ISSN 2277 – 8322

A Detailed Review on Designing of 1MW Solar Diesel Hybrid System with MPPT and Controller

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Abstract: Hybrid systems became an important solution to reach the remote area and maximizing the economic, technological, and environmental benefits. The hybrid system including renewable energy sources have been used in remote areas around the world. Military deployments are often done in remote places that are geographically far from the continent. In many cases, these places are not served by the major grid, requiring the use of diesel generators to provide the whole power need for the deployment.

This article contains the detailed information related to designing of 1MW, microgrid which contains the photovoltaic system and diesel generator. The application of this microgrid is generally used in islanding areas. The application of MPPT techniques also included for getting maximum output from solar system Incremental conductance.

Keywords: Photovoltaic System, Wind Energy System, Solar System, MPPT Techniques, Renewable Energy.

I. Introduction

Microgrid are decentralized group of electricity sources and loads that normally operates, connected to and synchronous with the traditional wide area synchronous grid (microgrid), but can disconnect from the interconnected grid and function autonomously in "island mode" as technical or economic conditions dictate. A microgrid has self- sufficient energy system that serves a discrete geographic footprint, such as a business center, or neighborhood, college campus and hospital complex.

Renewable energy sources utilized in distribution networks, in conjunction with the electrification of charging stations in smart grids, offer a means of increasing power conversion efficiency and reducing emissions.

The United States Department of Energy Microgrid Exchange Group defines a microgrid as a group of interconnected loads and distributed energy resources (DERs) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both connected or island-mode. An EU research project describes a microgrid as comprising Low-Voltage (LV) distribution systems with distributed energy resources (DERs) (micro turbines, fuel cells, photovoltaic (PV), etc.), storage devices (batteries, flywheels) energy storage system and flexible loads. Such systems can operate either connected or disconnected from the main grid.

II. Microgrid Classification

The purpose behind grid connected microgrids development is to reduce reliance on the traditional grid system, lower energy costs, provide reliable power to critical loads, and enable island operation during grid disruption. As per Lawrence Berkeley National Laboratory (LBNL), microgrids can be distinguished into the following two key types (LBNL, 2016a):

Customer microgrids or true microgrids are self-governed and are usually downstream of a single point of common coupling (PCC). Many of the most well- known demonstrations of microgrid systems are of this type. Just as a traditional customer has considerable leeway in the operation of the power system on its side of the meter, so the restrictions on the nature of a microgrid are relatively loose. For this reason, much of the early deployment of microgrid technology is of this type.

Utility or community microgrids involve a segment of the regulated grid. While, technically, they may not be different from microgrids, they are fundamentally different from a regulatory and business model perspective because they are integrated into utility networks.

Bloomberg's research group divides microgrids into five categories (BNEF, 2017) shown below that are used in this thesis for analysis.

Commercial or Industrial: Such microgrids serve single users and are typically deployed by commercial and industrial customers. Single users include facilities like data centers, hospitals, airports, etc.

Campus or Institutional: These microgrids aggregate existing on-site generation with multiple loads that are co-located in a campus or institutional setting. Examples include university and corporate campuses, industrial parks, prisons, etc.

Community or Utility: Such microgrids serve multiple customers or services within a community. Examples include municipal utilities, water districts, and small sized load-serving entities. It is possible that such microgrids are integrated into utility networks rather than located behind a customer's meter. In case of utility microgrids, it is also likely that the utility controls the system, and the distributed energy resources are subject to utility regulation.

Military: These microgrids are deployed with a focus on both physical and cyber security for military facilities to assure reliable power without relying on the macrogrid. Examples included installations of the U.S. Department of Defense (Navy, Air Force, etc.).

Off-grid or Remote: These micro grids are never connected to a utility network.

Examples include power systems for islands, remote sites, and other unconnected locations. Regardless of the classification, microgrids are typically managed by a smart controller often known as the microgrid controller. The sophistication and cost of the microgrid controller depends on the types of functions it is engineered to deliver.

III. Previous Research

Kotb, K. M. et al. (2020), currently stated that the global gives a unique awareness of sustainable development by exploiting renewables to provide the people with affordable and clean energy and preserve the climate. Their paper proposes a methodical and explicit framework of four phases, to design an autonomous hybrid renewable energy system in a community area in Egypt:

preliminarily assessment, design optimization analysis, findings evaluation, and power-quality assessment. In the first three phases which was performed by HOMER Pro software, five hybridization scenarios were evaluated and compared regarding their life-cycle cost, carbon outflows, and reliability to distinguish the extraordinary scenario to supply the addressed community area. Contrary to most studies that suffice only the first three phases, the fourth phase is proposed to perform a power-quality valuation based on a power management strategy (PMS). The results reveal that the optimal configuration consists of a photovoltaic generator, wind-driven generator, diesel-genset, battery-bank, and a power converter as shown in Figure 2.1 with the minimum net present cost of 351,223 $ and energy cost of 0.2262 $/kWh among all configurations. The optimal system has a negligible capacity shortage of 0.0955% and produces the least number of emitted gases by 50.43 tones/year due to the high renewable fraction (57%). Moreover, the optimal proposed system can recover the invested money after only 3.4 years [1].

Ahmad, Furkan, and Mohammad S. A. et al. (2018), present details of governmental initiatives in terms of acts, policies, mission, scheme & incentives since 2000, worldwide investment in the Indian power sector to promote the Renewable Energy Sources (RESs) and the feasibility of solar and wind-based electrical energy throughout Indian terrestrial. This work further presents a comprehensive framework for the deployment of microgrids in the Indian scenario. To validate the presented framework, 9 microgrid at different locations were considered deploying Homer as simulating and optimizing tool by incorporating environmental constraint and grid availability parameter [3].

Ishraque M. F. et al. (2021), stated in their research paper that system design and performance evaluation were conducted on a solar battery-based hybrid renewable energy system (HRES) with diesel backup for a school in a remote area located in the northern part of the country, where conventional power grid connectivity was not available. From field survey, a load demand of 10.468 kWh/day for a normal working day and a peak demand of 3.3 kW were considered in their work for the proposed site. For simulation purpose hybrid optimization model for electric renewable, very well-known software was used. The solar radiation data required for the work were collected from NASA Surface meteorology and Solar Energy database. Analysing the load requirements and metrological data a solar-battery diesel generator-based HRES was proposed for the school. From the analysis and simulation, the Net Present Cost (NPC) for the proposed system was found USD 6191 with a Cost of Energy (COE) of $0.125/kWh. Further, a comparative study was done, and the proposed system can reduce the COE and Green House Gas (GHG) emission of about 29.85% and 69% respectively than the conventional power plants [4].

Evbogbai M. J. E. and Ogbikaya S. et al. (2019), in their work stated that the solar energy is available for everybody, hence if harnessed, can sustain the electrical energy need for meaningful development in Nigeria. Although the initial cost implication may be high, but on the long run, it is more economical because of its renewable nature, less maintenance cost, and its environmental friendliness. Hence, for sustainable development to take place in Nigeria, the government, corporate bodies, and individuals should focus on photovoltaic power generation as one of the most viable options that could drive the civilization for ever [5].

Prakash S. S. et al. (2017), a methodology of designing a localized hybrid Microgrid for a rural area in the Pacific Island Countries (PICs) was presented in their paper. Nasau village was the chosen location for this design since necessary information of the village was provided by a local renewable energy sources (RES) installer. Typical loads found in rural villages were used to estimate the energy demand. This was accomplished using the bottom-up modelling strategy. Energy demand was then classified into three categories: typical village household, typical residential and commercial shop. Total energy demand of the village was then estimated from the product of each classification with respective quantities present in the village. This estimated energy in conjunction with input parameters were used in HOMER for the final simulation. The system configuration satisfies the design parameters and Sustainable Energy Industry Association of the Pacific Island (SEAPI) guidelines. It was observed that the proposed microgrid design was feasible after comparing the supply behaviour of the sources (PV, Battery Energy Storage System (BESS) and diesel generator) with the load profile [12].

Ramazan B. et al (2014), present an overall description and typical distributed generation technology of a microgrid. It also adds a comprehensive study on energy storage devices, microgrid loads, interfaced distributed energy resources (DER), power electronic interface modules and the interconnection of multiple microgrids. Details of stability, control and communication strategies were also provided in their study. This article describes the existing control techniques of microgrids that were installed all over the world and has tabulated the comparison of various control methods with pros and cons. Moreover, it aids the researcher in envisioning an actual situation using a microgrid today and provides insight into the possible evolvement of future grids. In conclusion, the study emphasizes the remarkable findings and potential research areas that could enrich future microgrid facilities [13].

K. Ravichandrudu et al (2013), this work analyses micro-grid operation of a system based on renewable power generation units. The system behaviour and technical issues involved with three operational modes in micro-grid scheme were identified and discussed. The investigation was performed based on simulation results using MATLAB/Simulink software package. Simulation results indicate that dump load and suitable storage system along with proper control scheme were additionally required for the operation of the study system in a micro-grid scheme. A control coordinator and monitoring system was also required to monitor micro-grid system state and decide the necessary control action for an operational mode. The required control schemes development for the proposed micro-grid system is currently under investigation by the authors [27].

IV. Operation and Components

The whole block design of the planned 1-MW microgrid system for the army is shown in Figure 1. PV, battery, and inverter are only few of the many sub-systems it contains. Each component system is described in detail below.

A. Technical Details of the Setup

The authors of this article suggest an isolated 1-MW microgrid system for military use. Phase-phase AC voltage output of 400V rms is specified for the system. After accounting for voltage loss across output LC filter, the output AC voltage of 400V rms requires a dc link voltage of around 665V at the input of the inverter. By charging and discharging the battery system with the aid of a dc-dc bidirectional converter, the authors of this study are able to keep the dc-link voltage constant at 665V. The same is described in the following parts.

B. Photovoltaics

The planned solar-powered islanded microgrid would rely mostly on renewable energy sources. The authors suggest a microgrid with a total solar capacity of 1 MW. In Fig. 1, the PV system block depicts the same thing. In order to meet the required PV system parameters, PV systems use series and parallel configurations of PV panels. The PV system is designed in such a way that a dedicated converter and controller are unnecessary for MPPT.

In the proposed microgrid idea, the 1Soltech 15TH-215-P solar panel module was used. A single solar panel can produce 213.15 watts of energy from a 29-volt open circuit at its maximum power point (MPP).

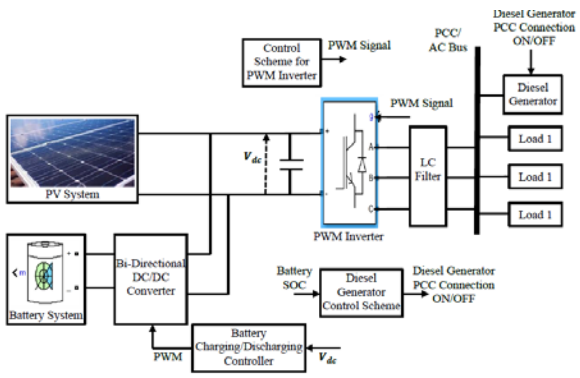

Figure 1. Block diagram of the proposed 1-MW microgrid

The MPPT is accomplished by serially linking 23 solar panel modules, eliminating the need for a controller and converter. Given an output phase-phase voltage of 400 V rms, the open circuit maximum power point voltage is 667V. Furthermore, since the battery dc-dc bidirectional converter maintains the dc link voltage, the PV system does not need an additional MPPT controller. The battery controller guarantees that the PV panel operates at its maximum power point voltage at all times.

V. Results & Conclusion

The goal of this thesis is to design and simulate 1MG micro grid (MG) system in islanded mode for the army and group members. To minimize environmental impact, the projected MG will use a 1MW photovoltaic (Photo-Voltaic) system as its primary renewable energy source.

Conclusion Intelligent networks are the future of traditional systems, and they may be realized more effectively by improving MGs, which are a variety of electrical and electronic devices. The distributed paradigm is becoming increasingly popular as customers and utilities desire more flexibility and autonomy. DC Microsystems conducts extensive study since they have more characteristics than AC systems. In the case of the central controller, the energy management system is at the core of MG control. However, it is not as trustworthy as the previously indicated control approach in the case of decentralization.

VI. Future Scope

In the future, MG might be an appealing alternative for integrating DG units into a smart grid, reducing reliance on fossil fuels and improving grid efficiency. However, issues remain due to the following factors: the quick dynamics and short reaction time of DG or distributed energy, the inherent imbalances of MG, limited energy storage capacity and lack of inertia, and huge numbers, large numbers, enormous numbers. Micro sources, power converters for electronic equipment and other circuits / equipment, high parameter uncertainty, modeling, and a high error rate are all commonly employed. This benchmark research allows for the investigation of transient stability, the testing of control techniques and hierarchical control structures, the exploration of isolated situations, the simulation of diesel generator dynamics, and the compensation for voltage distribution. Although it is highly dependent on the application and integration environment, the research may enlarge on the scenarios and topologies of linked AC /DC HMGs and enable dynamic analyses of various AC /DC HMG combinations.

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