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Meandering Vector Control Strategy as D - STATCOM in Renewable Cluster Grid for Power Optimization ✫

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Abstract

The aim of this project is to develop a dynamic model of a converter fed Microgrid operated in Islanded DER Control Mode to regulate its voltage and frequency in the islanded mode of operation. Controllers like PI, FUZZY, FUZZY-PI to be implemented to fine which is best controller for the developed control scheme. The microgrid has two operating modes: the grid-connected mode and the islanded mode. In the grid-connected mode, the MMS is locked and the microgrid can interchange the energy with the host lattice network. In this mode, the DER systems exchange real and reactive powers with the distribution network, according to the corresponding set points; the difference between the aggregate power generated by the DER systems and the power demanded by the local loads is balanced by the upstream network.

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Keywords: Distributed Energy Resources (DER), Microgrid, Fuzzy Controller, Islanded Mode.

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1. Introduction

The foremost modules of a microgrid are distributed generators (Solar photovoltaic arrays, wind turbines, fuel cells, internal combustion engines, micro turbines, etc.), distributed energy storage devices (flywheels, superconductor inductors, super capacitors, compressed-air systems, batteries, etc.), and loads. The two foremost cluster of taxonomy in generators are, based on their interfacing media [1] generators that consist of direct-coupled conventional rotating machines (e.g., a synchronous generator driven by a reciprocating engine or an induction generator driven by a fixed-speed wind turbine), and [2] electronically interfaced generators [3]. Distributed energy storage devices are engaged to recompense for the power deficiency within the microgrid, predominantly in the islanded mode when the generators may not be able to satiate the intact load power ultimatum [4]. They also preclude ephemeral variability of the microgrid by providing control in transients. The variability would occur in as many as DERs, such as rotating-machine based DERs, fuel-cells, etc., are moderately sluggish in retorting to power ultimatum variations; the transitory power famine in a microgrid can be remunerated by a fast energy storage scheme, e.g., a battery that is combined with the microgrid through a dc/ac converter [5]. Fig. 3.3indicates the single line plans of an instance microgrid which implants a photovoltaic (PV) system, a variable-speed wind system, and a battery energy storage system [6]. Every single DER is interfaced with its consistent cloud bus through a power-electronic converter and a modifier [7]. The microgrid is interfaced with Bus 1 of the top stream framework, at the Microgrid Point of Common Coupling (MPCC), through the Microgrid Main Switch (MMS), which in turn, Bus 1 is invigorated by high-voltage transmission lattice, over and done with a substation transformer[8].

2. Islanded Connected DER Control Mode

The microgrid is made to work in islanded mode of operation due to faults for maintenance purpose. During the operation in islanded mode the host grid is not connected. To get an optimized output DER Control is applied in islanding operation [9]. DER Control in islanding mode is responsible for frequency regulation and voltage regulation. Voltage regulation Strategy is required in the lattice network so as to maintain the network voltage. Real and reactive power in the system is responsible for maintaining the optimal power factor. The DER control is responsible for maintaining the real and reactive power of the system so as to maintain proper load sharing in the grid. The islanded mode of control can be centralized or decentralized. The centralized Control shown in fig. 1 needs proper communication link for data transfer whereas the decentralized approach does not require any communication link for data transfer. Centralized approach is preferred for small scale microgrid whereas the decentralized approach is preferred where the DER System is scattered.

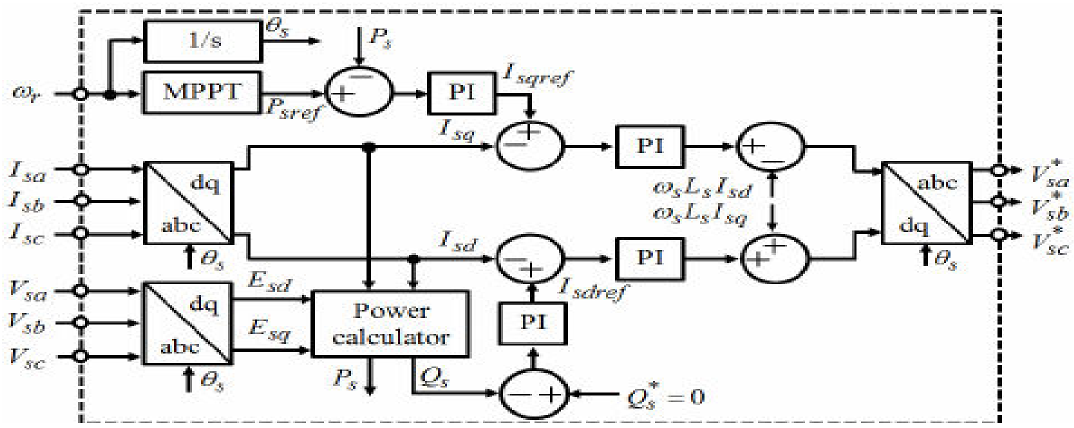

Fig.1. Islanded Connected DER System

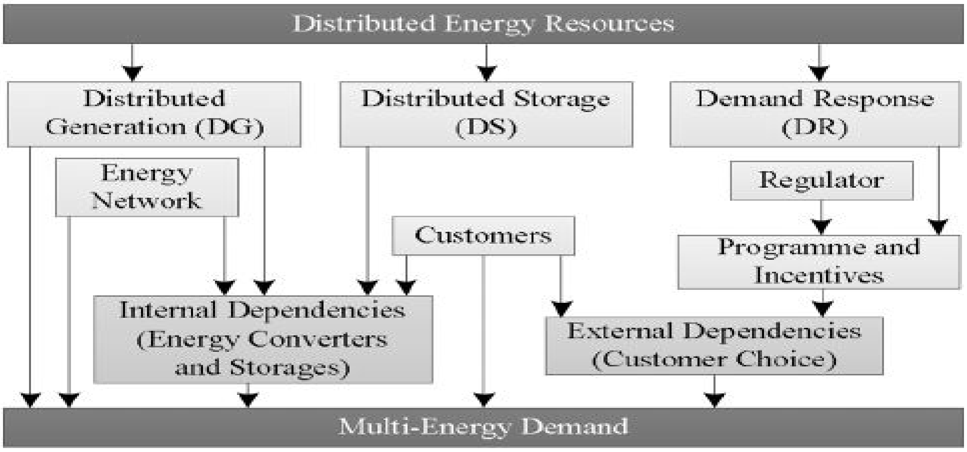

Fig.2 Decentralized DER Control

The projected DER control strategy in Decentralized approach in Islanding mode in Fig. 2 takes the benefit of Discrete Phase Locked Loop and thus evades the usage of an external frequency synthesizer. Also, under the suggested control technique, the islanded DER system owns black-start capability which is considered to be stout against frequent load switching conditions. Another that it allows the DER system to preserve the construction and control architecture that are established and optimized for grid-connected power-electronic systems; these include six-pulse SVPWM Voltage Source Converter, three-phase ac filters, current mode control schemes, synchronous dq reference frames, and Discrete PLLs.

3. Mathematical Modelling Of Islanded DER System

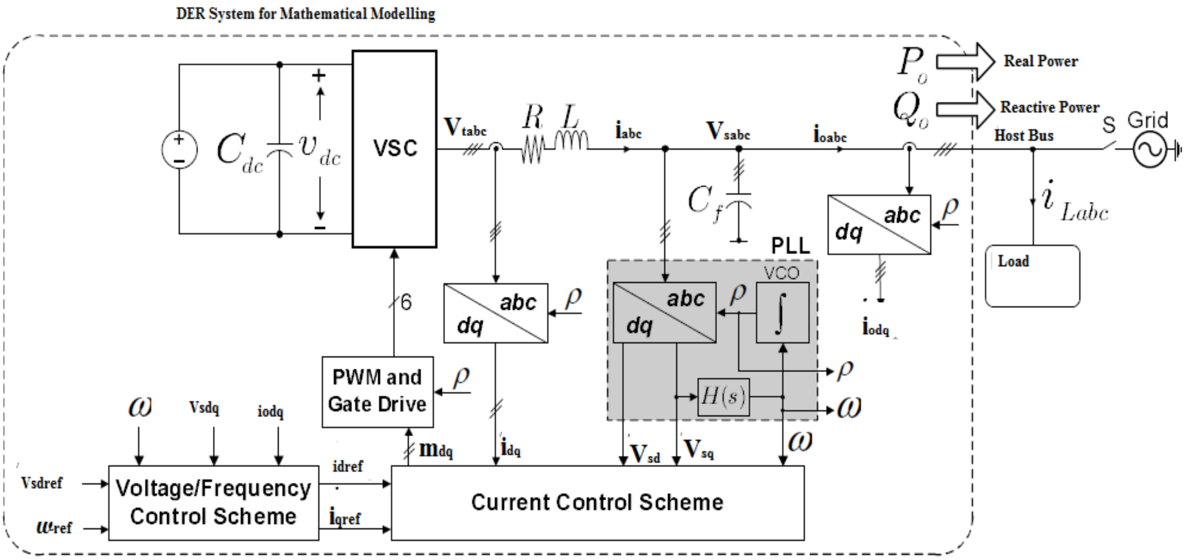

Fig.3. Islanded Mode DER Control Structure

The Mathematical Modelling of islanded DER Control Structure is analyzed using State Space analysis Fig. 3. With reference to fig.3 the host bus voltage and load voltage is described by the space vector Equ. 1 and Equ. 2.

$$C_f \frac{\overrightarrow{dV_s}}{dt} = \vec{i} - \vec{i_0} \tag{1}$$

$$f(t) = \left({}^{2}/_{3}\right)\left(f_a(t)e^{j0} + f_b(t)e^{j2\pi/3} + f_c(t)e^{j4\pi/3}\right) \tag{2}$$

Where $\left(f_a, f_b(t), f_c(t)\right)$are three phase signal of either voltage or current. Converting this three phase signal quantity to two phase orthogonal quantity we get the output parameter in terms of d & q. In Equ. 3.

$$f_{dq} = \left(f_d(t) + jf_q(t)\right)e^{j\delta t} \tag{3}$$

The d-q equivalent frame of eq. 1 in eq. 4.

$$C_f \frac{d}{dt}\left[(V_{sd} + jV_{sq})e^{j\delta}\right] = \left(i_d + ji_q\right)e^{j\rho} - \left(i_{od} + ji_{oq}\right)e^{j\delta} \tag{4}$$

Where δ is phase angle d-q frame. After simplifying and separating the real & imaginary part of equation 4 we get

$$C_f \frac{dV_{sd}}{dt} = (C_f\omega)V_{sq} + i_d - i_{od} \tag{5}$$

$$C_f \frac{dV_{sq}}{dt} = -(C_f\omega)V_{sd} + i_q - i_{oq} \tag{6}$$

Where

$$\frac{d\delta}{dt} = \omega(t) \tag{7}$$

ω (t) is the output of Discrete PLL in Eq. 5, 6 and 7.

The PLL Circuit locks the frequency of the entire system by its system frequency. The PLL is described by Equ. 8.

$$R\,(s) = H(s)V_{sq}(s) \tag{8}$$

The Islanded mode DER System employs a separate Current Controlled Strategy for VSC. Therefore the current i_d & i_q are separately controlled through its respective reference current command source in Equ. 9 and 10.

$$I_d(s) = G_i(s)I_{dref}(s) = \frac{1}{\tau_i S + 1} I_{dref}(s) \tag{9}$$

$$I_q(s) = G_i(s)I_{qref}(s) = \frac{1}{\tau_i S + 1} I_{qref}(s) \tag{10}$$

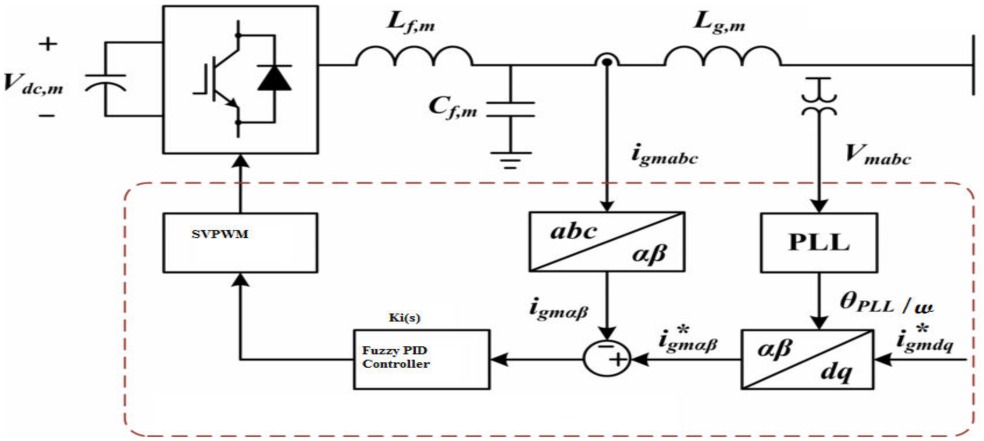

Fig.4. Current Control Scheme Schematic

Where τ_i is a design choice of integral time constant. The current control is implemented based on the block diagram of Fig. 4 in which the compensator Ki(s) is Fuzzy based PID compensator. Fig. 4 shows that ω is included in the current-control process as a feed forward term to decouple the orthogonal current control of id and iq.The State Space analysis of current control scheme for time invariant system is given by the general equation 11& 12

$$f(x,U) = x(\dot{t}) \tag{11}$$

$$g\,(x,U) = y(t) \tag{12}$$

For time varying system the state space modelling is done with the basic equation given in equ. 13 & 14

$$\dot{x}(t) = f(x(t), U(t), t) \tag{13}$$

$$y(t) = g(x(t), U(t), t) \tag{14}$$

The Current i_{Ld} and i_{Lq} are the output current for the nonlinear, Time Variant dynamic system for the input voltages V_{sd} and V_{sq} in Equ. 15 and 16.

$$\begin{bmatrix} i_{Ld} \\ i_{Lq} \end{bmatrix} = \begin{bmatrix} g_1(\,x_1, x_2, x_3, \dots \dots . x_{n\dots} \dots & V_{sd,}V_{sq}, t, \delta) \\ g_2(\,x_1, x_2, x_3, \dots \dots . x_{n\dots} \dots & V_{sd,}V_{sq}, t, \delta) \end{bmatrix} \tag{15}$$

$$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \\ \vdots \\ \vdots \\ \dot{x_n} \end{bmatrix} = \begin{bmatrix} f_1(\,x_1, x_2, x_3, \dots \dots . x_{n\dots} \dots & V_{sd,}V_{sq}, t, \delta) \\ f_2(\,x_1, x_2, x_3, \dots \dots . x_{n\dots} \dots & V_{sd,}V_{sq}, t, \delta) \\ \vdots & \\ \vdots & \\ f_n(\,x_1, x_2, x_3, \dots \dots . x_{n\dots} \dots & V_{sd,}V_{sq}, t, \delta) \end{bmatrix} \tag{16}$$

Where $x_1, x_2, x_3, \dots \dots . x_{n\dots}$ are State Variables, $V_{sd,}V_{sq}$, are the respective two phase orthognal voltages in Fig. 5.

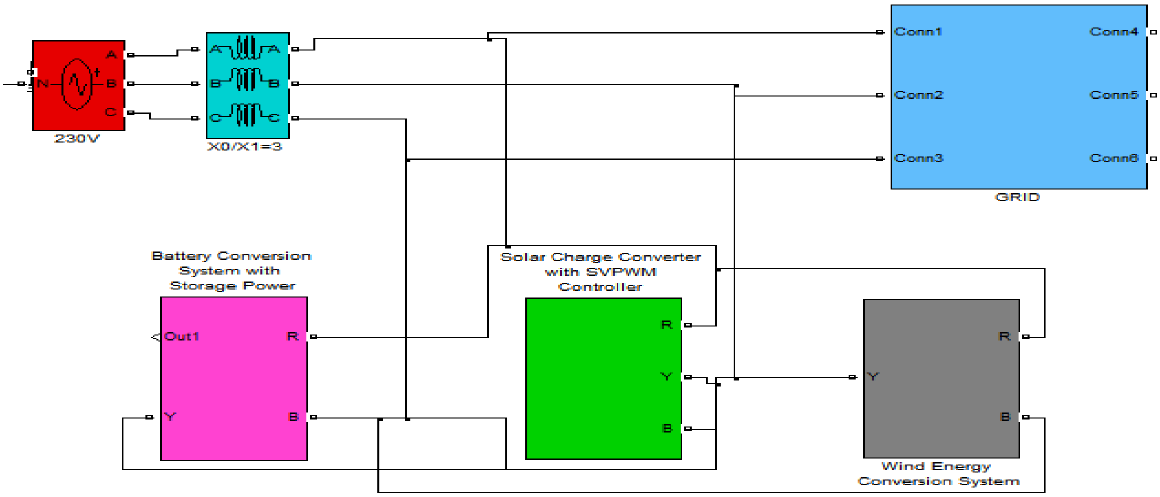

Fig.5. Microgrid Simulation Model

The Fig. 6 shows the Simulation result of Real and Reactive Power measurement on load side. On observing the result the real power on Load side is around 50KW whereas the reactive power is 25W which is comparatively very less and it can be neglected and hence the Power factor on the load side is Unity.

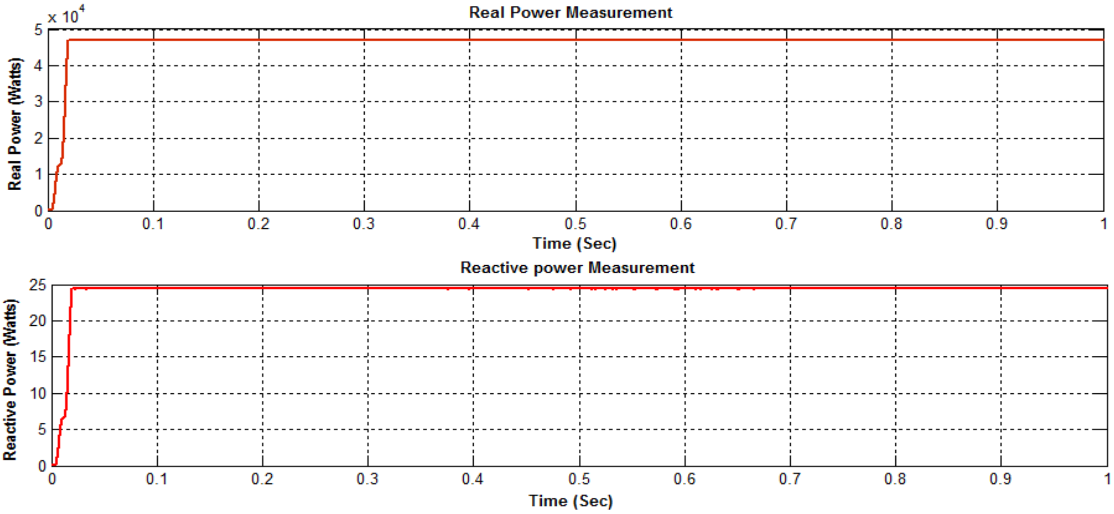

Fig.6. Real and Reactive Power Measurement on Load Side With RLC Load

4. Conclusion

The renewable power which can be produced from the renewable resources can be integrated by the accumulated model. By this accumulated model the power for the individual time can be calculated. At particular time, the load will be connected to the dc bus. The renewable power will be served to the load through dc bus. If there is any uncertainty affiliated with the forecast of aggregated wind and pv based power generation was created and used to quantify the energy reserve of the battery energy storage system. The battery is parallel connected with the super capacitor to form multi level energy storage. The battery plays critical role for compensating the power fluctuations. The control proposed is here adaptive droop control in that the voltage-power droop curves are modified depending on the outcome of operational optimization. These voltage-power droop curves satisfy the load forecast uncertainties. The resulting energy system serves local stationary and electric vehicle based mobile consumers, and it is a good citizen within the main gird as it reduces emission by local usage of wind and solar energy.

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