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A Review on A DC Distributed Solar Micro Grid using DC to DC Boost Control Technique

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Abstract: *This study proposes a standalone distributed photovoltaic system which includes two independently controlled solar power sources, battery storage and a resistive load. Each of the PV panels consists of cascaded DC-DC boost converters controlled through two independent sliding mode controllers. The design and simulation of the supervisory controller are also discussed. First, maximum power point tracking (MPPT) control strategy is introduced to maximize the simultaneous energy harvesting from both renewable sources.*

Keywords: *PV System; DC-DC boost converter; maximum power point tracking (MPPT); MATLAB Simulink software.*

1. Introduction

The energy demand towards 2030 will increase by around 50-55%. Renewable energy will be an essential alternative to meet this energy demand. In this context, the depletion of the primary energy sources of fossil origin and concerns about global warming are increasingly increasing the importance of alternative energy sources.

Increasing energy needs may cause interruptions that are due to economic and/or physical reasons such as the loss of power in the case of long distances, the lack of sufficient energy despite the increasing energy need and the unbalanced power distribution, etc. Therefore, a more intensive analysis is needed to ensure network safety. In this context, Distributed Energy Resources (DERs) has been used. Problems that may occur during network connections of the DERs are problematic for the plant, system, and consumer unless they are analyzed in detail. [1]

DERs can reduce the electrical and physical distances between the load and the resources, as well as improve the reactive power to increase the mains voltage and power quality. They can eliminate the need for energy in distribution and transmission lines and reduce line losses. However, when the Voltage Source Inverter (VSI) is checked, it is different when it is compared to the single DER connected to the network and the multiple DERs connected to the network. The Current Control Strategy (CCS) can control single DER. The multi-DERs network requires to be regulated faster since it has more than one power generation characteristic and capacities. During DERs working; may cause problems such as over and under voltage, surge voltage change, unstable network frequency and voltage. Therefore, it is difficult to meet the high-precision real-time control requirement in load fluctuations.[2]

1.1 Micro Grids

Consumption habits of users vary depending on time in daily, monthly and annual processes. Due to these differences, demand may be too low for sometimes when it is above average and at times, it may be high enough to force the capacity of the network. The micro-grids are structures that contain a group of loads fed by one or more distributed energy sources and part of the MV (Medium Voltage)/LV (Low voltage) distribution system.

The benefits of micro-grids to nature and the economy, and the acceptability of grid power in the industry because of these benefits depend primarily on the characteristics of controllers and properties of controllers. Control and participation of distributed energy resources (DER) to traditional power systems is essential due to load characteristics and power quality problems. [3]

The objectives of the micro-grids are to meet the demanded power and to keep the power quality at the best level. However, the active and reactive power changes of the

DERs and the voltage fluctuations due to non-linear loads impair the stability of the network.

1.2 Distributed Energy Sources

The voltage control is applied to the DER inverters when there is no main network to provide voltage reference to the network to which they are connected. In this respect, it is better to apply them to specific powerful DER inverters in terms of energy continuity. Voltage control algorithms with constant amplitude and frequency reference values for inverter output amplitude are typical inverter control techniques applied to the primary source inverter in single master applications. However, the use of a drop-based voltage control technique that does not require communication in multiple main source applications such as micro-grids is widely used.[4]

The fact is that the density of DERs with variable output in micro-grids makes it necessary to create different energy management mechanisms. The established management scenarios are made separately for the network connected situation for the independent operating state in which the micro-grid provides its voltage and frequency stability.

In recent years, modern loads (such as LED, power electronics) have been widely used in commercial establishments, dwellings, and the provision of energy supplies for these high-tech products through the DC distribution system connected to the micro-grid is discussed in another topic. On this subject a hybrid AC-DC micro-grid has been designed to minimize transducer losses. AC loads to AC grid, DC loads are connected to DC grid and the developed algorithm can provide regular energy flow (between AC-DC) and system stability. It is envisaged that the excess energy produced from DC output sources such as PV and solid fuel cells is carried to other units with high quality and high-efficiency DC distribution line.

In the DC micro-grid structure designed for rural areas where electrical energy cannot reach, instant power sharing can be made with distributed control of the network voltage and the available (obtainable) energy amount can be determined. The losses resulting from distributed storage of energy from the PV systems assumed to be installed in each house are minimized.[5]

1.3 DC-DC Converter

A DC-DC converter consists of a number of storage elements and switches that are connected in a topology such that the periodic switching controls the dynamic transfer of power from the input to the output, in order to produce the desired DC conversion. The basic block diagram is shown in figure mentioned below:

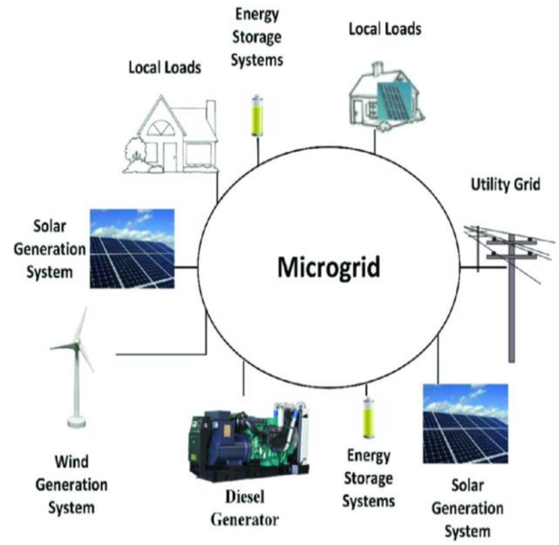

Figure 0. Micro grid

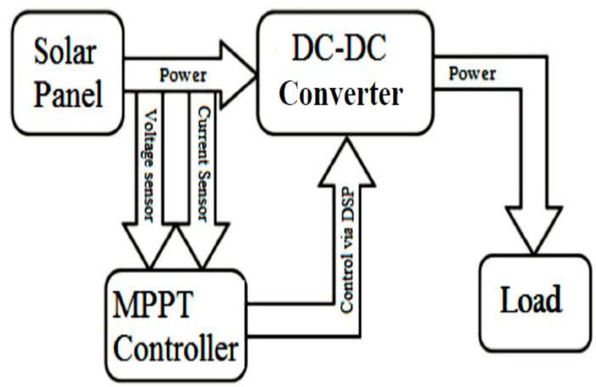

Figure 2 DC-DC converter for operation at the MPP

It consists of a solar panel, DC-DC power converter, MPPT controller, and load. Initially, voltage and current from the solar panel are sensed by using sensors. These voltage and current values can be inputted to the MPPT controller. Later these values can be processed according to the MPPT algorithm used to track the maximum power point of the solar panel. The output of MPPT block is used as input to DC-DC converter as the duty cycle. DC-DC converter helps in maintaining the operating voltage at the maximum power point of the solar panel by varying the duty cycle of DC-DC converter irrespective of solar irradiance and temperature.[6]

2. Literature Review

(T. Nasir et al., 2021) [9] The concept of smart grid was introduced a decade ago. Demand side management (DSM) is one of the crucial aspects of smart grid that provides users with the opportunity to optimize their load usage pattern to fill the gap between energy supply and demand and reduce the peak to average ratio (PAR), thus resulting in energy and economic efficiency ultimately. The application of DSM programs is lucrative for both utility and consumers. Utilities can implement DSM programs to improve the system power quality, power reliability, system efficiency, and energy efficiency, while consumers can experience energy savings, re- duction in peak demand, and improvement of system load profile, and they can also maximize usage of renewable energy resources (RERs). In this paper, some of the strategies of DSM including peak shaving and load scheduling are highlighted. Furthermore, the implementation of numerous optimization techniques on DSM is reviewed.

[10] [10] The Conceptual views on renewable energy sources, the use of unconventional sources and integration, future challenges for "Renewable energy sources (RES)" and strategies for controlling different types of microgrids are specified in this paper. The importance of RES has increased in the electrical system power network due to their periodic nature. Its generation does not coincide with load point when need for Energy Management Systems (EMS) is created.

(Eskandari & Savkin, 2021) [11] Fault ride-through (FRT) is essential for inverter- interfaced distributed generation (IIDG) units to protect semiconductor switches from being imposed to overcurrent conditions while the transients are securely passed. To this end, a current limiting strategy is adopted for IIDG units, mostly embedded in control loops, to limit the current within the withstand-able band and to make the IIDG units stay connected to the (micro) grid during the transient.

(Yasin et al., 2021) [12] The advantages offered by DC microgrids, such as elimination of skin effect losses, no requirement of frequency synchronization and high efficiency for power transmission are the major reasons that microgrids have attracted the attention of researchers in the last decade. Moreover, the DC friendly nature of renewable energy resources makes them a perfect choice for integration with DC microgrids, resulting in increased reliability and improved stability.

(Yousaf et al., 2020) [13] A nano-grid is an independent hybrid sustainable framework that utilizes non-renewable and renewable power resources for supplying continuous electrical energy to the load. Considering this scenario, in this research work, photovoltaic (PV) array, wind turbine, and fuel cell are taken as the three generation resources that have been used in the nano-grid. The active and reactive power of the all three generation resources is controlled using various controllers, i.e. integral, proportional-integral, proportional derivative, proportional integral derivative, fractional-order proportional-integral, fractional order proportional integral derivative (FOPID) and sliding mode controller (SMC).

(Macklin, 2020) [14] Solar panel costs have steadily declined to make them a very affordable option for distributed generation. However, battery costs have not declined at the same rate. The important figure of merit for microgrids is the efficiency of stored electricity. The architecture presented in this work is shown to minimize losses in stored electricity. Another key feature of the system is the ability to prioritize loads by controlling the power flow of the system.

(Belmahdi & El Bouardi, 2020) [15] Renewable energy based Distributed Generation (DG) in form of PV power system can tackle the growing demand of depletion of electrical energy resources and the increasing prices of oil. Smart grid is the innovation of recent infrastructure grid and DG is an essential part of it. The Moroccan government has also made significant changes to its renewable energy policy to promote clean energy. The aim of this paper is to show the way to implement the concept of simulating and optimizing the real time of dynamic data in that microgrid implementation in Morocco is beneficial with regards to both optimum solution and sensitivity analysis.

(Xiong & Yang, 2020) [16] Due to the exhaustion of fossil energy, the utilization of renewable energy resources is developing quickly. Due to the intermittent nature of the renewable energy resources, the energy storage devices are usually adopted in renewable power generation system to enhance the system reliability. In this paper, the photovoltaic-based DC microgrid (PVDCM) system is designed, which is composed of a solar power system and a battery connected to the common bus via a boost converter and a bidirectional buck/boost converter, respectively.

(Abdelgawad, 2020) [17] The primary objective of the research proposed is to control the output voltage or current of the PV array to generate maximum possible power at a certain irradiance and temperature. This can be achieved by implementing the maximum power theorem for load matching using the relationship between input and output impedances.

(Cucuzzella, 2020) [18] In this research, a distributed control scheme is proposed that achieves fair power sharing and weighted average voltage regulation in dynamical DC microgrids. A microgrid is considered where DGUs are connected through dynamic resistive-inductive power lines and supply so-called ZIP- loads. Furthermore, every distributed generation unit is complemented with a local controller that communicates with neighboring controllers over a communication network. Achieving fair power sharing and weighted average voltage regulation reduces maintenance cost and prevents DGUs for breakdown which increases the stability and reliability of a power system.

(Zheng et al., 2019) [19] In this paper, a practical PI-PD controller parameter tuning method is proposed, which uses the in center of the triangle and the Fermat point of the convex polygon to optimize the PI-PD controller. Combined with the stability boundary locus method, the PI-PD controller parameters that can ensure stability for the unstable fractional-order system with time delay are obtained.

3. Microgrid System

As “electric distribution technology” evolves into the 21st century, new advancements are emerging that will have a significant impact on the energy supply. Demand side increases in availability and efficiency of energy, as well as supply-side integration of “distributed generation and peaks-having technologies”, are driving these changes in both directions.

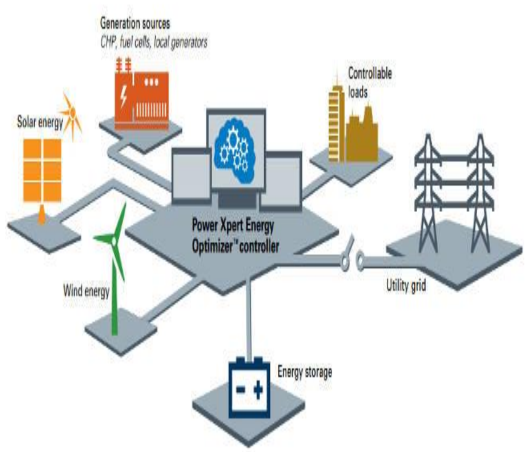

Figure 3 Microgrid Structure

As a consequence of deregulation and an increase in distributed energy supplies, power systems are now experiencing significant changes in their operational needs. Many distributed energy resources (DERs) make use of diverse technologies that enable the production of energy on a small scale (microsources), and some of them use RES like solar, wind, or hydro energy. Reduced transmission losses and avoided network congestion are two advantages of using microsources near to the load. Customers on low voltage (230 V or 110 V) distribution grids may avoid power outages since nearby microsources, programmable loads, and energy storage devices can all function independently in the event of major system problems. Today, this is referred to as a “microgrid”. A typical microgrid is shown in the diagram. In comparison to a low voltage distribution feeder, the characteristic microgrid is the same size and seldom exceeds “a capacity of 1 MVA and a distance of 1 km in length”. It is common for the microgrid to provide both electricity and heat to the consumers through CHPs, gas turbines, fuel cell systems, PV systems, wind turbines, and other sources. Typical energy storage devices include “batteries and flywheels”. [2]

An energy storage device in the microgrid acts as a rotating reserve for traditional grid-scale power producers, ensuring that energy production and consumption remain balanced during periods of rapid change in demand or supply.

When it comes to the needs of the end user, microgrids provide both the necessary thermal and electrical energy, as well as increasing local dependability, decreasing emissions, and enhancing power quality by minimizing voltage spikes and dips, all while possibly lowering the cost of energy delivery. Distributed energy sources may lessen the utility's need for transmission & distribution infrastructure. Dispersed generation near loads will lower transmission and distribution circuit flows with two major effects: loss reduction and the possibility to possibly replace network assets. With the generation close to demand on hand, consumers may notice a better service as a result. In times of stress, microgrids may help networks by easing congestion and assisting in fault recovery. The development of microgrids may help reduce “greenhouse gas emissions and mitigate climate change”, as well. Renewable and low-emission micro-sources are available, as well as new technology for distributed generating units, making this possible.

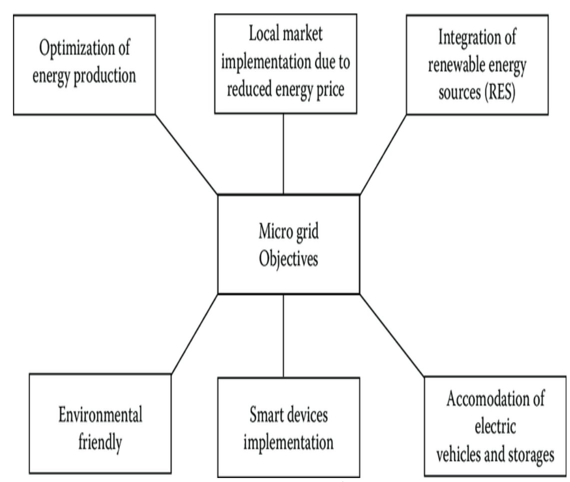

Figure 4 Advantages of Microgrid

End-users, utilities, and society all benefit from microgrids in various ways, including increased energy effectiveness, reduced complete energy consumption, decreased emissions of greenhouse gases and other pollutants, enhanced “service quality and reliability”, and the ability to replace ageing electricity infrastructure at a lower cost. [1]

When it comes to operating and controlling microgrids, the hurdles are enormous. In order to keep a microgrid's inverters operating at stable frequencies and voltages even when their loads fluctuate arbitrarily, it is necessary to create complex control systems for the microgrid's inverters. Many scholars and government agencies in Europe, the United States, and Japan have been intrigued by the microgrid idea in light of these factors. The integration and operation of microgrids, on the other hand, has its own set of challenges.

4. DSM-PI Controller

The gains are locked to a certain value in a "conventional PI controller". Differently the value of the "DSM-PI controller" is continuously altered by mistake. This "DSM-PI controller" lowers response time by continuously monitoring the proportional and integrated gains of Kp and Ki. This system's main perk is that it shortens response times by dampening vibrations and tremors.

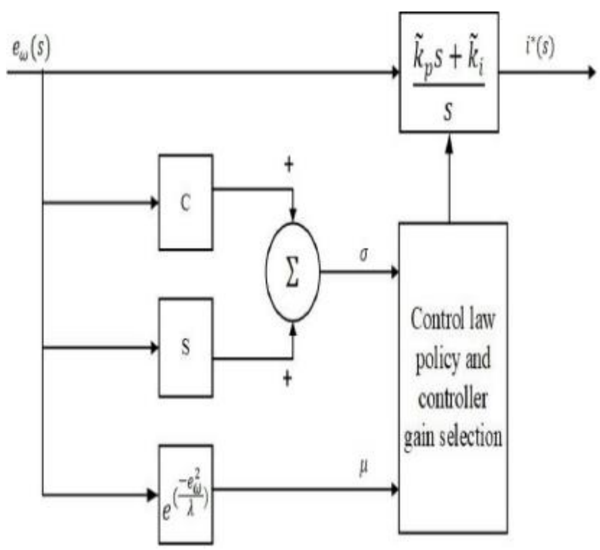

Figure 5 DSM-PI block diagrams

Therefore, the "DSM-PI controller" accelerates the speed response and causes reduced oscillations and perturbations. [59]
"DSM-PI controller continually monitors Kp and Ki's gains of proportional and integral gains," therefore the reaction time is much decreased. Reduced oscillations and disturbances speed up the speed-time response, which is a major benefit of this design.
Figure 5.4 depicts a block schematic of the DSM PI controller under consideration. Sliding surface blocks C and S determine the switching laws that define the "DSM PI controller gains kp and ki."

4.1 Comparative Analysis between PI and DSM-PI Controllers

Since the error produced by the system is not constant, the fixed gains in a PI controller are a detriment while it is in use. To improve time responsiveness and thusly get around this restriction, a "Dual Sliding Mode with Proportional and Integral (DSM-PI) controller" is used.
Because of the DSM-PI controller's constant monitoring of "proportional gains and integral gains," the reaction time is greatly reduced. Reduced oscillations and disturbances speed up the speed-time response, which is a major benefit of this design.

5. Conclusion

Complete modeling and analysis of the proposed two PVA module system with load compensation during different operating conditions is shown. The comparative analysis is done when the booster converters are operated with SM-PI and DSM-PI controllers proving that DSM-PI controller is more efficient as it is extracting more from PVA modules. It is also shown that power from PVA is stored in battery during excess power generation and battery provides change during deficit power from PVA modules due to low solar irradiation conditions.

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