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SOLAR POWERED NANOGRID FOR HOME APPLICATION

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ABSTRACT Nanogrids are the building blocks of a microgrid which is powering a single building. Low voltage DC distribution system within building structures is called a LVDC nanogrid. DC electronic loads like LED Lights, BLDC fans, PC, battery system and renewable sources can be connected to the nanogrid. LVDC nanogrid is a low power DC distribution system suitable for residential applications with an efficient power and control architecture. The Nanogrid power architecture consists of subsystems such as the Nanogrid system controller, Nanogrid power Switch/socket, Battery Management System, Solar PV Converter and backup AC/DC converters. The average load demand in the nanogrid is provided by the local renewable energy resources like solar PV. A battery management system ensures uninterruptible power supply to the high priority loads. The objective of the work is to investigate the power and control architecture to evolve the specifications, to implement Low Voltage Direct Current (LVDC) Nanogrid for residential applications. Protocol for LVDC communication is based on CANopen standard (EN 50325-4). Control Strategies for optimal power management in Nanogrid is highlighted in this work.

KEYWORDS : LVDC; Zigbee; CAN; BDC; Master controller; Slave controller

INTRODUCTION

At present most of the electronic equipment/devices which we are using regularly work on DC directly or indirectly such as LED TV, Mobile phones, Computers, LED lights etc. This devices are plugged into typical AC wall sockets through adaptors to convert AC into DC for powering and charging.

This conversion process is not hundred percent efficient due to inherent losses. Renewable resources like solar PV and energy storage elements such as batteries are also DC systems inherently. Multistage power conversions are necessary to integrate them into the conventional AC distribution system. When integrating into an AC system, the DC output from a solar PV is first converted into another DC voltage and then to AC using an inverter.

Many of the electric loads that we use daily are DC in nature at some point. We can use them efficient by feeding them directly from a DC source instead of AC with limited conversions. This results in reduction in energy consumption reduced costs and volume. Today, LED lights are available with reduced energy consumption compared to conventional lighting schemes, it also needs a primary conversion from AC to DC. In solar inverter the DC voltage tapped from the PV array is converted into AC for further usage. Moreover, in energy storage systems (battery) the electric power is treated (charge/discharged) inherently in DC state. In all these cases discussed above, we can see an extensive loss is associated with each number of conversion stage; it's clear that as the number conversion stage increases the total loss will also increase. The energy savings obtained by using LVDC Nanogrid systems for home applications have been given [6]– [9].

In this paper an LVDC Nanogrid for home application is discussed, the proposed architecture with efficient power management scheme has been implemented by Power Electronics Group, C-DAC Thiruvananthapuram, India and the project is funded by National Mission on Power Electronics Technology, Ministry of Electronics & Information Technology (MeitY), Government of India.

I.PROPOSED LVDC NANOGRID ARCHITECTURE The proposed architecture is shown in the figure 1 with

consists of subsystems such as the Nanogrid system controller, Nanogrid power Switch/socket, Battery Management System, Solar Converter and backup AC/DC converters.

Nanogrid system controller is the master controller in the system. It controls and manages all the sub systems. It communicates with the other nodes in LVDC communication network, remotely controls and monitors nodes like LVDC power socket, solar PV controller and battery charge controller. It has Zigbee channels to communicate to a smart meter or to the outside network. LVDC power socket is an intelligent outlet that has the ability to measure and control electrical devices plugged in this socket. Each socket has a power line and an LVDC data line. When a device is plugged into this socket, the power and data lines get interfaced. The system also comprises an integrated control and communications system which connects the power electronic converters with the Nanogrid system controller.

The DC Nanogrid voltage is chosen as 48 V DC. LED Lamps, BLDC fans, desktop PC SMPS with 48V DC are available in the market. 48V DC is considered because the user can safely usage DC Nanogrid without any risk.

Home appliances are one of the main loads in dc-based nanogrid. Theses home appliance are connected or disconnected from the nanogrid network according to the user requirements. From the above literature review shows that even with the central controller plug-and-play operation of the system is limited to the source only. But for DC Nanogrid it requires to control the load also for its effective operation. The control technique must allow plug-and-play operation of the system where the new systems can be added or removed from the nanogrid network seamlessly. Home appliances are system which normally doesn't have an inbuilt communication system. So to connect this system smart LVDC power sockets are introduced. No communication between loads is required because the loads are plugged to the nanogrid network using theses Smart LVDC power socket. LVDC socket and switch management algorithm limits the home power consumption to a maximum allowable peak power limit.
The Solar PV Supply the base load and any excess power from the Solar PV if available is used to charge the battery. During shortages of power from Solar PV Converter, power is drawn from the storage devices. Backup generation the AC/ DC converter (Grid Connected Mode) is brought when the storage power is depleted due to a long-term shortage in solar PV power. Modes of Operation LVDC Nanogrid is as listed below

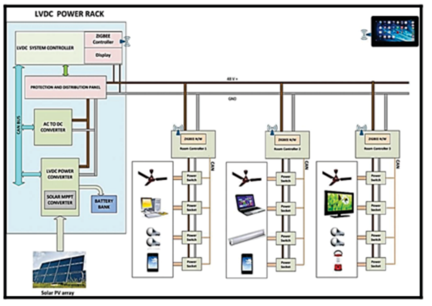
1. Islanded Mode (default mode)

a) Solar PV– Fully delivers the Load demand and charges the battery.
b) Battery – Powers the Load in the event of Renewable sources not

able to supply the Load demand

2. Grid Connected Mode

a) Inverter Mode – Energy supplied to the grid, with excess energy available from Renewables.



b) Rectifier Mode – Energy drawn from the grid when Renewables and Battery unable to deliver the load demand.

A. LVDC Communication layers

Communications coupled with DC distribution can create buildings that are more efficient and easier to operate. Multilayer Communication networking facilitates efficient, flexible and cost effective network interface to the Nanogrid systems. All the power devices are provided with a reliable Controller Area Network bus, which are connected together by CAN network, a Room Controller with Zigbee feature sends information and receiving commands from the Nanogrid system controller. The system also comprises an integrated control and communications system which connects the power electronic converters with the NSC (Nanogrid system controller) and slaves (room controllers) will perform wireless communication over the LVDC architecture. Protocol for CAN communication is based on CANopen standard (EN 50325-4). Each node are provided with an address. The multilayer communication network is illustrated in fig 2.

The figure above shows the block model of the LVDC Battery system composed of The Power Circuit and the Control Circuit. The bidirectional DC-DC Converter plays a key role for the system controlling the Charging and Discharging Modes of the Battery, correspondingly the Buck and Boost Modes of the Converter. The microcontroller controls the operations of the Converter based on the Voltage and Current parameters of both the 48Vdc DC Bus side and the 24Vdc Battery side. From the LVDC system point of view this controller acts as the local controller connected to the Main EMS controller through a communication network, in this setup through Zigbee Communication Interface based on CAN open.

48 V, 42 Ah Lead acid battery system is used for energy storage option for the LVDC system. It is connected to the 48V DC bus through a bidirectional DC-DC Converter which controls the power flow to and from the battery, deciding the modes of operation – charging (boost mode) and discharging (buck mode).

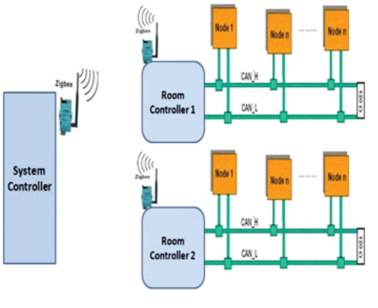


Fig 2: LVDC multilayer communication network

B. Nanogrid System Controller (NSC)

Nano grid system controller is the master controller in the system. It controls and manages all the sub systems. It communicates with the other nodes in LVDC communication network, remotely controls and monitors nodes like LVDC power socket, solar PV controller and battery charge controller. It has Zigbee channels to communicate to a smart meter or to the outside network. Following automotive standards as reference, the CAN (Controller area Network) is increasingly being used in home automation and other areas, so it is considered for LVDC network. The main services the NSC provides are communication networking management, decision regarding the mode of operation, management of power socket and switch and controlling the battery management system operation

C. Nanogrid Power Converter

LVDC power converter module is the main converter in LVDC system which consist of MPPT based solar converter and bidirectional DC-DC converter (BDC), LVDC Battery system composed of the power circuit and the control circuit.

1. Battery Management System

Lead acid battery is set for energy storage option for the Nanogrid system. It is connected to the 48V DC Bus through a Bidirectional DC-DC Converter which controls the power flow to and from the battery, deciding the modes of operation – Charging & Discharging. A microcontroller controls the overall working of the battery system which is interfaced to the LVDC communication network

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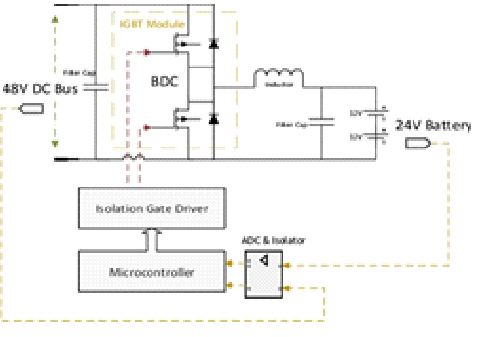

Fig 3: Nanogrid Battery System Block Diagram

1. PV Converters for Nanogrid

A boost Converter topology along with the buck converter topology is used for the power conversions. This topology supports Large Input-Voltage Range DC-DC Converter for High-Efficiency PV Applications.

Large input voltage range and high efficiency is required for Nanogrid. MPPT algorithm is used to track maximum amount of power. The battery management stores the excess power generated during the peak hours by the Solar PV, and supplies the load at night or in cloudy conditions. Boost Converter topology along with the buck converter topology is a better choice for the solar converter, as it can generate a stable 48V DC bus distribution voltage with different solar panels. This converter is interfaced with the LVDC Controller through an LVDC communication network.

The solar panel output has 50V maximum with 25V swing voltage range. The power conditioner linking between this solar panel and the battery has to take care of MPPT as well charging levels of the battery. A full bridge converter with magnetic isolation will take care of this operation. The schematic representation of the power circuit of solar charger is as shown below.

The various stages used in this configuration

1.Boost Converter stage with MPPT tracking

2.Voltage Isolation Amplification

Full bridge converter with high frequency transformer Phase Shifted PWM Control for 48V DC output

3.Full-Bridge rectification and filtering

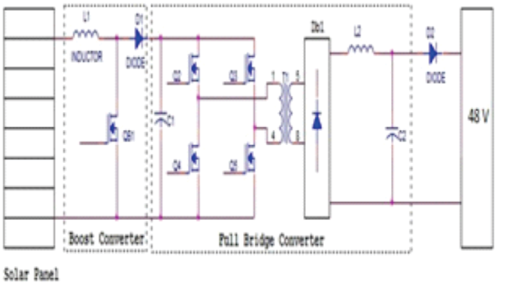

Fig 4: Nanogrid PV Converter Block Diagram

Nanogrid Grid Converter

DC converters are required to form 48V DC bus in the Nanogrid network. It incorporates a power factor pre-regulator (PFC) to take care of input power factor and provides a regulated DC output. Power factor pre-regulator of boost converter topology will be used in this stage with average/peak current control for input current shaping w.r.t input voltage. A full bridge converter follows the PFC stage with a magnetic isolation in this stage. Phase modulation technique is used to Control the output voltage. This converter is interfaced with the Nano grid controller through the CAN network.

A.Nanogrid Power Socket and Switch

Nanogrid power socket is used to connect removable load or plug load in the Nanogird network whereas Nanogrid power switch is used to connected and control fixed loads like fans and lights. Nanogrid Socket and switch are has the ability to control and measure devices connected or plugged in it. Each socket is having power line and communication lines. A device when it is plugged into this socket, power and data lines will get interfaced. This socket provides a 48V, 5 V (Power USB) stable DC output. Using the energy manag DC Nanogrid home requires control technique that allow plug- and-play operation of the system where the new systems can be added or removed from the nanogrid network seamlessly. Home appliances are system which normally doesn't have an inbuilt communication system. So to connect this system smart LVDC power sockets are introduced. No communication between loads is required because the loads are plugged to the nanogrid network using this Smart LVDC power socket. LVDC socket and switch management algorithm limits the home power consumption to a maximum allowable peak power limit.

This Nanogrid power switch is mainly used in distance connected fixed DC loads. Block schematic of a power switch er in the NSC controller, all the device plugged in to this socket can be turned on or off remotely.

CONCLUSION

LVDC power switch which is an intelligent outlet which has the ability to measure and control electrical devices connected is the main element in this system. Communications coupled with DC power distribution, storage, and load can create buildings that are more efficient and easier to operate. Multilayer Communication networking facilitates efficient, flexible and cost effective network interface to the Nanogrid systems. Monitoring, regulating, controlling and managing the power sources and the loads in the system is the task of the Nanogrid system controller which basically forms the brain of the entire system. The operating modes of the subsystems for the optimum flow of energy from the various sources to drive the load demands gives rise to devising control methods and strategies. Islanded and grid connected modes along with the critical task of maintaining a stable DC Bus become a major design and control constraint given the various operating conditions and scenarios. Energy storage option provides significant benefits to the DC system though it adds more complexity. It can be concluded that the LVDC Nanogrid is an energy efficient architecture that can transform the existing AC system to the DC for home.

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