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A Review on Design and Simulation of Solar PV DC Microgrid for Rural Electrification

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Abstract - In this paper we present the analysis and design of the dc microgrid system for electrification. The proposed architecture is superior in comparison with existing architectures for rural electrification because of its a) generation and storage scalability, b) higher distribution efficiency (because of distributed generation and distributed storage for lower line losses), c) ability to provide power for larger communal loads without the requirement for large, dedicated generation by extracting the benefit of usage diversity and d) localized control by using the hysteresis-based voltage droop method, thus eliminating the need for a central controller. We compute that the excessive cost of power (COE) for the proposed dc microgrid framework will be under minimal charges as put forth by the electrification governing agency according to the per kW-hr. The results show the reasonableness of the introduced dc microgrid design has totally inflicts with the main grid feasibly and found out to be very easy to implement without any extra cost to the system as far as the rising districts and the number of population in such districts are concerns.

Key Words: Microgrid, framework, power, governing, consistent, feasibly, Distributed Generation, Rural Electrification, Solar PV etc .

1. INTRODUCTION

A. Overview of architecture

According to the International Energy Agency (IEA), 1.3 billion people living in developing countries, i.e., ~ 17.5% of the world's population, do not have access to electricity . Due to the remoteness and geographical location (usually far from the grid) of the rural and remote areas, connecting with the grid is expensive and difficult to achieve. The huge investment needed to connect with the grid, as well as the economic condition of developing countries and their inhabitants makes the problem more challenging. Worldwide, nearly 660 million children are enrolled in primary schools and about 188 million children (about one third) attend primary schools that do not have electricity access. Data suggests that in sub-Saharan Africa approximately 90% of children go to primary schools without electricity. The development of mega projects for the rural electrification of these communities in developing countries is constrained by the limitation of resources.. This number is anticipated to increment in spite of expanded network tied age since there is as yet a significant control deficit in urban territories . Microgrids have been seen as a reasonable choice to give power to country zones where the expense of framework expansion is restrictive. As of late, the falling expense of sun based vitality has started expanding enthusiasm for creating sustainable techniques for country electrification. Indian power producers and discoms are facing high international coal prices, while domestic coal supply has already been struggling to meet demand in the past six months, according to experts. High demand for domestic coal amid high international prices had led to rolling power cuts in a number of states in October 2021 as several thermal power plants ran out of coal stock. In any case, battery costs have not declined at indistinguishable rate from sun based photovoltaic (PV) boards. Since the dominating private use is amid evening time hours, the expense of put away power use is a key figure of legitimacy. In such manner, dc microgrids have exhibited guarantee as a suitable technique for empowering enhanced efficiency and versatility for off-network frameworks. In this paper, we present and tentatively exhibit a dc microgrid design that gives an adaptable answer for country electrification. We ascertain the levelized cost of power (LCOE) of the depicted engineering dependent on BOM expenses of the proposed framework and field.

Currently used power systems are primarily based on the constraints on distribution systems that were imposed over a century ago. AC power systems enable efficient transformation of voltage from one level to another, allowing power to be carried for long distances with minimum line losses . This has rendered AC power networks the preferred choice for power transmission and distribution.

A review of the dc microgrid engineering is appeared in Fig. 1. The key parts of the framework are 1) the most extreme power point following (MPPT) source converter, 2) the fanout hubs, and 3) the family unit control the executives units (PMUs). An ostensible appropriation voltage somewhere in the range of 360 and 400 V is utilized to keep line misfortunes unobtrusive while conforming to the developing norms for dc influence. The decision additionally empowers utilization of promptly accessible 600 V control semiconductor gadgets. The matrix voltage is changed over to 12 V at the family units for capacity and machine use.

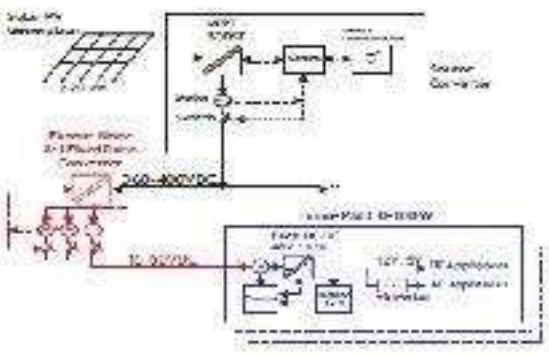


Fig. 1. An architectural overview of the dc microgrid system.

1.1. Related Works

There are plenty of studies proposing microgrids for rural electrification applications in developing countries. For example, authors in discussed the past and current practices to improve energy access, as well as promoting rural electrification using microgrids in China, India, The Philippines, Africa, and North America. On the other hand, as per, different kinds of microgrids such as AC, AC/DC or DC are studied for rural electrification applications. Authors in presented the reliability, economic and environmental analysis of a microgrid composed of diesel generator, PV system, wind and battery.

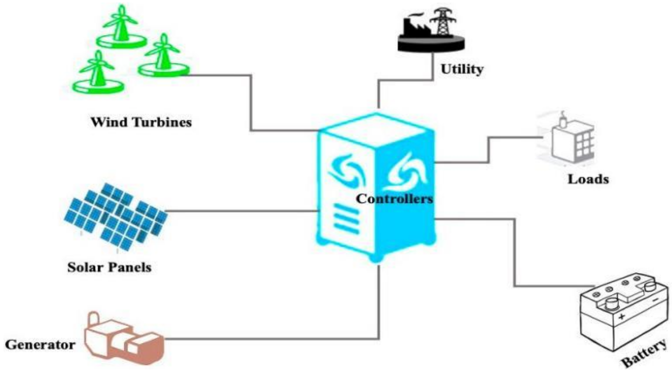
The authors also presented the design and model of DC microgrid consisting of solar PV and battery banks for residential buildings. The authors considered distributed and centralized DC microgrids to supply loads of the five houses with a centralized battery bank system. For the case of the distributed systems, the DC microgrid is designed to supply loads of the houses independently which is the houses have rooftop mounted solar PV and battery bank. In the case of the centralized system, the centralized battery bank system is responsible for the demand when there is a shortage of power generation and to store the power when there is surplus generation. The authors in also presented the design and analysis of DC microgrids for rural electrification.

1.2. Microgrids

A microgrid is a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously. The grid connects homes, businesses and other buildings to central power sources, which allow us to use appliances, heating/cooling systems and electronics. But this interconnectedness means that when part of the grid needs to be repaired, everyone is affected.

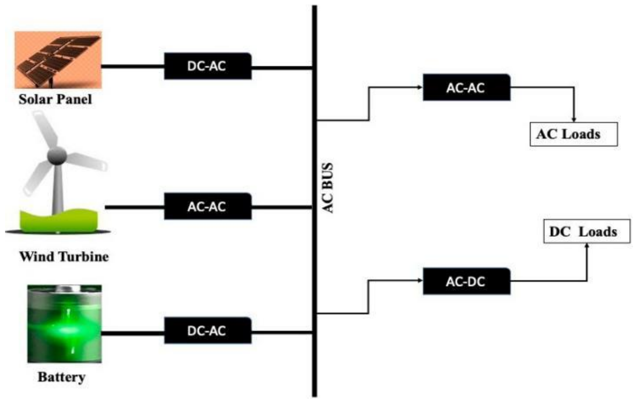
This is where a microgrid can help. A microgrid generally operates while connected to the grid, but importantly, it can break off and operate on its own using local energy generation in times of crisis like storms or power outages, or for other reasons

In the last couple of decades, a major shift has been observed in power systems due to the change in generation and transmission systems. The need of improving power quality, optimizing the operation and maintenance cost, increasing energy access in places where the power grid far away, environmental and social sustainability, are some of the main reasons behind these changes. The increasing penetration of renewable energy sources along with the depletion of fossil fuels and its associated environmental issues and investment costs, are among the factors for the observed power system changes [46]. However, with the randomness and intermittence of renewable sources, like wind and solar power, it is necessary to integrate different renewable sources for their better utilization and to have continuous energy supply. With this regard, microgrids can have a key role to achieve these goals and accommodate the changes required in the current power system, as well as to supply energy locally for people located in rural and remote locations of developing countries.



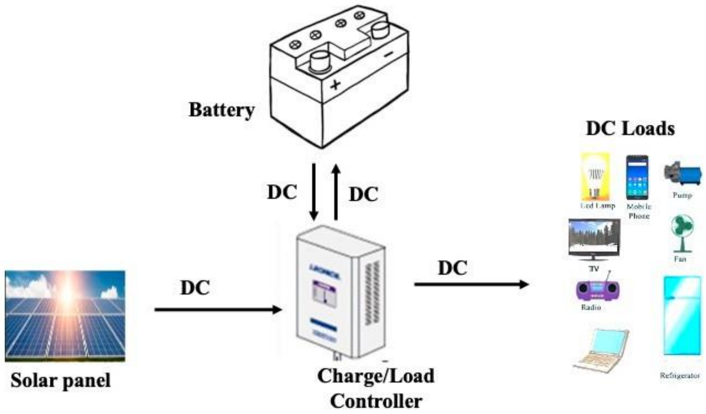
A microgrid not only provides backup for the grid in case of emergencies, but can also be used to cut costs, or connect to a local resource that is too small or unreliable for traditional grid use. A microgrid allows communities to be more energy independent and, in some cases, more environmentally friendly.

1.3. AC Microgrid



As shown in the figure, an AC bus is created and all sources with variable frequency and variable voltage are connected to the AC bus through AC/AC and DC/AC converters. The DC/AC inverters are necessary to convert the outputs of DC sources, such as battery storage and photovoltaic systems for any type of AC microgrids, whereas the sources with AC output is connected with AC/AC converters. Furthermore, AC to DC converters are installed to supply DC loads. Therefore, due to the use of different power electronics devices and conversions of power outputs from AC to DC or DC to AC, AC microgrids present higher losses.

DC Microgrid



Compared with AC microgrids, DC microgrids have several advantages: (1) higher efficiency and reduced losses due to the reduction of multiple converters used for DC loads; (2) elimination of synchronizing generators requirements, with rotary generating units, allowing to operate at their own optimum speed; (3) easier integration of various DC distributed renewable energy resources, such as energy storage, solar PV, small wind turbines and fuel cells, to the common DC bus with simplified interfaces; (4) more efficient supply of an increasing number of high efficiency DC loads, like LED lights, fans, computers, TVs, refrigeration; and (5) providing higher safety level and easier primary control. Therefore, in terms of high reliability, easy operation and maintenance, smaller size, high efficiency, lower design and operating cost, modularity and fault tolerance, DC microgrids in th low-medium power range (below 100 kW) are the best option for off-grid applications compared with AC microgrids.

CONCLUSIONS

This paper presented the Concept Design and implementation of a scalable dc microgrid architecture for rural electrification. We experimentally demonstrated the operation and stability of the dc microgrid with distributed voltage control. The load-line control scheme implemented by the PMUs enables inte-gration of completely variable sources and requires minimal regulation overhead. Relative ratios of load-lines determine the power-sharing between the different PMUs, thereby allowing for load prioritization.

The dc microgrid described in this paper allows for maxi-mizing efficiency of stored electricity, a key figure of merit for off-grid system. The architecture shows promise in addressing the economic and technical challenges of electrifying rural emerging regions.

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