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A Small Rural Village Energy Source: A Hybrid Microgrid

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Abstract*: Hybrid microgrids can offer a reliable and lasting energy solution to remote rural small settlements that lack access to centralized electricity. Hybrid microgrids ensure the provision of continuous electricity supply through the application of multiple renewable energy types (solar, wind, biomass, etc.) as well as contingency actions such as diesel generators or batteries. The plan is a low impact on the environment, powering the poor, and reducing dependence on fossil fuels. The microgrid architecture is modelled to suit the demand of the load as well as the availability of the resources at the local level, creating economic growth and energy efficiency. This paper focuses on the design, components and benefits of hybrid microgrids and demonstrates how decentralized and clean generation of power can transform rural electrification and lead to resiliency within a community.*

Keywords*: Smart grid system, Battery storage system, Islanded grid system, Neural networks, Fuzzy logic*

I. Introduction

In isolated or undeveloped regions, low-cost reliable energy remains a significant problem to many of the small rural communities. Traditional grid expansion is often not feasible due to low populations densities and difficult terrain, as well as costly infrastructure, particularly on an economic and logistical level [1-2]. To this response, hybrid microgrids present themselves as a sustainable and an efficient alternative to rural electrification. A hybrid microgrid integrates multiple energy sources, most of them from renewable sources such as biomass, solar and wind, with backup facilities such as storage plants or diesel generators. This blend reduces the use of fossil fuel and its degrading impacts to the environment and ensures a strong, constant and round-the-clock supply of power. Hybrid microgrids are flexible, scalable, and economical because they tie the available local resources to the electricity demand. All of this drastically increases the quality of life in the countryside since by sustaining key functions, such as local business, healthcare, education, and lightning they make the living there much easier. This research looks into the design, operation, and benefits of hybrid microgrids as an energy source to small villages in rural areas [2-4].

II. Research Method

The research employs the mixed-method approach that has merged feasibility analysis, simulation, modelling, and site-specific data gathering. First, the local availability and energy demand are analysed based on field survey and meteorological data (solar irradiance, wind speed, and biomass availability). Thereafter, a hybrid microgrid model is designed via HOMER Pro software to represent a number of scenarios that involve a combination of diesel backup, and battery and renewable energy [5]. The various factors that are considered are environmental, technological, and economic such as emissions, dependability, and energy costs. They also obtain stakeholder interviews and community input in order to consider social acceptance and long-term sustainability and ensure that developed solution is appropriate to local requirements and conditions.

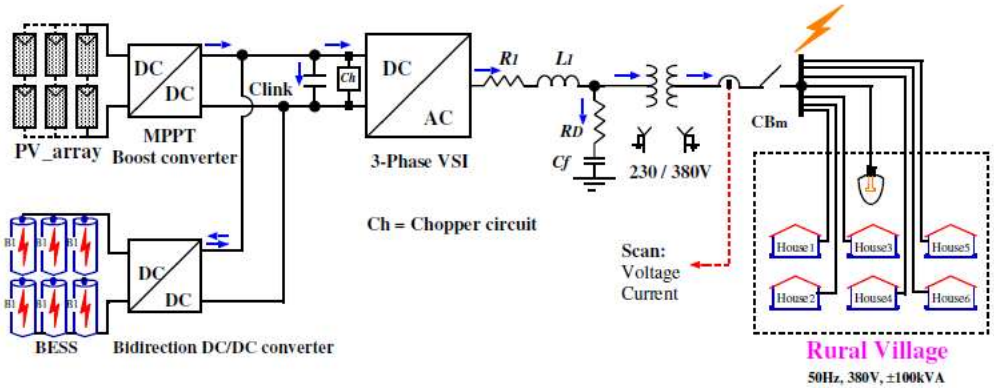

Fig 1: Topology of proposed system

III. Battery Storage and Inverter System

In rural application of villages such a hybrid microgrid, battery storage along with inverter systems are critical components where grid connections are unreliable or nonexistent. Due to the variation in generation or demand, in case of low generation or excess demand, battery storage devices provide constant energy supply by storing the excess generation due to renewable sources like solar and wind. These aids in load balancing, robust volts& frequency and enhances energy firmness. The most widely used battery technologies are lithium-ion, lead-acid and as of late, flow batteries due to efficiency and scalability. Battery and renewable energy power is converted into alternating current (AC), which local inverter system can utilize and use. It also guarantees a good distribution of energy since the sources, storage and loads of power are regulated. The contemporary inverters have features of smart load management, remote observation, and grid-forming, which are vital to self-sufficient microgrids operation. Combining battery storage with inverters strengthens the system and reduces the use of diesel generators, as well as appealing to sustainable, day-and-night electrification in small rural locations.

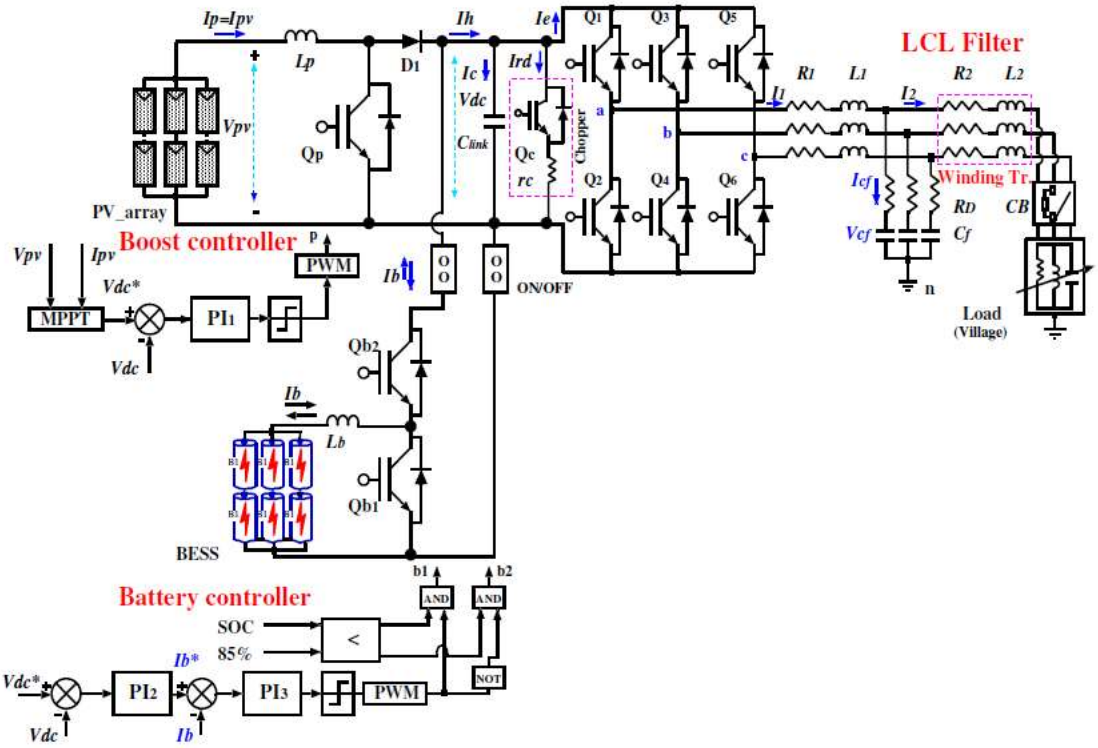

Fig 2: Configuration of proposed system

IV. Control of the System

To make a hybrid microgrid stable and efficient, control system is a must, as it is required to synchronize generation, storage, and energy consumption. It monitors the real-time data including the load demand, the battery state of charge, and renewable resource availability to maximize the power distribution. One of the examples of control strategies is demand-side management, load forecasting and source prioritization which gives more preference to renewables. The control strategy done by decentralized or centralized controllers makes the decision-making automatic and lowers operating costs and fuel usage and balances supply demand. Intelligent algorithms allow integrating different power sources such as solar, wind, biomass, and backup diesel generators without any discontinuities. Protective mechanisms, synchronization and defect detection are handled by the system as well. There is greater reliability and fewer outages and the hybrid microgrid becomes standalone, making rural communities have ready, clean electricity with minimal human intervention.

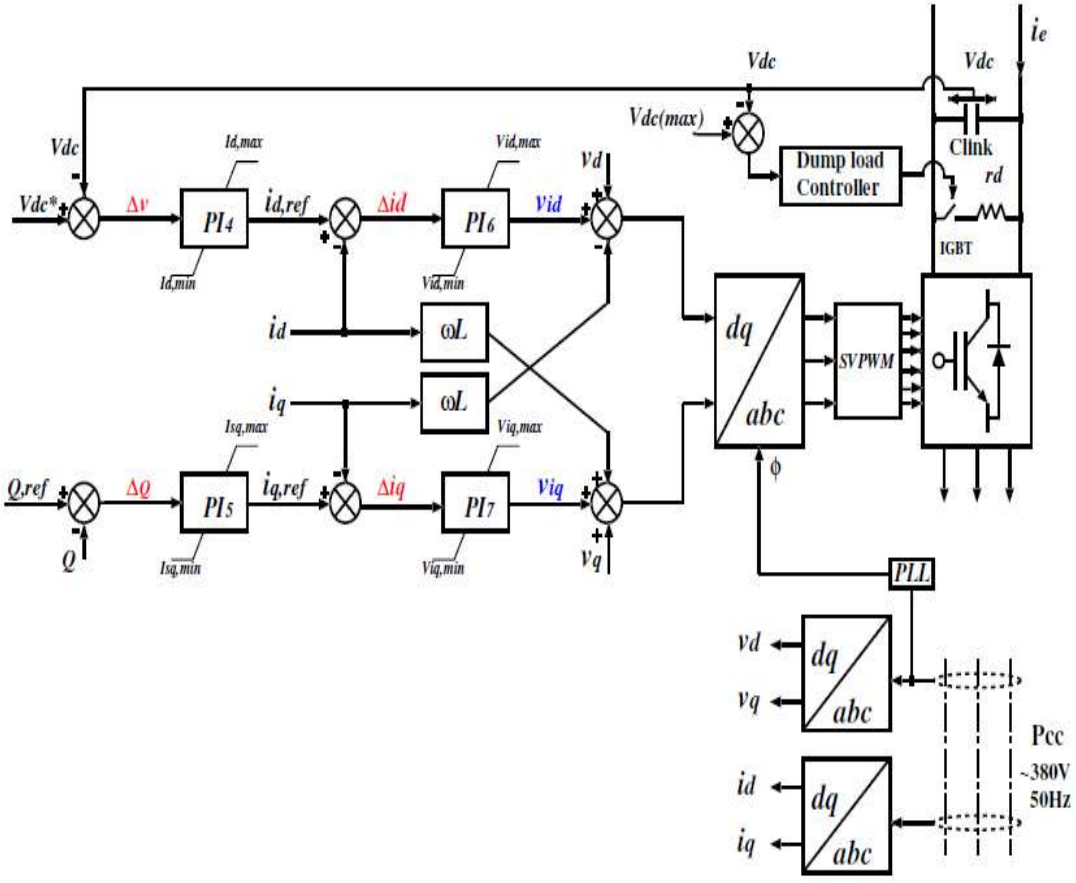

Fig 3: Grid side of the proposed system

V. Results and Discussion

The investigation and modeling of a hybrid microgrid of a small rural village indicate greater cost-effectiveness, sustainability, and energy reliability. When solar and wind are coupled with battery storage, the demand on diesel generators is significantly reduced and reduces both pollution and the costs of fuel. The system maintains a stable voltage and a constant source of power even in the periods of high demand or low renewable generation. Comparative economic analysis will make the energy cost lowered off when compared to a complete diesel system. Social feedback stresses better medical service, education, and illumination. The discussion shows that hybrid microgrids are a feasible, scalable rural electrification package that facilitates the sustainable development of communities and energy self-sufficiency.

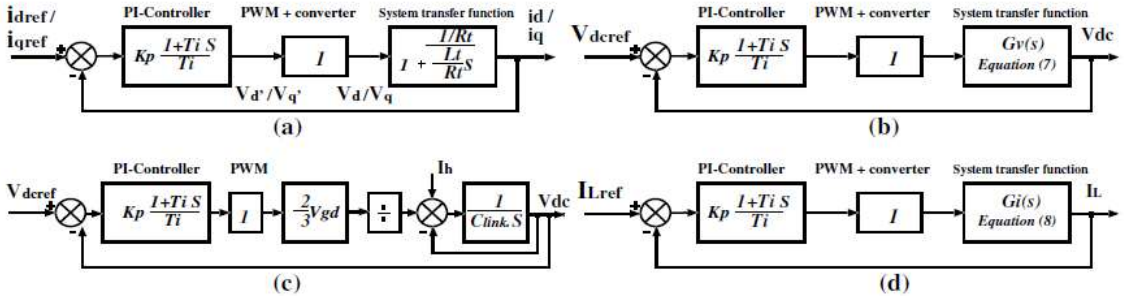

Fig 4: Ccontrol loops of block diagram

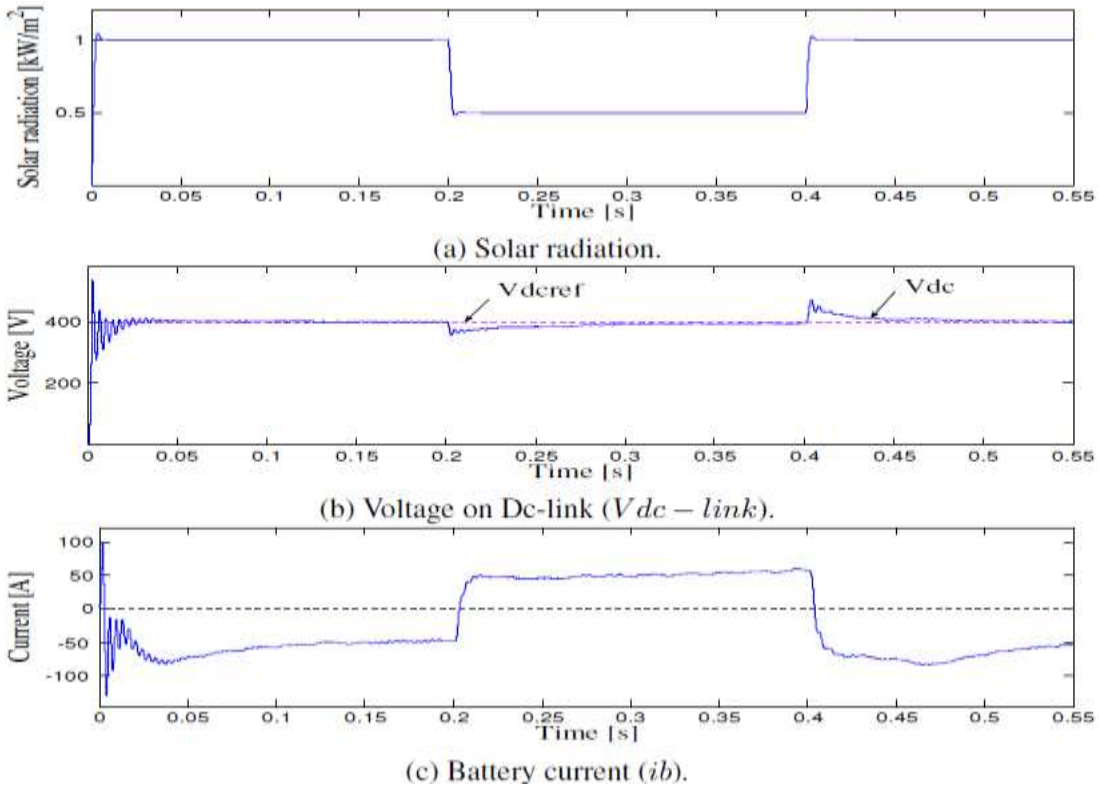

Fig 5: Simulation results on grid side

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