International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.1, 2015

RESEARCH ARTICLE

ISSN: 2321-7758

GRID AND ISLANDED OPERATION OF MICROGRID

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Article Received: 19/01/2015 | Article Revised on: 31/01/2015 | Article Accepted on:05/02/2015

ABSTRACT

This paper presents the configuration of a micro grid. The proposed micro grid comprises of a micro-turbine and a photo voltaic array which constitutes the main propagation units in the micro-grid and proton exchange membrane fuel cell is accessory the variable power rendered by thephotovoltaic array. a lithium ion battery is admitted in the micro-grid for abridge the burden of the power rendered by the micro-grid throughout the peak period of time.The all those unlike distributed generations units is align to control the energy management systems throughout the grid connected operation and islanded mode of procedure.The general framework enhances the force quality and dependability of the force dispersion framework that the micro-grid is joined with.The control design utilizes the output regulation (OR) theory. Kalman filters utilized to educe the harmonic component of the load current, and appraisal the state percipient gain and frequency tracking .The simulation studies confirmed through diverse experiment.

Index Terms—Distributed generation (DG), micro-grid, output based controller (ORC), active power filters, kalman filter, uninterruptible power supplies.

INTRODUCTION

Now a days using of the power electronics devices poses a power quality problems and the concept of microgrid is useful (helpful) to consumer for reliable and efficient power supply and reduce[1] the per unit cost of the electrical load and reduce the total energy losses and also the interconnection of microgrid to the utility grid with the help of power electronics devices poses power quality problems. The power quality problems like voltage sag/swell, frequency deviation, harmonic supply voltage and load current in the microgrid. The Micro-grid could be seen as a gathering of DG that could work either joined with the lattice or purposefully islanded.

To overcome all those power quality problems uses different power conditioning devices. Such as like active power filters[2], uninterruptible power supplies[3], dynamic voltage restorers[4] and unified power quality conditioners[5] are protected their consumers loads and protects the system against the power quality problems.

This paper represents the microsource devices are connected to the utilitygrid through dc to dc converters and voltage source inverters at the point of common coupling (PCC). At point of common coupling different electrical loads are connected to. The proposed microgrid consists of a photovoltaic array, proton exchange membrane fuel cell and lithium ion storage battery. The photovoltaic array operates main generation unit of the microgrid. During the sunless hours proton exchange membrane fuel cell operates the main generation unit. The lithium ion storage battery is implemented to operate the peak shaving during the grid connected operation and islanded operation. As such modern control theories are used toimplement the system. Such controllers' presents in this paper as output regulation based controller (ORC)[6],[7], this controller regulates the dc link voltage of the system.

In the course of the most recent decade, proficient and solid correspondence and control innovations, coupled with an increment in more intelligent electrical offices, for example, electric vehicles and shrewd meters, have brought about an expanding number of customers taking an interest sought after reaction administration (DRM). This task speaks to the micro source gadgets are associated with the utility matrix through dc to dc converters and voltage source inverters at the purpose of basic coupling (PCC).[14] At purpose of normal coupling diverse electrical burdens are associated with. The proposed micro matrix comprises of a photovoltaic cluster, proton trade layer power module and lithium particle stockpiling battery. The photovoltaic show works principle era unit of the micro-matrix. Amid the sunless hours proton trade film power module works the fundamental era unit.

The lithium particle stockpiling battery is actualized to work the crest shaving amid the matrix joined operation and islanded operation. As being what is indicated cutting edge control hypothesis is utilized to actualize the framework. Such controllers' available in this undertaking as yield regulation based controller (ORC), this controller controls the dc join voltage of the framework.The momentum exploration is likewise centered around accomplishing a more brilliant matrix through interest side administration (DSM), expanding vitality saves and enhancing the force nature of the conveyance framework, for example, symphonious remuneration for nonlinear burdens [1]–[4]. These new patterns empower larger amounts of infiltration of renewable era, for example, wind and sun powered force into the matrix. The joining of renewable sources can supplement the era from the appropriation framework. On the other hand, these renewable sources are discontinuous in their era and may bargain the unwavering quality and dependability of the circulation system. Therefore, vitality stockpiling gadgets, for example, batteries and ultra-capacitors, are obliged to adjust for the variability in the renewable sources[14].

II SYSTEM DESCRIPTION AND MODELLING

A. System Description

The figure1 shows the configuration of microgrid presented in this paper that is operated to operate grid connected and islanded modeof operation. The proposed microgrid consists of 15KVA micro turbine(MT),5KW_p photovoltaic arrayThe pv array is connected to grid through dc to dc converter and voltage source inverter (VSI). The microgrid and pv array operates as primary generation units. .20Ah of lithium ion storage battery(SB) and 5KW proton exchange membrane fuel cell (PEMFC) . the sb is connceted to grid through buckboost conveter and vsi. The pemfc and sb are back up protection of the pv array and will supply the power for any shortage in the generated power to ensure the stable operation of the overall system. The parameters of the Grid are shown in the given table. The heap on the micro-matrix was demonstrated utilizing (1) and (2). So as to look at the impact of the heap demonstrate on the microgrid recurrence and voltage deviations, the distinctive burden parameters were differed separately while altering the remaining burden parameters.

Grid Parameters	
Voltage (line to line)	480V
Frequency	60Hz
Grid Resistance	0.02Ω
Grid Inductance	0.3 mH
DG Inverter Controller Parameters	

When the fault occurs on the upstream of the distribution network the circuit breaker is disconnect the micro-grid from utility grid. Then the generation of the main DG's units are able to meet the load demand the system must be stable otherwise PEMFC and SB are supply the power unless it cannot meet the load demand shutdown the system completely. In this segment of this section, the created models are recreated with the assistance of MATLAB/Simulink programming. The mimicked microturbine model is of single shaft sort with control frameworks equipped for managing its yield power. The Simulation results are exhibited for the created model of the MTG framework under burden conditions.

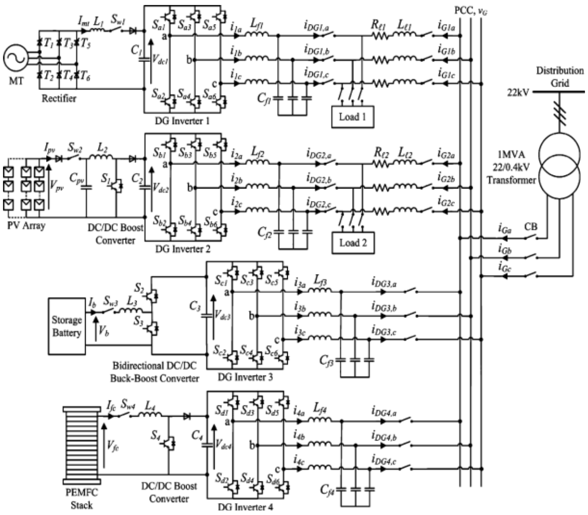


Fig 1: Blok diagram of micro-grid

Power balance equation of the system during grid connected mode is

$P_{mt}+P_{pv}+P_b+P_{fc}=P_L$ (1)

Here P_{mt} and P_{pv} are power delivered by the MT and PV array. And P_b is the storage battery power subjected to charging and discharging constraints is

$P_b \le P_{b,\,max}$ (2)

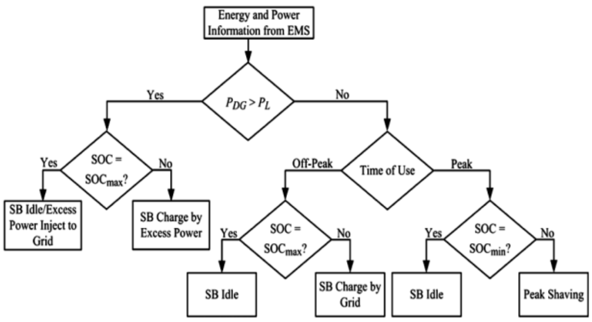


Fig 2:Operation of the SB during grid-connected operation.

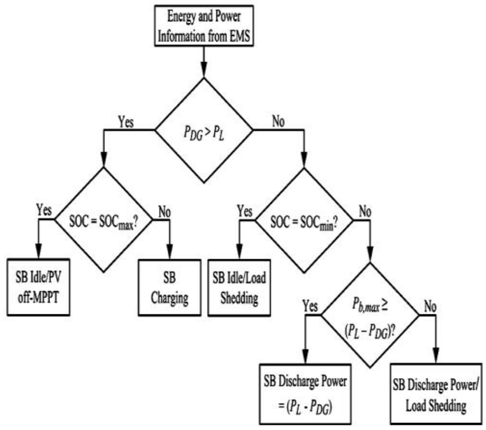


Fig 3:Operation of the SB during islanded operation

Pfc is the power delivered by the PEMFC and PL is the load power .The storage battery energy constraints is given by

SOCmin < SOC ≤ SOCmax (3)

SOC [8-9] of the battery cannot be determined directly, it can be find by different techniques is presented.

B. Modelling

In this model we explain the DG inverter modeling. The figure [4-5] shows the single phase circuit representation of DG inverters during grid connected and islanded operation respectively[14]. The output voltage across the DG inverters is U_jV_{dcj}. Where U_j is the control input i.e. j=1,2. And L_f, Cf is the filter which protects from the high switching frequency harmonic. R_f is the resistance loss of the DG inverter.

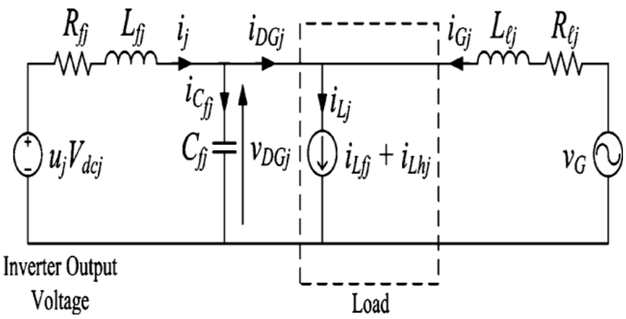


Fig 4: DG inverters during grid connected

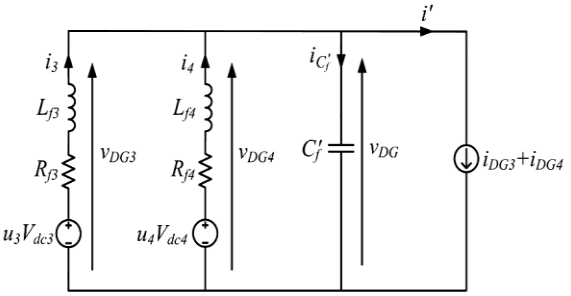


Fig 5: DG inverters during Islanded connected

The load current i_L is the sum of current delivered to the load. $i_L$includes the fundamental and harmonic component therefore i_L can be written as

$i_L = i_{L1}+i_{L2}$(4)

$= i_{Lf}+i_{Lh} = i_{Lf}\sin(wt-\theta_{Lf})+\Sigma^{N}_{h=3,5.} i_{Lh}\sin(hwt-\theta_{Lh})$

$= i_{Lf,\,p}+i_{Lf,\,q}+i_{Lh}$(5)

Where θ_{Lf} and θ_{Lh} are the respective phase angles of the fundamental and harmonic component of the load current i_L.The current supplied by the DG inverter is given by

$I_{DGj}=(i_{Lf,p}-i_g)+i_{Lf,q}+i_{Lh}$ (6)

To determine the state space model of the DG inverter amid lattice associated and islanded operations, is to just apply the Kirchhoff's voltage and current law to the system is indicated in the figure6.

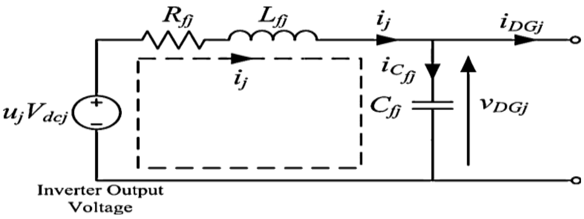


Figure 6. State space representation of micro-grid

$$\frac{di_j}{dt} = -\frac{R}{L_{fj}}i_j - \frac{1}{L_{fj}}v_{DGj} + \frac{V_{dcj}}{L_{fj}}u_j \qquad (7)$$

$$\frac{dv_{DGj}}{dt} = \frac{1}{C_{fj}} - \frac{1}{C_{fj}}i_{DGj} \qquad (8)$$

Where i_j is the current flowing through L_{fj}.therefore grid connected DG inverter can be modeled in state space can be written as

$A_{gj}x_{gj}+B_{gj1}v_j'+B_{gj2}u_j$ (9)

$y_{gj}=C_{gj}x_{gj}+D_{gj1}v_j+D_{gj2}u_j$ (10)

Where g represents the grid connected operation and j represents the operation of the DG inverter (j=1,2)(1=MT,2=PV).

$A_{gj} = -\frac{R_{fj}}{L_{fj}}$; $B_{gj1}=\begin{bmatrix}-\frac{1}{L_{fj}} & 0\end{bmatrix}$ $B_{gj2}=\frac{V_{dcj}}{L_{fj}}$; $C_{gj}=1$

$D_{gj1}=\begin{bmatrix}0 & -C_{fj}\end{bmatrix}$; $D_{gj2}=0$

$x_{gj}=i_j$is the state $V_j'=\begin{bmatrix}v_{DGj} & \frac{dvDGj}{dt}\end{bmatrix}^T$ is the exogenous input, u_j is the control input, with $-1\le u_j \le 1$; and$y_{gj}= i_{DGj}$ is the output.

The islanded operation of SB and PEMFC is derived in state space model is obtained

$\dot{x}_{ij}=A_{ij}x_{ij}+B_{ij1}\,i_j'+B_{ij2}u_j$(11)

$y_{ij}=C_{ij}x_{ij}+D_{ij1}i_j'+D_{ij2}u_j$ (12)

where i denotes model of the DG inverters j during islanded operation. Where$j$=1,2,3,4 and

$$A_{ij}=\begin{bmatrix}-\frac{R_j}{L_{fi}} & -\frac{1}{L_{fi}}\\ \frac{1}{C_f'} & 0\end{bmatrix};\ B_{ij1}=\begin{bmatrix}0\\ -\frac{1}{C_j'}\end{bmatrix};\ B_{ij2}=\begin{bmatrix}\frac{V_{dcj}}{L_{fi}}\\ 0\end{bmatrix};\ C_{ij}=\begin{bmatrix}0 & 1\\ 1-\frac{C_{fi}}{C_j'} & 0\end{bmatrix}$$

$$D_{ij1}=\begin{bmatrix}0\\ \frac{C_f}{C_f'}\end{bmatrix};\ D_{ij2}=\begin{bmatrix}0\\ 0\end{bmatrix}$$

With $C_f' = \sum_{j=1}^{4} C_{fj}$;$x_{ij}=\begin{bmatrix}i_j & v_{DGj}\end{bmatrix}^T$ is the stete vector; $i_j'=i_L - \sum_{n\neq j} i_n$ is the exogenous input of the DG inverter j; u_j is the control input , with $-1\le u_j \le 1$ and $y_{ij}=\begin{bmatrix}v_{DGj} & i_{DGj}\end{bmatrix}^T$ is the output, which will regulated to track the desired reference. i_j' can be derived using a Kalman filter applied to the output $y_{ij}=\begin{bmatrix}v_{DGj} & i_{DGj}\end{bmatrix}^T$.

CONTROL PHILOSOPHY

The aim of the controller is to maintain the output of the plant is $y=(v_{mg}\ i_g)^T$ it is to track the reference signal $r=(v_{mg}^*\ i_g^*)^T$, under a periodic disturbance $(v_{mg}\ i_g)^T$. The reference signals $v_{mg}^*$and i_g^* both are pure sine waves 50Hz frequency without any harmonic distortions.

A. Model of the exogenous signal

The exogenous signalsv_g ,i_L ,v_{mg}^* ,i_g^* are periodic signals all those are represented in state space model. For example v_g can be expressed in state space model is

$\xi_{vg}=A_{vg}\,\xi_{vg}$ (13)

$v_g=C_{vg}\,\xi_{vg}$ (14)

$i_{L,\,vmg}^*$, ig^* are modeled into state space form

$\tilde{A}\,\xi$ (15)

$(v_g\ i_L)^T = \hat{C}_w\,\xi + w$ (16)

$r=(v_{mg}^*\ i_g^*)^T= \hat{C}_d\,\xi$ (17)

Which is called as exogenous system is presented in this paper.

Output Based Regulation Controller *(ORC)*

Subtitling the exogenous equations into the state space model of the plant, the following model is obtained: $= Ax + B0\xi + B2u$ (18)

$y = Cx + D_0\,\xi + D_2u$ (19)

The control law for the OR is proposed as

$u = U\,\xi + F(x - X\,\xi)$ (20)

Where u is the control signal which generated by the controller used for switching scheme for the plant. *x* and ξ are the outputs of the exogenous and plant kalman filter(13).

$X\tilde{A} = AX + Bo + B_2U$ (21)

$= CX + D_o + D_2U$ (22)

$$\frac{d}{dt}(x - X\xi) = (A + B_2F)(x - X\,\xi) \quad (23)$$

$e = (C + D_2F)(x - X\,\xi)$ (24)

Where 'e' is the error tracking (y-r). F can be find from the $(A+B_2F)$ is Hurwitz and the closed loop system is stable.

SIMULATION RESULTS

The simulation model of the microgrid is implemented in MATLAB/SIMULINK is shown in the figure. The microgrid consists of two types of loads i.e non liner and linear loads rated of P_{L1}= 15KW , Q_{L1}=9.7KVAr and P_{L2}=5KW , Q_{L2}=3KVAr are respectively.

Test case1:Power Quality Improvement With Load Sharing During Grid-Connected Operation: This case demonstrates the improvement of power quality of the distribution network during grid connected operation and compensate the harmonic injection into the distribution network during grid connected operation. In this mode of operation the storage battery is charge and stores the energy for 0≤t≤0.4sec.the total load current is the sum of the microgrid current and current supplied by the grid current.The waveform of load current i_{L1}(top),current supplied by the DG1(middle)and grid current(bottom) is shown in the figure.8.the below figure.9 shows the grid voltage and current waveform.

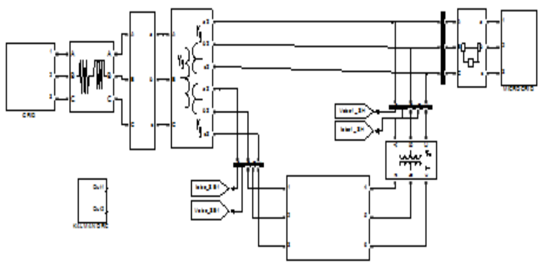


Fig 8: simulink model of grid connected operation

The total real and reactive power delivered by the load is 20KW and 12.7KVAr during grid connected mode of operation the DG1 inverter and DG2 inverter shares the power is DG1=7.5KW and DG2 is 3KW is shown in the figure.10, reactive power supplied the load is shares the DG1 and DG2

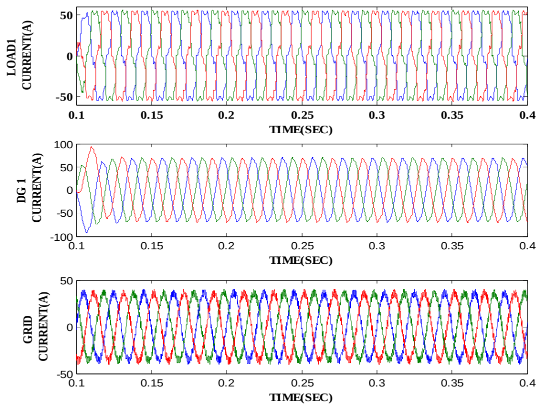


Fig.9:load1current(top),DG1current(middle),gridcurrent(bottom)

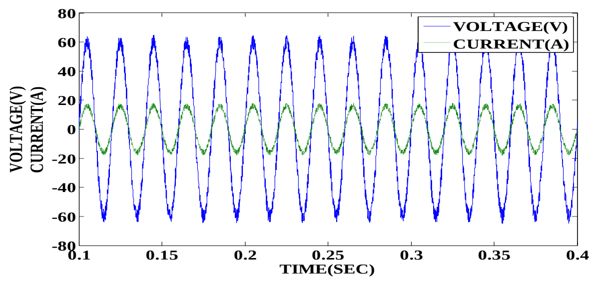
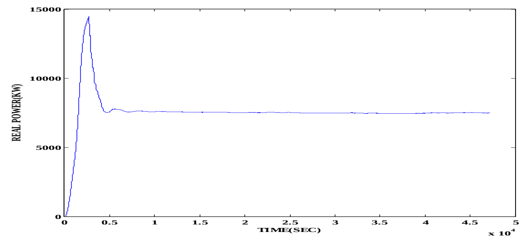
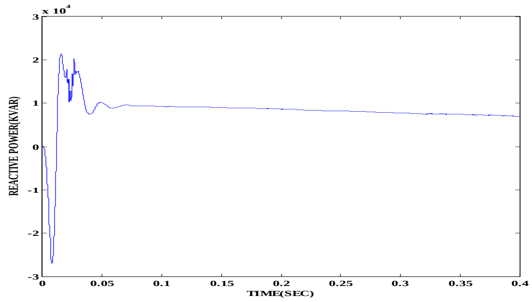


Fig10:. voltage and current waveform of grid





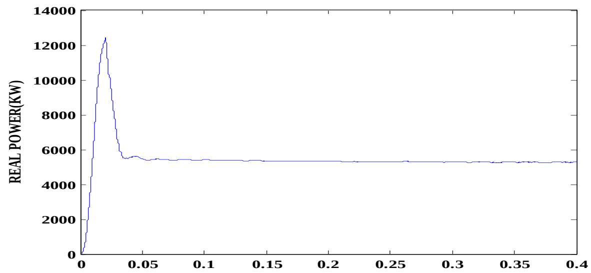


Fig.11:power supplied by MT and PV array

The remaining power is supplied by the grid is shown in the figure.11. 7.5KW(50% of P_{L1}) and 2KW(20% of P_{l2}).

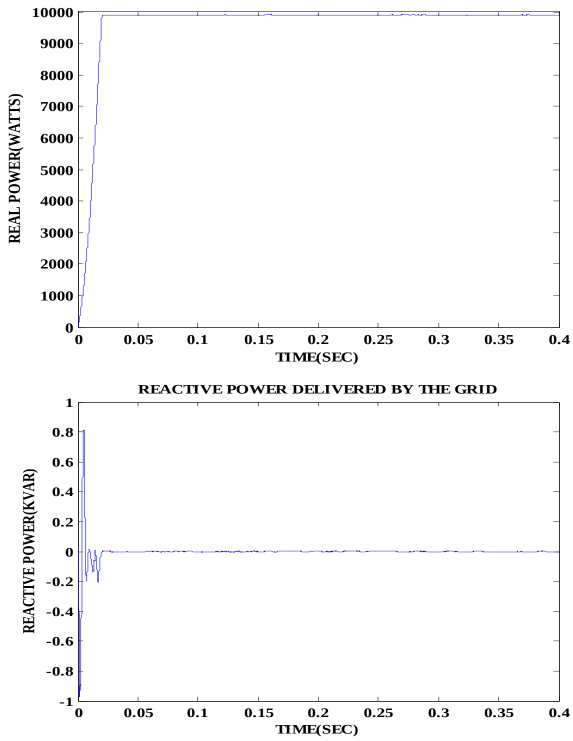


Fig.12: power supplied by grid

Test case 2:load sharing during Islanded operation

This test case demonstrate the islanded mode of operation of microgrid. The circuit breaker is initially fully isolated, when ever fault occurs on the upstream network, the circuit breaker disconnect the microgrid from the distribution grid.

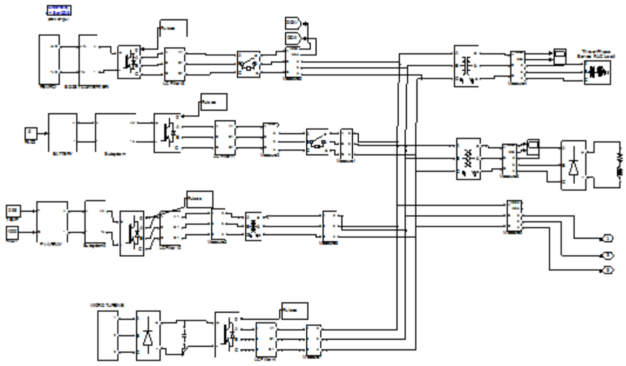


Fig 12: simulink model of isolated mode of operation

This test is employed to momentarily provide the sharing of real and reactive power of storage battery SB and PEMFC.during the interval of 0≤t≤0.4sec, at 0.2sec the circuit breaker swicth opened,the amount of real power delivered by the SB and PEMFC is shown in the figure.12.at t=0.2 sec the SB is supplies the 3.28KW and PEMFC is supplies the 2.28KW.initially the SB is idle or charge now in islanded mode the SB is supplies the power is shown in the figure.12.the real power is supplied by the MT and PV array is increased.

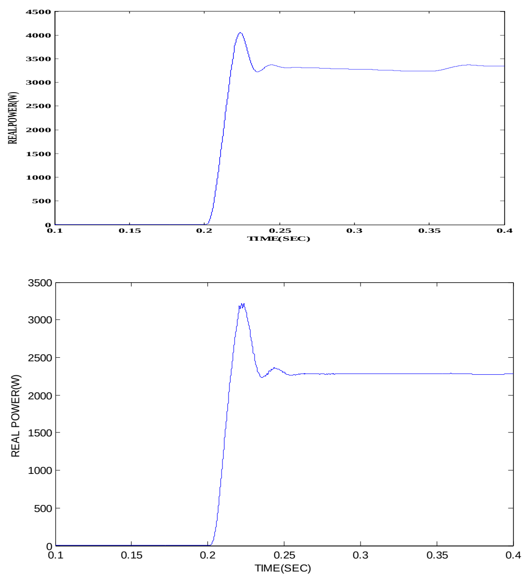


Fig.13: Power delivered by SB and PEMFC

CONCLUSION

This undertaking introduces the outline of micro-grid is proposed and operation of micro-grid during grid connected and islanded mode of operation has been given the assistance of MATLAB/SIMULINK.. The offered system incorporates with Kalman filter in a control design and Kalman filter is guess the state observer gain and infusions the harmonic compensation in the supply voltage and load current. The control design comprises of output based controller. The system is tested under unlike test cases and a formalize results are displayed in this undertaking.A control philosophy for the UPQC, which is versatile to the varieties of the supply and load working states of a power distribution system, has been proposed.This controller configuration haves of the ORC, Kalman channels and a LQR-based approaching oneself circuit.

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