A Review on Nano-grid Technologies

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Abstract - Nano-grids are smaller micro-grids which are already common today, in the form of USB-powered devices off a PC, electrical systems in vehicles and power over Ethernet distribution systems. The main quest of the work is to develop controlled circuit with power management using DC Nano-grids for household devices. A nano-grid is a power distribution system for one house or for a small building, with the potential to connect or disconnect from other power entities down a gateway. Nano-grids are considered as building cells of a Micro-grid. The independent nano-grid system mainly comprises of PV panel, converter, an Inverter, storage devices and the nano-grid controllers. The nano-grid controllers is the most significant subsystem in the nano-grid which regulates the act of the nano-grid. This paper is entirely pivoted on the combination of naturally obtained sources and the storage systems in the required province.

***Key Words*:** nano-grids, PV panel, converter, inverter, storage systems, nano-grid controller

1. INTRODUCTION

In present day scenario, because of the rise in population, there is an extended demand for the power in our everyday living, the use of artificial resources has lead the way to the present researchers to find out the answer for the issue. As we all know fossil fuels are subjected to exhaustion after a certain period of time. Down the line in another 50 years we will not be left with these fossils fuels. Hence nature is alarming us to take a call to preserve them and also at the same time to make use of other alternative sources of energy such as wind, solar, biomass etc.

A Nano-grid is a power distribution system for a single house/small building, with the ability to connect or disconnect from other power entities via a gateway [13]. There is potential in the market of generating solar power to build eco home for the next generation [1]. For a Nano-grid network fast, reliable and robust communication network is required, as it directly affects the energy flow and power management [7]. The solar power is highly dependent on the climatic conditions such as the irradiance and the temperature, which 2 main factors are determining the quantity and quality power generated by the PV system. The conventional way to generate electricity is through the process of burning natural gas and petroleum to produce combustion gases and spins through the blade of the turbine to generate electricity [1]. The price of electricity generated from the solar panel could be cheaper in the sun-rich regions, while in some countries which are low in sunlight, solar electricity tends to be more expensive compared to the commercially generated electricity [1]. Hence an energy storage system is required in the standalone PV Nano-grids.

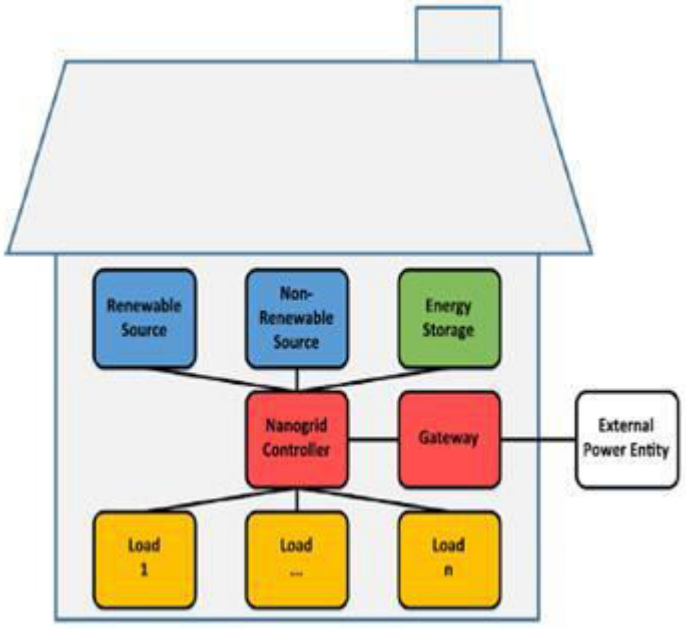

Figure 1. Block diagram of Nanogrid system [13].

The paper is organized as follows. Section 2 gives the definition and the components of nanogrids. Section 3 describes the types of nanogrid. The different implementation of nanogrid technologies are listed in section 4. Lastly the paper is concluded in section 5.

2. DEFINITION AND COMPONENTS OF NANOGRIDS

A nanogrid is a single domain for price, voltage, quality, and reliability [16]. The nanogrid consists of a controller, storage, loads and gateways. Storage of electric power is essential when the renewable energy sources are used. Gateways are used to interface one or more entities. Electricity and communications flow through the gateway.

A. Local power production

Local power generation using renewable energy is essential in the implementation of the Nano-grids. One of the main features of nanogrids is its ability to increase the efficient use of residential sized distribution generation [13]. The handling of renewable energy sources requires distilled arrangements and operation planning based on the concept of technologies. The large-scale distributed renewable generation system requires a more flexible, reliable, and smarter grid [13, 17].

B. Loads

Loads in a nanogrid can be any electrical devices such as resisters, inductors or capacitors. Power usage will depend upon the loads connected to the system. Home appliances are one of the main loads in dc-based nanogrids [7]. The operation of the system should be managed whenever a new load is added or disconnected from the system. Generally home doesn't have an inbuilt communication system hence to connect this system nanogrid power sockets are introduced [7]. No communication between loads is required because the loads are plugged to the nanogrid network using the power sockets [7]. Some examples are electric boilers, heaters, coolers, TV etc.

C. Gateways

The gateway provides the Bi-directional power connection between the nanogrids and other microgrids, nanogrids or national grids. This will include the communication with other power entities, conveying the nanogrid power requirements [13]. The gateway also have the ability to disconnect from the entire external systems and allowing the nanogrids to operate in islanded mode [13].

D. Energy Storage

Due to the use of renewable energy sources and the production depends on the climatic changes. As climatic changes are unpredictable, it is difficult to determine the capability of the amount of electricity produced [1].The energy storage is considered optional in a nanogrid structure but is usually present, as it adds stability to the system [13].
It has the ability to store the electricity on days with better irradiance and temperature and to compensate to the system on poor climatic weather.

E. Controller

Nanogrid system controller is the master controller in the system which controls and manages all the sub systems [7]. The nanogrid controller takes measurement readings from the output voltage after passing through the DC-AC inverter and before supplying it to the residential unit [1]. When the output voltage is less than 230V, the nanogrid controller has the feature to control and withdraw energy from the energy storage system to compensate for the difference before supplying it to the residential unit [1].

3. TYPES OF NANOGRIDS

3.1 DC Nanogrids

A basic block diagram of DC nanogrids is displayed in fig. 2 As shown in the block diagram the DC source has no limitations as to what type of renewable/non-renewable resource is used to generate power [13]. The commonly used renewable resources are solar PV cells, wind, which generates DC power and then it is converted into AC by using power electronic converters. Power electronics equipment has the capability to convert power from one form to another by using controlled electronic switches, and hence called power electronics converters.

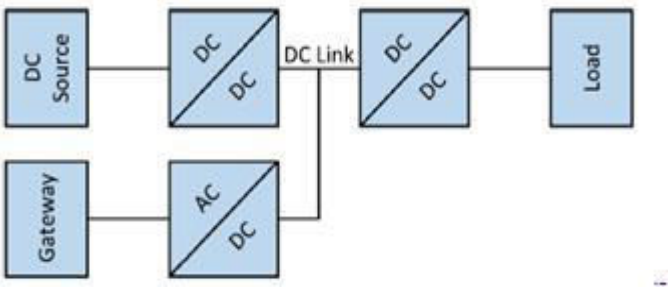

Figure 2. Block diagram of DC nanogrid [13].

The main task of the power electronics interface is to condition the energy supplied by the source to match the grid requirements and to improve the performance of the energy source. For instance, they are used to convert direct current (DC) power to alternating current (AC) power that matches the grid requirements. Such converters are referred to as DC/AC converters. With DC energy sources, the power electronics interface may consist of one DC/AC converter or an intermediate DC/DC conversion stage can be added to achieve a specific goal. The load has a DC/DC converter to interface it with the DC bus and the gateway requires AC power.

3.2 AC Nanogrids

When compared to the DC nanogrid, the AC has additional conversions that take place to ensure the correct power is supplied to the load [13]. Figure below shows the arrangement of AC nanogrids.

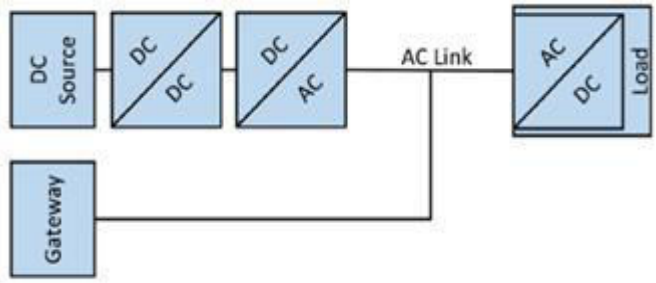

Figure 3. Block diagram of AC nanogrid [13].

The arrangement that consists of AC/DC and DC/AC converters is also referred to as frequency converter, since it

connects two different AC systems with possibly two different frequencies together. The DC-AC converter takes the DC voltage from the source converter and outputs which can be used by major loads. The AC voltage is then converted to DC, this conversion takes place in a power adaptor.

As there are two types of grids, the differences between the DC grid and the AC grid are important to know. The DC nanogrid is more efficient, stable and easy to control when compared to the AC nanogrids but, it will cost more to build a DC nanogrid [1].

4. IMPLEMENTATION

A. STANDALONE NANOGRID

A standalone nanogrid system consists of five main components, the solar panel with an MPPT controller, and the DC to DC converters, energy storage system, DC to AC inverters and the nanogrid controller. The below fig. 4 shows the block diagram representation of a standalone PV based nanogrid System. The solar panel helps to extract the energy from the sun and convert it into electricity. The PV cells are a low voltage sources hence a DC-DC converter is used to boost the voltage to the required level. An MPPT controller is connected to the boost DC-DC converter to track the maximum voltage and current produced by the solar energy based on the sunlight available. The boosted voltage is transmitted to the energy storage system and to the inverter to obtain AC voltage. This AC voltage is further transmitted to the electrical sockets
[1]. The excessive energy is stored in the battery and used as a back-up to the system during poor climatic conditions.

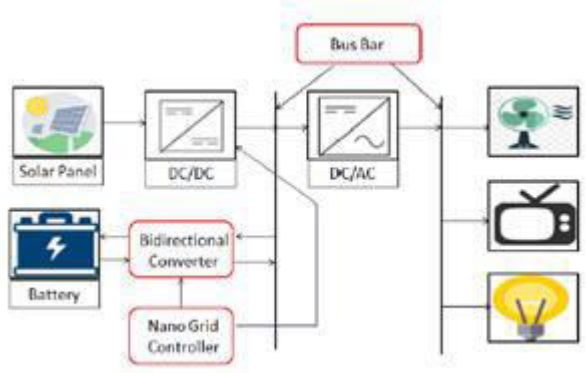

Figure 4. Block diagram of standalone PV based Nanogrid System [1].

The operating voltage is adjusted in order to move the operating point at the maximum power point. Maximum power point tracking (MPPT) algorithms are incorporated within the interfacing technology of a PV unit in order to adjust the operating voltage. The MPPT algorithms implemented here is the Incremental Conductance algorithm technique since it is an improvement of the Perturb and observe as it ensures higher efficiency and accuracy while working on atmospheric conditions [1].

B. LVDC Communication layers

The communication system coupled with DC power distribution, storage, and load can create buildings that are more efficient and easier to operate [6]. The fig. 5 below shows the multilayer communication network.

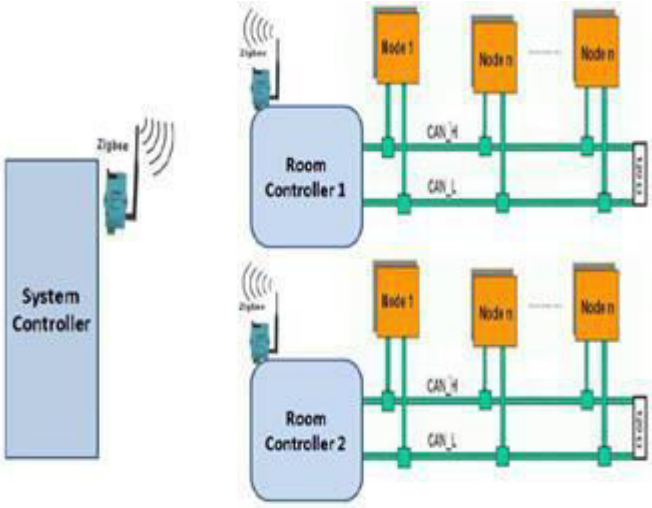

Figure 5. LVDC multilayer communication network [6].

Multilayer Communication networking facilitates efficient, flexible and cost effective network interface to the Nanogrid systems [7]. 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 [6]. The system also comprises an integrated control and communications system which connects the power electronic converters with the Nanogrid system controller and slaves will perform wireless communication over the LVDC architecture [7].

DC Nanogrid home requires control techniques that allows Plug-and-play operation of the system where the new systems can be added or removed from the nanogrid network seamlessly
[7]. Home appliances are the systems which are normally not connected to the communication system, so to connect this system smart LVDC power sockets are installed [7]. LVDC socket and switch management algorithm limits the home power consumption to a maximum allowable peak power limit
[6]. The figure below shows the block diagram of power switch.

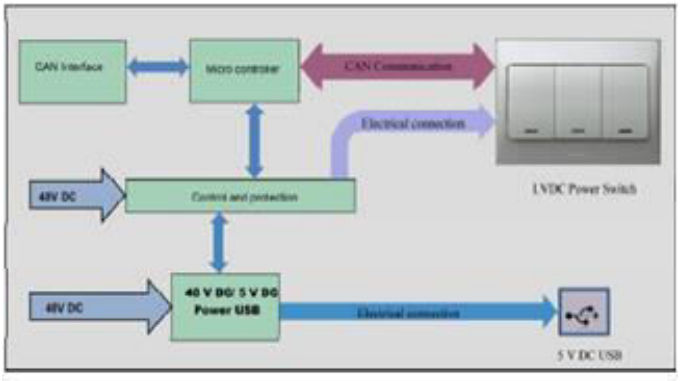

Figure 6. Block diagram of power switch [6].

5. CONCLUSIONS

The potential for nanogrids in future power systems has only just begun to be discovered. Their diversity and modular nature makes them ideal for implementing a bottom up approach designing power systems. There are a number of aspects to consider and compare between DC AND AC nanogrids. DC nanogrids are more efficient, stable and easy to control. The nanogrids hardware consists mainly of DC-DC, AC-DC and DC-AC converters. The converters are used to manipulate the power produced by a source, to meet the demands. The converters are designed to increase the efficiency of the system. There are various method in designing the converters so as obtain efficient operation of the system.

REFERENCES

[1] Lim Rong Jie, R. T. Naayagi , "Nanogrid for Energy Aware Buildings", 978-1-5386-7434-5/19, IEEE 2019.
[2] Aurelio Paolillo, Domenico Luca Carni, Mostafa Kermani, Luigi Martirano, Andrea Aiello, "An innovation Home and Building Automation design tool for Nanogrids Applications" IEEE Trans. 978-7281-0653-3/19, IEEE 2019.
[3] Stefano Bracco*, Federico Delfino, Giorgio Piazza, Federica Foiadelli, Michela Longa**. "Nanogrids with Renewable Sources, Electrical Storage and Vehicle-to-Home Systems in the Household Sector: Analysis for a Single-Family Dwelling" 978-1-53866-4722-6/19, IEEE 2019.
[4] Milind D. Bagewadi, Sanjay S. Dambhare, "A Buck-Boost Topology Based Hybrid Converter for Standalone Nanogrid Applications", 978-1-5090-4479-5/17, IEEE 2019.
[5] Nikolay Lyuboslavov Hinov*, Rad Hristov Stanev**, Gergana Ilieva Vacheva*, "A Power Electronic Smart Load Controller for Nanogrids and Autonomous Power Systems", 978-1-5090-2883-2/16, IEEE 2016.
[6] Sigi C Joseph, Dr Ashok S, Dhanesh P R, "Low Voltage Direct Current(LVDC) Nanogrid for Home Application", 978-1-5090-6255-3/17, IEEE 2016.
[7] Sigi C Joseph, Dr Ashok S, Dhanesh P R, "An Effective Method of Power Management in DC Nanogrid for Building Applicatiom" 978-1-5386-3864-4/17, IEEE 2017.
[8] Weimin Wu, Houqing Wang, Yuan Liu, Min Huang, Frede Blaabjerg, "A Dual Buck-Boost AC/DC Converter for DC Nano-Grid with Three Terminal Outputs" IEEE Trans. On Industrial Electronics.
[9] Sigi C Joseph, Dr Ashok S, "Smart Power Management for DC Nanogrid based Building", 978-1-5386-7336-2/18, IEEE 2018.
[10] Indrek Roasto, Argo Rosin, Tanel Jalakas, "Multiport Interface Converter with an Energy Storage for Nanogrids", 978-1-5090-6684-1/18, IEEE 2018.
[11] Gergana Vacheva, Nikolay Hinov, Rad Stanev, "Modelling of Power Electronic Converter for LED Lighting System Powered by Micro and Nanogrid", 978-1-5386-6730-9/18, IEEE 2018.
[12] Liyao Wu, "Development of a Solar-Power-Based Nanogrid System for Village Huts in Haiti Mountain Area", 978-1-5090-3270-9/16, IEEE 2016.
[13] Daniel Burmester*, Ramesh Rayudu, Winston Seah, Daniel Akinyele, "A review of nanogrid topologies and technologies".
[14] Manjula. J, T B Dayananda, "Bi-directional converter- A Nanogrid", IJEECS.
[15] Periyasamy Muthuvel, S. Arul Daniel*, D.G. Yazhini, "Retrofitting domestic appliances for PV powered DC Nano-grid and its impact on net zero energy homes in rural India".
[16] Nordman B., Christensen K. "Local Power Distribution with Nanogrids" IEEE 2013.
[17] M. A. Islam, M. Hasanuzzaman,"electrification and renewable energy generation", a review article.