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Smart Energy Management using a Centralized Control Algorithm in a Hybrid Microgrid With Integrated Sources

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Abstract: ***The energy requirement around the world is increasing faster along with the increase in industry throughout the world which in turn increase the pressure on normal grid systems, almost most of the continents has abundant source of solar and wind energy that can be used to reduce the pressure on the conventional grid systems. The goal of this research is to combine the renewable sources with the conventional source to reduce stress on the conventional grid and to provide a backup during blackouts, in this paper we are going to design a power flow control algorithm for a small scale Hybrid microgrid and explore different real life situations through simulations of a prototype***

Index Terms: ***About four key words or phrases in alphabetical order, separated by commas.***

I. INTRODUCTION

Continuous increase in population also increases our energy demand , putting conventional grids under pressure since the centralized grids are not upgraded throughout the decades because of the expenditure and complexity in upgrading the transmission and the generation systems , also our conventional grids (CG) are heavily affected from energy deficit and continuous black out cause of high demand around the earth also the need of uninterrupted supply and quality of supply has increased over period, this led to the introduction of smart grids and micro grid systems to be connected to the CG that can operated either in grid connected mode or in grid isolated mode. These systems has more advantages at CG like more efficiency, high reliability, optimal operation, reducing stress on utility and the usability on remote areas. In the present day dominance of DC loads I clearly visible in almost every fields both industrial load and domestic load, the significant development semiconductor technology almost all the devices need DC supply, currently the DC loads are supplied from the conventional AC grids which has more conversion losses. *Hybrid* microgirds with renewable sources are getting popular cause they supply DC loads directly avoiding conversion losses also by avoiding harmonics and synchronization issues. also the control and simple in *Hybrid* grids when compared to AC grids. The main objective of DC microgram is to harvest maximum power form the nonconventional sources like Wind, PV cells etc, reducing the stress on the CG also reducing the carbon emission by feeding to the local grid loads in more efficient way possible under grid connected and grid isolated modes. Since renewable sources are not constant there is a need for storage devices or storage systems (SS), for these storage systems Hybrid systems which uses Battery-ultracapacitors combination are used which can effectively control all AC/DC functions in a Microgrid which also increases the battery life and reduce the cost of the storage systems. To ensure the optimal use of energy resources, an effective energy management scheme is required. Most of the methods discussed in the reference papers are either talking about fully grid connected or fully isolated conditions. Very few papers discuss about all possible conditions on a *Hybrid* microgrid system (HBMG). From the analysis of the reference papers it is observed that they all lack in a basic aim which is reducing the burden on the CG by using effective smart energy management systems if different grids at different levels works the similar way it will only increase the stress on the CG instead of decreasing it .to avoid that a simple power flow control method is designed and proposed

II. HYMG SYSTEM ARCHITECTURE

With a separate DC bus system makes it easy to connect all the electronic DC loads allowing us to avoid AC/DC the conversion losses if they are directly supplies from an AC supply. The HYMG system built here is shown in fig:1. It has a PV array which is connected through a unidirectional Boost converter to the DC bus which executes the need on diodes which decreases the additional cost and losses in the converting process with buck converter. voltage control is used to extract maximum power from PV cell instead of current control because the maximum power point(MPP) voltage is not changed with insolation and it also gives benefits like fast tracking, faster regulation and accurate measurements.

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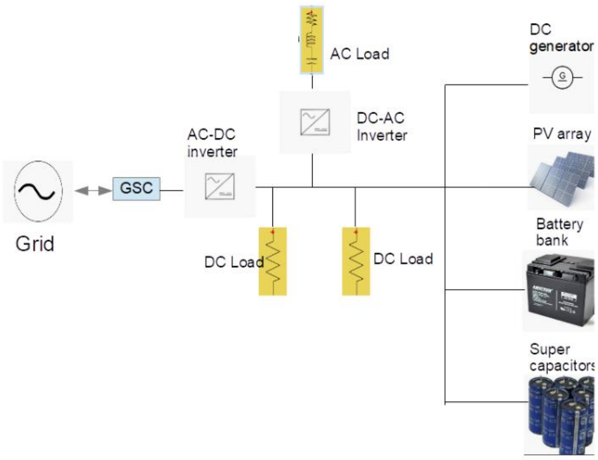


Fig:1 Block Diagram of the HYMG structure

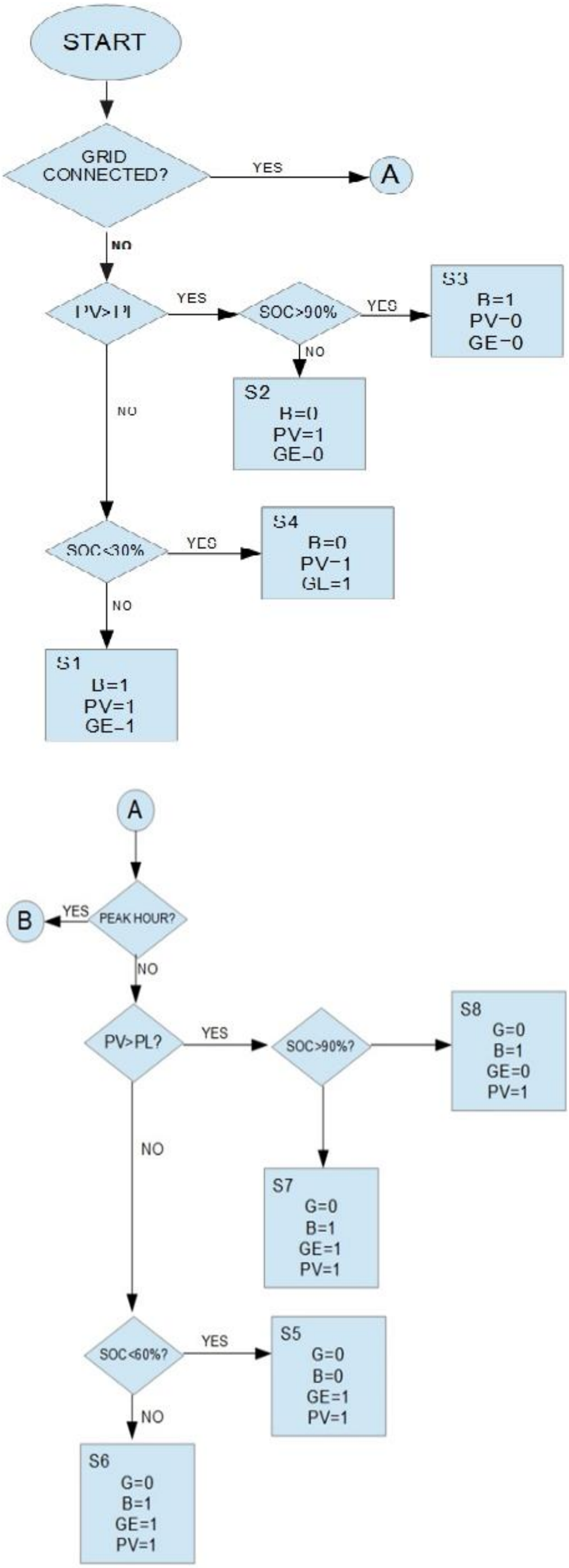
A Grid side converter is connected in-between the HYMG and the AC grid via a transformer to transfer power to and from the CG. The GSC is designed using a full H-bridge topology. Ultracapacitors and lead acid battery is used as the Storage System which are linked to the HYMG half H-bridges separately that holds inherent capability of carrying power in both direction. Both the battery and the ultracapacitors have unique separate features battery only shares the low frequency power component and the rest is sent to the ultracapacitors with the help of low pass filter (LPF) and rete limiter which reduces the stress on the battery. The loads are categorized as AC loads and DC loads. DC are directly supplied from the and the AC through an inverter.

There are relays placed in between the DC bus to have control over the them based on the input signal. At any point the sum of generated power is equal to the power consumed by the loads considering the conversion loss is zero.

III.POWER FLOW CONTROL ALGORITHM

The proposed power flow control algorithm(PFCA) mainly focuses on the energy distribution during the peak hours that is when the demand is high than the normal hours and for the optimal use of the renewable sources. it has been shown in fig:3 the PFCA play a very important role in this whole energy distribution scheme

Where the current references are synthesized for every single converter's inner loop depending upon the operating modes. Some advantages of PFCA are (1) reduce stress on the GC during peak hours (2) lowers the carbon emission level by using renewable sources



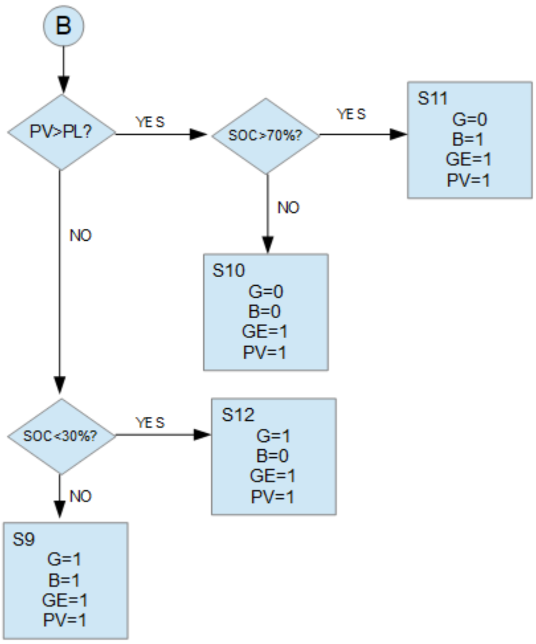


Fig:3 the proposed power flow method

There are three modes depending on the grid availability

They are as follows;

1) grid disconnected
2) grid connected
3) Peak hour

Once again each of these modes are further classified into four sub modes depending upon the values of P_{pv} , p_L and SoC_b. Ultracapacitor is only used as a high power density storage for transition periods between the different scenarios for a smooth mode transfer and it never absorbs or supplies average power. SOC of the ultracapacitor is always assumed to be within the limits

Throughout the system operation.

Symbols in PFCA elaborated as G-CG; B-Battery; UC-Ultracapacitor, PV-power from solar array, GE-generator, SOC-Battery percentage.

In the fig 3 flowchart X=1 means the device is connected and X=0 means the device is disconnected.

Where X=G,B,PV&GE.

1) Peak hour: in this mode the priority is given to either supplying to grid or to draw minimum power to run the essential loads in grid interactive HYMG by making sure that the DC bus voltage is under the limits, there are mainly 4 operating conditions in this mode which are

Case1: ($p_{pv} > p_L$ & $SoC_b < 70\%$) In this case the amount of energy produced is greater than the demand and if the battery is charged to the predetermined value the extra power from the HYMG is supplied to the utility grid through the GSC and the battery remains idle.

Case2: ($p_{pv} > p_L$ & $SoC_b < 70\%$) The previous mode is continued till the battery SoC_b gets below the predetermined value then the extra power is used to charge the batter. which eventually puts the GSC into the idle mode.

Case3:($p_{pv} < p_L$ & $sOc_b > 30\%$) this case happens when the generation is less than the demand . in that case first the battery's SOC is checked against sufficient values. if there's enough the battery starts to discharge and the grid remains idle.

Case4:($p_{pv} < p_L$ & $SoC_b > 30$) it is a continuation to the previous case (case3) and it comes into when SoC_b drops below the predetermined value Load shedding is incorporated for prioritized loads in this mode on the basis of *b SOC* cut off values. As per this paper, If 30% *b SOC*, least preferred load is cut off first then second least preferred load is shed when *b SOC* fall below 20%. References current are same as previous mode until *b SOC* reaches below 10%. Once it become below 10%, then essential loads are only fed from GSC and reference currents given as

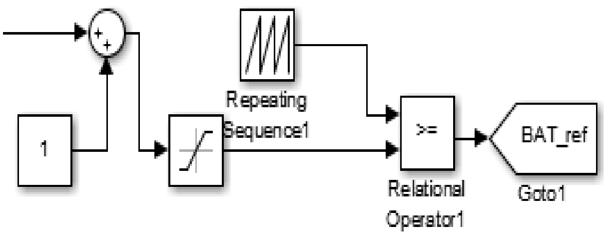
1) Grid connected mode: in this mode the charging of batteries is done along with the full load supply from the grid because the GC is now fully able to supply enough power to the loads at low cost and the stored power can be used at pear hour period on CG. Also the GC should not be put under the peak mode which will increase the stress and also the carbon footprint. Thus there's a limit put on the SOC of the battery. If the SOC is higher than the pre-determined value (>90%) the battery system remains idle and the excess power is fed to the grid. Otherwise (SOC<90%) grid is disconnected and the battery is charged. In load dominating situation, if the SOC is greater than the predetermined value (>60%), then the battery is feeding the loads.

2) Grid disconnected mode: this mode comes into action when the CG grid completely fails , here the HYMG is operated in all worse conditions like low generation than the load demand with a critically low SoC_b and excess generation with high battery SOC value, in the first condition load shedding is done and battery is used to charge or discharge based on the condition which are given in the flow chart (fig 3) here the case 4 is same as the case 4 in the peak hour mode except here the grid is absent

IV.CONTROL LOOPS (PFCA)

A. Battery, Generator and Ultracapacitor inner loops

The PFCA uses the reference values based on the mode of operation and fed it to the booster circuits . The controller gives the duty ratio as output which governs the input of battery and the ultracapacitors.

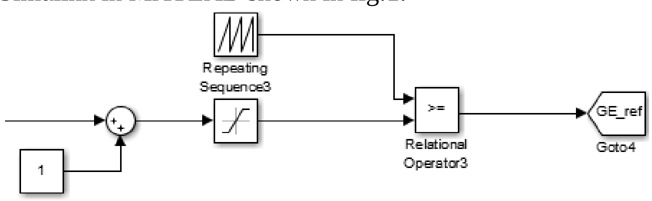


B. PV Inner control loop

The PV is operated at maximum power condition always except when there is surplus power production and the batteries are fully charged here the PV is put into bus regulation. PFCA decides the mode of operation for the PV. MPP tracking (MPPT) method provides reference voltage (V_{pref}) which is tracked by PV source voltage (V_{pv}) and its output produce required duty ratio (d_{pv}). Similar procedure is followed in bus regulation case except reference voltage set to DC bus voltage.

V.SIMULATION RESULTS

The simulation is carried out using the grid system in Simulink in MATLAB shown in fig:1.



The proposed PFCA is executed in the Matlab using state flow chart. Considering that all the loads are purely resistive they are split into two parts. First there is DC loads and the other is AC loads.

The proposed design of PFCA is explored under all possible operating scenarios such as variations in renewable source (PV power) and faults/blackouts on CG. The assessment on PFCA are spit in to three major parts, the peak hour and Non-peak hour modes during the grid connected condition and the other is grid isolated condition. PV sources are always operated at MPP using P&O method in the first two modes. In all these cases the power fed to the HYMG is considered as positive and the other way is considered as negative

Case:1 (Grid disconnected)

Here the simulation is run with the grid disconnected from the HYMG first the absence of grid is identified and the data is fed to the control algorithm by a PI controller, after that the PFCA with the data given (PV,PL,SOC,Gin) chooses the best mode of operation following the algorithm programmed.

There are 4 different scenarios programmed under grid disconnected operation mode S1,S2,S3,S4 as given in the flow chart above fig:3, let's consider a situation where the PV>PL and the SOC is lesser than 90%

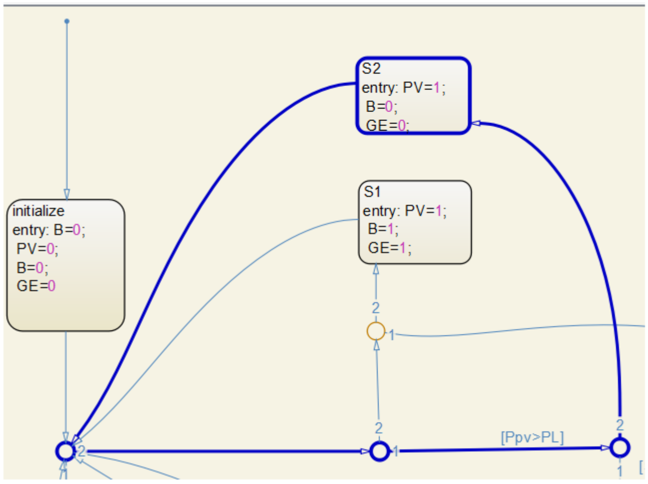


Fig 5:

From fig 5: we can see that the algorithm chooses scenario 2 as the suitable operating mode where the PV>PL and the SOC is lesser than 90%

From fig5: we can see that the algorithm chooses scenario 2 as the suitable operating mode where the PV array and Battery are connected to the grid and the Generators are not

If the PV < PL and SOC is less than 90% it goes to scenario 1 fig:6 where all the devices PV array, battery and the generators are connected to the grid.

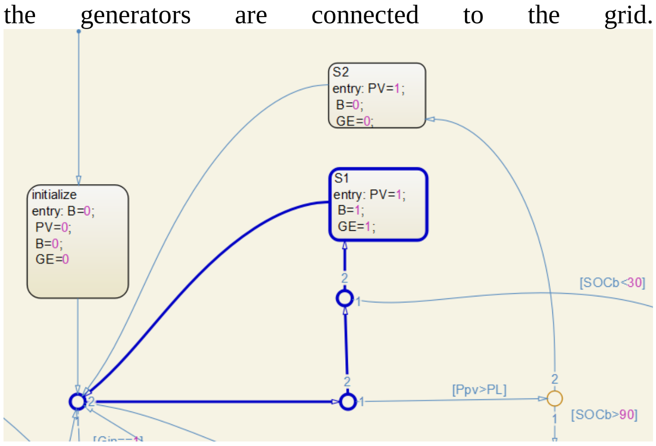


Fig:6

Similarly, the other two scenarios (S3&S4) are selected for respective values of PV<PL&SOC.

Case:2 (Grid connected & Non-peak hour mode)

Here we have a functional conventional grid connected to the micro grid which is detected by the PI controller after detecting that the grid is connected the control algorithm gets the inputs of PV, PL&SOC. it also checks if this is a peak hour or non-peak hour. After getting the inputs the suitable scenario is selected.

Here in the simulation the SOC given lessen than 90% & the PV>PL.

The algorithm decides that the scenario 7 as the optimal operating mode fig 7

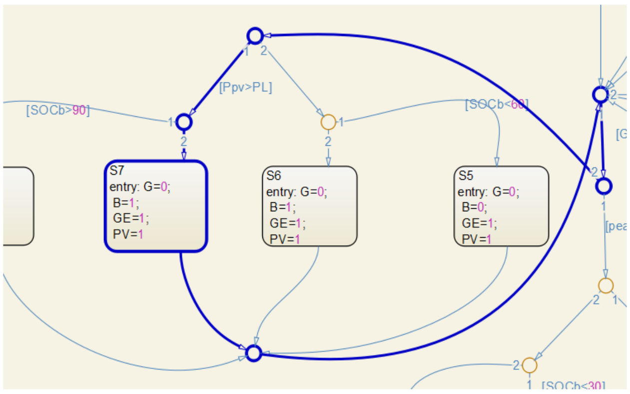


Fig:7

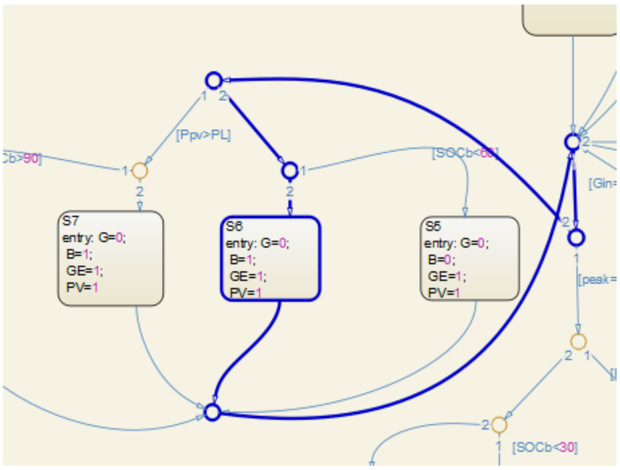


Fig:8

In fig:8 the scenario 6 is selected as the optimum operating mode because the PV<PL and SOC is greater than 60%,,the other scenarios (S8&S5) are selected in the respective conditions given in fig:3

Case:3 (Grid connected & peak hour mode)

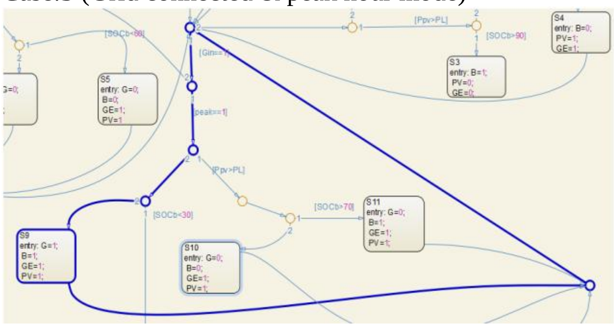


Fig:9

In this mode the conventional grid is connected to the HYMG, but here the peak-hour condition is enabled means that the loads are critical and they must be supplied without any absolute interruptions , let's consider that the PV<PL in the simulation model and the SOC is greater than 30% , normally the battery would be disconnected in this condition but since it is peak hour mode the battery is also to connected to ensure uninterrupted supply to the critical loads, the PFCA selects scenario 9 as optimal operation mode fig 9.

In fig 10 the scenario 11 is selected because the PV>PL and the SOC is greater than 70%. the PFCA switches to other scenarios in this case (S10&S12) based on the respective conditions.

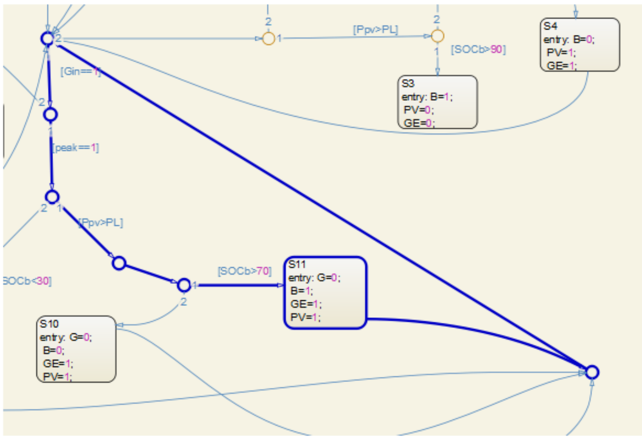


Fig:10

Battery parameters :

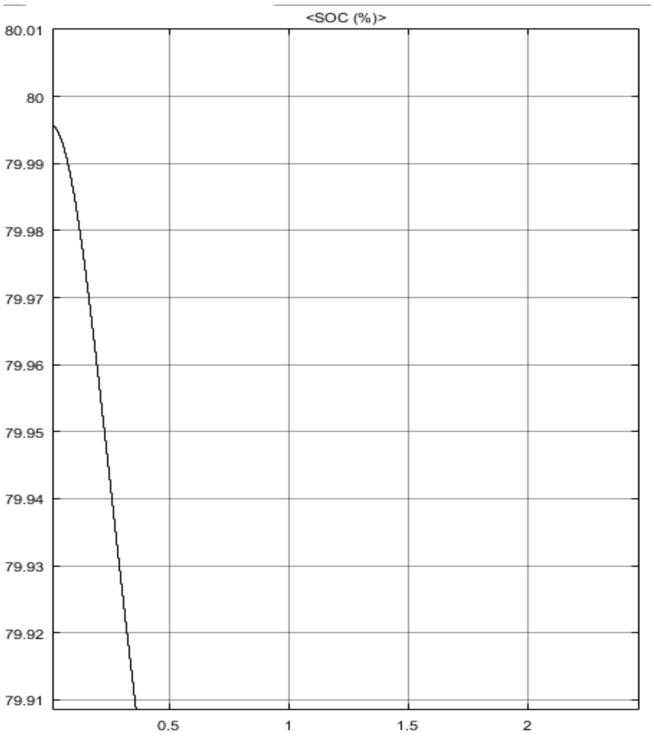


Fig:11 Battery SOC

The above figure shows how the battery gradually discharges with time when its connected to the micro grid DC bus. The SOC value plays an important role in determining the operating scenario.

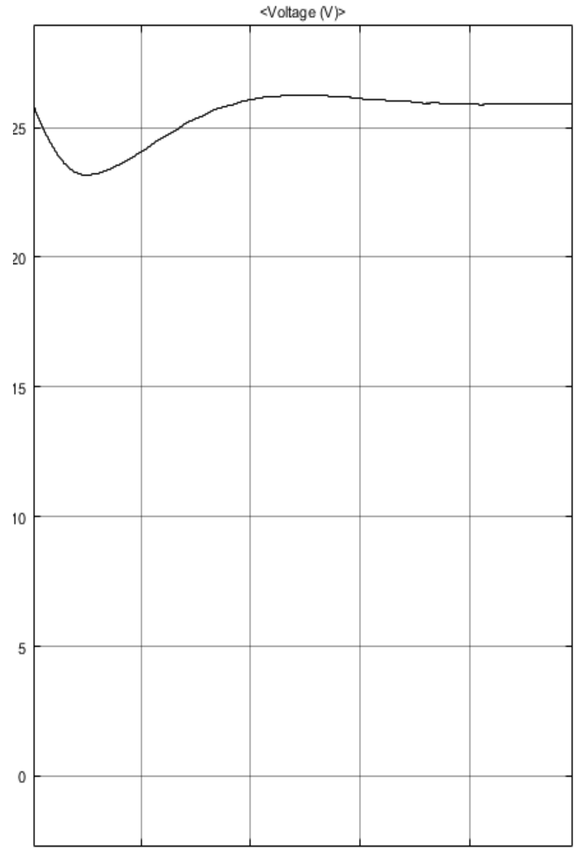


Fig:12 battery voltage

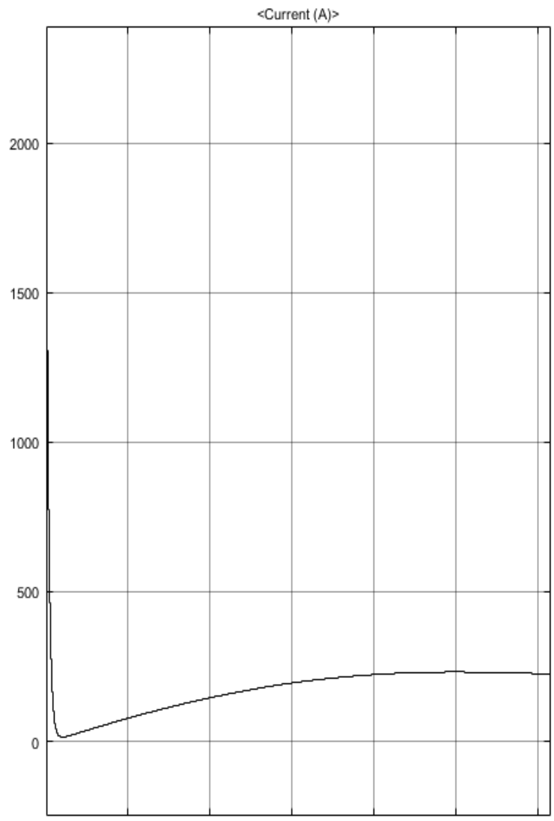


Fig:13 battery current

DC micro grid bus:

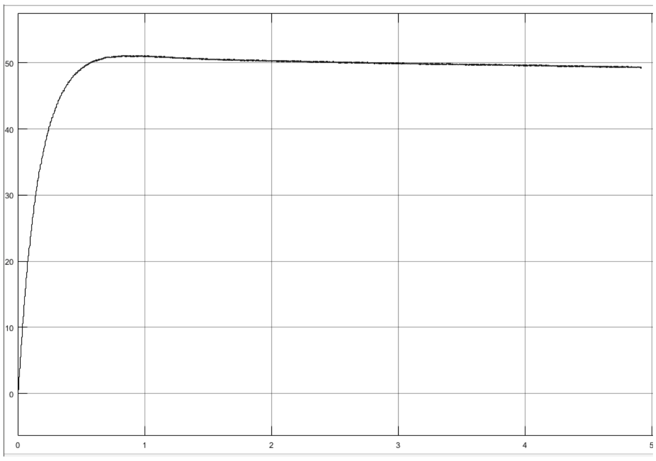


Fig:14 DC bus voltage

The whole aim is to maintain this voltage without interruption and by putting less stress on the conventional grids.

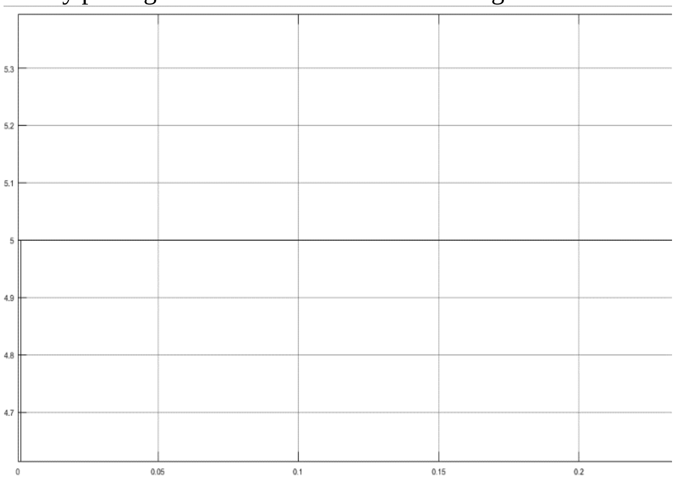


fig:15 DC bus current

this is the amount of current flowing through the DC grid if it's in positive values that means the current is drawn from the conventional grid, if the current is negative the current is fed to the conventional grid from the HYMG.
(All these parameters given can be different for different operating modes and different real life conditions)

CONCLUSION:

A simple power flow control strategy for a hybrid micro grid has been proposed to control the energy flow during various conditions and real life situations. a prototype was designed in matlab using Simulink and the scenarios were simulated, the algorithm was found to be working successful in selecting the optimal working mode reducing the stress on the conventional grid and efficiently using the sources connected to the hybrid micro grid.

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