An Energy Storage Management and PV Active Power Control Strategies for Microgrids

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Abstract: *A microgrid is a localized group of electricity sources and loads that normally operate connected to and synchronous with the traditional wide area synchronous grid (macrogrid), as the number of DC-generating renewable energy sources is higher as compared to AC-generating sources, lesser converter units are required. This increases the overall efficiency of DC microgrid. A DC micro grid system is using a power network that enables the introduction of a large amount of solar energy using distributed photovoltaic generation units. This research deals with the design and performance analysis of a DC microgrid with battery-supercapacitor energy storage system under variable supercapacitor operating voltage. MATLAB 9.4 is using to implement the model and analysis.*

Keywords: **DC, Microgrid, Energy, Battery, Supercapacitor.**

1. INTRODUCTION

Tremendous advancements occurred over the next century: the development of induction and synchronous machines, electric meters, high voltage transmission, gas turbines, nuclear reactors, wind turbines, and solar photovoltaic's, to name a few. All of these technologies were turned to the development, advancement, and expansion of "the grid;" the system of large-scale centralized generation connected to energy users through a network of transmission and distribution. But while a seemingly endless supply of effort and funding was being poured into "the largest machine ever built", in recent years another trend in research started, as some began to explore the advantages to moving in the other direction: distributed, decentralized, local grids: microgrids.

Solar photovoltaic and fuel cells produce dc current directly, and many wind power systems can easily produce dc current, or are interfaced to the ac grid through a dc link.

Energy storage is typically DC

Batteries and supercapacitors use dc current by their na- ture for charging and discharging. This includes the batteries in electrical vehicles, meaning dc power systems can easily integrate with vehicle-to-grid systems.

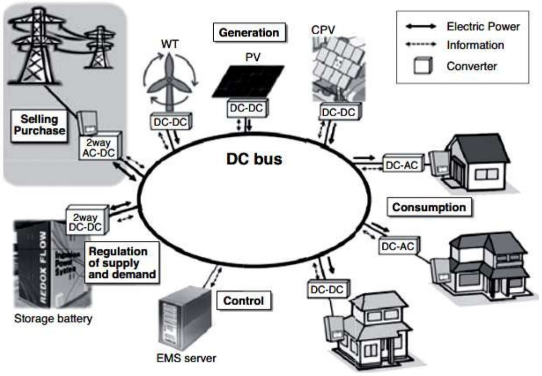

Figure 1: Schematic diagram of a DC microgrid system

Many types of electrical loads use dc power natively

The majority of electronics (such as computers, servers, and TVs) use dc power. LED lights also use dc power natively. Many types of motors and drives (especially variable speed drives) use dc power. In all three cases, these sources, storage systems, and loads require converters when- ever they interface with ac power systems; thus switching to a dc power system eliminates the need for such converters, eliminating the losses which are inherent in any type of power conversion. To date, key areas of implementation for dc power systems have included data centers, spacecraft, airplanes, shipboard power systems, traction power systems (for trains, trolleys, trams, etc), and telecommunication infrastructure. Developments in these areas have spurred research on dc microgrids, and in some cases provided test-beds for establishing functional dc microgrids (particularly in the case of data centers and telecoms, where the cost savings potential is significant).

2. LITERATURE REVIEW

S. Sinha et al., [1] the objective of this work is to present a comparative study of charging and discharging process of both battery and SC banks and hence understand their application areas in a DC microgrid. Also the rate of charge-discharge and its control to prevent over charging or under-discharging of the storage devices is presented here.

N. MENG, Libei et al., [2] present an improved droop control based on hybrid compensation is adopted to realize bus voltage stability and power sharing in the system. Finally, simulation analysis is carried out, and the experimental results verify the feasibility of the control strategy mentioned above.

P. Mohammadi et al., [3] in this work, novel DC-DC single-inductor double-input bidirectional converter is presented for integrating the HESS to the DC micro-grid. The steady-state analysis of present converter is presented. Small-signal model of the converter is derived out and control strategy is demonstrated. Finally, detailed simulations are carried out in MATLAB SIMULINK. The capability of present converter for proper power-sharing between the battery and the super capacitor is validated through simulations.

P. Goleij et al., [4] present new hybridization concept for tackle the negative effects of harmonic loads and nonlinear load is present. In this strategy super capacitor (SC) is used for compensate the oscillation that generate by harmonic loads. In addition, present strategy improves system performance under load changes and variations. To investigate the effect of harmonics and confirm the present method, simulation of a hybrid system has been implemented in MATLAB/SIMULINK environment. The simulation results prove the effectiveness of the present strategy.

L. Zekun et al., [5] present strategy which can avoid the unnecessary switching between the master and slave source, ensure the system stable under large disturbances and help the system quickly return to the stable state. The criterion and stability control strategy are simple and can be easily implemented. Simulation results demonstrate that the stability criterion and the control strategy are effective.

T. K. Roy et al., [6] this work presents a strategy for dynamic stability analysis of hybrid islanded DC microgrids using nonlinear backstepping controllers (NBCs) with different microgrid components. The main components of the DC microgrid are a solar photovoltaic system, a diesel generator with rectifier, loads, and a battery energy storage system.

S. Gupta et al., [7] presents the microgrid system which consists of a Energy Storage System (ESS) which is connected via a bidirectional buck-boost converter. The overall stability of the microgrid is maintained by the control action of the ESS. DC microgid system have been analyzed and simulation done using MATLAB.

U. Manandhar et al., [8] present control approach the voltage error term and the uncompensated power from the battery is added to the supercapacitor current reference to achieve faster DC link voltage restoration and less stress in the battery system. The system parameters design and closed loop system stability analysis of the present control approach are discussed in detail in the paper. The effectiveness of the present control approach is verified by simulation studies.

Q. Xu et al., [9] implement the present EDC method, a detailed design procedure is present to achieve the control objectives of stable operation, voltage regulation, and dynamic current sharing. System dynamic model and relevant impedances are derived and detailed frequency domain analysis is performed. Moreover, the system level stability analysis is investigated and system expansion with the present method is illustrated. Both simulations and experiments are conducted to validate the effectiveness of the present control strategy and analytical results.

H. Zheng et al., [10] present the present hybrid AC/DC micro-grid structure is reasonable, and the control strategy and performance of the components is good. The whole system has fast response speed, and can well satisfy the requirement of system security and stability.

P. H. Shaikh et al., [11] this work presents the performance analysis of an integrated renewable energy based power generation system with DC micro grid setup. The designed system comprises of wind generator (WG) system, photovoltaic (PV) panels, battery, charge controllers and DC loads as its major components.

S. Kotra, et al., [12] this work presents the small signal analysis and two loop control design of a DC microgrid with control strategy based on the output of DC link voltage controller. The employed control strategy generates current references to PV, grid, battery and supercapacitor converters based on the average of DC link voltage controller output.

3. PRESENT MODEL

The major contribution of this research work is to accurate modeling of DC microgrid with hybrid energy storage system (HESS) for performance improvement so that it can be more useable in home and industrial applications.

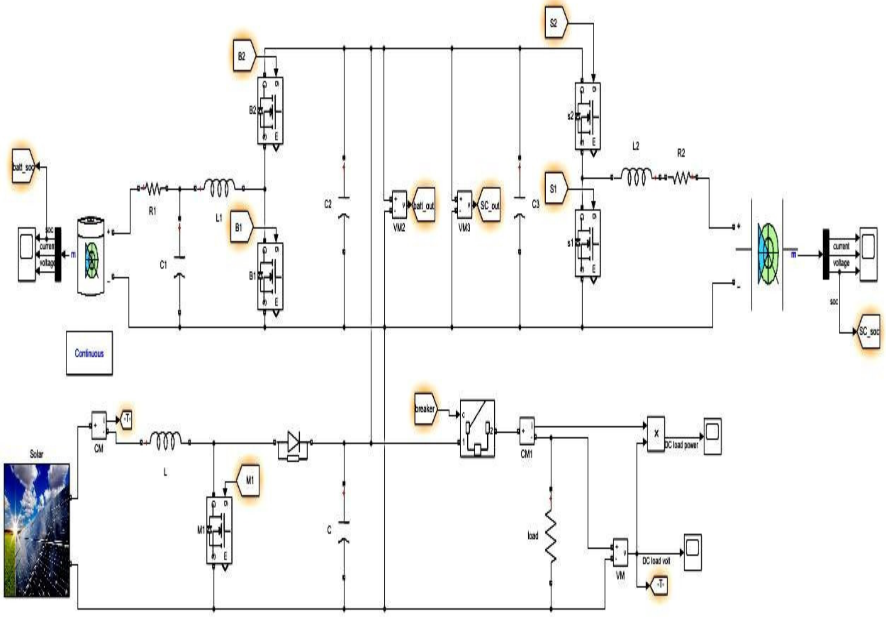

Figure 2: Present Model

Present model consist various sub models which is described in details.

Sub-Modules

- Solar power
- MPPT Algorithm
- PWM Switching
- Boost converter
- Bidirectional converter and mode of operation
- Battery
- Super capacitor

There are four possible operating modes. The control strategy regulates the DC link voltage in all the four operating modes using battery or PV source. The four operating modes are explained below.

1) **Battery Discharging Mode (BDM):** In this mode, the PV power is less than the load power and the battery SoC is within limits. Therefore, the battery discharges to regulate the DC link voltage.
2) **Load Shedding Mode (LSM):** In this mode, the PV power is less than the load power and the battery is fully discharged. Therefore the loads are disconnected and the available power is used to charge the battery.
3) **Battery Charging Mode (BCM):** In this mode, the PV power is more than the load power and the battery SoCis within limits. Therefore, the battery regulates the DC link voltage by charging with the excess power available.
4) **PV Off-MPPT Mode (POM):** In this mode, the battery has fully charged, therefore, the PV is operated in off-MPPT mode to regulate the DC bus voltage.

Photovoltaic (PV), micro-grids, battery cells and energy storage, and other potential DERs output either directly DC or AC with fluctuant frequency and voltage. Therefore, the above outputs need to be changed into DC, and then access to traditional AC power grid through the inverter. DC distribution grid facilitate DERs directly access to power grid.

4. SIMULATION AND RESULT ANALYSIS

The implementation and simulation of the present model is done over MATLAB 9.4.0.813654 (R2018a). The various electrical toolbox and blocks helps us to use the functions available in MATLAB Library for various design strategy.

MODE(i) Battery Discharging Mode (BDM): In this mode, the PV power is less than the load power and the battery SoC is within limits. Therefore, the battery discharges to regulate the DC link voltage.

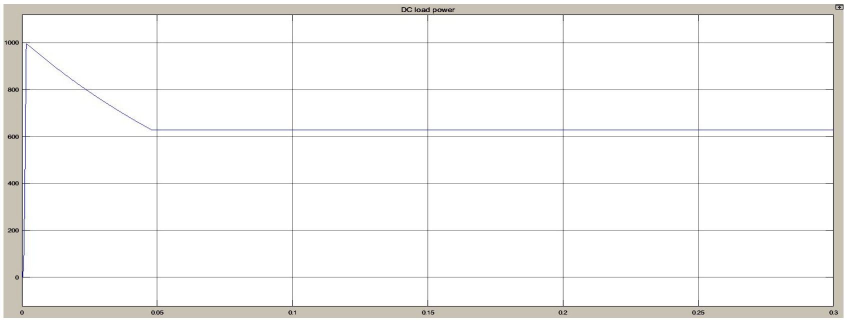

Figure 3: DC Load Power

Figure 3 is showing DC load power graph. Here X axis is denoting as a time scale and Y axis is denoting as a value of power. So load power value is 630W.

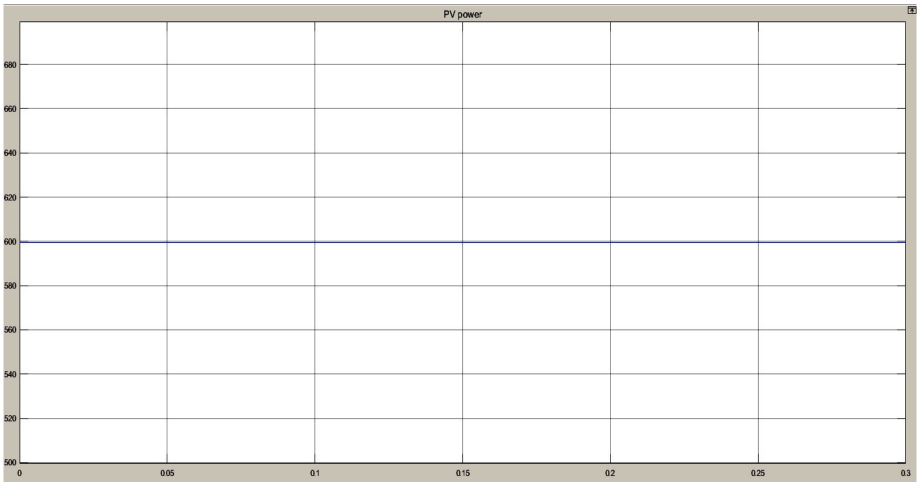

Figure 4: Solar (PV) Power

Figure 4 is showing solar power graph. Here X axis is denoting as a time scale and Y axis is denoting as a value of PV power. So Solar (PV) power value is 600W. Here, the solar power is 600watts < load power is 630watts

Mode(ii) Load Shedding Mode (LSM): In this mode, the PV power is less than the load power and the battery is fully discharged. Therefore the loads are disconnected and the available power is used to charge the battery.

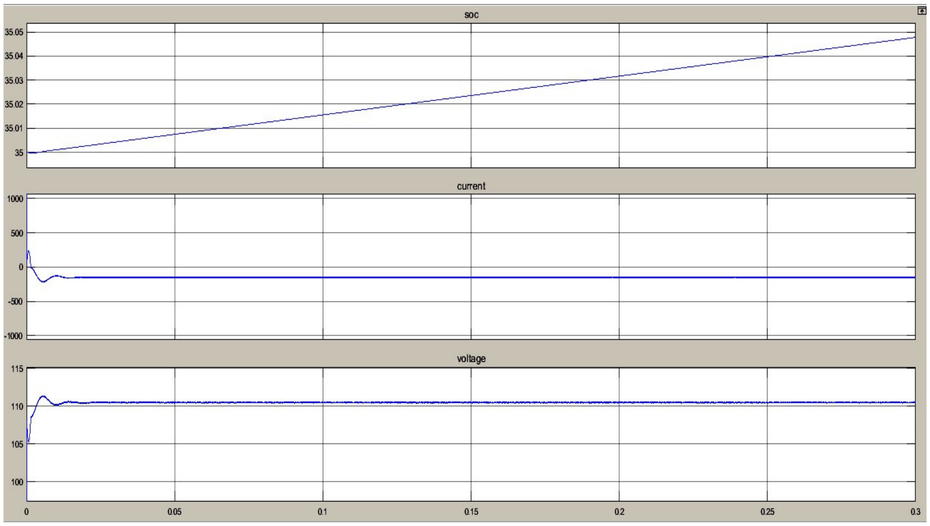

Figure 5: Battery (SOC, Current, Voltage)

Figure 5 is battery state of charge, voltage and current graph. Here X axis is denoting as a time scale and Y axis is denoting as a state of charge, value of current and voltage. Here, the battery is discharged below the lower limit.

MODE(iii) Battery Charging Mode (BCM): In this mode, the PV power is more than the load power and the battery SoC is within limits. Therefore, the battery regulates the DC link voltage by charging with the excess power available.

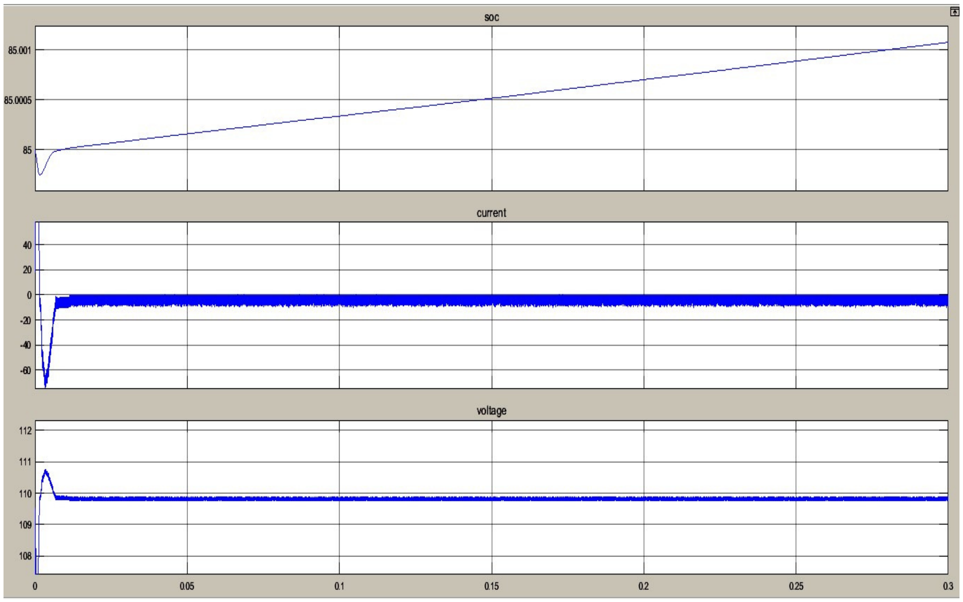

Figure 6: Battery (SOC, Current, Voltage)

Figure 6 is battery state of charge, voltage and current graph. Here X axis is denoting as a time scale and Y axis is denoting as a state of charge, value of current and voltage. Here, the battery is charging.

<u>Mode(iv) PV Off-MPPT Mode (POM):</u> In this mode, the battery has fully charged, therefore, the PV is operated in off-MPPT mode to regulate the DC bus voltage.

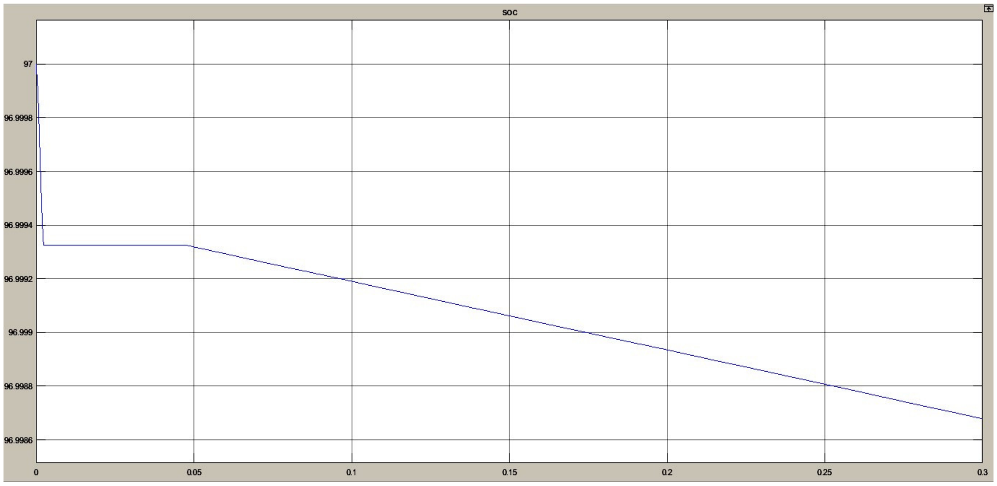

Figure 7: Battery

Figure 7 is showing battery state of charge. Here X axis is denoting as a time scale and Y axis is denoting as charge percentages. Here, the battery is fully charged soc>95%.

Therefore present model simulation result for performance is better than previous model in terms battery, load, and super capacitor. Present model gives significant improved results.

5. CONCLUSION

The effect of super capacitor voltage variation on the stability of DC micro grid is analyzed with its accurate small signal model. An optimal super capacitor voltage based DC link voltage controller HESS model design method is present to ensure the sufficient voltage and current stability at all super capacitor voltages. The simulation and experimental results confirmed that the present design provides performance than that of the conventional design. Therefore, the present model design achieves superior dynamic response over a wide range of super capacitor operating voltages.

REFERENCES

1. *S. Sinha, A. K. Sinha and P. Bajpai, "Analysis of hybrid storage system in DC microgrid," 2016 21st Century Energy Needs - Materials, Systems and Applications (ICTFCEN), Kharagpur, 2016, pp. 1-5, doi: 10.1109/ICTFCEN.2016.8052754.*
2. *N. MENG, Libei, L. Jiahao, H. Jianhui and Susu, "Coordinated operation control strategy and droop improvement method for DC microgrid," 2018 International Conference on Power System Technology (POWERCON), Guangzhou, 2018, pp. 1214-1223.*
3. *P. Mohammadi, J. S. Moghani and G. B. Gharehpetian, "A Novel DC-DC Single-inductor Double-Input Bidirectional Converter for Hybrid Energy Storage System in DC-Micro Grid," 2018 Smart Grid Conference (SGC), Sanandaj, Iran, 2018, pp. 1-6.*
4. *P. Goleij, S. HajiAghasi and A. Salemnia, "A New Hybridization Concept for Distributed Generation and Microgrids under Harmonic and Nonlinear Loads," 2018 Smart Grid Conference (SGC), Sanandaj, Iran, 2018, pp. 1-6.*
5. *L. Zekun, P. Wei and K. Li, "Large-disturbance Stability Analysis of DC Microgrid with Constant Power Load and its Transient Voltage Stability Control Strategy," 2018 China International Conference on Electricity Distribution (CICED), Tianjin, 2018, pp. 1686-1690.*
6. *T. K. Roy and M. A. Mahmud, "Dynamic Stability Analysis of Hybrid Islanded DC Microgrids Using a Nonlinear Backstepping Approach," in IEEE Systems Journal, vol. 12, no. 4, pp. 3120-3130, Dec. 2018.*
7. *S. Gupta, D. M. S. Das, and D. Mishra, "Modeling and Simulation of Hybrid Wind/Photovoltaic for Improvement of Reliability of The DC Microgrid", IJOSCIENCE, vol. 4, no. 8, pp. 1-7, Aug. 2018. DOI:https://doi.org/10.24113/ijoscience.v4i8.15.*
8. *U. Manandhar, B. Wang, A. Ukil, G. H. Beng, N. R. Tummuru and S. K. Kollimalla, "A new control approach for PV system with hybrid energy storage system," IECON 2017 - 43rd Annual Conference of the IEEE Industrial Electronics Society, Beijing, 2017, pp. 2739-2743.*
9. *Q. Xu et al., "A Decentralized Dynamic Power Sharing Strategy for Hybrid Energy Storage System in Autonomous DC Microgrid," in IEEE Transactions on Industrial Electronics, vol. 64, no. 7, pp. 5930-5941, July 2017. doi: 10.1109/TIE.2016.2608880*
10. *H. Zheng, H. Ma, K. Ma and Z. Bo, "Modeling and analysis of the AC/DC hybrid micro-grid with bidirectional power flow controller," 2017 China International Electrical and Energy Conference (CIEEC), Beijing, 2017, pp. 280-284.*
11. *P. H. Shaikh, T. Jan, A. R. Solangi, Z. H. Leghari, A. A. Baloch and M. A. Uqaili, "Performance analysis of wind-photovoltaic-battery based DC microgrid setup for off-grid applications," 2017 IEEE 3rd International Conference on Engineering Technologies and Social Sciences (ICETSS), Bangkok, 2017, pp. 1-7.*

12. *S. Kotra, M. K. Mishra and N. P. Chaithanya, "Design and small signal analysis of DC microgrid with hybrid energy storage system," 2017 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC), Bangalore, 2017, pp. 1-6.*