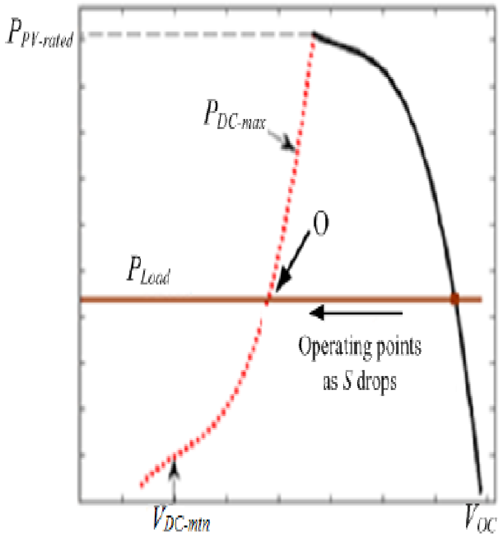


Fig. 5 : Steady-state characteristic of PV operating zone

The operating zone is the area specified by VDC-min, PPV-rated and VOC in Fig.5. As S drops, the operating point (for a given load) moves towards the PDC-max curve (Fig. 5). At the intersection of PLoad and PDC-max (point O), for any reduction in S, the AG is turned on (when VDC becomes less than a threshold) to compensate for the shortage of energy. In cases with conventional static droop, drops in S of one unit causes reductions in power output of all other units (to comply with the new operating frequency), regardless of their available generation capacities. As a result, more energy will be demanded from AG. To solve this problem, the droop gains.

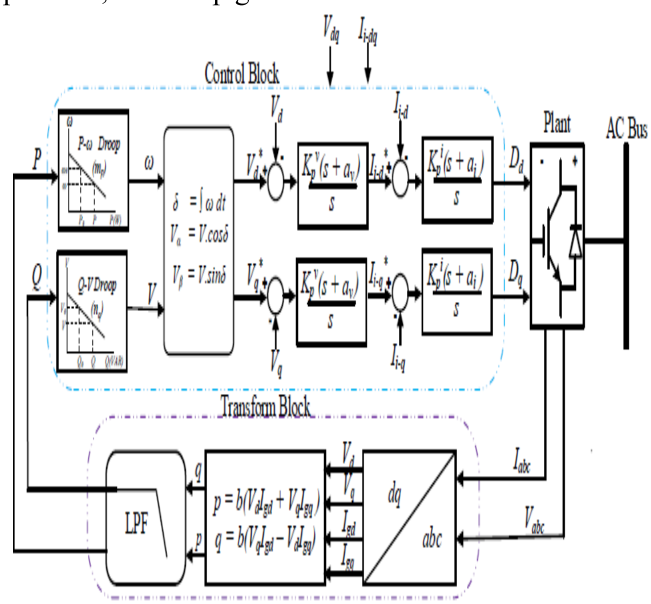


Fig. 6 : Control block for DG in d-q frame must vary according to the maximum power point curve of their associated PV array (i.e. PDC-max):

$$m_{p-n} = \frac{\Delta\omega}{P_{DC-max-n}} \qquad (8)$$

Where n is number of PV array = 1, 2… N

Although (7) can be used in denominator of (8), it will impose an unnecessary complexity. After all, it is only needed to have an inverse relationship between mp and VDC (which in turns varies with S). So (7) can be approximated as PDC-max≈kVDC+c where, k and c are constants which are used to get a linear approximation of (7). Please note that the idea is to make the droop mechanism sensitive to the available solar power. However, since droop mechanism is based on the relative ratio between units, it is not necessary to use (7) and a linear approximation of it works satisfactorily. This equation describes the simplest maximum power point tracking method explained in literature [35]. Droop gains must still be proportional to the rating of their associated units. Therefore, (7) is approximated for each PV unit as:

$$V_{DC-max-n} = k_n V_{DC-n} + c_n \qquad (9)$$

where kn and cn are gains to get a linear approximation of the PDC-max (i.e. (7)) of the nth PV array. Therefore, the allowed frequency variation will be:

$$\Delta\omega = m_p1(k_1 V_{DC-1} + c_1) = m_p2(k_2 V_{DC-2} + c_2) \dots.. = m_pN(k_N V_{DC-N} + c_N) \qquad (10)$$

Doing so, when S is the same on the units, the load is shared proportional to their ratings which is the same as conventional units (see result in Fig. 8). However, any reduction in S of one unit (e.g. unit 1 in Fig. 7), does not force the other units to reduce their generation as mp is now sensitive to VDC. Moreover, as illustrated in Fig. 7, the other units will increase their generation through reducing mp (provided that enough S is available) to compensate for the power reduction from the first unit. This significantly reduces the energy demanded from AG compared to conventional static droop method (see Fig. 9 for results).

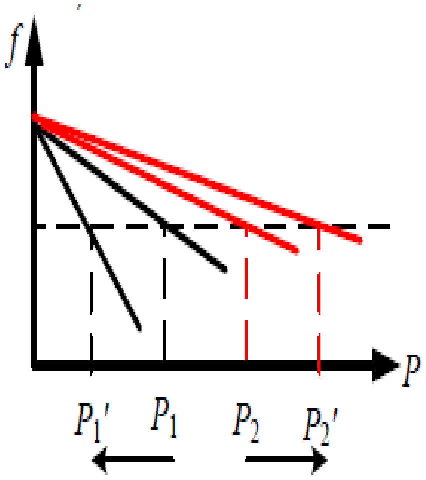


Fig. 7. Dynamic droop operation

D. Three-Phase System Control Scheme

The diagrammatic description of the control plan of every inverter-based DG can be approximated utilizing the immediate PI control approach (i.e. overlooking food forward way for pivot decoupling) as appeared in Fig. 6. Synchronous reference outline parameters are produced utilizing the Park and Clarke varies. The droop piece is utilized for exact sharing of P and Q; where P differs with system frequency and Q with system voltage. Where b = 1.5 for a three phase system. The low pass filter (LPF) is utilized to conclude normal estimations of P and Q individually. The voltage controller linears the terminal voltage and creates reference for the present controller [9].

A voltage sustain forward approach was utilized in the present controller to battle transport voltage unsettling influence and for voltage drop compensation; with the transport voltage utilized as reference. Pay terms are added to disintegrate coupling impacts. The present controller produces the control motion for the PWM. Hard point of confinement square sets as far as possible to shield the system from over current (i.e. confine the upper and lower cutoff points of reasonable reference voltage). The d and q parts are controlled freely. Where'd' controls dynamic power (P) and "q" manages the reactive power (Q).

The dynamics of the control scheme depends mainly on the bandwidth of the PQ controller, since the bandwidth of the current and voltage controller are much higher than that of the PQ controller [37]. The instantaneous active and reactive power is given by (11).

$$p=\frac{3}{2}(V_d I_{gd} + V_q I_{gq})$$
$$q=\frac{3}{2}(V_q I_{gd} + V_q I_{gq}) \qquad (11)$$

LC filter is interfaced at the output of the inverter to reduce switching harmonics of the output voltage (THD < 5%); filter parameters were chosen as discussed in [10].

E.Auxiliary Generator Control

The DC link voltage of DGs is an indicator for regulating the AG (see Fig. 2). When the DC link voltage of either DG decreases below a threshold (here 0.85pu), AG is switched ON to compensate for the energy shortage in order to maintain the demand power. The AG reference power (Fig. 2) is:

$$P_{aux}{}^{*}=-3\sum_{n=1}^{N} V_{DC-n} \qquad (12)$$

The proposed method in this paper studies the active power sharing not reactive power. Thus the PQ control scheme was adopted in the AG control, for injecting active power into the network when needed, Where Qref for the PQ controller is zero and Pref is set by (12). The load reactive power is shared appropriately using the classical Q-V droop.

III. STABILITY ANALYSIS OF THE PROPOSED SCHEME

For an immediate stable operation the modulation index D must be kept under 1. This zone investigates the effect of the assortment of p-f droop get (mp) on the operation of a 3-arrange inverter. It has been showed up in various compositions [12] that the components (low-repeat shafts) of the DG is mainly controlled by the information excdroope limit of the droop control sharing control show showed up in Fig. 8. Regardless, with a particular ultimate objective to ensure completeness, this examination will be established in general linearized state-model of the DG.

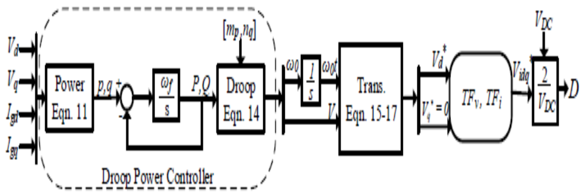


Fig. 8: Control model of power droop controlled PV system

$$P(s) \approx \frac{\omega_f}{s+\omega_f}\mathbf{p}$$

$$Q(s) \approx \frac{\omega_f}{s+\omega_f}\mathbf{q} \qquad \mathbf{(13)}$$

Eq. (4), (5), (11), and (13) is combined and linearized around an operating point:

$$\begin{bmatrix}\Delta\delta\\ \Delta P\\ \Delta Q\end{bmatrix}=\begin{bmatrix}0 & -m_p & 0\\ 0 & -\omega_f & 0\\ 0 & 0 & -\omega_f\end{bmatrix}\begin{bmatrix}\Delta\delta\\ \Delta P\\ \Delta Q\end{bmatrix}$$

$$\ldots+\frac{3}{2}\omega_f\begin{bmatrix}0 & 0 & 0 & 0\\ V_d & V_q & I_{gd} & I_{gq}\\ V_q & -V_{dq} & -I_{gq} & -I_{gq}\end{bmatrix}\begin{bmatrix}\Delta I_{g-d}\\ \Delta I_{g-q}\\ \Delta V_d\\ \Delta V_d\end{bmatrix} \quad \mathbf{(14)}$$

$$\begin{bmatrix}\Delta\omega_0\\ \Delta V\end{bmatrix}=\begin{bmatrix}0 & -m_p & 0\\ 0 & 0 & -n_q\end{bmatrix}\begin{bmatrix}\Delta\delta\\ \Delta P\\ \Delta Q\end{bmatrix}$$

The output of the power droop controller (**v**(t)) is transformed to d-q components to yield Vqd* for the voltage controller [13]: Using Clarke transform, **v**(t) can be rewritten as

$$\mathrm{v(t)}=\begin{bmatrix}\omega_0\\ V\end{bmatrix}=\begin{bmatrix}V_\alpha^*\\ V_\beta^*\end{bmatrix}=\begin{bmatrix}V\cos\omega_0 t\\ V\sin\omega_0 t\end{bmatrix}=\begin{bmatrix}V\cos\delta\\ V\sin\delta\end{bmatrix} \quad \mathbf{(15)}$$

Parke Transformation representation equals:

$$\begin{bmatrix}V_d^*\\ V_q^*\end{bmatrix}=\begin{bmatrix}\cos\delta & \sin\delta\\ -\sin\delta & \cos\delta\end{bmatrix}\begin{bmatrix}V_\alpha^*\\ V_\beta^*\end{bmatrix} \qquad \mathbf{(16)}$$

Vdq* is linearized and simplified using (14) and (16):

$$\begin{bmatrix}\Delta V_d^*\\ \Delta V_q^*\end{bmatrix}=\begin{bmatrix}V & 0\\ 0 & -1\end{bmatrix}\begin{bmatrix}\Delta\delta\\ \Delta V\end{bmatrix} \qquad \mathbf{(17)}$$

Variation for different mp

As discussed, the open loop poles moves towards instability as active power p decreases. So here remembering the true objective to consider the most desperate result possible, p=0.05pu while mp varies from 0.11 to 0.13.

Fig. 13 has five arrangements of complex conjugate poles. Four shaft consolidate is far to the other side (not showed up) whose components has immaterial effect on strength and they move a long way from the imaginary axis as mp increases.

A drop in VDC because of a lessening in irradiance level causes an expansion in droop pick up (mp) to diminish the power commitment from the DG. Then again, a diminishment in VDC likewise expands the adjustment record D to conform to (1). D is limited to 1 where VDC=VDC-min (see Fig.9). This point defines a practical stability limit for mp (mp-max) where using (1): VDC-min ≈ 2VdC

The practical stability limits for the PV systems simulated in this study are:

Therefore, it can be concluded that mp-limit>>mp-max which is illustrated in Fig. 14. Note that mp-max-n is the practical limit that the droop gain can be reduced to. This happens when the solar irradiation is very low and Vdc=Vdc-min, D=1.

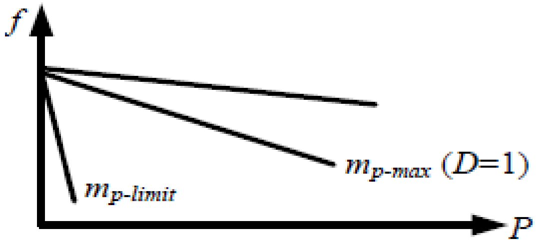


Fig. 9: Stability limit of the proposed dynamic droop

This study demonstrates that the practical stability limit which is imposed by modulation index of the inverter is much less than the theoretical stability limit which is imposed by a very large droop gain mp. In other words, the dynamic droop method does not add a further limitation on the operation of an inverter-based unit.

IV. FUZZY LOGIC CONTROLLER

Fuzzy logic controller

In this manner, we have seen that the planning of a Fuzzy Logic Controller (utilizing the Mamdani Fuzzy Model) requires:

1. The choice of proper inputs and their fuzzification.
2. The meaning of the information and output enrollment capacities.
3. The meaning of the Fuzzy Rule Base.
4. The defuzzification of the output got after the handling of the semantic variables with the assistance of an appropriate defuzzification method.

The three variables of the FLC, the error, the system in error and the output, have five triangle membership functions for each. The basic fuzzy sets of membership functions for the variables are as shown in the Figs. 1 and 2. The fuzzy variables are expressed by linguistic variables „positive big (PB)‟, „positive small (PS)‟, „zero (ZE)‟, „negative small (NS)‟, „negative Big (NB)‟, for all three variables. A rule in the rule base can be expressed in the form: If (e is NB) and (de is NB), then (cd is NB). The rules are set based upon the knowledge of the system and the working of the system.

The rule base adjusts the duty cycle for the PWM of the inverter according to the systems in the input of the FLC. The number of rules can be set as desired. The numbers of rules are 25 for the five membership functions of the error and the system in error (inputs of the FLC).

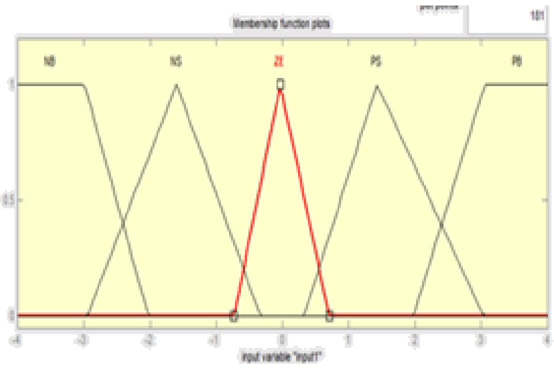


Fig 1 Membership functions for error and system in error

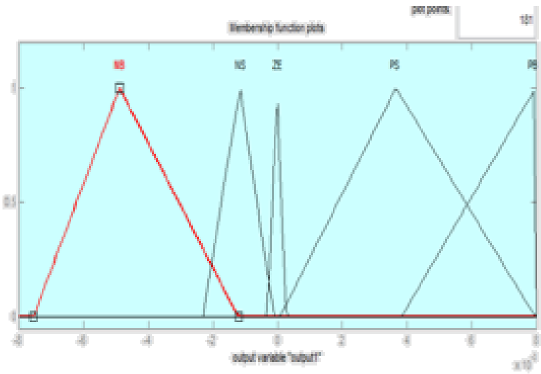


Fig 2. Membership functions for output

Table: Rule base of FLC

e/Δe	NS	NB	ZE	PB	PS
NS	PS	PB	ZE	NS	ZE
NB	PS	ZE	PS	NS	ZE
ZE	PS	PB	ZE	NB	NS
PB	ZE	PS	NS	ZE	NS
PS	ZE	PS	ZE	PB	NS

V. SIMULATION RESULTS

TABLE I

SYSTEM'S PARAMETER **Variable**	**Value**
Prating1	0.64 pu
k1 and c1 (Eq. 9)	76.48 and -50692.01
Prating2	0.36 pu
k2 and c2 (Eq. 9)	43.05 and -28442.60
Δf and ΔV	2% and 5%
PLoad	0.75 pu
DC link capacitor, C0	800 μF
Line to line voltage VL-L	415 V
LCL line parameters	10mH/6 μF/0.2mH
LPF bandwidth (ωf)	45 rad/s

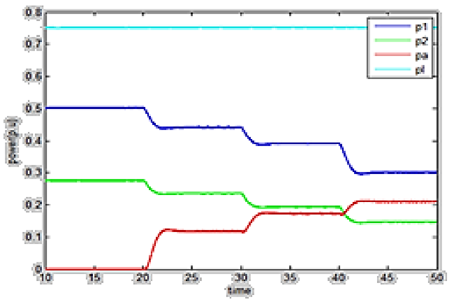
The test model consists of two DGs and one AG feeding a 3- phase load. Each DG has its own control scheme as shown in Fig. 2 and the load sharing scheme is simulated for both conventional static droop gain and the proposed dynamic droop gain.

Various testing were conducted and results were observed in MATLAB/SIMULINK to analyze the test network depicted in Fig. 2. Note that all results are presented in pu based on the total system rating (not each PV system).

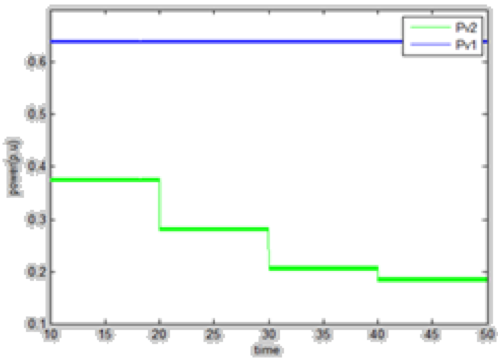
A. Conventional Static Droop Scheme

Conventional static droop load sharing was tested for two PV DG sources shown in Fig. 2, with droop gain set by (4) & (5) using values for Prating1 and Prating2 given in Table I.

The results in fig.10 show how the load shared between the two DGs when the sun based light of DG2 varies as the load is constant . Upto some extent of time the load is shared according to there rating. Since the solar power of DG2 drops ,the frequency changes.This results in change in operating point of DG1(Fig.10(a)).Then the generation is less than load causing in reduction of Vdc so the AG is turned on for replacing the shortage of energy.So by this(Pa1+Pa2)<PLoad i.e no need of AG .So by this results there no enhanced use of an AG.



a

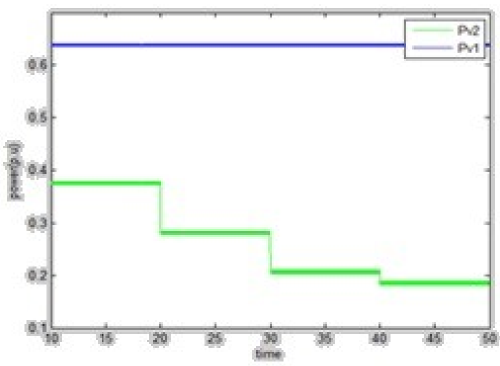


b

Fig. 10: Simulation results of two DG systems using conventional static droop (a) active power in pu, 1-PLoad , 2-P1 , 3-P2, 4-Paux , (b) available solar power in pu 1-Pa1, 2-Pa2

B. Proposed Dynamic Droop Implementation

The simulation was repeated with droop gains set by (11) using the available solar power for load sharing. Fig. 10(a) shows that the power is shared properly (i.e. based on rating) - when the solar irradiances are the same. As the solar irradiance on DG2 decreases, its droop gain increases which decreases the power contribution of DG2 to the overall load. However, the droop gain of DG1 proportionally reduces to compensate for the power drop in DG2 (since DG1 has extra capacity to compensate for DG2). The DGs are acts in the respective 'operating zone', since DG1 make up the reduce power in DG2 without the use for the AG (power contribution from AG = 0 as shown in Fig. 10(a)). The pliability of proposed scheme helps with the excess energy support between the DG(s)-for instance at time 30 - 40s, the DG(s) fully supply the demanded power since the combined total available power (0.86pu) is more than total load (0.75pu). The dynamic droop when compared with the conventional droop scheme saves energy, since DGs compensate for one another which minimize the energy demanded from AG.



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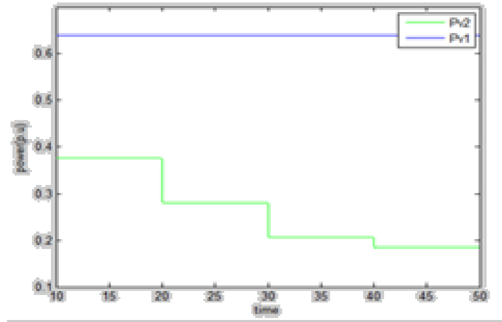
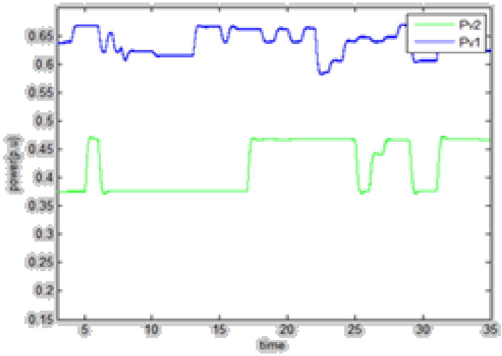


b

Fig.11: Simulation results of two DG systems using the available solar power for dynamic load sharing (a) active power in pu, 1-PLoad , 2-P1 , 3-P2, 4-Paux , (b) available solar power in pu 1-Pa1, 2-Pa2.

C. Simulation Results with Real-Time Solar Irradiance Variation



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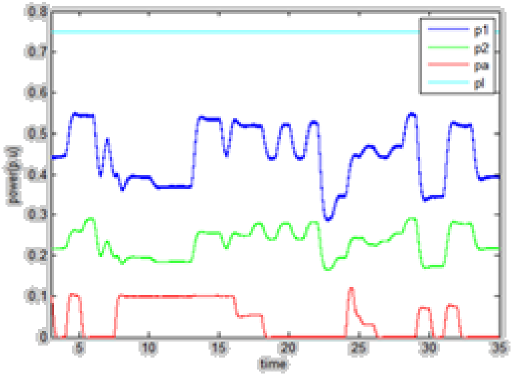

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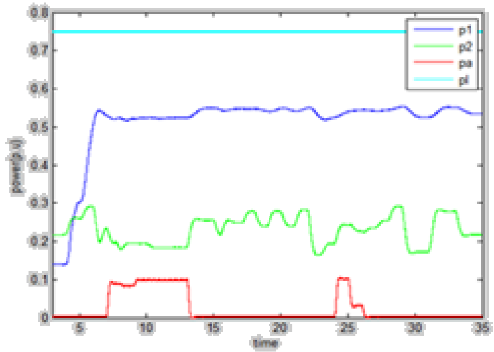
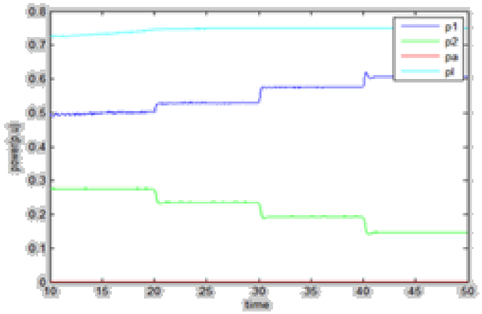


c

Fig. 12 : Simulation results of two DG systems using the real-time solar data (a) available solar power in pu 1-Pa1, 2-Pa2 (b) active power using conventional droop in pu, 1-PLoad , 2-P1 , 3-P2, 4-Paux , (c) active power using proposed dynamic droop in pu, 1-PLoad , 2-P1 , 3-P2, 4-Paux , (d) AG Energy profile for Conventional and Dynamic droop in pu, 1-Conventional Droop, 2-Proposed Dynamic droop.

Simulation results using fuzzy logic controller:



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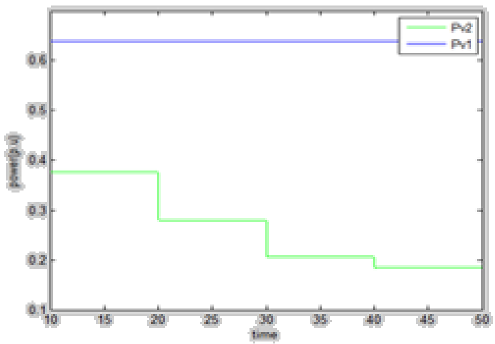
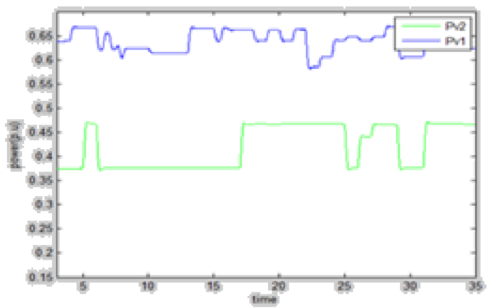


b

Fig. 13: Simulation results of two DG systems using the available solar power for dynamic load sharing (a) active power in pu, 1-PLoad , 2-P1 , 3-P2, 4-Paux , (b) available solar power in pu 1-Pa1, 2-Pa2



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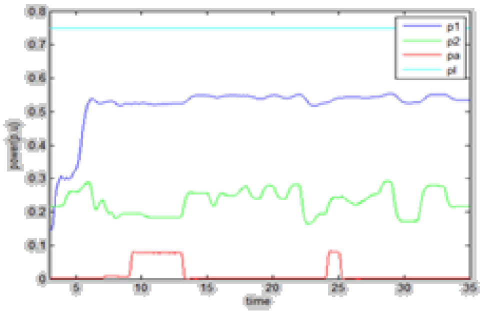

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Fig. 14: Simulation results of two DG systems using the real-time solar data (a) available solar power in pu 1-Pa1, 2-Pa2 (b) active power using conventional droop in pu, 1-PLoad , 2-P1 , 3-P2, 4-Paux

VI. CONCLUSION

The solar powers of DGs are studied using dynamic droop load sharing .the proposed dynamic droop load sharing with fuzzy logic controller can be designed using matlab/simulink software. The simulation results shows the dynamic droop based on solar power of DGs can be used for optimum load sharing.

The presented method was validated for several PV systems with different irradiance conditions; and power sharing is proportional to the rating of the solar power available in units are same.One pv array drops the power then other pv generate the more power to compensate the load requirements with out any use of other supports.

Compare the results of pI controller with proposed FUZZY controller to gives better performance .and also fuzzy logic controller saves the more energy compared to PI controller

VII. REFERENCES

[1]. J. M. Guerrero, H. Lijun, and J. Uceda, "Decentralized Control for Parallel Operation of Distributed Generation Inverters Using Resistive Output Impedance," IEEE Trans. Ind. Electron., vol. 54, no. 2, pp. 994-1004, Apr. 2007.

[2]. K. T. Tan, X. Y. Peng, P. L. So, Y. C. Chu, and M. Z. Q. Chen, "Centralized Control for Parallel Operation of Distributed Generation Inverters in Microgrids," IEEE Trans. Smart Grid, vol. 3, no. 4, pp. 1977-1987, Dec. 2012.

[3]. K. Jong-Yul, J. Jin-Hong, K. Seul-Ki, C. Cdroophee, P. Jine-Ho, K. Hak-Man, and N. Kee-Young, "Cooperative Control Strategy of Energy Storage System and Microsources for Stabilizing the Microgrid during Islanded Operation," IEEE Trans. Power Electronics, vol. 25, no. 12, pp. 3037-3048, Dec. 2010.

[4]. R. Arghandeh, M. Brown, A. Del Rosso, G. Ghatikar, E. Stewart, A. Vojdani, and A. von Meier, "The Local Team: Leveraging Distributed Resources to improve Resilence," IEEE PES vol. 12, no. 5, pp. 76-83, Aug. 2014.

[5]. N. Jenkins, R. Allan, P. Crossley, D. Kirschen, and G. Strbac, Embedded Generation. London: The Institute of Electrical Engineers, 2000.

[6]. J. M. Guerrero, H. Lijun, and J. Uceda, "Control of Distributed Uninterruptible Power Supply Systems," IEEE Trans. Ind. Electron. , vol. 55, no. 8, pp. 2845-2859, Jul. 2008.

[7]. M. Fazeli, G. M. Asher, C. Klumpner, and L. Yao, "Novel Integration of DFIG-Based Wind Generators Within Microgrids," IEEE Trans. Energy Conversion, vol. 26, no. 3, pp. 840-850, Aug. 2011.

[8]. P. Paigi and R. H. Lasseter, "Autonomous Control of Microgrids," IEEE PES Meeting, Monreal,, Jun. 2006.

[9]. J. Rocabert, G. M. S. Azevedo, A. Luna, J. M. Guerrero, J. I. Candela, and P. Rodriguez, "Intelligent Connection Agent for Three-Phase Grid-Connected Microgrids," IEEE Trans. Power Electronics, vol. 26, no. 10, pp. 2993-3005, Oct. 2011.

[10]. M. Fazeli, J. B. Ekanayake, P. M. Holland and P. Igic, "Exploiting PV Inverters to Support Local Voltage:A Small-Signal Model," IEEE Trans. on Energy Conversion, , vol. 29, no. 2,pp. 453-462, May 2014.

[11]. S. R. Nandurkar and M. Rajeev, "Design and Simulation of three phase Inverter for grid connected Photovoltaic systems," Proceed. Of Third Biennial National Conf., NCNTE,, pp. 80-83, Feb. 2012.

[12]. Y. Mohamed and E. F. El-Saadany, "Adaptive Decentralized Droop Controller to Preserve Power Sharing Stability of Paralleled Inverters in Distributed Generation Microgrids," IEEE Trans. Power Electron., vol. 23, no. 6,pp. 2806-2816, Nov. 2008.

[13]. R. Majumder, C. Balarko, G. Arindam, M. Rajat, L. Gerard and Z. Firuz, "Improvement of stability and load sharing in an autonomous microgrid using supplementary droop control loop," IEEE Trans. Power Sys., vol. 25,no. 2, pp. 796-808, May. 2010.

[14]. R. Majumder, A. Ghosh, G. Ledwich, and F. Zare, "Load sharing and power quality enhanced operation of a distributed microgrid," IET Renewable Power Generation, vol. 3, pp. 109-119, Mar. 2009.

[15]. S. Anand, B. G. Fernandes, and M. Guerrero "Distributed Control to Ensure Proportional Load Sharing and Improve Voltage Regulation in Low-Voltage DC Microgrids," IEEE Trans. Power Electron. , vol. 28, no. 4, pp. 1900-1913, Oct. 2013.