DC Nanogrid with Battery System

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Abstract— The nanogrid is a small scale power system that consists of renewable and non-renewable power resources that supply power to nearby loads. The performance of the nanogrid is not totally satisfactory as large over shoot may occur in the output voltage, and current disturbances may occur at load side. Also power electronics system can become unstable when the source interface converters are connected to load interface converters rather than separate loads.A nanogrid is a standalone system that uses renewable and non-renewable sources to supply power to local loads. A nanogrid is similar to the microgrid concept, but smaller in size than a microgrid. It has a capacity in the order of 2-20 kW. However, there are some considerations to improve the system response and extend the functionality of the DBS towards AC loads and harmonics mitigation.

Keywords: Battery Management system (BMS), Nanogrid System Controller (NSC), Nanogrid Switch/Socket

I. Introduction

Nanogrid can be termed as the subset microgrid which can be used powering a single building or house. Low voltage DC distribution within building or house structures can be called as DC Nanogrid. DC power electronic loads like BLDC fans, LED Lights, battery management system and renewable sources like solar PV Converters can be connected to the Nanogrid, more efficiently when compared to normal AC because of the elimination of the various power conversion stages. DC Nanogrid is low voltage DC distribution system, which is very much suitable for residential power applications [1]. The average power demand in the Nanogrid is provided by the renewable energy resources like wind and solar PV. The battery management system is used to ensure uninterruptible supply to high priority loads and also to sustain stable operation of the Nanogrid.

The architecture for the DC Nanogrid is as shown in the Figure 1 which mainly consists of subsystems such as the Nanogrid system controller for system management and the network coordination, smart power switch and socket for connecting DC based load to the DC Nanogrid, Battery Management System for the battery charging and discharging control, Solar PV Converter which is the default powering element in the DC Nanogrid and AC/DC converter which power the DC Nanogrid when both PV and battery powers are unavailable. In this DC Nanogrid, 48V DC is chosen due to the fact that the user can handle this voltage level without any serious risk and also 48V is sufficient enough to drive highly efficient DC powered loads such as BLDC fans, LED lights, which are very common in home [2]. Various simulations studies and experimental analysis also have shown that 48V is an ideal voltage level for light loads. Nanogrid system controller manages and controls all the subsystems and connected loads. Nanogrid system controller communicates with subsystem using its controller area network and remotely control and monitors its operation parameters. It also monitors and control Nanogrid power socket, which are used to connect the DC loads like BLDC fans and LED lights.

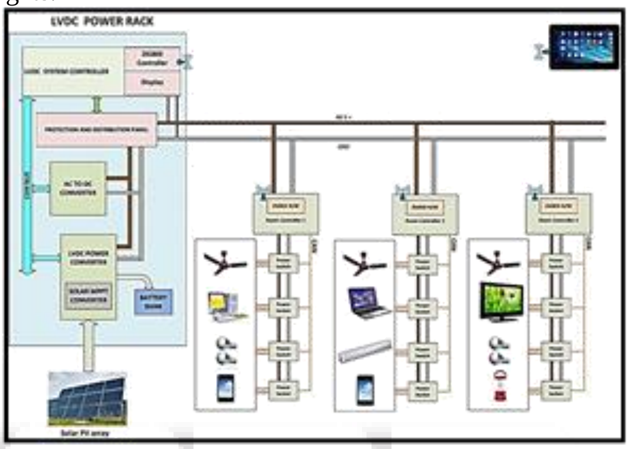


Fig. 1: Nanogrid Power Architecture

DC Nanogrid can operate in various modes based on the energy taping [3, 4]. The default operation mode of the DC Nanogrid is the Islanded Mode in which the solar PV converter delivers the required power as well as charges the battery with its remaining available power. In case the solar PV power is not able to meet the load demand, BMS supplies remaining power to the load. Power is drawn from the grid when renewable and battery unable to deliver the load demand and it is called the grid connected rectifier Mode. Nanogrid system controller manages the mode controlling activities, based on the information shared between the subsystems.

In this paper a battery management system for DC Nanogrid application is discussed, the proposed BMS for DC Nanogrid architecture with has been implemented at Power Electronics Group of C-DAC, Thiruvananthapuram.

II. Proposed Battery Management System for DC Nanogrid

The battery management system (BMS) is a critical component of DC Nanogrid. The purpose of the BMS is to guarantee proper DC bus voltage for the functioning of DC Nanogrid system. The configuration for BMS consists of two converters: a buck converter to charge the battery and a boost converter for the battery to power the DC Nanogrid connected load [5,6,7]. Figure 2 shows the block model of the BMS which composed of power and the control circuit.

A 24V, 100AH Lead acid battery is set for energy storage option for the DC Nanogrid. It is connected to the 48V DC Nanogrid Bus through a bidirectional DC-DC converter which controls the power flow to and fro from the battery, based on the modes of its operation. The DSP based controller, controls the operations of the converter based on the current and voltage parameters of both the 48V DC Nanogrid bus side and the 24V DC battery side. Controller in the BMS is designed to take care of mode transition, boost to buck and buck to boost mode based on DC Nanogrid Voltage and also based on the command from the Nanogrid System Controller through the communication network.

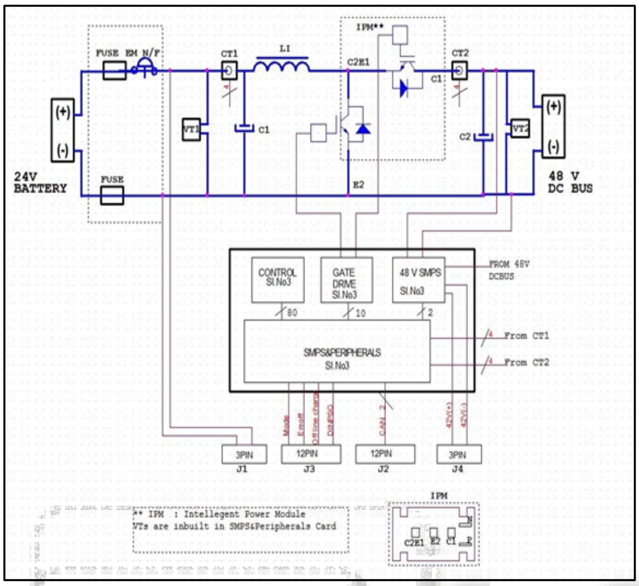


Fig. 2: Block Model of the BMS of DC Nanogrid

The Power Circuit Topology -Two half-bridge IGBT are used to realize the bidirectional Buck-Boost topology. In the buck mode, shown in Figure 3a, the lower Switch SWD is off and the upper Switch SWU operates at the set switching frequency with the lower switch diode DL acting as the freewheeling path. When SWU turns-on and diode DL cutoff, the voltage at the two ends of the inductor is V48-V24, with the inductor current increasing linearly, part of the power is stored in the inductor and charges the battery. When SWU turns-off, the inductor energy is freewheeled through DL, releasing energy to the battery, and the current in the inductor linearly decreases. The output current or voltage is controlled by the duty ratio of SW_U.

In the Boost Mode as shown in the Figure 3b, SWU would cut off and SW_D operates with the set switching frequency, with the upper switch diode D_U acting as the freewheeling path. When SW_D turns-on, the energy is transferred to the inductor which stores the energy, the current in the inductor increases linearly, while the power of the DC Nanogrid load is supplied by the capacitor. When SWD turns-off, DU conducts transferring the stored energy in the inductor and the battery to the load and the capacitor. The output of the DC Nanogrid is regulated by SW_D ‘s duty cycle.

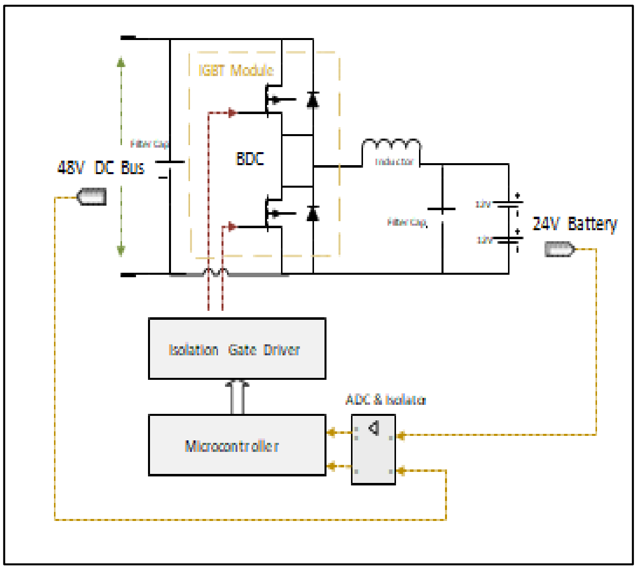
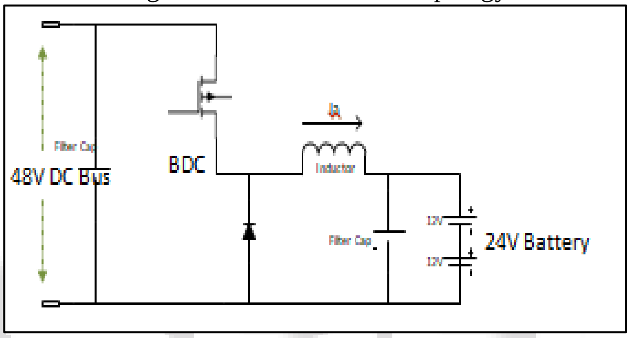
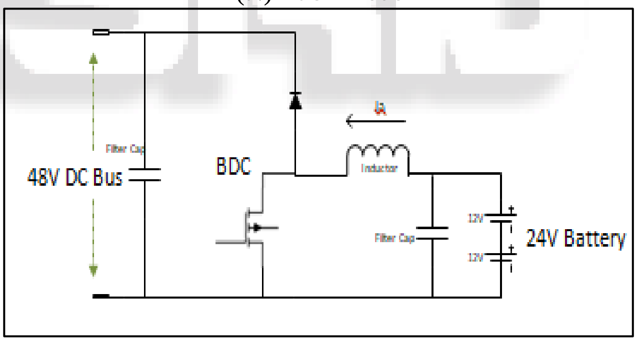


Fig. 3: BMS Power circuit topology



(a.) Buck Mode



(b.) Boost Mode

The Control Circuit –The control circuit consists of a DSP controller, a sensor board with current and voltage for battery side and also for the DC Nanogrid side. An isolated driver circuit board is used to interface IGBT. DSP TMS320F28234 built-in A/D converter converts the analog value, obtained from the sensor board which reads the voltage and current of both the 48V DC Nanogrid Bus side and the 24V battery side to digital form as feedback. The BMS control circuit and controller design is as shown in figure 4.

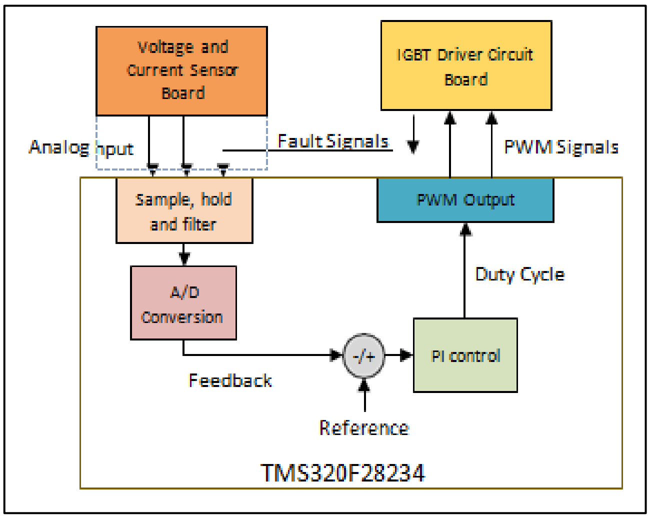


Fig. 4: BMS Controller Design

III. SYSTEM CONTROL DESIGN

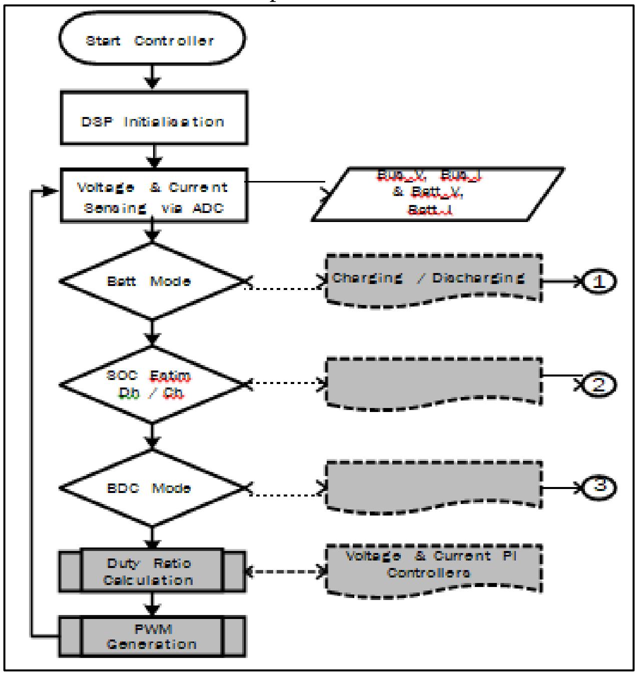
Battery SOC is estimated [8,9], based on the battery SOC the BMS mode of operation is decided. The overview of the BMS Mode is as shown in the Table 1:

Battery – Charging Mode	Battery – Discharging Mode
SOC<100	SOC<40
SOC>60=> Limited Charging Mode	SOC<60 => Limited Discharging Mode
SOC<50 => Full Charging Mode	SOC>80 => Full Discharging Mode

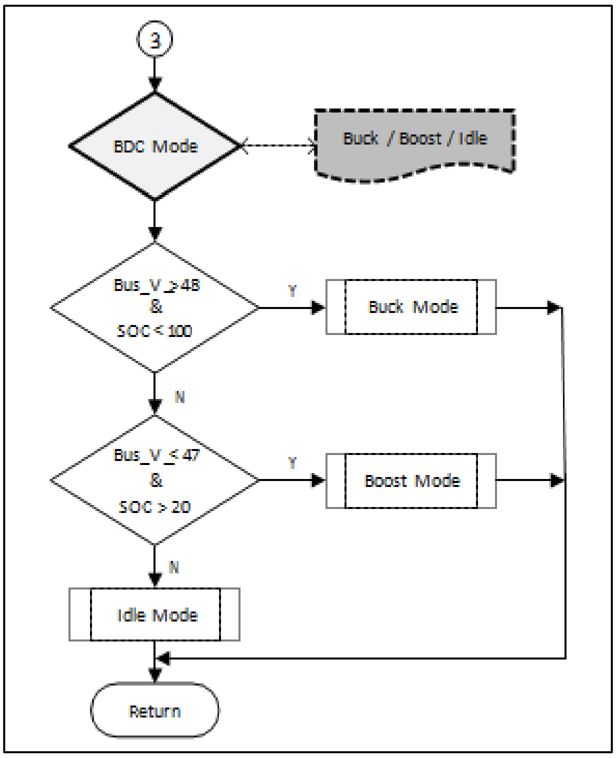
Table 1: BMS Mode Description

The system control algorithm of the implemented DSP program for carrying out the functions is shown through the simple flowchart as shown in, Figure 5

Flow chart for the BMS operation Part-I



Flow chart for the BMS operation Part-II



Flow chart for the BMS operation Part-III

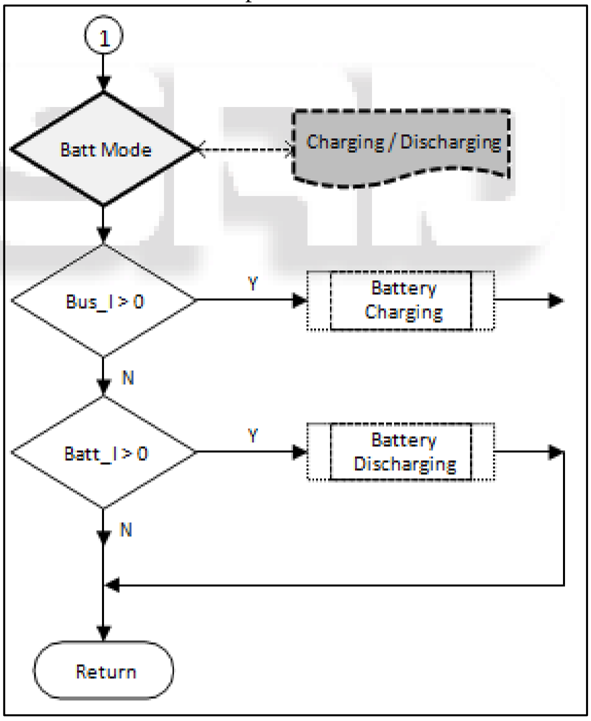


Fig. 5: Flowchart for BMS operation

IV. BMS HARDWARE SETUP

The hardware setup of BMS is shown in Figure 6. For testing the BMS, the Nanogrid DC Bus is driven by varying voltage sources, the observations and results are presented hence.

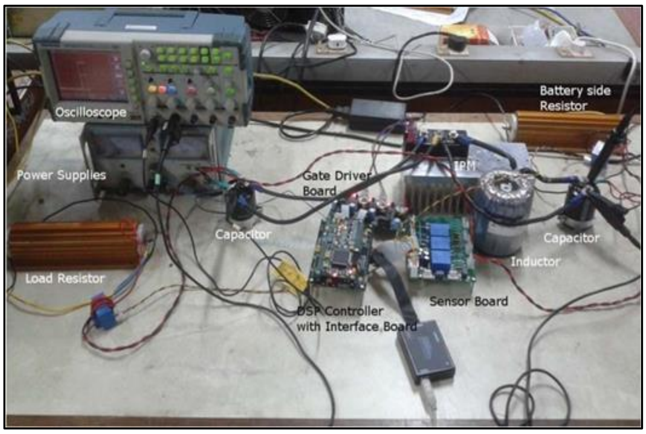


Fig. 6: BMS Hardware Setup

The setup is turned on at t=2.5s with the DC Bus Voltage above 48 V, about 52V, so the BMS operates in Buck Mode till t=7.5s, as observed. Variations in the DC Bus voltage from 52V to 50V still keeps the Buck side output voltage steady at 28V to charge the battery. This is done by the PI controller programmed in the DSP controller which adjusts the Duty cycle of the PWM given to the IGBT to track the constant voltage.

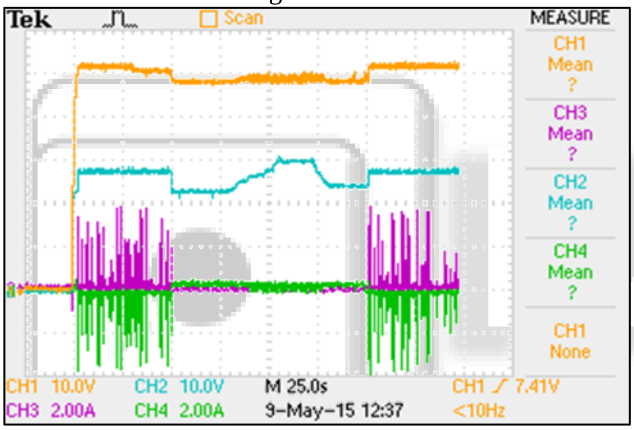


Fig. 7: BMS Waveforms

CH1 – DC Bus voltage CH2 – Battery voltage
CH3 – DC Bus current CH4 – Battery current

At t=2.5s when the DC Bus voltage drops below 48V the BMS mode changes to Boost Mode and the Battery goes into discharge indicating its actual voltage, about 24V, as observed. The Battery discharges with the BMs boosting the voltage to steadily maintain the DC Bus Voltage at 48V. Irrespective of the changes in the Battery voltage, the DC Bus voltage is maintained at 48V. This is again done by the PI controller programmed in the DSP controller which adjusts the Duty cycle of the PWM given to the IGBT to track the constant voltage. Even if the sources driving the DC bus is unable to supply the load, the battery provides the backup supply maintaining the 48V. This continues till the Battery is unable to drive the load, i.e. its voltage drops below the critical voltage, whence the Boost Mode is programmed to be cut off. Here the Buck Mode continues till 17.5s when the DC Bus voltage goes above 48V, changing the BMS mode to Buck again, charging the battery at 28V as observed.

V. Conclusion

The Battery System for the DC Nanogrid system is successfully designed and implemented giving the expected results and desired performance. The working of the modes of operation of the bidirectional converter – Buck and Boost with the battery working in charging and discharging modes are clearly observed. The observations and results are verified with the battery system subsystem of the Nanogrid system that is implemented, in earlier section. Design of the DSP controller ensured the proper tracking of the sensed voltages & currents at the battery side and the DC Bus side giving a closed loop system performance. The BMS runs in Buck mode if the DC Bus voltage is above 48V to charge the battery at 27V till it gets fully charged. If the Bus voltage drops below 48V then the BMS runs in Boost mode discharging battery to drive the DC Bus by boosting the battery voltage to 48V. Both the Boost and Buck modes operated as per the design specifications.

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References

[1] "A New Vision for Residential Power", Energy Gesidn Update, VOL. 35, NO. 3 • MARCH 2015
[2] K. Garbesi, V. Vossos, and H. Shen, “Catalog of DC appliances and power systems,” Oct 2011.
[3] A Agustoni, E. Borioli, M. Brenna, G. Simioli, E. Tironi and G. Ubezio, "LVDC distribution network with distributed energy resources: analysis of possible structures" in CIRED,pp. 1-5,2005
[4] "TomislavDragicˇevic´, Juan C. Vasquez, Josep M. Guerrero, and DavorŠkrlec, “Advanced LVDC Electrical Power Architectures and Microgrids"", IEEE Electrification Magazine, 18 March 2014.
[5] G. Iwansky, P. Staniak W. Koczara “Power management in a DC Microgrid Supported by Energy Storage” in Industrial Electronics(ISIE) Gdansk 2011 pp. 347-352.
[6] Peterson, K. “Algorithm for Management of Energy in the Microgrid DC Bus.” Zakis, J. (Eds.). 13th International Symposium: Pärnu, Estonia, January 14-19, 2013 (170 – 174).
[7] Hamid R. Karshenas, Hamid Daneshpajooh, Alireza Safaee, Praveen Jain and Alireza Bakhshai (2011). “Bidirectional DC - DC Converters for Energy Storage Systems, Energy Storage in the Emerging Era of Smart Grids”, Prof. Rosario Carbone (Ed.), ISBN: 978-953-307-269-2.
[8] M. Brandl et al., "Batteries and battery management systems for electric vehicles," 2012 Design, Automation & Test in Europe Conference & Exhibition (DATE), Dresden, 2012, pp. 971-976, doi: 10.1109/DATE.2012.6176637

[9] E. Karden, P. Mauracher, and A. Lohner, “Battery management system for energy-efficient battery operation: Strategy and practical experience,” in Proc. Int. Electric Vehicle Symp., vol. 2, 1996, pp. 91–98.