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A Review on Hybrid Renewable Energy Sources Microgrid and Energy Storage System

M.Tech. Scholar Sumit Kumar Mehta, Asst.Prof. Mithilesh Gautam
Department of Electrical Engineering
Truba college of science & Technology,
Bhopal,MP,India
Sumitkr.Mehta35@gmail.com, Mithlesh.gautam1@gmail.com

Abstract- This paper deals with the design and stability analysis of a DC micro grid with battery-super capacitor energy storage system under variable super capacitor operating voltage. The conventional design method reported in the literature considers the rated super capacitor voltage in the modelling and design of controllers. The conventional method of controller design can potentially make the system unstable or introduce ringing in the DC link voltage at low super capacitor voltage. In this the sensitivity of DC micro grid stability with respect to super capacitor voltage variation is analyzed and a control design method is proposed to ensure the stability of DC micro grid in all operating modes. The voltage regulation of DC microgrid is a challenging task in order to prevent circulating current among different distributed energy sources connected in parallel. Another crucial issue is to manage active power among the distributed sources, loads and connected utility grid. Energy storage systems help to combat these challenges. In this work, review on a small scale DC microgrid is considered which is comprised of photovoltaic energy source, local loads and hybrid energy storage system. A decentralized control strategy based on DC bus voltage regulation is proposed for energy management in the system.

Keywords –ESS, MPPT,Grid, Solar power MPPT Algorithm, Boost converter Bidirectional converter, Super capacitor.

I. INTRODUCTION

The power system networks worldwide are dominated by AC systems. The revolutionary advancement of semiconductor technology and the power electronic converters creating increasing interest on implementation of the DC power systems. The rising attention for DC system lies in the inherent advantages of the DC system over the AC one. Many domestic loads such as computers, microwave oven, lighting consumes DC powers and conversion of AC to DC causes significant energy loss which is about 10-25% [1]. In industrial applications, like DC electric arc furnaces consume less energy than AC furnaces Another catalyst for development of DC systems. The DC based RES such as photovoltaic (PV) and fuel cells can directly be integrated in the network which avoids the conversion stages and thus increases the energy efficiency of the system [3]. The use of energy storage (ES) technology which increases the reliability of power supply is more facilitated by the DC than AC systems. Microgrid (MG) is defined as the controllable local energy network that includes distributed generations (DGs), loads and storage systems. Due to simpler structure and higher energy efficiency of the DC systems, the concept of DC microgrid is gaining popularity [4]. The 2 technology of AC MG has already been established whereas DC MG technology still requires further research to

resolve the challenges of stable and reliable implementation. The operation of DC microgrid is simpler than the AC grid due to the absence of phase, frequency and reactive power. It is required to balance active power to maintain the DC bus voltage in a DC microgrid [4]. DC microgrid also does not increase the short circuit capacity of the main grid at the point of common connection (PCC) due to the interconnecting AC-DC converter and this converter also prevents the power quality problems on the DC side [5][6]

Energy Storage System (ESS) In microgrid applications, normally the generation capacity is very close to the load power demand. Energy storage system is essential for stable operation of DC microgrid in case of any discrepancy between the total generation and total load of the system. One of the goals of microgrid application is to facilitate the integration of the renewable energy sources. But the intermittent power generation from the renewable sources may cause the instability in the system especially in islanded mode of operation of microgrid. In microgrid, energy storage system serves as spinning reserve in the conventional power system to maintain the power 13 balance [7].Quick response ESS can effectively minimize electromechanical oscillations in the power system by sharing sudden change in power requirement [8]. Therefore, in DC microgrid energy storage system is required to maintain stability, increase penetration of renewable and also to improve the power quality. In the literatures, various energy storage system have been reported for use in the DC microgrid application such as batteries [9], electric double layer capacitors [10], flywheel energy storage (FES) [11] and superconducting magnetic energy storage system (SMES) [12].

Battery Energy Storage System (BESS) Battery stores energy electrochemically and it is one of the most cost effective energy storage technologies. Battery energy storage system is formed by series and parallel combination of low voltage/power battery module in order to get the desired electrical characteristics. In microgrid applications, lead-acid batteries are widely used to form BESSs for their high energy density. Lead-acid batteries can be valve regulated and flooded type. The valve regulated battery is more reliable due to its less maintenance requirement .the authors presented the control of BESS for both grid connected and islanded mode of a PV based DC micro grid. They validated the simulation results with experimental test and used lead-acid batteries for that purpose. The results demonstrated the efficacy of proposed control scheme in controlling DC voltage and maintain stable micro grid operation. The operation and control system of DC micro grid consisting of wind generation, battery energy storage system, variable loads and AC grid has been presented .The authors proposed control system to maintain DC voltage of micro grid for three operating modes: normal grid connected mode, grid fault mode and islanded mode.[13][14][15].

II. LITERATURE SURVEY

The design and stability analysis of a DC micro grid with battery-super capacitor energy storage system under variable super capacitor operating voltage. The conventional design method reported in the literature considers the rated super capacitor voltage in the modeling and design of controllers. However, the super capacitor unit can discharge a slow as 10% of its rated voltage due to self-discharge. It is observed that the conventional method of controller design can potentially make the system unstable or introduce ringing in the DC link voltage at low super capacitor voltage. In this work, the sensitivity of DC micro grid stability with respect to super capacitor voltage variation is analyzed, an optimal super capacitor voltage to be considered in the design is calculated and a design method is proposed to ensure the stability of DC micro grid in all operating modes. The stability of the DC micro grid with controllers using the proposed method is evaluated with digital simulation and experimental studies.

Hierarchical Control In hierarchical control, there are three control levels of hierarchy: primary, secondary and tertiary. This control architecture increases the system flexibility enabling integration of more distributed power sources. This control strategy also works for different operating modes of the micro grid: grid connected mode, islanding mode and load shedding or generation curtailment mode [8]. 4 The primary control level regulates the load sharing among distributed power sources based on the droop characteristics of the interfacing power electronic converters. The secondary control deals with voltage fluctuation control and also responsible for restoration and synchronization of DC grid with

other grids. The tertiary control handles the energy management [6].

Primary Control In order to regulate the output voltage and power sharing among distributed generations two methods are used. These are (i) passive control method (droop concept) and (ii) active load sharing method. In DC micro grid applications, droop control is a widely used method for effective load sharing among the parallel power sources connected to the common bus. In AC micro grid, the droop concept is the variation of active and reactive power of synchronously rotating AC generators 7 with respect to frequency and generator terminal voltage respectively [9]. But in case of DC micro grid the droop concept means the variation of active power with respect to DC voltage. The load sharing can be maintained without the need of communication system. In DC micro grid, the droop characteristics of power electronic converters can be expressed as a linear function of voltage and current or power and voltage [6].

Hybrid Control In order to achieve better result, the hybrid control structure accommodates the advantages of aforementioned techniques for better performance. A hybrid control strategy is proposed for optimal operation of a stand-alone DC micro grid in [5]. As part of the central energy management the authors used communication system to observe bus voltages, power flow and converter status. In case of any failure of communication link, DC bus signaling technique is proposed as back up control strategy.

Jinsong Kang et.al (2019) with the development of renewable energy such as hydrogen energy, renewable energy supplies have been an important part of DC micro grid. Related control and power management has become the focus of current research. The Photovoltaic /fuel cell/hybrid energy storage DC micro grid in this paper consists of Photovoltaic (PV), fuel cells, lithium-ion batteries, and super capacitors, along with associated DC/DC and DC/AC converters. To guarantee the stability of the PV/fuel cell/hybrid energy storage DC micro grid, in this paper, a comprehensive control and energy management system is proposed. The proposed control and power management system stably regulate the bus voltage and well balance the power, mainly through automatic control of each module's voltage and power. Under the control and Power management system, when the load changes suddenly, the bus voltage remain stable and power remain balanced. The simulation is carried out to verify the performance of the proposed method.

S Sheik Mohammed et.al (2019) This paper concentrates on the design and control of a DC micro grid with PV, controlled Energy Storage System consists of battery, super capacitor, DC loads, Electric Vehicle and Energy Management System (EMS). The main objective is to effectively manage the load requirements. A simple Adaptive energy management control is implemented. The system is simulated under different input and load condition in MATLAB/Simulink and the results are taken. It is observed from the obtained results that the dc microgrid with proposed energy management control satisfies the requirement under all conditions.

Srikanth Kotra et.al (2015) this paper proposes a unified energy management system (EMS) for a grid interactive hybrid micro grid with a hybrid energy storage system (HESS). The proposed EMS achieves a continuous and reliable power supply to local loads and exports/imports power to/from grid. The proposed EMS considers the PV power variations, grid availability, electricity pricing and variations in local loads. A single phase voltage source converter (VSC) transfers real power between DC grid and utility grid and provides ancillary services such as reactive power support, unity power factor and harmonic mitigation at point of common coupling (PCC). The EMS also addresses extreme operating conditions like load shedding, off-MPP operation of PV, critical oscillation of HESS powers, islanded operation and resynchronization with grid. The efficacy of proposed EMS is verified by time-domain simulation.

PinitWongdetet.al (2018) the one problem in standalone micro grid with photovoltaic (PV) and wind energy systems is the fluctuation of power output. The battery energy storage system (BESS) is used to improve reliable operation of micro grid by managing the power output. However, the intermittent power charge/discharge of BESS is the one factor that harmful effect to its lifespan. In recent years, the hybrid energy storage system (HESS) with BESS and super capacitor (SC) has been proposed for increase performance of the system and extend BESS's lifespan. The SC has high power density and longtime life cycle but low energy density. Presently, the SC is developing and may fully use in micro grid in the future. This paper studied the HESS topology of BESS and SC by considering the ramp rate power

limitation to control the operation of HESS. The results showed the significantly improved for extending the lifespan of BESS by smooth of power exchanged and increased efficiency in the micro grid. The simulation is carried out in MATLAB-Simulink program.

Li Jing et.al (2016) Battery and ultra-capacitor respectively has the advantages of high energy density and high power density. Combining them into a hybrid energy storage system (HESS) can meet multiple requirements of micro grid. Balanced system power and stable DC bus voltage are achieved by establishing the power management strategy. A HESS control strategy is designed to meet charging/discharging demand and reduce battery damage caused by frequent charge/discharge current. The model of DC microgrid system with HESS is built on Matlab/Simulink platform and the simulation results verify the feasibility of the control strategy.

III. PROPOSED APPROCH

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 are not discussed in detail. Instability in DC microgrids can occur due to various reasons such as dynamic variation of generation and load, changes in system operating conditions, variation in system component values and controller parameters. In the conventional design .the DC link voltage controller is designed by considering the rated super capacitors voltage. However, the system in practical condition may not always operate at rated super capacitors and voltage.

In low super capacitors operating conditions, the DC microgrid voltage control loop with conventional design has very low gain margin and phase margin and it can introduce 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 supercapacitors operating voltage to achieve stable operationIn the conventional design reported that the DC link voltage controller is designed by considering the rated super capacitor voltage. Accurate modelling of DC micro grid with HESS. Sensitivity analysis of DC micro grid with super capacitor voltage variation. Finding the optimal super capacitor voltage to be considered in the design such that the DC micro grid is stable at all super capacitor operating voltages. Designing the DC link voltage controller such that it provides sufficient gain margin and phase margin at all Super capacitor operating voltages.

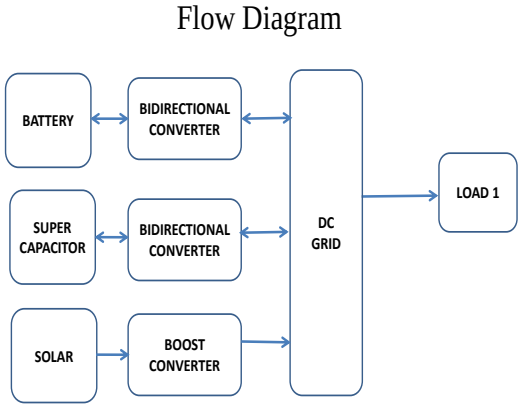

Fig. 1 proposed flow diagram.

IV. CONCLUSION

An optimal super capacitor voltage based DC link voltage controller design method is proposed to ensure the sufficient gain margin and phase margin at all super capacitor voltages. The simulation and experimental results confirmed that the proposed design provides higher gain and phase margins than that of the conventional design. Therefore, the proposed controller design achieves superior dynamic response over a wide range of super capacitors operating voltages. DC micro grid has the potential for improving power system stability, reliability and efficiency. In this work, low voltage small scale DC micro grid with PV source and hybrid energy storage system is developed.

Different control strategies for controlling DC microgrid are discussed. Among them decentralized control strategy without requiring any communication technology is proposed for the energy management in the microgrid. DC bus voltage is used for coordination among different modules of microgrid to maintain power balance during both grids connected and islanded modes of microgrid. This increases reliability by avoiding the use of communication links.

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