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Research Article

Adaptive Droop Voltage Control on Parallel Connected Converters for DC Microgrid Systems

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Abstract

Distributed Generators (DGs)are widely used as power sources in power system. The converters and control algorithm are used for sharing current between the load and microgrid. The three control types - centralized, decentralized and master-slave are used in DGs ,have their deficiency to maintain continuous power supply. The communication link between master-slave makes time delay and affects controlling system. The traditional droop control set point according to load is the main problem for DC micro-grid. This paper mainly deals with, an adaptive and flexible control of microgrid with parallel operation of converters to maintain the system stable for any load. The solar PV, wind generator and batteries are connected in parallel to microgrid and its performance is simulated and analyzed by MATLAB 2019a Simulink.

Keywords— Solar PV, wind turbine, converter, dc microgrid control, current sharing and adaptive droop control algorithm

INTRODUCTION

Electric power is one of the main sources for human being's daily life. Renewable energy, which is simple to use in rural areas, has many economic and environmental advantages. As we know, distributed generations and storage batteries are connected together.

The converters are connected together in parallel connection for continuous power supply. Energy storage batteries are used as backup as well as additional source for the grid. Several current sharing methods like centralized, master-slave and traditional droop control methods are used, but advancing control algorithm to increase the efficiency and availability of the power. In this system, the drawback of the master slave converter can be overcome by using Parallel converter. Circulating current minimization is basic for control design. Design of adaptive system, which controls current circulation performance and converter load running, is valued [1].

The parallel operation of converters is used for continuity of power to load in a DC microgrid. This system is advantageous because all converters connected to the system are operated to maintain continuous power supply. Depends on the load connected, system gives priority and the converters are operated [2]. This type of design for microgrid is very important because in case any failure in any one of the converters then the other converter works as usual and possible for maintenance without discontinuity of load for the system. Distributed generatoris connected toa DC/DC in PV panel and AC/DC, DC/DC in wind energy generation.

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DGs connected in parallel operation to boost converter for PV and buck converter for wind energy generation.
The parallel connected converters to DC bus share current and enhance the performance of the system (DC-DC) converters [3].
The droop control method relies on impedance between the output of each unit and DC-grid and the load impedance RL.

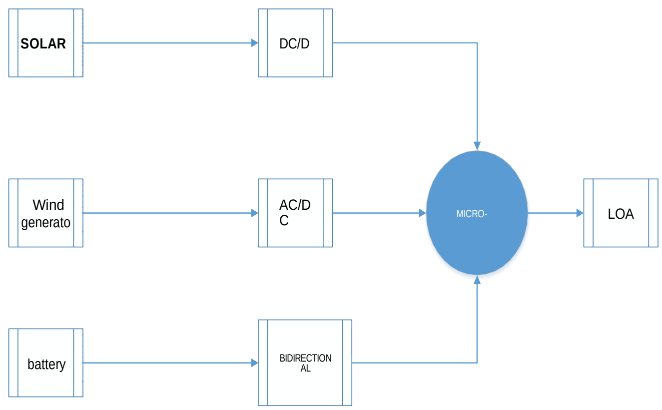


Fig.1 Parallel connection

Classical approach for droop control

This approach completes the parallel connected converters, which have its own DC-voltage (Vdc), and Current (I) connected to DC-bus and the terminal voltage. The output voltage of solar is maintained at maximum by using a P&O MPT algorithm then boosted to set the voltage. Wind energy also generates AC voltage converted to DC by rectification process and using a buck converter to maintain at the DC bus level. The battery is also connected tothe DC-bus using bidirectional converters for charging and discharging to maintain the power and based on SoC it will be controlled by coding algorithm [4].

DC BUS

I1

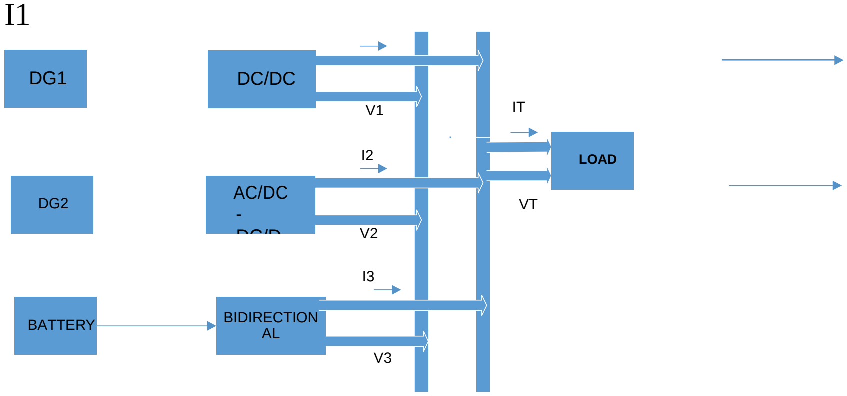


Fig.2 Classical droop control

Fig.2 shows that two DGs (solar PV and wind energy) have v1, I1 and v2, I2 from converters is directly connected to a DC-bus and the battery system to [5].
The drawback of classic droop control is that it does not update the output.The output for any unit of converter is found by using set point for each converter and the gain is also considered to maintain an approach to reference voltage. [6]

System adaptive droop control

The set point for each converter is sated. Integrating renewable energy sources by using power electronic interfaces gives flexibility in conversion and power level. DC microgrid plays a major role, as it is highly efficient, reliable, controllable and economical. In DC microgrid system, converters are used to interconnect renewable sources and loads [7]- [8].

converters designed for battery management in the system.

VL

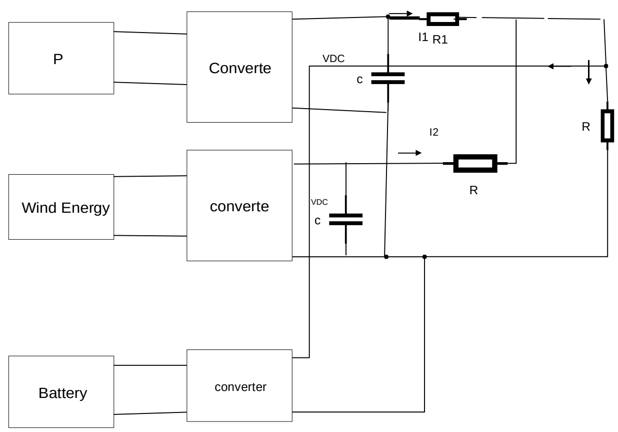


Fig.4 Converter combination.

V. Performance analysis of parallel converter

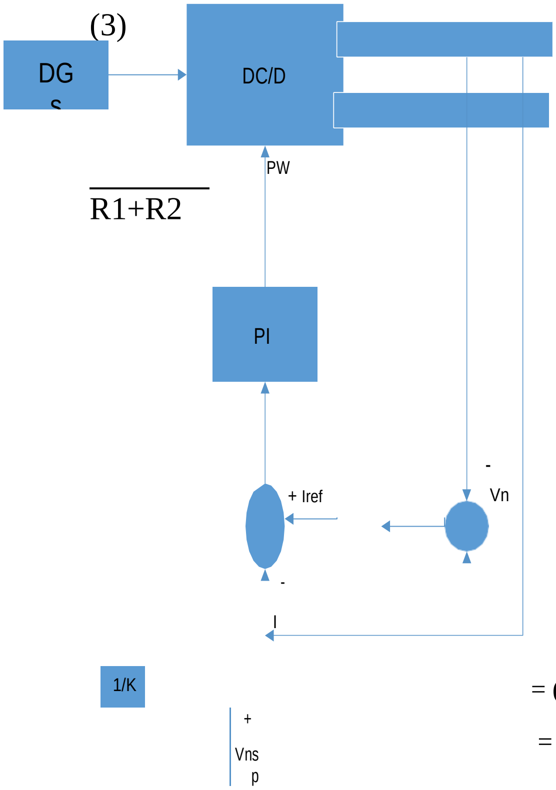
The voltage V_{DC1} and V_{DC2} are the output voltages of converters (solar PV and wind energy) respectively with their currents I_1 and I_2. There are circulating currents between converters I_{C1} & I_{C2} i.e the two converters.

$V_{DC1}-I_1R_1-I_LR_L=0$ (1)

$V_{DC2}-I_2R_2-I_LR_L=0$ (2)

The currents I_1 and I_2 are derived from (1) and (2) and the circulating current between the converters are equal and opposite direction and it is $I_{c12} = -I_{c21}$.

$$I_{c12} = -I_{c21} = \frac{(V_{DC1}-V_{DC2})}{(R1+R2)}$$



(3)

R1+R2

= $(I_1\text{-}I_2)/2$ if (R1=R2) (4)

$= \frac{(I1R1-I2R2)}{}$ if (R1≠R2) (5)

The voltage and circulating currents from converter-1 and

Fig.3 Control scheme for single unit.

converter-2 are VDC1, I1 and VDC2, I2 respectively. The circulating currents for the two converters can be obtained from eqn. (1) and (2).

This control method updates the output voltage set point of each converter. In fig.3, V_n , converter output and Vref (Vnsp) reference voltage with Inand Iref is output from gain

$$I1=\frac{(R2+RL)VDC1-RL\,VDC2}{R1R2+R1RL+R2RL}$$

$$I2=\frac{(R1+RL)VDC2-RL\,VDC1}{R1R2+R1RL+R2RL}$$

combined with a PI controller to control the pulse of boost and buck converter [9]- [10].

IV. The Design of adaptive model controller

The designed model is combination of boost converters for solar PV, buck converters for wind energy and bidirectional

If the voltage in resistor R1 and resistor R2 in the converter set are same (equal), then the circulating current becomes zero. In case, the set point of converters is different or the resistance R1 and resistance R2 are not equal, then Rdroop is added to the converters to minimize the circulating current. Fig.4 will be modified by adding the resistance ,Rdroop, which is variable and the circulating current can be minimized. The

Rdroop (Rdroop1 and Rdroop2) added for both converters and new DC voltage will be as follows.
V_{DC} (new) = $V_{DC} - I_{DC}$* Rdroop (8) Where, I_{DC} is the current flow in converter.

Battery management system operation
Battery and its control system is shown in Fig. 5

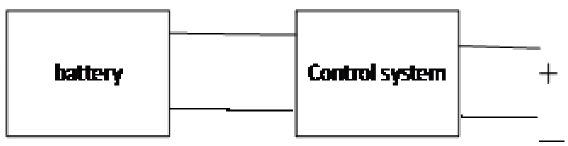


Fig. 5 Battery management system

The battery control system for storage is used to achieve the energy management. This can be performed by using an algorithm in which the system contains three modes.The system configuration is coded and used for controlling charge- discharge system with State of Charge.
Three modes are coded for switching the battery.

When SoC is greater than 80%, then the battery discharges and supports the load with bus connected.
When SoC is below 80%, both charging and discharging will be performed.
Finally, when SoC is below 40%, only charging mode is activated.

The mode and its operation can be performed by switching the bidirectional converters designed for charging and discharging of the battery system.

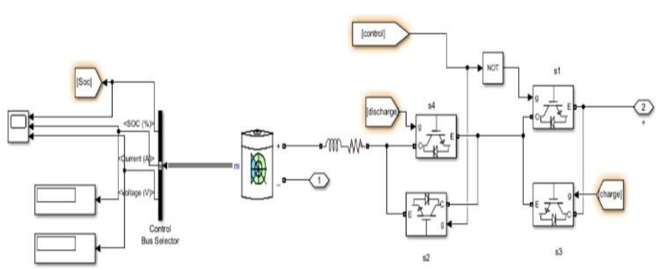


Fig.6 Control system for battery

In the Fig.6. The switch system has S1, S2, S3 and S4. When S1 and S4 are closed, the battery discharges and when s2 and s3 are closed the battery charges, as the switch direction

Shown in the fig.6. Charge-discharge can be based on SoC control algorithm depending on type of load and distribution resources.

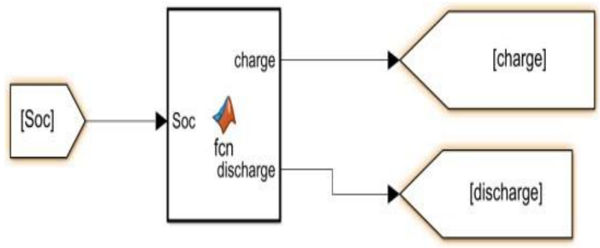


Fig. 7 MATLAB Simulink model for battery charging and discharging

Based on SoC, the algorithm is coded to perform the operation of the system with the three modes of operations as follows:

<u>Mode 1: Discharging Mode:</u>
When Vdc < VL by 80% i.e., SoC is greater than 80%, then the battery discharges and supports the load. During this mode, switch S1 and S4 are closed.

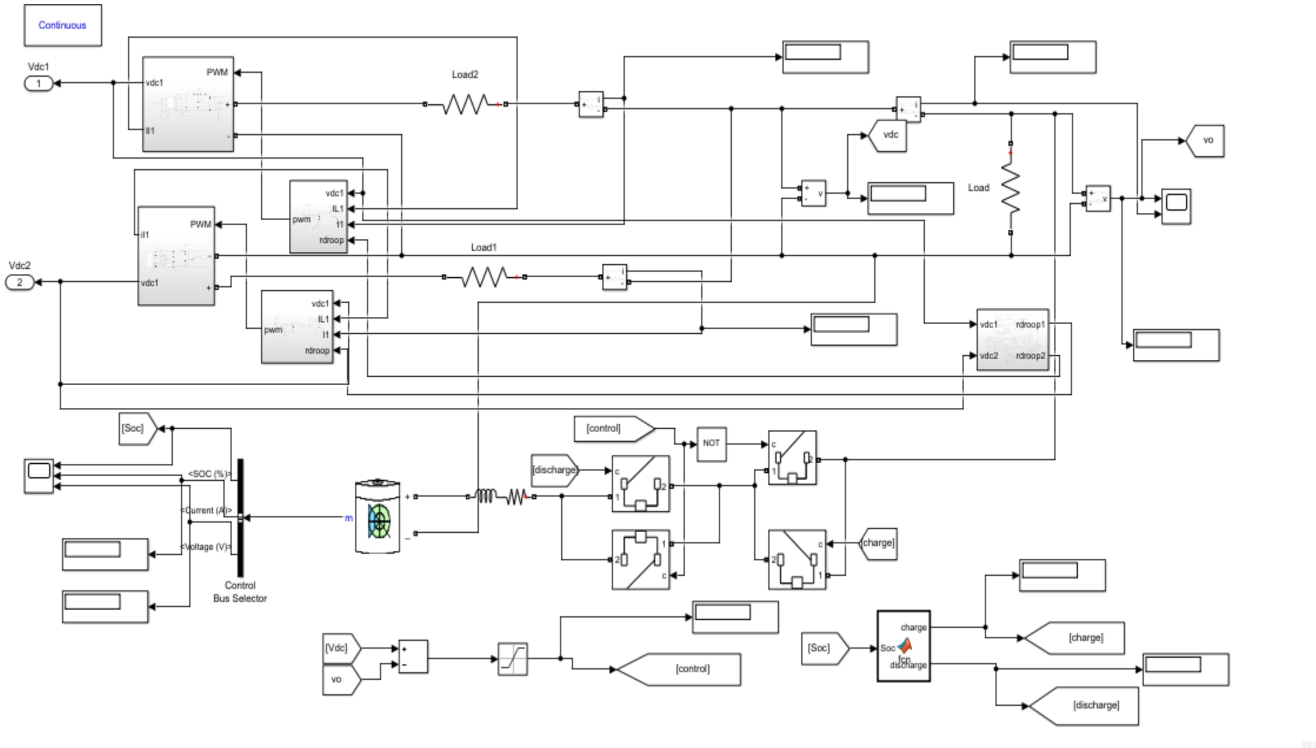
<u>Mode 2: Charging and Discharging Mode:</u>
When Vdc > VL by 80% i.e., SoC is below 80%, then both charging and discharging will be performed. During this mode, switch S1 and S4 are closed during charging & switch S2 and S3 are closed during discharging.

<u>Mode 3: Charging Mode:</u>
When Vdc > VL by 40% i.e., SoC is less than 40%, then the battery Charges and disconnected from the load. During this mode, switch S2 and S3 are closed.

Simulation and analysis of output

The MATLAB Simulink model for adaptive droop voltage control on parallel connected converters of the system is shown in fig.8 and both converters are connected in parallel to load. Boost converter to increase the output of solar pv voltage and a buck converter for wind power to regulate the voltage to reference one.

Fig. 8 MATLAB Simulink model for adaptive droop voltage control on parallel connected



converters

For boost converter, input voltage is from PV, DC voltage of 31.5V, L and C are 422e-6H and 20.09e-6F respectively with Rload of 10Ω. The reference voltage is 50V with a switching frequency of 4KHzfor different solar irradiation. At irradiation of 526 and temperature of 26°C, the voltage 26.49V and power of the PV 165.2W model become maximum.

The buck converters have input voltage of DC 78V and output is set to 52V DC voltage. The resistance, R1=R2=10Ω and RL=100Ω are used for this simulation.

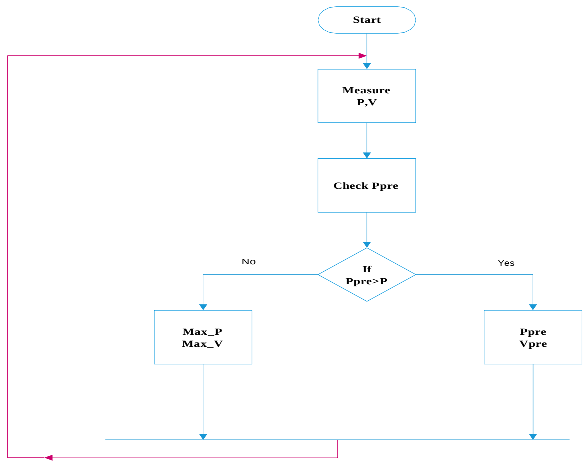


Fig.9. flowchart of perturb & observation for PV model

The circulation current I1 and I2 are input to the node and IL(load current).

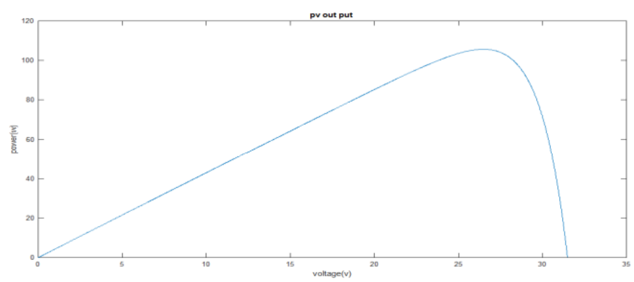
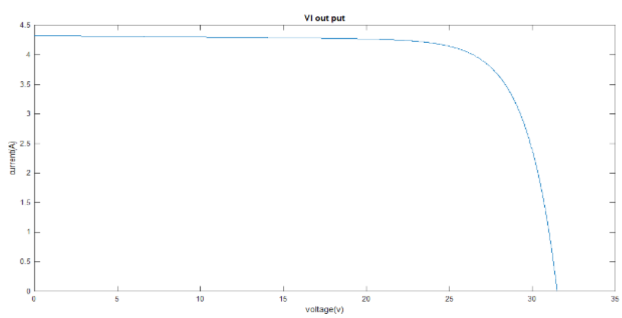


Fig.10.a).Voltage–power characteristics of PV



b).V-I characteristics of PV

The control algorithm for battery output is simulated on the same way as the coded algorithm for charging and discharging and also for charging operation.

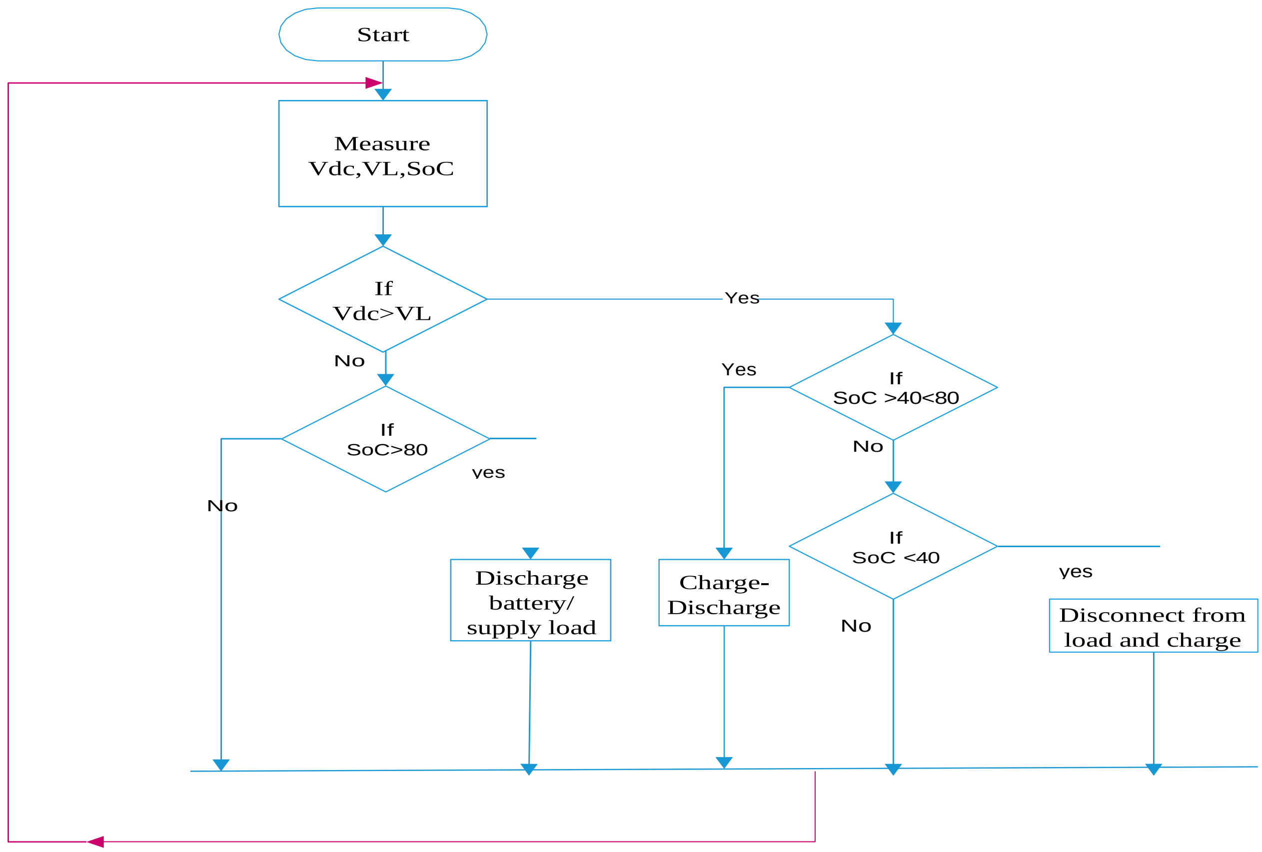


Fig.11.Flowchart of battery management system.

The Output voltage of the DC bus is sated at 51.95 for discharging of the battery energy case and 51.45 at charging of the battery. In general, the designed system and the control loop with algorithms are connected together to maintain the system updated in all cases. The system updates itself to deliver the load and battery management is done by the control system.

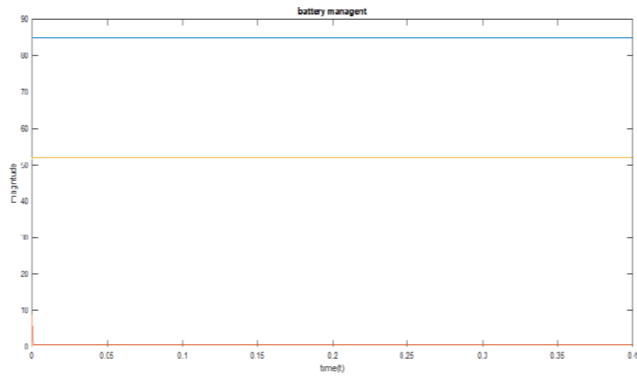


Fig 12. Battery discharging (SoC, V and Ib) output

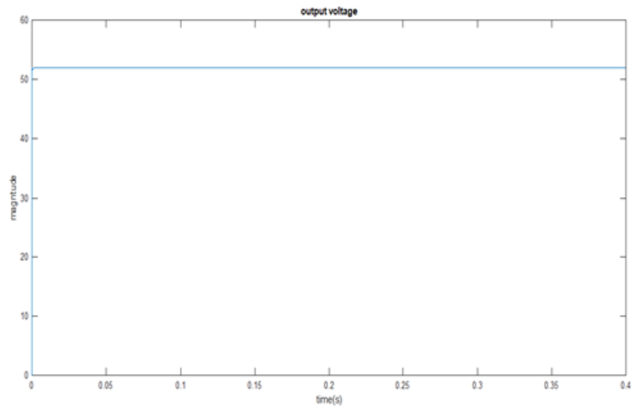


Fig13. Output voltage of the load

The Rdroop values are 0.2Ω and its performance is analyzed in this way. The output voltage is constant at desired values in the system by using an algorithm, which is designed to improve the system. The system efficiency and valuable design proves that the problem in micro grid operation during current sharing between loads and valuable results are achieved.

Conclusion

The adaptive voltage droop control on parallel-connected converters is designed and simulated in this paper. The circulation of current in converters maintained by designing the droop control. The whole system is set to the required voltage and the designed algorithm is executed. The energy storage battery is used for backup purpose; the algorithm based on SoC and the system voltages also maintains the charge-discharge of the battery. The whole system performs in a designed way and results are satisfied

Recommendations

In this paper, adaptive droop voltage control on parallel connected converters of DC micro-grid systems is modeled and simulated for system using adaptive control algorithm. However, there is a wide scope of improving this project in area like: -Advanced model on current circulation between the systems are needed and this is continuous improving part of this topic to make zero as well as increasing capacity of power generation can be increased by adding a greater number of micro sources like diesel power generators. Using artificial neural network or Adaptive neuro fuzzy interface

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