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An Higher Case Operation and Analysis of a Multiple Renewable Resources Connected To A Dc Load Through Dc Bus

G. Mahesh Kumar, P.G. Scholar, Y.Damodharam, M. Tech, S. Suresh, M. Tech
Kuppam Engineering College Kuppam.
Assoc.Proffesor, Kuppam Engineering College Kuppam.
Asst.Professor, C. R. Engineering College, Tirupati.

ABSTRACT
In our nation the usage of electricity is increasing day-by-day. According to that conserdations, the generated power from the non-renewable sources will not satisfy the demands properly. so for these purpose, by using multiple renewable sources, it will be very useful to some type of dc applications. The power produced from the individual renewable sources will not be satisfy the demand at all times. So by integration of a multiple renewable sources such as wind and solar a huge amount of power will be produced. These power will be coordinated to the ac grid or directly to dc consumers. For integration of renewable sources an aggregated model has to be proposed. In according to these operation BESS (battery energy storage system)is equipped with the system for maintaining the power balance. For obtaining the power balance the adaptive droop control technique has to be proposed and droop curves are evaluated. The droop characteristics are selected on the basis of the deviation between the optimized and real-time SOC of the BESS. In these paper, the operational analysis can be performed when real time soc is higher than the optimised soc and droop curves are plotted.
Operational controls with in the micro grid [such as cost have to be optimized at the same time it will satisfy the demand] are designed to support the integration of wind and solar power. By these process micro grid real time supply and demand will be maintain in symmetry. The simulation results are to be developed in MATLAB SIMULINK process for renewable power generation and fast charging load connected to the dc bus, droop control based responses.

Index terms- distributed energy resources, fast charging, droop control, electrical vehicle, micro grid, multilevel energy storage, power electronic conversion, emission constraint

I. INTRODUCTION

An electrical system that includes multiple loads and distributed energy resources that can be operated in parallel with in the border utility grid is called micro grid. Most countries generate electricity in large centralized facilities, such as fossil fuel (coal, gas powered), nuclear large solar power plants or hydro power plants. These plants have tremendous economies of scale, but usually transmit electricity long distances and can negatively affect the environment. Distributed generation allows collection of energy from many sources and may give lower environmental impacts and improved security of supply. Distributed generation reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building. This also reduces the size and number of power lines that must be constructed. Micro grid generation resources can include fuel cells, wind, solar, or other energy sources.

The combination of wind and solar energy leads to reduced local storage requests. The combination of battery energy storage system and supercapacitor technologies in turn can form multilevel energy storage. The battery energy storage system employs for balancing the supply and demand where as supercapacitor provides cache control to compensate for fast power fluctuations and smoothen the transients encountered by a battery with higher energy capacity.

Micro grids or hybrid energy systems have been shown to be an effective structure for local interconnection of distributed renewable generation, loads and storage. With the ongoing and increasing demand for improved reliability and energy efficiency across all commercial buildings, a wonderful opportunity exists to capitalize on the benefits of DC micro grids.

Throughout building interiors and exteriors, several electrical systems rely on standard alternating current (AC) to be converted to direct current (DC) to be used by their components. HVAC, motor loads, pumps, lighting, information technology equipment, security, etc. all of these systems require the renovation of power from AC to DC for their operation. Having directly available DC power can increase energy efficiency by eliminating losses associated with this renovation, as well as increase reliability due to the eradication of several transformer components.

Having a DC micro grid included into the infrastructure of building interiors provides extraordinary flexibility for the occupants. Electrical systems, such as lighting, can be easily reconfigured and relocated according to changing needs of the space without rewiring.

Sustainability initiatives and zero net energy goals are driving the use of renewable energy sources, such as from solar photovoltaic, wind, and other alternate source systems. These DC power sources may be integrated for direct use by a micro grid system, eliminating the DC-AC-DC conversion losses.

The paper presents in which process the usage of output power generated from the renewable sources through dc link and optimization operation on the micro grid. The dc link voltage was shown to be maintained by a adaptive droop control that relates the dc link voltage to the power output of the renewable sources. The proposed operational optimization is further distinguished in that it quantifies the uncertainty associated with renewable generation forecast, emission constraints and EV fast charging.

II. LAYOUT OF THE DC MICRO GRID

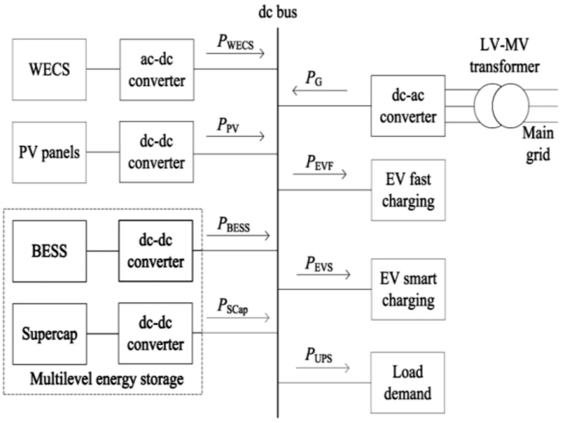

Fig:1 Outline diagram of the dc micro grid

The schematic of the dc micro grid with the arrangement of renewable sources, multilevel energy storage comprising Bess and super capacitor, ev fast charging, smart charging and grid interface.Through wind energy conversions systems, wind power can be produced in ac and it is can be converted into dc through ac –dc converter. Rather dc is fed to the dc bus. Solar power will be produced from pv panels and these power will be fed to the dc bus through dc-dc converter.

Multilevel energy storage consisting the battery energy storage system for maintaining the supply in balance condition and it will satisfy the demand, whereas super capacitor has much less energy capacity than the Bess. Rather it is aimed at compensating for fast fluctuations of power and so provides cache control.

Thanks to the multilevel energy storage, the intermittent and volatile renewable power outputs can be managed, and a deterministic controlled power to the main grid is obtained by optimization. The multilevel energy storage mitigates potential impacts on the main grid.

In building integration, a vertical axis wind turbine may be installed on the rooftop. PV panels can be co-located on the rooftop and the facade of the building. Such or similar configurations benefit from a local availability of abundant wind and solar energy. The fast charging station is realized for public access at the ground level. It is connected close to the LV–MV transformer to reduce losses and voltage drop. EVs parked in the building are offered smart charging within user-defined constraints.

III. OVERVEIW OF THE OPTIMISED SCHEDULING APPROACH

The step by step procedure of the optimised scheduling approach for the micro grid is shown below.

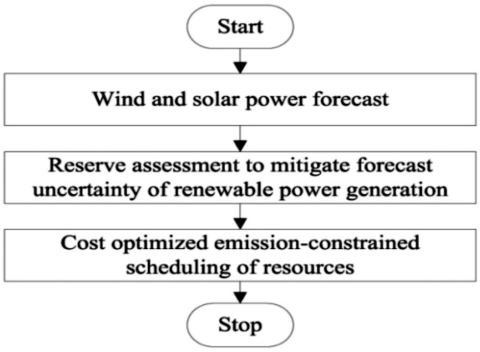

Fig: 2 Overview of optimised scheduling approach

In first stage wind and solar power forecast, that means wind and solar power can be aggregated. The example of aggregated uncertainty data can be available from the wind and solar sources as shown in below table-1.from these data power can be calculated for a day-a-head scheduling and these processes can be explained clearly by mathematical equations in below SECTION-4(a).

In the next step the aggregated power generation data are used to assign hourly positive and negative energy reserves to the BESS for the micro grid operation. The positive energy reserve of the BESS gives the energy stored that can be readily injected into the dc bus on demand. The negative energy reserve gives the part of the BESS to remain uncharged to capture excess power on demand. Energy reserve assessment is performed according to the aggregated renewable power generation forecast.

In order to compensate for the uncertainty of the forecast, a method is devised to assess positive and negative energy reserves in SECTION-4(b).

Finally, the emission constrained cost optimization is formulated to schedule the micro grid resources for the day-ahead dispatch. The optimized scheduling is formulated in SECTION-4(c)

a) MICROGRID OVERVIEW OPERATION ANALYSIS

In these section by using wind and solar power generation forecast uncertainty data a three state model has to be presented. In these three state model the individual states is **k=3**.From these, micro grid has two renewable sources with three states then by mathematical fourmale $N=K^2$ which is equal to the nine combined states will be produced. In each combined state the power of the each state is summed up and the probability of a combined state is the product of the probabilities in individual states. Again the nine combined states should be reduced into aggregated states. To aggregate the combined states M aggregated states are defined. Here **m=3** and denoted by m is shown in table-2.

TABLE-1
WIND AND SOLAR POWER FORECAST DATA

Individual state	**State1**	**State2**	**State3**
Wind forecast probability	0.25	0.50	0.25
Wind power(kw)	40	50	60
Solar forecast probability	0.25	0.50	0.25
Solar power(kw)	15	20	25

TABLE-2
COMBINED STATES OF WIND AND SOLAR POWER FORECAST

Combined state, n	**Counter, l**	**Aggregated state, m**	**Power output, $\tilde{p}_{l,m}$(kw)**	**Probability, $\tilde{pr}_{l,m}$**
1	1	1	40+15 =55	0.25*0.25 =0.0625
2	2	1	40+20 =60	0.25*0.50 =0.1250
3	1	2	40+25 =65	0.25*0.25 =0.0625
4	2	2	50+15 =65	0.50*0.25 =0.1250
5	3	2	50+20 =70	0.50*0.50 =0.2500
6	4	2	50+25 =75	0.50*0.25 =0.1250
7	5	2	60+15 =75	0.25*0.25 =0.0625
8	1	3	60+20 =80	0.25*0.50 =0.1250
9	2	3	60+25 =85	0.25*0.25 =0.0625

The aggregated state **m** covers number of combined states **l** than the probability of the aggregated state is obtained by the summation of the probabilities of these combined states and the power of each aggregated state is average weight of all power outputs. The mathematical fourmale for calculating the probability and power is given by

$$\tilde{pr}_{A,m} = \sum_{l=1}^{L} \tilde{pr}_{l,m} \qquad (1)$$

$$\tilde{p}_{A,m} = \frac{\sum_{l=1}^{L} \tilde{pr}_{l,m} * \tilde{p}_{l,m}}{\tilde{pr}_{A,m}} \qquad (2)$$

The power and probability have to be calculated for 1 hour at state 1

$$\tilde{pr}_{A,1} = 0.0625 + 0.1250 = 0.1875$$

$$\tilde{p}_{A,1} = \frac{55 \times 0.0625 + 60 \times 0.1250}{0.1875} KW$$

$$= 58.33KW$$

Likewise power and probability have to be calculated for 1 hour at state 2 and 3 and also for remaining hours. The power data can be used for calculating reserve assessment operation in the Bess for the micro grid.

b) BATTERY ENERGY STORAGE SYSTEM ALLOCATION PROCESS

Based on the operation strategy Bess storage capacity is allocated. the depth of discharge, positive reserve, operational area, and negative reserve are allocated in the Bess. In normal operational mode the Bess can be charged and discharged in the operation area. The Bess can be operating in positive reserve and negative reserve in order to compensate the uncertainties of the power generation and load demand.

The positive reserve means the energy stored in the Bess that can be readily injected into the dc bus and the positive reserve can be calculated by the summation of energy obtained at state 2is subtracted from energy of state 1for all hours. When excess of energy can be generated from the renewable sources at that time dc bus go to unbalance. so for balancing the energy some amount of energy will be stored in the negative reserve of the Bess. Finally the negative reserve can be calculated by summation of energy obtained at sate 3is subtracted from the energy of state 2 for all hours.

c) FORMULATION OF OPTIMIZED SCHEDULING OF MICRO GRID

By considering the below objective function, the operation cost of the micro grid can be minimized in the interconnected mode and provide ups service in the autonomous mode. The objective function will be

$$F(\mathrm{P_G}, \mathrm{P_{EVS}}) = \sum_{i=1h}^{T} C_{1KWH(\mathrm{i})} \times \mathrm{P_{G(i)}} \times \tau_h$$

$$+\sum_{i=1h}^{T} C_{1KWH(\mathrm{i})} \times \mathrm{P_{EVS(i)}} \times \tau_{\mathrm{h}} + \sum_{i=1h}^{T} EFBF \times \overline{EMS} \times \mathrm{P_{G(i)}} \times \tau_{\mathrm{h}} \qquad (3)$$

The first term in the objective function above expresses the energy cost, the second term defines the cost of EV smart charging, and the third term describes the emission cost. The optimization program determines a solution that minimizes the operation cost of the dc microgrid. Thus, a monetary value is assigned to emission reduction by this approach. This objective function is subject to the constraints as follows.

I. Power limitation of the grid interface introduces a boundary constraint to the optimization

$$P_{G-} \leq P_{G(\mathrm{t})} \leq P_{G+} \,\forall t \in T \qquad (4)$$

where $\mathbf{P_{G-}}$ is the lower boundary of the grid power, and $\mathbf{P_{G+}}$ is the upper boundary of the grid power.

II. The BESS power has to be within the limit

$$P_{BESS-} \leq P_{BESS(\mathrm{t})} \leq P_{BESS+} \,\forall t \in T \qquad (5)$$

where $\mathbf{P_{BESS-}}$ is the lower boundary of the outgoing power from the BESS to the dc bus, $\mathbf{P_{BESS}}$ is the BESS power to the dc bus, and $\mathbf{P_{BESS+}}$ is the upper boundary of the BESS power.

III. The availability of EV and charging power limits should be met

$$0 \leq P_{EVS(\mathrm{t})} \leq P_{EVS+} \,\forall t \in T_{EVS} \qquad (6)$$

Where $\mathbf{P_{EVS}}$ is the EV charging power, $\mathbf{P_{EVS+}}$ is the upperboundary of the EV charging power, and $\mathbf{T_{EVS}}$ gives the hours in which EVs are available for smart charging.

IV. The power balance equation has to be valid at all simulation time step

$$\tilde{P}_{A,\,2(\mathrm{t})} + P_{BESS(\mathrm{t})} + P_{G(\mathrm{t})} - \tilde{P}_{EVF} - P_{EVS(\mathrm{t})} = 0 \forall t \in T \qquad (7)$$

Where$\mathbf{\tilde{P}}_{\mathrm{A,2}}$ is the average power forecast of renewable energy sources wind and solar at aggregated state 2, and $\mathbf{\tilde{P}}_{\mathrm{EVF}}$ is the EV fast charging power forecast.

V. The objective function is also subject to a constraint of the SOC of the BESS. The constraint can be defined as

$$E_{BESS-(\mathrm{t})} \leq E_{BESS-0} - \sum_{j=1\min}^{t} \Delta E_{BESS(\mathrm{j})} \leq E_{BESS+(\mathrm{t})} \quad \forall t \in T \qquad (8)$$

VI. The total required EV smart charging energy for the day-ahead scheduling is to be met. This is defined by an equality constraint

$$\sum_{i=1h}^{TEVS} P_{EVS(\mathrm{i})} \times \tau_h = \tilde{E}C_{EVS-ch} \qquad (9)$$

Where $\mathbf{T_{EVS}}$ is the time that EVs are available for smart charging by the micro grid, $\mathbf{P_{EVS}}$ is the smart charging

Power of EVs, and $\mathbf{\tilde{EC}_{EVS\text{-}ch}}$ is the total EV smart charging energy forecast for the day-ahead scheduling.

IV. PROPOSED TECHNIQUE FOR BESS

In these section real time operation of the microgrid in the interconnected and the autonomous mode is studied.In the interconnected mode of operation, an adaptive droop control is devised for the BESS. The adaptive droop characteristic of the BESS power electronic converter is selected on the basis of the deviation between the optimized and real-time SOC of the BESS, as calculated in section 4.Details of the method are provided in section5(a). In autonomous mode of operation, the BESS is responsible for keeping the voltage of the dc bus in a defined acceptable range for providing UPS service. The autonomous mode of operation of the microgrid is described in secton5(b).

a) Dc voltage Droop control in interconnected mode:

In these mode, the devised droop controls of the Bess are depicted as shown in **figs 3-5**.The dc bus voltage can be taken in x-axis and change in battery power will be taken in y-axis.the change of battery power $\Delta \mathrm{P_{BESS}}$ is modified as a function of the dc voltage.

The first droop curve, as shown in fig:3 is devised for a case where the real-time SOC of the BESS is within the close range of the optimized SOC of the BESS from the scheduling calculated in section 4(c). The acceptable real-time SOC is determined through definition of upper and lower boundaries around the optimized SOC. If the real-time SOC is within these boundaries, the droop control of the BESS power electronic converter is selected as shown in fig:3 to support the dc voltage. In this case, the upper boundary and the lower boundary lead to a symmetrical droop response.

In the voltage range between $\mathbf{V_{Bm1-}}$ and $\mathbf{V_{Bm1+}}$**,** battery storage does not react to the voltage deviations of the dc bus. In the voltage range from $\mathbf{V_{Bm1□}}$ to $\mathbf{V_{Bm2□}}$ and also from $\mathbf{V_{Bm1}}$+ to $\mathbf{V_{Bm2+}}$,the droop control of the BESS reacts. Therefore, □$\mathbf{P_{BESS}}$ modifies the power output $\mathbf{P_{BESS}}$ to mitigate the voltage deviation of the dc bus. Finally, in the voltage range from $\mathbf{V_{Bm2□}}$ to $\mathbf{V_{BC□}}$ and also from $\mathbf{V_{Bm2+}}$ to $\mathbf{V_{BC+}}$, the droop curve is in a saturation area, and thus the BESS contribution is at its maximum and constant.

The second droop curve as shown in fig:4 is devised for a situation where the real-time SOC of the BESS is lower than the optimized and scheduled SOC of the BESS. Therefore, the BESS contributes to stabilizing the dc bus voltage by charging at the same power as shown in fig:3. However, the upper boundary of the BESS droop response is reduced by the factor □, and it is equal to □$\mathbf{\Delta P_{BESS-D}}$. This way, the SOC can come closer to the optimized and scheduled SOC.

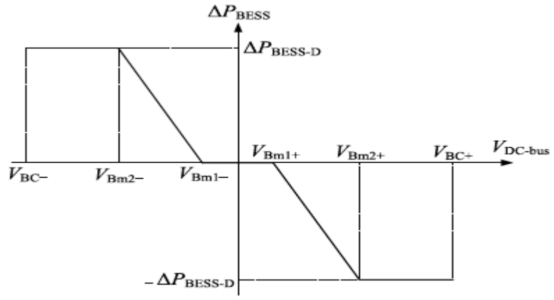

Fig:3 Droop control based responses to mitigate power deviations of dc microgrid in normal soc of the Bess

The third droop curve as shown in fig:5 is devised for a situation where the real-time SOC of the BESS is higher than the optimized and scheduled SOC of the BESS. Therefore, the BESS contributes to stabilizing the dc bus voltage by discharging at the same power as shown in fig:3. However, lower boundary of the BESS droop response is modified by the factor □, and it is equal to − □□ $\mathbf{P_{BESS-D}}$.

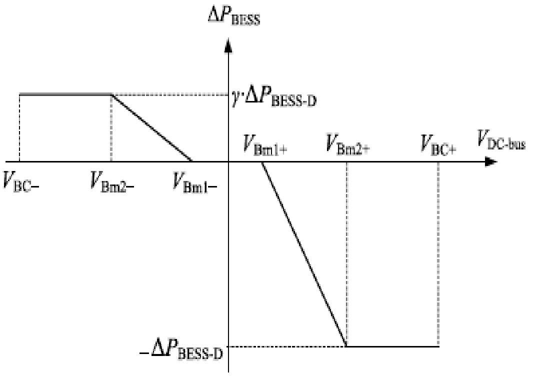

Fig:4 Droop control based responses to mitigate power deviations of dc microgrid in lower than the scheduled soc of the Bess

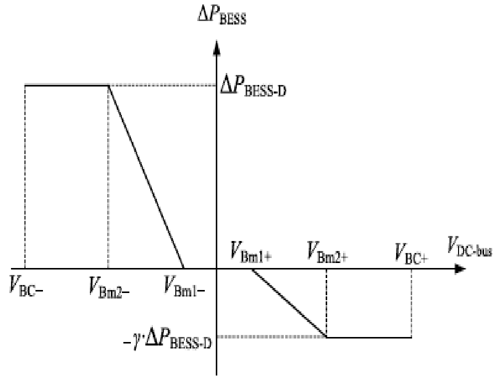

Fig:5 Droop control based responses to mitigate power deviations of dc microgrid in higher than the scheduled soc of the Bess

In real-time operation and interconnected mode, the SOC of the BESS is measured and compared against the optimized SOC of the BESS, and the proper droop will be selected as described above.

b) Dc voltage droop control in autonomous mode:

In the autonomous mode, the main grid is disconnected. Then the fast charging service has less priority compared with the supply of other loads. The control of the Bess converter is also defined by the voltage-power droop as discussed. The Bess so support the voltage of the dc bus.

V. VERIFICATION BY SIMULATION

The proposed operational method of the urban micro grid in day-head scheduling and real time operation is verified by simulation. The simulation block for proposed method is shown below.

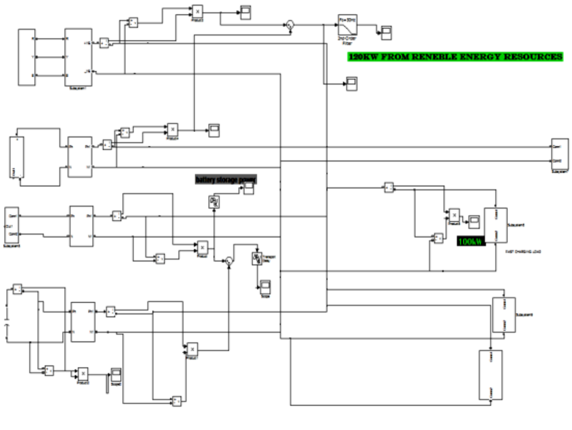

Fig:6 Dc microgrid simulation block

Here the installation capacity for wind is 100kw and solar is 50kw and bus voltage capacity is provided for 390volts for proposed operation. In this section around 17.00pm generated power 130kw will be produced. At the same time fast charging load will be connected to the dc bus with 100kw.so for compensating the power fluctuations the Bess will be charged the power up to satisfy the load demand. The results for generated power,fast charging load, droop control responses and bus voltage profile.

i. GENERATED POWER

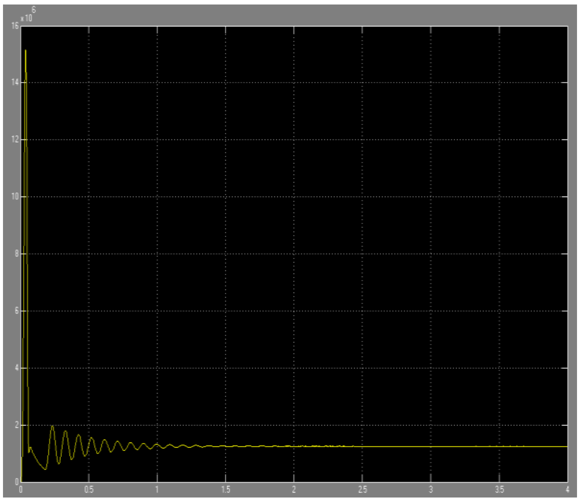

Fig :7 Renewable power generation with x-axis time(s) and y-axis power(kw)

The simulation results shown above for the case real time soc is higher than the optimised soc.

The results for the case real time soc is lower than the optimised soc but in these process battery will discharging the power.

ii. FAST CHARGING LOAD

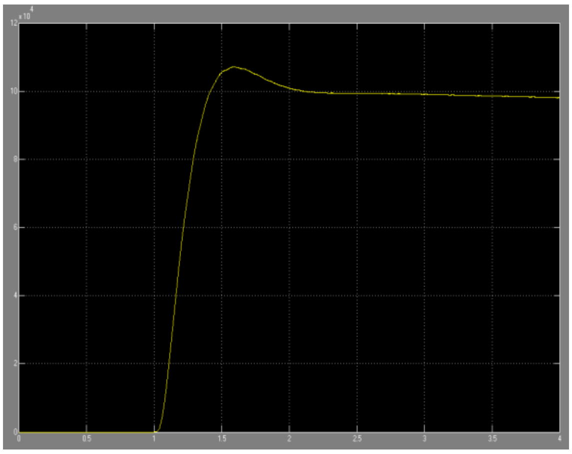

Fig:8 Fast charging load connected to dc bus with x-axis time(s)and y-axis power(kw)

iii. DROOP CONTROL RESPONSES

BATTERYDISCHARGING POWER TO THE DC BUS

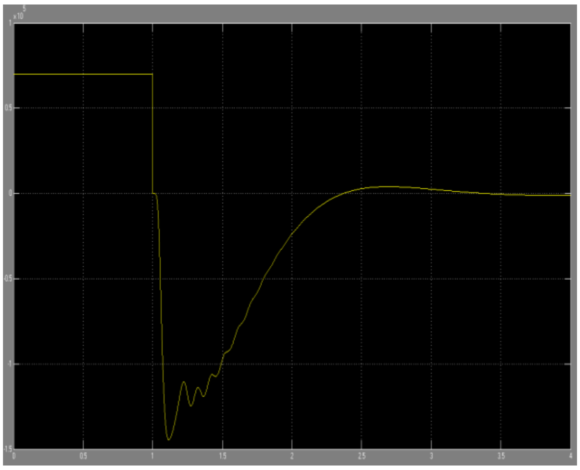

Fig:9 Battery discharging power to the dc bus with time(s) on x-axis and power(kw) on y-axis

SUPER CAPACITOR DISCHARGING POWER TO THE DC BUS

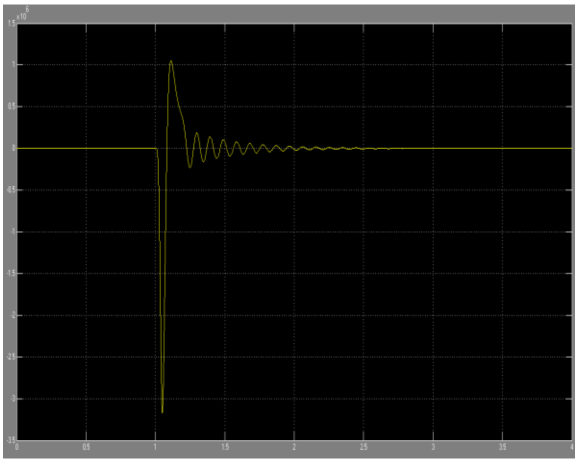

Fig:10 Super discharging power to the dc bus with time(s) on x-axis and power(kw) on y-axis

iv. DC BUS VOLTAGE PROFILE

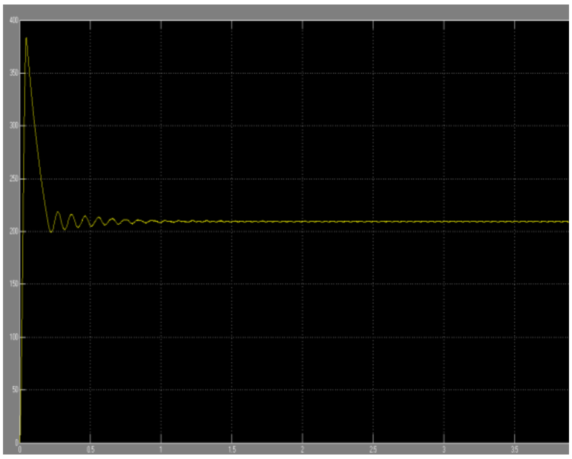

Fig:11 Dc bus voltage with time(s) on x-axis and bus voltage(v) on y-axis

VI. 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 ev 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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G.MAHESH KUMAR has received the B.Tech degree in EEE from Siddartha Institute of Science and Technology, puttur in the year of 2012. Present he is pursuing M.Tech in power electronics in Kuppam Engineering College, Kuppam.

Y.DAMODHARAM has obtained his B.Tech in EEE from Kuppam Engineering College affiliated to JNTUH in the year 2006. He completed M.Tech in power system emphasis on High Voltage Engineering from JNTU Kakinada in the year 2010. Currently working as Associate Professor in Kuppam Engineering College in the Department of EEE. His area of research is renewable energy sources, high Voltage engineering, power systems technology.

S.SURESH has obtained his B.Tech and M.Tech in Kuppam Engineering College in the year 2010,2014.currently working as Assistant professor in C.R.Engineering college in the department of EEE. His research includes the areas of interest in power electronics.