ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 3, March 2014

Coordination Control for Grid Connected Photovoltaic and Fuel Cell system

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ABSTRACT: Power system plays important role for the generation of power from conventional sources, transmutation and distribution power at different consumer applications it will faces a so many problems. This can be overcome to implement the micro grid concept. The micro grid concept introduces the power is generated from the renewable energy sources like P.V Wind, Fuel cell, Micro Turbine etc will give signifying moment in near future. These power generating stations interconnected to form a micro grid system. IN this paper power generated from P.V and Fuel Cell (PEM). Here Both are the DC power generating stations for the purpose of power generating from the P.V in night time, rain session and cloud time face difficulties. this can be overcome to power is generating by using fuel cell and without any interruption of energy supplies to load and this system can interconnected to the utility grid and coordinately between these two system by using P-Q control theory in bidirectional converter system. This concept to reduces multiple reserve conversions and it will consists of both A.C and D.C networks connected to distribution generation through multi-bidirectional converters and to maintain stable operation of system by using proposed coordination schemes in the MATLAB simulink environment.

KEYWORDS: micro grid, grid-tied mode, coordination control operations, PV system, Fuel Cell power generation.

I.INTRODUCTION

The ever increasing energy consumption, the soaring cost and the exhaustible nature of fossil fuel, and the worsening global environment have created increased interest in green [renewable based energy sources] power generation systems. Wind and solar power generation are two of the most promising renewable power generation technologies. The growth of wind and photovoltaic (PV) power generation systems has exceeded the most optimistic estimation. Nevertheless, because different alternative energy sources can complement each other to some extent, multisource hybrid alternative energy systems (with proper control) have great potential to provide higher quality and more reliable power to customers than a system based on a single resource. Because of this feature, hybrid energy systems have caught worldwide research attention [1]. Photovoltaic (PV) generation systems and isolated Fuel Cell systems are considered among the renewable systems to be viable alternatives for the designer of such remote power supplies. Nevertheless, systems based on either solar or fuel cell energy are unreliable due to seasonal and diurnal variations of these resources. The control of such a scheme is also far from straightforward, especially where there is a high penetration [2]. Furthermore, it decreases the advantage of clean and no pollution energy achieved from the renewable sources. A system that is based fully on renewable resources but at the same time reliable is necessary and hybrid wind and solar systems with small battery storage meet these requirements.

A hybrid scheme consists of wind PV[3] array and fuel cell with power electronic convertors and power balancing controls are proposed in this paper for the purpose of reduces the reversible covert ions smooth power variation between sources and maintain stable operation in the system. The battery bank, which is charged during the daytime, will supply the inverter during the night to provide fuel cell necessary. when solar irradiation reaches its peak, the proposed scheme with appropriate choice of the sizes of the PV array and fuel cell[10] ensures almost an uninterruptible supply throughout the year.

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II. GRID OPERATION

Wherever the basic main diagram of a AC/DC micro grid shows it will consists two renewable energy sources one is P.V the output of P.V array is connected to the boost converter. A capacitor is supplies the high frequency ripples of P.V output voltage .the energy storage battery is connected to the D.C bus through DC-DC boost converter. The rated voltage of D.C bus is 400v respectively. Another renewable energy device is wind generation with DFIG is connecting to ac sources through A.C bus. Three phase bidirectional DC/AC main converter wit R-L-C connected between DC bus and AC bus.

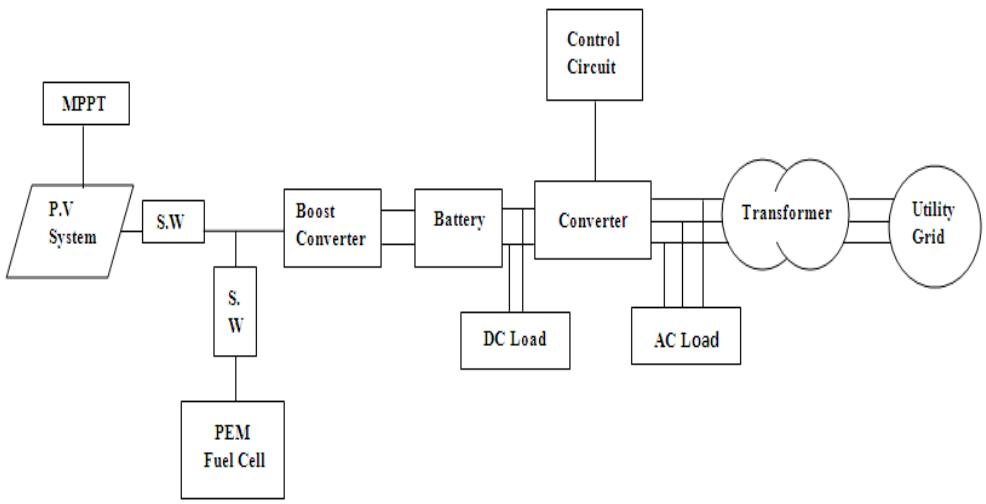

Fig.1. Block diagram of micro grid

The grid can operate in two modes One is grid-tied mode and isolated mode the present work is did in grid-tied mode The boost converter and WTG are controlled to provide the maximum power. the main converter is to provide stable dc bus voltage and required reactive power and to exchange power between the ac and dc buses. When the output power of the dc sources is greater than the dc loads, the converter acts as an inverter and injects power from dc to ac side. When the total power generation is less than the total load at the dc side, the converter injects power from the ac to dc side. When the total power generation is greater than the total load in the hybrid grid, it will inject power to the utilygrid.

III. MODELLING OF P.V SYSTEM

In Generally, a PV module comprises of a number of PV cells connected in either series or parallel the classical equation of a PV cell describes the relationship between current and voltage of the cell (neglecting the current in the shunt resistance of the equivalent circuit of the cell) as

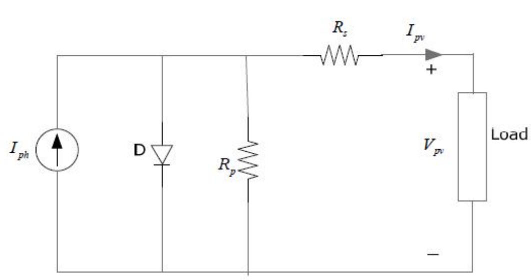

Fig.2. Equivalent circuit of PV cell

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$$I_{ph} = I_L - I_O \left[\exp\left(\frac{V_{ph} + R_{se} I_{ph}}{A} \right) - 1 \right]$$

$$I_O = n_p I_{ph} - n_p I_{rs} \left[\exp\left(\frac{K_o V}{n_s} \right) - 1 \right]$$

Where *I*o denotes the PV array output current, *V* is the PV output voltage, is the cell photocurrent that is proportional to solar irradiation, is the cells reverse saturation current that mainly depends on the temperature, is a constant, *n* and are the numbers of series strings and parallel strings in the PV array, respectively.

MPPT (P&O method)

Define Perturb-and-observe (P&O) method is dominantly used in practical PV systems for the MPPT control due to its simple implementation, high reliability, and tracking efficiency. Shows the flow chart of the P&O method [4-5]. The present power *P (k)* is calculated with the present values of PV voltage *V (k)* and current *I (k)*, and is compared with the previous power *P (k-1)*. If the power increases [6-7], keep the next voltage change in the same direction as the previous change.

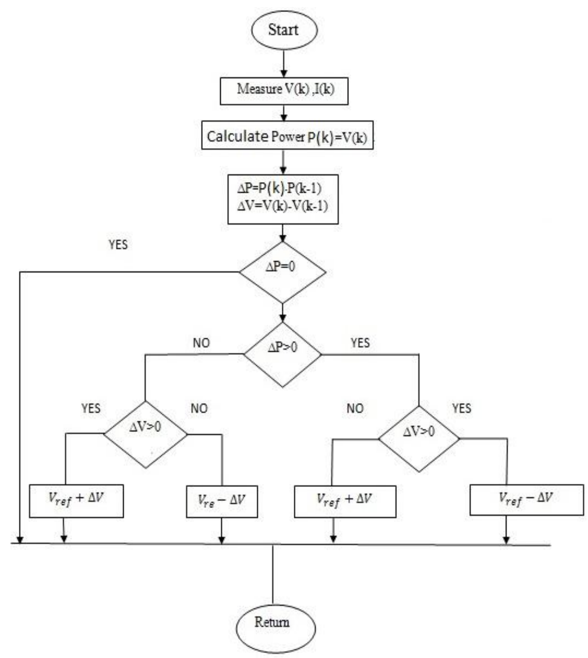

Fig.3. Flow chart for MPPT algorithm

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IV.DYNAMIC MODELLING OF BOOST CONVERTER

main objective of the boost converter is to track the maximum power point of the PV array by regulating the solar panel terminal voltage using the power voltage characteristic curve.

$$Vin - L\frac{di_1}{dt} - (1 - D)V_C - ESRi_1 = 0$$

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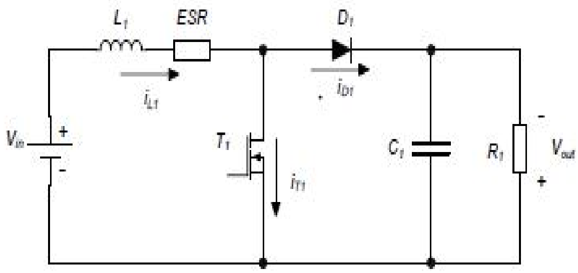

Fig.4. Boost Converter

$$\begin{bmatrix}\dot{i}_{L_1}\\ \dot{v}_{C_1}\end{bmatrix} = \begin{bmatrix}\frac{-ESR}{L_1} & \frac{-(1-D)}{L_1}\\ \frac{1-D}{C_1} & \frac{-1}{R_1C_1}\end{bmatrix}\begin{bmatrix}i_{L_1}\\ v_{C_1}\end{bmatrix} + \begin{bmatrix}\frac{1}{L_1}\\ 0\end{bmatrix}[V_{in}]$$

$$[V_{Out}] = [0 \quad 1]\begin{bmatrix}i_{L_1}\\ v_{C_1}\end{bmatrix} + [0][V_{in}]$$

V.MODELING OF BATTERY

Battery acts as a constant voltage load line on the PV array and is charged both by PV array and induction generator .the battery is modeled as a nonlinear voltage source whose output voltage depends not only[8-9] on the current but also on the battery state of charge(SOC), which is non linear function of the current and time.

$$V_b = V_O + R_b i_b - K\frac{Q}{Q + \int i_b dt} + A\exp\left(i_b dt\right)$$

VI.FUEL CELL MODEL

PEM fuel cell electrochemical process starts on the anode side where H_2 molecules are brought by flow plate channels. Anode catalyst divides hydrogen on protons H^+ that travel to cathode through membrane and electrons e^- that travel to cathode over external electrical circuit[12-13]. At the cathode hydrogen protons H^+ and electrons e^- combine with oxygen O_2 by use of catalyst, to form water H_2O and heat. Described reactions can be expressed using equations.

$$H_2 \rightarrow H_2O + 2e^- (Anode)$$

$$\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O(Cathode)$$

Amount of chemical energy released in these reactions depends on hydrogen pressure, oxygen pressure and fuel cell temperature. Using change in Gibbs free energy, this amount can be expressed as:

$$\Delta g_g = \Delta g^o{}_f - RT_{fc}[\ln(PH_2) + 0.5\ln(PO_2)]$$

where $\Delta g^0{}_f$ is change in Gibbs free energy at standard pressure, R universal gas constant, T_{fc} PEM temperature and p_{O2} and P_{H2} are gas pressures. Because electrical work done by fuel cell is equivalent to released chemical energy, value of open circuit fuel cell voltage E meets equation:

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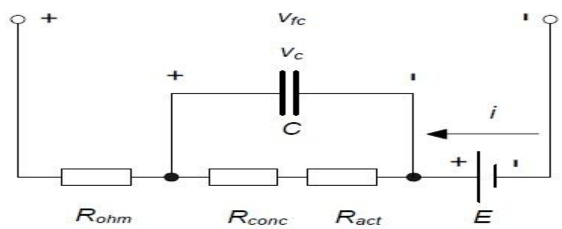
$$E = -\left(\frac{\Delta_{gf}}{2F}\right) \text{ where } F \text{ is Faraday's constant.}$$

To attain actual cell voltage (on electrical couplings) v_{fc}, voltage drops caused by activation, concentration and ohmic losses have to be deducted from open circuit voltage. Cathode and anode activation losses are result of breaking and forming electron-proton chemical bonds, and parasitic electrochemical reactions caused from hydrogen proton migration through membrane at zero current. Their voltage drop was calculated using formula:

$$V_{act} = V_0 + V_a(1 - e^{-C_1 i})$$

where activation voltage drop at zero current density v_0 depends on fuel cell temperature, cathode pressure and water saturation pressure Va=f(T_{fc}, P_{ca}, P_{sat})Voltage drop v_a inserts in (5) correlation with current density i and depends on fuel cell temperature, oxygen pressure and water saturation pressure Va=f(T_{fc},P_{o2},P_{sat}) and c_1 is activation voltage constant.

VII.FUEL CELL EQUIVALENT ELECTRIC CIRCUIT



$$V_{fc} = E - V_c - iR_{ohm}$$

$$C\frac{dV_C}{dt} + \frac{V_C}{R_{act} + R_{conc}} = i$$

$$V_{fc} = E - \left(\frac{R_{act} + R_{conc}}{(sc(R_{act} + R_{conc} + 1))} + R_{ohm}\right)i$$

Proposed coordination control of the grid-connected mode

boost is to track the maximum power from P.V array by regulating the terminal voltage and which are synchronize with corresponding grid. the main converter is designed to operate bidirectional to incorporate complementary characteristics of solar and fuel cell sources and to maintain a stable dc-link voltage for variable DC load and to synchronize with the AC link utility system.

The role of the battery acts as a constant voltage load line on the PV array and is charged by the PV array under atmosphere conditions. The above modes are considered under normal weather conditions when the PV power output is available. However, on cloudy days, the PV/battery system will only function as a battery energy storage system due to the absence of PV power output. In such cases, if the daily load profile creates sufficient price differences between peak and off-peak load periods, battery will be charged during off-peak periods and discharged during peak periods for economic. The load is fully supplied by the battery in situations where there is inadequate irradiation [15]. During nights the excess energy if any is used to change the battery being fully charged and unable to accept this excess energy on other hand, during the daytime, in the event of the battery being disconnected to prevent overcharging.

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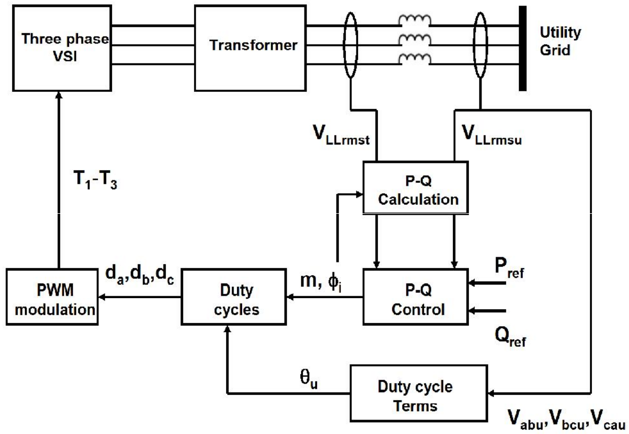

Fig.6. Control block diagram of main converter

The proposed P-Q controls are applied to the boost converter, main converter, for the power balancing between the AC sources, DC sources, and utility grid under varying load conditions. This thesis the main converter is plays important role it will acts as a voltage source to proved a stable voltage and frequency for the grid and operates either in inverter or converter under varying load conditions for smooth power balancing between the AC links and DC links. the battery converter operates either in discharging or charging condition based on the power balance in system. The power under varying load and supply conditions should be balanced .Calculation of real and reactive power control equations for main converter

$$P=[V_T*V_U*Sin(\Phi)/WL_t]$$

$$Q=V_T[V_T-V_U*Cos(\Phi)]/WL_t$$

'V_t' voltage at transformer , 'V_u' voltage at utility grid and 'φi' is the phase angle of the voltage on the inverter side and 'Lt' is the leakage inductance of the transformer. For calculation purposes, the transformer is considered to be ideal; hence the angle lag due to Y-Δ connection is neglected.

VIII.SIMULATION RESULTS

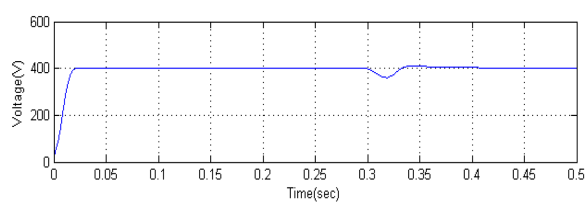

Fig.8. PV output voltage

Fig.8.shows the output voltage of PV array corresponding solar irradiation it will increases at 0.025 to 0.3 voltage constant using P&O method. At the period of 0.3 to 0.0325 voltage drop occur during the load and source condition .the boost controller quickly recovers this drop and gives constant voltage.

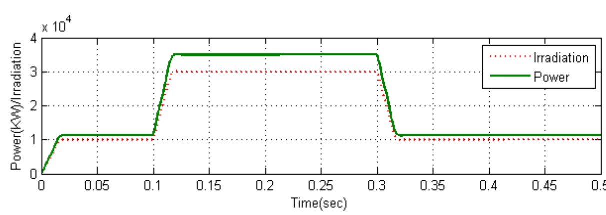

Fig.9.PV output power and sola irradiation

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Fig.9. shows the output power of PV is correspondingly increases with solar irradiation. Output power is increases 12kw to 37kw due to changing the temperature. When temperature is fixed at 0.12sec to 0.3sec power generation is fixed.

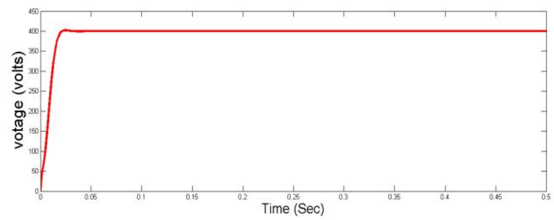

Fig.10. PEM output voltage

Fig.10. shows output voltage of PEM fuel cell corresponding to chemical reaction of the system initially generation voltage low when chemical done quickly correspondingly increase the voltage at certainly this voltage will be constant.

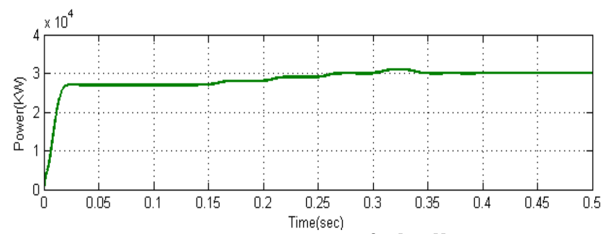

Fig.11. Output power PEM fuel cell

Fig.11.shows PEM fuel cell power corresponding to chemical reaction

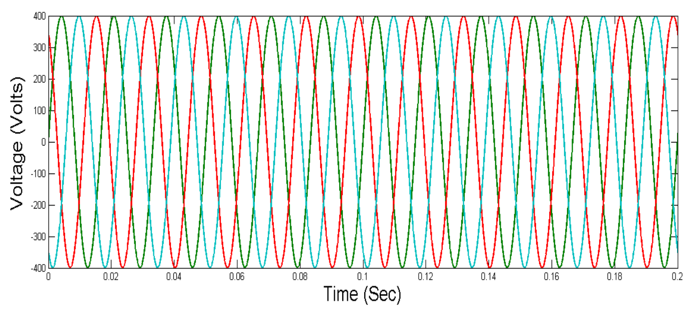

Fig.12. three phase output voltage at load

Fig.12. shows there phase voltage at load and this will be interconnected to utility grid by using the bidirectional converter it will be controlled by using p-q controller.

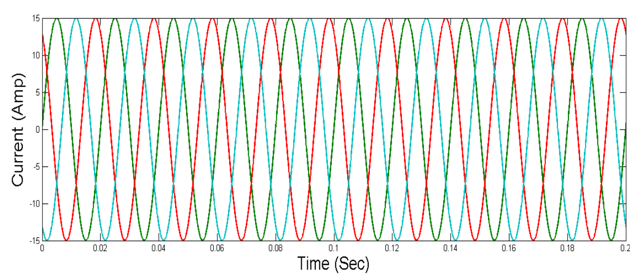

Fig.13Fig.13. three phase output voltage at load

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Fig.13. shows there phase current at load and this will be interconnected to utility grid. by using the bidirectional converter it will be controlled by using p-q controller.

IX. CONCLUSION

This paper simply provides the alternative energy solution for different consumer applications. the design and developed micro grid for power system configuration is done in MATLAB/SIMULINK environment. In this paper reduces the process of AC/DC and DC/AC conversions in individual AC or DC grid. Although MPPT algorithm is used to harness maximum power from DC source .here proposed controllers are developed for all converter to maintain the stable system under various resource and load changing conditions and coordinate power exchange power between the load grid. future work this paper modeling of power generation from wind using MATLAB/SIMULINK environment this can be interconnecting to AC/DC micro grid and coordinately operate the system and implementing in Indian military applications.

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