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Hybrid Energy Management and Control Strategy of Photovoltaic Generation Systems

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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.

***IndexTerms* - DC, Microgrid, Energy, Battery, Supercapacitor.**

I. 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 nature 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).

II. PROPOSED 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.

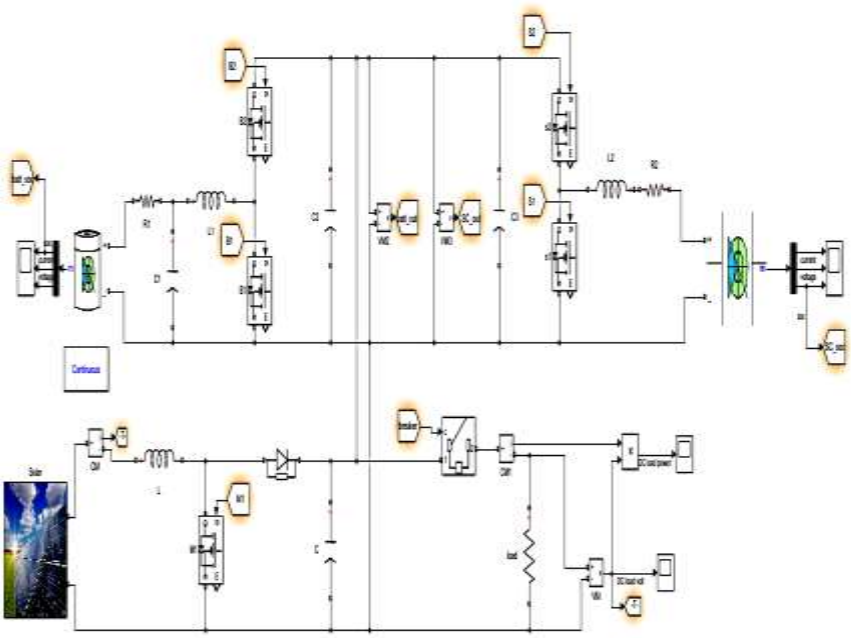

Figure 2: Proposed Model

Proposed 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.

III. SIMULATION AND RESULT ANALYSIS

The implementation and simulation of the proposed 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.

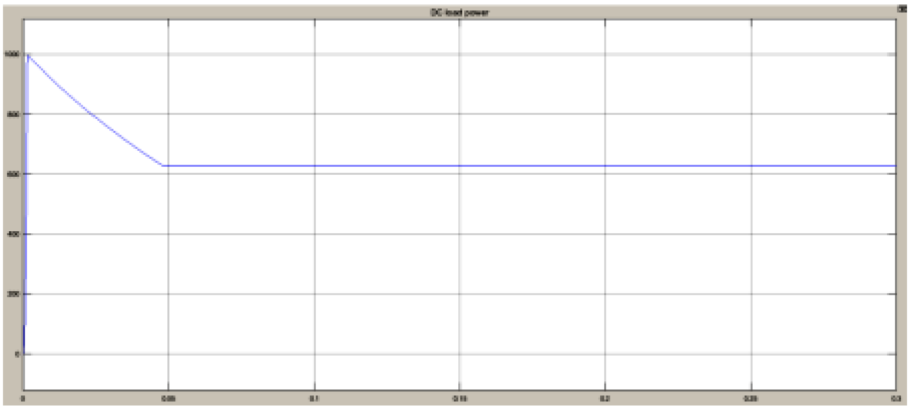

Figure 3: DC Load Power

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.

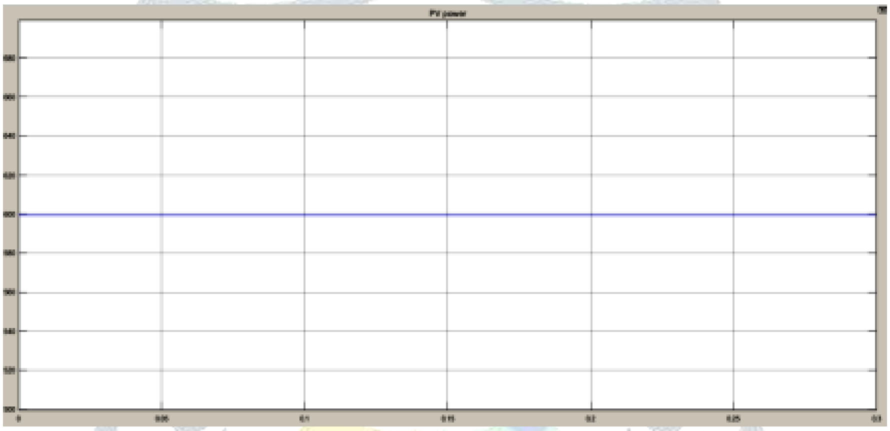

Figure 4: Solar (PV) Power

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.

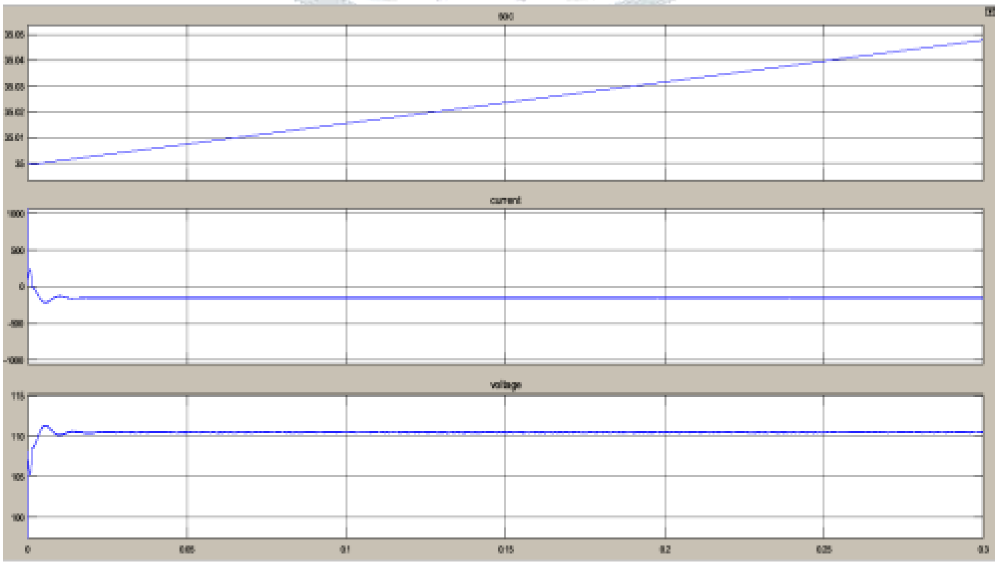

Figure 5: Battery (SOC, Current, Voltage)

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.

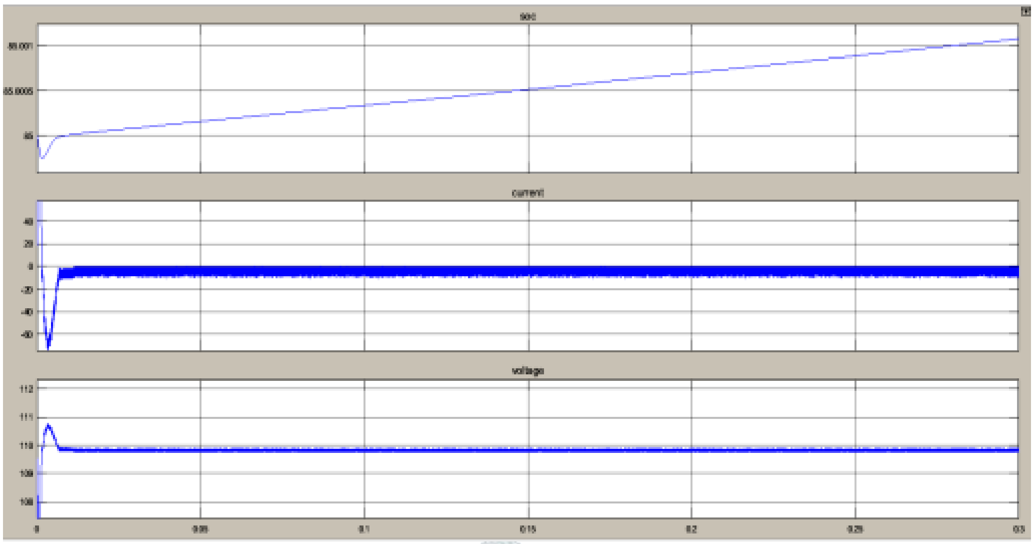

Figure 6: Battery (SOC, Current, Voltage)

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.

Mode(iv) 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.

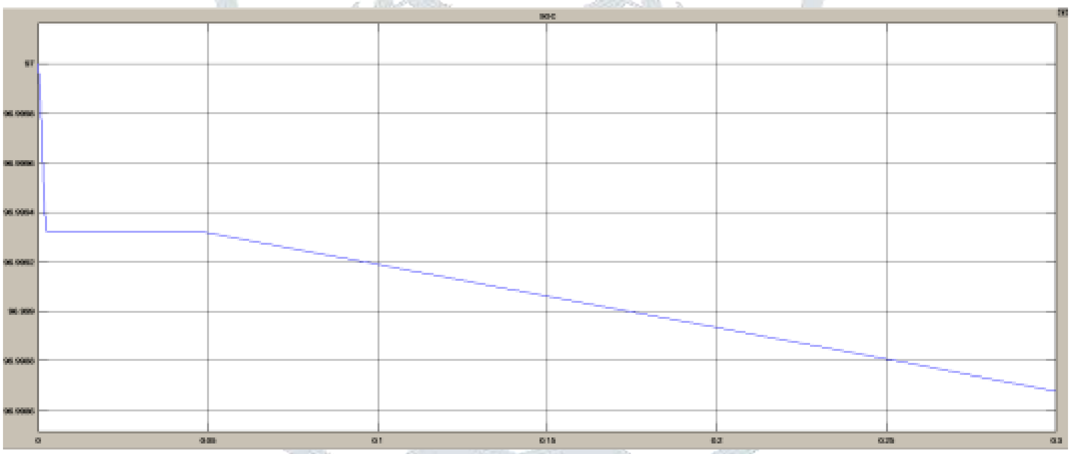

Figure 7: Battery

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%.

Table 1: Comparison chart of proposed work with Base Work

Sr No.	Parameters	Previous Work	Proposed Work
1	Battery Voltage (Discharge)	100V	110V
2	Supercapacitor Voltage (Discharge)	111V	112-120V
3	Battery Voltage (Charge)	112V	110-120V
4	Supercapacitor Voltage (Charge)	NA	112-120V
5	State of Charge (SOC)	20 to 100%	95%
6	Mode of operation	7	4
7	Sub-Module	PV, MPPT, Bi-directional converter,	PV, MPPT, Bi-directional converter, Supercapcitor

8	Controller	Conventional incremental conductance MPPT technique and PI Controller	Energy Control Controller

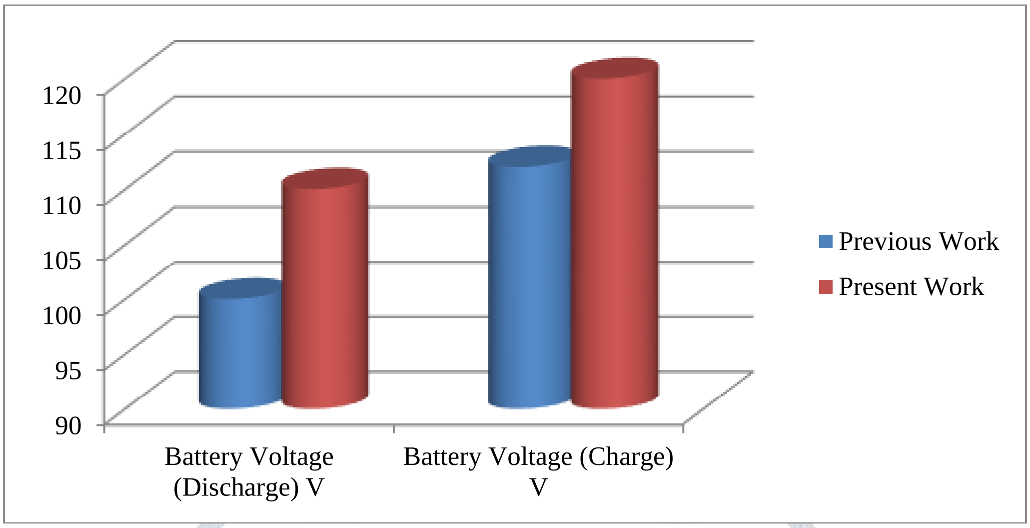

Figure 8: Battery voltage charge and discharge

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

IV. 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 proposed to ensure the sufficient voltage and current stability at all super capacitor voltages. The simulation and experimental results confirmed that the proposed design provides performance than that of the conventional design. Therefore, the proposed model design achieves superior dynamic response over a wide range of super capacitor operating voltages.

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