Design, Control and Stability Analysis of DC Microgrid with Hybrid (Battery-Supercapacitor) Storage System

Ms. Pawar Ashwini S.
Department of Electrical Engineering
G.H. Raisoni Institute of Technology, Wagholi
Pune, India.

Prof. Patil Sangita B.
Department of Electrical Engineering
G.H.Raisoni Institute of Technology, Wagholi
Pune,India

Abstract- This paper explores the structure and stability evaluation of a DC microgird with battery-supercapacitor energy unit under variable operating voltage of the supercapacitor. The traditional design approach described in the literature takes into consideration the graded supercapacitor voltage in controller modeling and design. However ,Because of self discharge ,the supercapacitor unit can discharge as low as 10% of its rated voltage It is observed that the traditional controller design method will potentially render the device unstable or introduce ringing at low supercaoacitor voltage In this research, the sensitivity of DC microgrid stability with respect to variance of the supercapacitor voltage is evaluated, an appropriate supercapacitor voltage to be used in the design is estimated and a design method is proposed to ensure DC microgrid stability in all operating modes. We have presented necessary results performed at Matlab/Simulink Platform.

Keywords- Hybrid Energy Storage System (HESS), Microgrid, supercapacitor.

I.INTRODUCTION

The awareness of microgrids has increased considerably with a recent drive for clean and renewable energy sources. Microgrids will provide an excellent alternative to incorporate the production of localized renewables. Power Quality and efficiency are also guaranteed with energy storage and generators to sustain loads by sacrificing a renewable source. While the bulk of microgrid research is concentrated on AC (AC) systems, DC (DC) offers many advantages. For instance, the system efficiency is boosted by reducing the losses created by conversion from DC to AC. The system does not have reactive power because the voltage is constant, and is therefore simpler. Also, there's no need to think about synchronization when connecting to an AC utility, because the microgrid has no frequency. While there are many advantages of DC microgrids, as there is concern for stability and due to the high penetration and heterogeneity of renewable resources. Just for short periods the power loss can be an enormous annoyance to the user. Frequent power outages interfere with consumer operation but are also especially troubling on a university campus, as outages can disrupt research efforts. Energy storage is built into the microgrid to combat stabilization issues. Energy storage, like batteries, operates by injecting current into the device at periods when there are no renewable resources. Energy storage is not free and optimum storage location will reduce the cost of building the device.

This technique for establishing a model of a complex structure. The method relies heavily on physical details such as calculated cable lengths and footprints for the construction. To link sources and loads to the grid, a Dual-Active Bridge (DAB) DC-DC converter technology is employed. This topology converter is used in the design of the system. The final focus of this paper is analyzing the system to realize optimal placement of energy storage. The methodology relies on the properties of the state space model for the system. The system's controllability is considered in order to maintain the voltage. Additionally, system eigenvalues are used to help determine the placement of energy storage. The results of the analysis are evaluated using simulations of the system model. Although, the battery-super capacitor based energy storage systems are employed in above literature, the modeling, design and stability aspects of microgrid with such storage systems aren't discussed intimately. Instability in DC microgrids can occur thanks to various reasons like dynamic variation of generation and cargo, changes in system

operating conditions, variation in system component values and controller parameters [21]. In the conventional design reported in [3]–[10], the DC link voltage controller is supposed by considering the rated super capacitor voltage. However, the system in practical condition may not always operate at rated supercapacitor voltage. In low supercapacitor operating conditions, the DC microgrid voltage control loop with conventional design has very low gain margin and phase margin and it can introduce ringing in the DC link voltage and may lead to instability if not addressed. In this work, a new design method is proposed to ensure sufficient gain margin and phase margin at all values of supercapacitor operating voltage to achieve stable operation. The major contributions of this work are:

1) Accurate modeling of DC microgrid with HESS.
2) Sensitivity analysis of DC microgrid with supercapacitor voltage variation.
3) Finding the optimal supercapacitor voltage to be considered in the design such that the DC microgrid is stable at all supercapacitor operating voltages.
4) Designing the DC link voltage controller such provides sufficient gain margin and phase margin in the least supercapacitor operating voltages

1.1 PV Module

It is used for solar power harvesting which is that the main source of energy for the sensor node. The output power from PV isn't stable and depends on the irradiance and temperature. The output power from PV array is different at different irradiance and temperature level. At the particular irradiance and temperature level, the PV curve of the photovoltaic panel is non-linear and a maximum power point exists. Therefore, for maximum utilization of solar energy, we require a maximum power point tracker (MPPT).Detailed modeling of PV module and MPPT algorithm.

1.2 Role of Battery and Supercapacitor

Li-ion battery and ELDC are used for electric storage. In which battery is employed as primary storage and supercapacitor is employed as auxiliary storage. This hybrid storage technique offers increased lifetime. Due to low leakage charge battery is employed for holding the charge for an extended time and is discharged only solar power isn't available and supercapacitor storage is exhausted. The role of supercapacitor changes in accordance with the mode of operation, when solar power is available it smoothens the energy flow to match the charging profile of the battery and keep the voltage of the DC bus constant. During unavailability of solar energy, the supercapacitor is dripped charged from the battery to provide the height power. To check the inefficiency caused thanks to leakage charge supercapacitor is charged just before the arrival of the height demand.

1.3 Role of Different Converters

The converters are used to control the power flow through the circuit. Although a wide variety of converter topologies are available, only a dozen basic ones are used in practical power design.

1.4 DC-DC Buck Converter

A Buck converter steps down the DC voltage and is required wherever source voltage is above the load voltage. This converter interfaces the PV panel with internal DC bus and is employed to understand the MPPT of the panel. The controller adjusts the duty cycle of the switch to control the input voltage V_{PV} for maximum power point. As the name suggest it's a bi-directional converter that's wont to interface battery with DC bus. This converter allows bi-directional flow of power with different topologies. The converter operates in step-down mode during the charging process and in step-up mode while discharging. This choice is dictated by the voltage level of the battery with respect to the DC bus. The converter has a current controlled loop, reference for which is determined by the power manager. This converter is responsible for controlling DC bus voltage in a narrow band by acting as a source or sink depending on the instantaneous power budget. The proposed architecture is based on the direct transfer of solar power to load bus. Due to intermittent nature of solar power, the energy mismatch between source and cargo is normal, which manifests as undesired conditions of under and over voltage on DC bus. Supercapacitor acts as a shock to the system and smoothens out these energy fluctuations,

1.5 Battery Charge-Discharge Controller:-

Charge Controller for avoiding capacity degradation constant voltage charging mode is not used so the charge controller has to control the charge current only, a variable duty cycle generator based on hysteresis control is employed because the charge controller. Discharge Controller Two types of discharge controllers are used one for providing the load current to the system and second (Battery charge Scap Controller) for charging supercapacitor when PSOLAR is not available. The need for this controller arrives due to very small impedances of battery and supercapacitor, direct charging will result in a very high current (about 500 Ampere's) which will destroy the battery. Supercapacitor Charge-Discharge Controller: - A single double loop PI controller is used for implementing

charge-discharge controller, the outer loop is slow acting and act as master and decides the reference for inner loop which is fast in action and acts as slave to the outer loop.

The rest of this paper is organized as follows. Section II summaries the literature survey. Section III introduces the proposed methodology. Result and discussion in Section IV. Section V focuses on the conclusion.

II. LITERATURE SURVEY

In this section, we have discussed different papers referred, based on Separation of speech based using various techniques.

In [1], A battery vitality the board framework (BEMS) for microgrid, during which PVs and diesel generators (DGs) are the principal wellsprings of power. The curiosity of the proposed BEMS exists in the vitality the board of numerous sorts of batteries attributes and diminishing DGs working hours all the while. Further, the proposed BEMS likewise considers various attributes of batteries while controlling the charging and releasing choice so on expand the battery lifetime. World information of microgrid burden and PV power ages are wont to confirm the viability of the proposed BEMS. Through numerical reproduction contextual analyses, it's shown that the proposed BEMS is equipped for accomplishing: (a) decrease in DGs working hours, (b) decrease in PV power changes, and (c) simultaneous administration of numerous batteries of different qualities and expansion of battery lifetime by controlling battery charge and release rate. The capacity and microgrid are planned to figure during a network steady way. Additionally, these ESSs found a workable pace inside its protected condition of charge limits. Thus, bolstered all the above limitations, a suitable lattice versatile force the board methodology (GA-PMS) is planned to encourage current references for RES, ESS, and microgrid-associated converters. Besides, this calculation incorporates consistent microgrid activity under strange conditions, need based burden shedding, and guaranteeing power quality models at the nearby transport.

The exhibition of proposed GA-PMS is tried and approved through the recreation and test examines [2].[3]Introduced dynamic model and security investigation of hang based ACmC Hybrid microgrid. The office electronic interface on air conditioning side of the miniaturized scale matrix contains voltage source inverters and consequently the dc side establish of dc/dc converters. The created model was linearized at a working point to look into the consistent quality investigation of this half and half framework. Impact of solidness edge with hang gain is examined personally utilizing eigenvalue examination. The examination was been confirmed through time area utilizing MATLAB Simulation. In [4] proposed a supervisory force the board framework (PMS) for a lattice intelligent microgrid with a half and half vitality stockpiling framework. The key element of the proposed PMS is diminished number of sensors required to actualize the PMS. The PMS thinks about inexhaustible force variety, network accessibility, power evaluating and changes in nearby loads. It can identify the working method of framework without estimating load flows and powers. One stage voltage source converter moves genuine force between DC lattice and utility framework other than offering auxiliary administrations like symphonious alleviation, responsive force backing and solidarity power factor at the reason for basic coupling. Inside the proposed framework, a far superior DC connect voltage guideline is accomplished and in this manner the use of super capacitors decreases the current weight on battery the battery. The PMS additionally addresses extraordinary working conditions like burden shedding, off-greatest point following activity of PV, disposal of basic wavering of HESS powers, islanded activity and resynchronization with matrix. The exhibition of the proposed PMS is checked by computerized recreation and exploratory investigations. A vitality the executives' framework (EMS) for an islanded microgrid with photovoltaic age and battery stockpiling. The framework utilizes a prescient way to deal with line operational calendars to constrict framework wide blackouts inside the microgrid, explicitly through pre-emptive burden shedding. Four-time day by day refreshed online climate estimates are joined with the photovoltaic framework model to anticipate vitality creation over a 48 hour term. These expectations are utilized, nearby burden figures and a model of the vitality stockpiling framework, to foresee the condition of-charge and portray potential up and coming blackouts. Blackout relief activities utilizing pre-emptive burden shedding are then arranged and executed to keep away from blackouts or limit the span of unavoidable blackouts [5].

Proposed technique thought was share the heap current oscillatory and dc parts among the DG units bolstered their evaluated power by allocating proper yield impedance esteems and hang coefficients to each DG unit. The voltage control square might be a multi-circle voltage control unit utilized to direct the microgrid voltage. The nitty gritty model of the proposed control engineering is built up, and in this manner the framework elements is examined. Since the blend of a region controller utilizes just data of the

relating DG unit, the arranging method is totally decentralized. The exhibition and dynamic reaction of the proposed control plot are confirmed through broad recreation contemplates and test results[6].[7]The new vitality the executives technique upheld the photovoltaic (PV) half breed power molding framework (HPCS) of 4 kW with a vitality memory gadget (ESD). The use of ESD like lithium-particle battery improves the vitality proficiency of by and large framework depending on schedule and climate. Additionally, the proposed framework gives the new capacity to vitality the executives progressively without the meteorology while it considers the office ages from PV framework, private burden varieties, and power cost. At the end of the day, the proposed vitality the executives' framework (EMS) can diminish the power cost by charging the vitality of evening time electrical force. Additionally, it can smother the network voltage varieties brought about by the huge measure of PV ages during daytime concerning moderately less burden request.

In [8] controller accurately handles the link impedances. The controller on every converter speaks with just its neighbor converters on a correspondence chart. The diagram might be an inadequate system of correspondence joins spread over the Microgrid to encourage information trade. The overall powerful model of the Microgrid springs, and style rules are given to tune the framework's dynamic reaction. A low-voltage dc Microgrid model is about up, where the controller execution, clamor versatility, link failure strength, and along these lines the fitting and-play capacity highlights are effectively confirmed. The primary test here was to oversee power streams among all sources appropriated all through the two sorts of sub-networks, which is positively harder than past endeavors created for just air conditioning or dc microgrid. This more extensive extent of control has not yet been examined, and would absolutely depend on the planned activity of dc sources, air conditioning sources and interlinking converters. Appropriate control and standardization plans are presently produced for controlling them with the general half and half microgrid execution previously checked in recreation and trial [9]. A determinist vitality the board framework for a microgrid, incorporating progressed PV generators with inserted capacity units and a gas micro turbine. The framework is composed by various capacities and is executed in two sections: a focal vitality the board of the microgrid and a nearby force the executives at the client side. The force arranging is planned by the expectation for PV power creation and the heap anticipating. The focal and nearby administration frameworks trade information and request through a correspondence arrange. As indicated by got matrix power references, extra capacities are additionally intended to oversee locally the force streams between the different sources. Application to the instance of a crossover super capacitor battery-based PV dynamic generator is introduced [10].

III PROPOSED METHODOLOGY

A] Architecture of Proposed Scheme

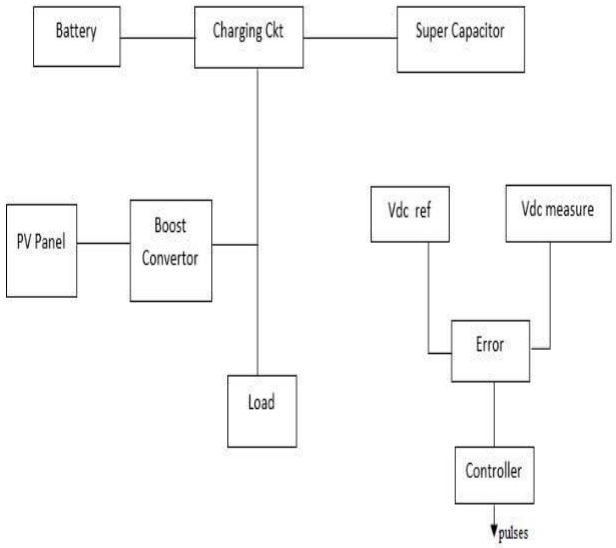

Fig. 3.1 Proposed Scheme

The schematic of the DC microgrid considered during this work is shown in Fig. 1(a). The control strategy proposed in is tailored for the DC microgrid considered during this work as shown in Fig. 1(b). There are four possible operating modes as shown in Fig. 2. The control strategy regulates the DC link voltage altogether the four operating modes using battery or PV source. The four operating modes are explained here. An optimal supercapacitor voltage is taken into account rather than the rated voltage within the design of DC link voltage controller such an equivalent controller ensures sufficient gain margin, phase margin and bandwidth in the least supercapacitor operating voltages. The present controller design remains same as that of the traditional design. The effect of variation of supercapacitor voltage on the steadiness of microgrid is discussed below. 1) Battery Discharging Mode (BDM): during this mode, the PV power is a smaller amount than the load power and therefore the battery SoC is within limits. Therefore, the battery discharges to manage the DC link voltage. 2) Load Shedding Mode (LSM): during this mode, the PV power is a smaller amount than the load power and therefore the battery is

fully discharged. Therefore the hundreds are disconnected and therefore the available power is employed to charge the battery. 3) Battery Charging Mode (BCM): during this mode, the PV power is quite the load power and therefore the battery SoC is within limits. Therefore, the battery regulates the DC Link voltage by charging with the surplus power available. 4) PV Off-MPPT Mode (POM): during this mode, the battery has fully charged, therefore, the PV is operated in off-MPPT mode to manage the DC bus voltage.

IV. RESULT AND DISCUSSION

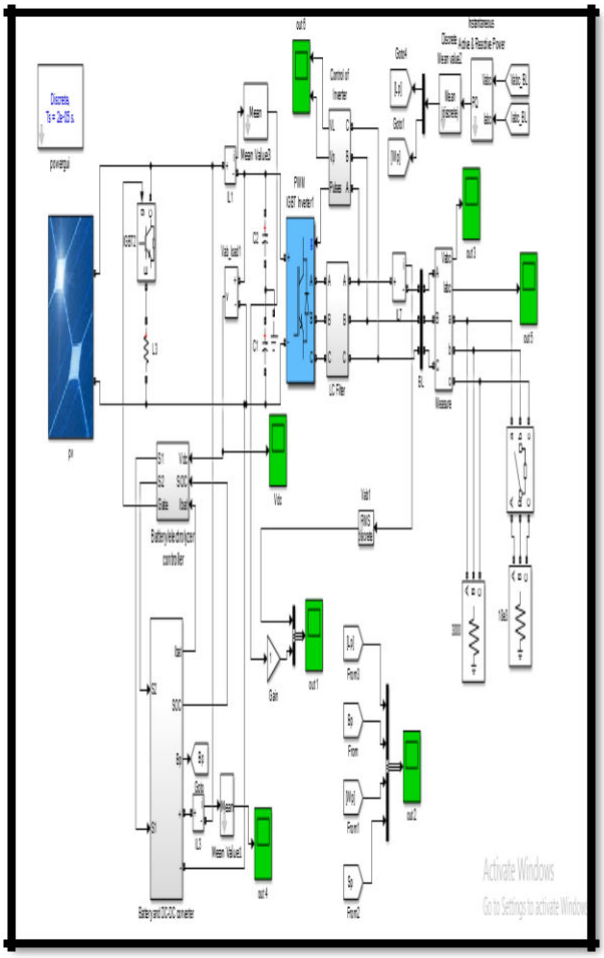

Fig 4.1: - Simulation Model

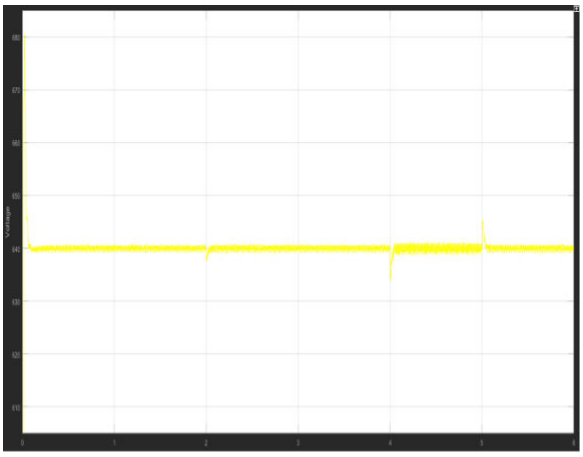

Fig 4.2: PV Voltage

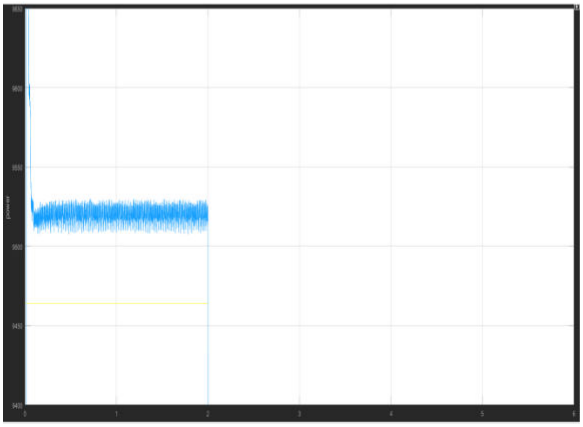

Fig 4.3: PV Power

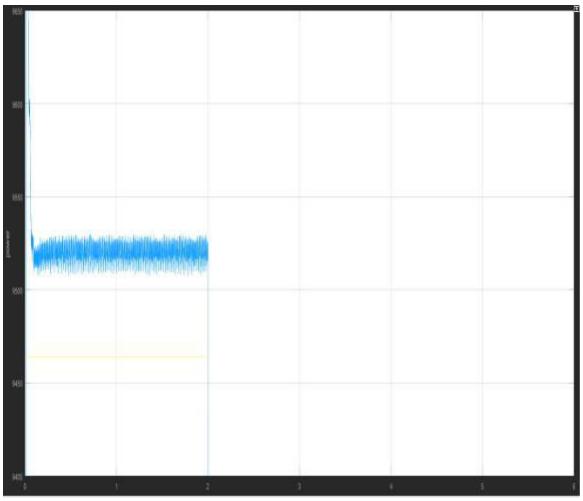

Fig 4.4: SOC & Battery Voltage

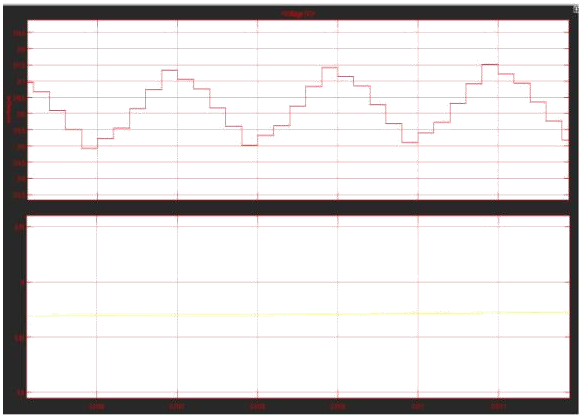

Fig 4.5: Battery Current & Voltage

V. CONCLUSION

Another utilization of an interleaved converter as a force interface in a half breed microgrid. The converter is answerable for directing the DC microgrid voltage while controlling the force course through the framework. The creators proposed another technique for tuning the voltage controller so as to improve the heap unsettling influence dismissal, which is a profoundly wanted usefulness in such application. Besides, the creators introduced a profound displaying of the MIMO framework so as to execute the control plan and a steadiness and power examination. At long last, test results were introduced approving the proposed topology and demonstrating.

The tuning system end up being effective in structuring the voltage controller targeting getting hearty aggravation dismissal qualities while keeping up legitimate reference following conduct. Moreover, the exploratory outcomes demonstrated that the topology and control consider a good activity of the microgrid in regards to its voltage profile (high force quality), other than taking into account the decrease of the yield DC-interface capacitors, because of the got low-swell yield current, diminishing the framework's size and weight.

REFERENCES

1) Kannan Thirugnanam, See Kim Kerk, Chau Yuen, Nian Liu and Meng Zhang “Energy Management for Renewable Microgrid in Reducing Diesel Generators Usage with Multiple Types of Battery”, IEEE Transactions On Industrial Electronics,2018.
2) Nikhil Korada and Mahesh K. Mishra,“ Grid Adaptive Power Management Strategy for an Integrated Microgrid With Hybrid Energy Storage”, IEEE Transactions On Industrial Electronics, Vol. 64, No. 4, April 2017
3) Dharmendra Kumar Dheer, Suryanarayana Doolla, Akshay K. Rathore, “Small Signal Modeling and Stability Analysis of a Droop Based Hybrid AC/DC Microgrid”,IEEE 2016
4) Srikanth Kotra, Mahesh K. Mishra,“A Supervisory Power Management System for a Hybrid Microgrid with HESS”, IEEE Transactions On Industrial Electronics,2016
5) Dennis Michaelson, Hisham Mahmood and Jin Jiang,“A Predictive Energy Management System using Pre-emptive Load Shedding for Islanded Photovoltaic Microgrids”, IEEE Transactions On Industrial Electronics,2016
6) Mohsen Hamzeh, Amin Ghazanfari, Yasser Abdel-Rady Mohamed,” Modeling and Design of an Oscillatory Current Sharing Control Strategy in DC Microgrids”, IEEE Transactions On Industrial Electronics,2015
7) Seung-Tak Kim, SunHo Bae, Yong Cheol Kang and Jung-Wook Park, “Energy Management Based on Photovoltaic HPCS with Energy Storage Device”, IEEE Transactions On Industrial Electronics,2013
8) Vahidreza Nasirian, Seyedali Moayedi, Ali Davoudi, and Frank L. Lewis, “Distributed Cooperative Control of DC Microgrids”,2013 IEEE
9) Poh Chiang Loh, Ding Li, and Frede Blaabjerg “Autonomous Operation of Hybrid Microgrid with AC and DC Sub-Grids”,IEEE 2011
10) Hristiyan Kanchev, Di Lu, Frederic Colas , Vladimir Lazarov, and Bruno Francoi “Energy management and operational planning of a microgrid with a PV-based active generator for smart grid applications”, IEEE Transactions On Industrial Electronics, Vol. 58, No. 10, October 2011