CONVERSION SOLUTION FOR INTEGRATING MULTIPLE ENERGY SOURCES FOR GRID-CONNECTED HYBRID RENEWABLE ENERGY SYSTEMS

SaedAmer, Postdoctoral at Tennessee State University, USA (samer01@my.tnstate.edu)
Landon Onyebueke, Professor at Tennessee State University, USA (lonyebueke@tnstate.edu)

ABSTRACT

A proposed hybrid renewable energy system employs viable renewable energy sources such as solar, wind and hydropower to reduce the dependency on fossil fuel as the main energy source. Such system is usually reinforced with a storage system that collects the surplus energy and supplies it when the renewable sources depreciate. Though sound promising, but renewable energy sources alone suffer from inconsistency due to the intermittency. Hence, a backup diesel generator is integrated in the system to overcome such shortcomingwhen the renewable energy power is insufficient. This study describes a technique that encapsulate the variable power sources obtained from the renewable energy, battery and the diesel generator to ensure a robust and steady supply to meet the required demand. The proposed technique guarantees a robust power management scheme that ensures maximum utilization of the clean and abundant renewable energy. The main objective is to develop higher-level high frequency-based power converter system using efficient and smart power converters to be integrated between the variable energy sources and the utility grid. The proposed converter system will maximize the utilization of renewable energy sources and enhance the quality of the injected power. A simulation tool is constructed to demonstrate and monitor the performance of the system under various circumstances. The dynamic modeling for each part in this system is simulated to analyze the performance of the hybrid power system with battery storage and a backup diesel generator. Various types of simulations were performed and a number of algorithms were developed to verify the effectiveness of the power conversion and management schemes.

INTRODUCTION

One of the major drawbacks of the renewable energy sources, while abundant and inexpensive, is the unpredictable availabilities and the intermittency which challengesitsreliability.Coal, petroleum, and natural gas provide what is called the conventional energy sources. The majority of the energy used is usually supplied from such conventional energy sources raising more concerns of environmental, political and sustainability issues. The main interest for current and future power production is seekingsources with desirable properties, such as sustainability, low carbon emission and environmental impacts, stable economic, safe, and independent of geographical constraints. Renewable energy technologies, suchas wind power, solar power, hydropower, and geothermalpower, can be used to reduce the emission of greenhouse gassesignificantly and at the same time reduce the dependency onthe oil industry [1]. Some types of renewableenergies such as wind power, hydropower, and geothermalpower have either very close or even better levelized cost of energy values compared with the conventional energy sources. However, there are some challenges when put to work such as intermittency. Table 1 provides a comparison among power sources in terms of power production, CO_2 emission, geographical constraint and environmental impact [2].

One of the considered solutions for intermittency of the renewable sources is integrating multiple renewable energy resources that currently sit ready to produce when needed [3]. The suggested integration of the clean electricity resources considers the reliable conventional energy sources for backup. The integrations of conventional dispatchable forms of electricity have some drawbacks such as beating the purpose of lowering the carbon intensity of electricity production. By requiring additional conventional source as a backup to smoothen renewable production, a limit is set on the fraction of electricity that can come from the carbon-free sources. Furthermore, a balancing mechanism is crucial to integrate intermittent sources beyond some level of penetration [4].

Table 1: Energy Sources Comparison Table [2]

Energy Source	**Power**	**CO2 Emission (g/kWh)**	**Geographic Constraint**	**Environment**
Coal	Base-load	1001	None	Poor
Natural Gas	Base- & peak-load	469	None	OK*
Nuclear	Base-load	16	None	Minimal
Photovoltaicsolar power(PV)	Intermittent	46	Yes	OK
ConcentratedSolar Power(CSP)	Intermittent	22	Yes	OK
Wind	Intermittent	12	Yes	Minimal
Biomass	Intermittent	18	Some	OK**
Geothermal	Base-load	45	Yes	Minimal
Hydroelectric	Base- & peak-load	4	Yes	Minimal
Ocean	Base-load	8	Coastal	Minimal***

*Fracking **Some CO_2 emission ***Marine life impact should be studied

Another solution that leaves a profound significance in the renewable energy industry is the utilization of energy storage systems. It has been noted that spatially uncorrelated renewable electricity productionmay have a balancing effect of its own. Electricity can be overproduced wherethe renewable energy sources areavailable and are, therein, dumped into the environment as waste. Such discarding of the surplus energy defies the purpose of the renewable energy solution by abusing the availability of energy and transforms harmless environmental phenomena into harmful ones. The main goal of this paper is to present a solution that optimally manage the production of electricity via renewable energy sources and increase its reliability by considering a storage system and a conventional diesel generator. This work proposes a smart energy conversion solution that facilitates the integration process of the multiple energy resources [5].

THE GRID-CONNECTED HYBRID RENEWABLE ENERGY SYSTEM

Hybrid systems can be designed through different layouts and by integrating several sources of energy that may include one or more renewable energy sources, one or more traditional energy sources and energy storage mechanism. Renewable sources can be combined with 2^n-1 number of possibilities where '*n*' is the type of renewable energy resource [6]. The team at the Design Methodologies Laboratory at Tennessee State University proposes a Hybrid Energy System that aims to demonstrate profound energy attributes such as reliability, environmental safety, cost effectiveness and minimal conventional energy usage.Figure1 shows that the proposed system consists of photovoltaic generators, wind generators, power conversion units, battery bank and diesel generator to back up the load [7].

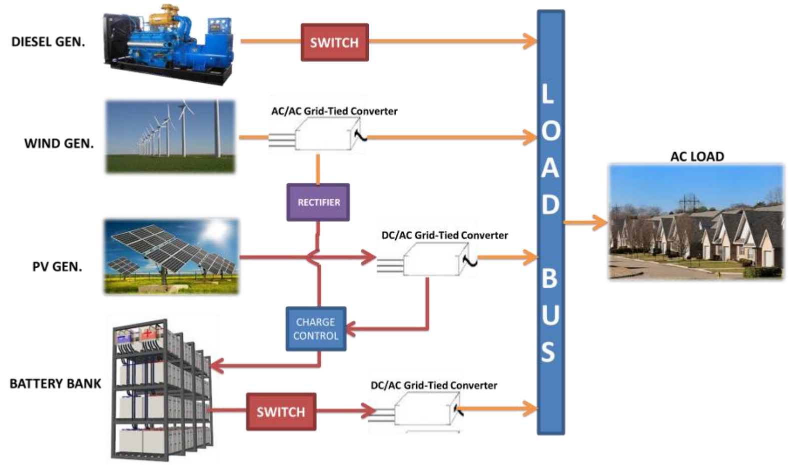

Figure 1: Hybrid Energy System Layout

The design of the proposed Hybrid Energy System was simulated based on a series of operating conditions established represent the assortment of scenarios that would be anticipated. During the evening, for example, solar radiation is unavailable; meanwhile, the power output of a wind turbine installed at a particular location is greatly affected by power output curve of the wind turbine, wind speed distribution of the selected location as well as the hub height of the wind tower [8]. The model was constructed to maintain full control of the test environment, conditions and parameters of each component by considering different loading, source availability, and time of day conditions. The system was simulated to follow a load profile for a commercial charging station where daily peak load of nearly 20kW for a given hour. The load was active for 16 hours and the pattern was simulated for 365 days. As depicted in Figure 2, the various source components were managed andsized [9].

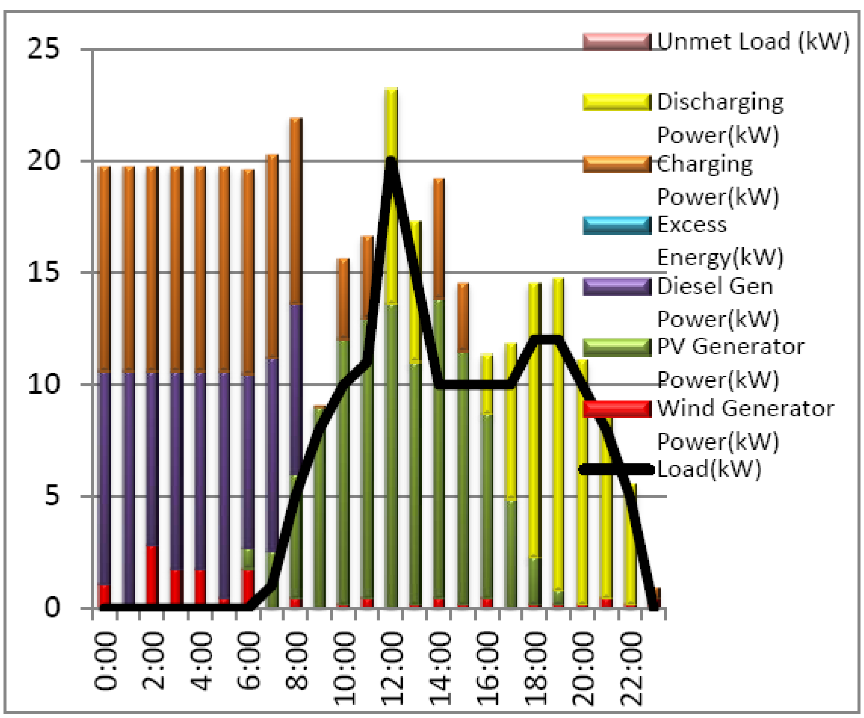

Figure 2: Fulfillment of Load Demand Using Hybrid Energy System [9]

THE CONVERSION TECHNIQUE

The proposed conversion technique suggest the exploitation of the new smart convertors that allow variable voltage inputs and guarantees the output to be consistent and ready to be injected to the grid. Such convertors are usually referred to as the Grid tied convertors; in this project a control ready convertors are proposed to allow the monitoring and the switching of the flow energy. Grid tied convertors consist of a step-up dc–dc converter, a grid-tied inverter and an automatic AC transfer switch. The renewable energy generators produces electrical energy is fed to the step-up dc–dc converter to boost the array voltage to a higher level. The grid-tied inverter inverts the DC power produced by the renewable energy sources into AC power aligned with the voltage and power quality requirements of the utility grid and the transfer switch changes supply source and also selects serving loads according to availability [10].

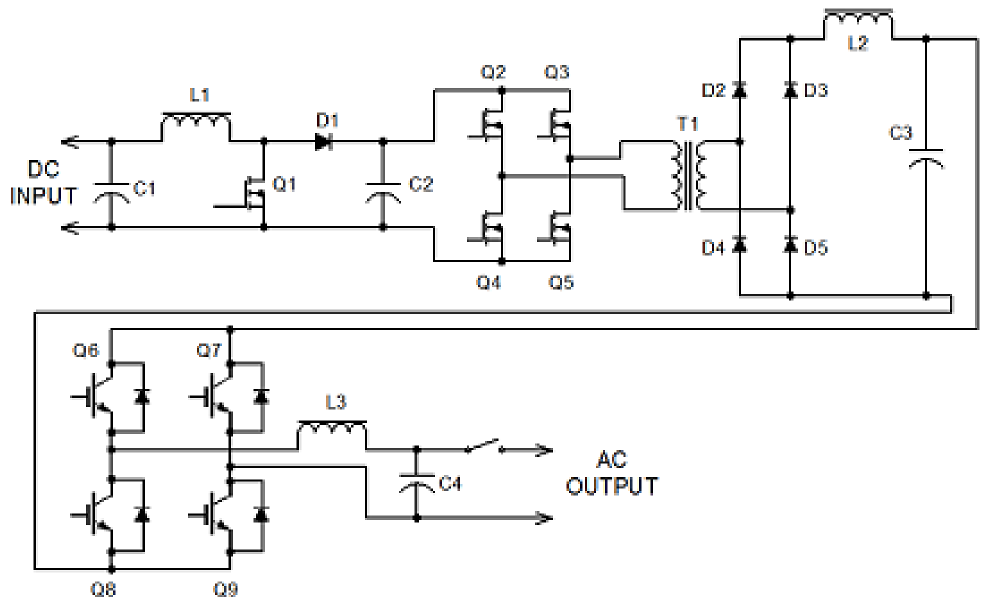

Figure 3: Grid-Tied Convertor Schematic [10]

The Grid Tied Inverter is the major component of the proposed system which not only regulates the voltage and current received from the wind, solar or battery sources, it also ensures that the power supply is in phase with the grid power. On AC side, it keeps the sinusoidal output synchronized to the grid frequency. In order to guarantee the supply that meets the loads or even supplies excess power to the utility, the voltage of the inverter output needs to be variable and slightly higher than the grid voltage. The operation principle of the proposed conversion system considers three power stages as illustratedin Figure 3. The first stage consists of a boost converter to step up the DCinput using an inductor L1, MOSFETQ1, diode D1 and capacitor C2. The second stage is used to ensure that the voltage is higher than the peak of the utility AC voltage. This stage is basically a pulse-width modulator DC-DC converter with a high frequency transformer T1 used to provide isolation between the first and the second conversion stages. The third conversion stage is a full bridge converter where the DC voltage is converted into AC byutilizing Insulated Gate Bipolar Transistorsand anLC-filter to reduce the high frequency harmonics and produce a sine-wave voltage.

THE CONTROL SCHEME

The main purpose of the proposed system is to guarantee maximum utilization of the available renewable energy supply while ensuring stability and consistency of the supply to meet the demand. In order to achieve this goal, the system follows a predefined protocol that gives priority to the renewable energy allowing for the diesel generator as the last resort. As showing in Figure 4, the control scheme first search for availability of the renewable energy, then searches for available stored energy to be added to the supply, and finally considers adding the Diesel energy.

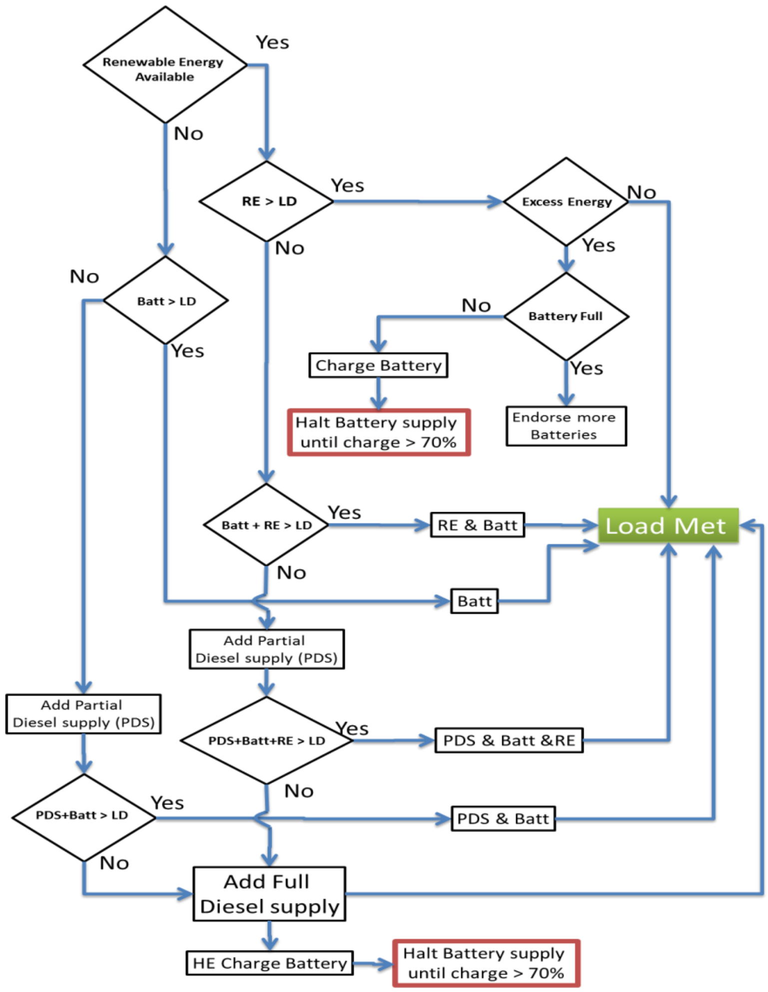

Figure 4: Hybrid Energy System Control Scheme

The system follows an algorithm that guarantees optimum exploitation of the abundant renewable energy (RE) sources with several stages and different scenarios. One of the scenarios suggests maximum availability of renewable energy that meets and/or exceeds the load demand. In this case the demand is supplied solely by the RE and, if available, the excess energy is utilized to charge the battery.Another scenario assumes that the renewable energy is available but does not meet the load demand and the battery energy is available. In this case, the system augments the battery energy to the renewable energy and supply the demand. The third scenario occurs when the RE is less than the load and the battery does not hold enough charge. Here the diesel generator kicks in with partial capacity to be added to the RE and supply the demand. Gradually the system keeps giving priority to the RE then to the energy stored from RE and finally resorts to utilize the diesel generator.

SIMULATION AND RESULTS

The system was simulated using a validtool that performs economic modeling for renewable energy and perform optimization analyses with different components arrangements. The study uses HOMER software (Hybrid

Optimization Model for Electric Renewables) provided by HOMER Energy LLC which navigates the complexities of load cost effective and perform load management when combining traditionally generated, renewable power and storage. HOMER was used to compare the feasibility and optimality of the proposed system against the conventional energy, conventional energy with battery as storage, and hybrid energy systems.

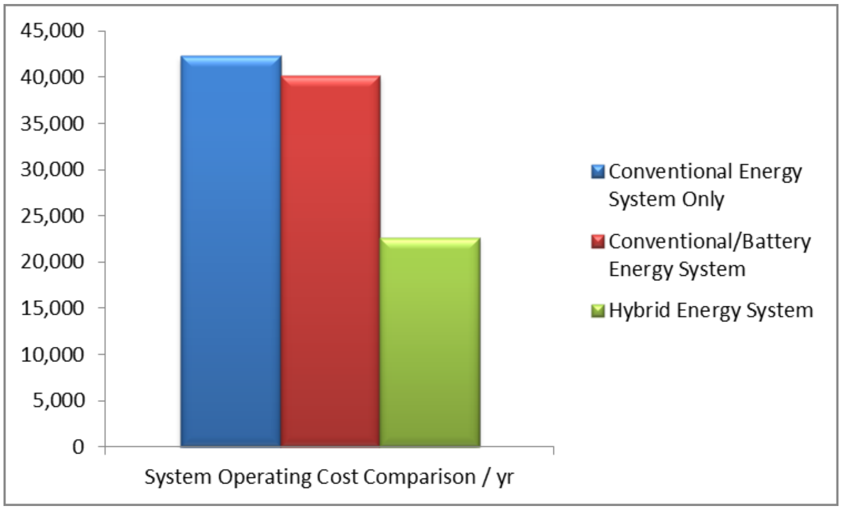

Figure 5: Operating cost comparison of the modeled systems [9]

As shown in figure 5, the operating costof the convention energy resources is nearly double that of the hybrid energy system giving the hybrid energy system superiorityover conventional energy and conventional and battery energy systems resulting in lower cost over the 25 years lifetime of the system. Net present cost analysis reviles that the Hybrid Energy System costs about 96% of the conventional system over the lifetime of both systems [9].

CONCLUSION:

Aiming to reduce waste and conventional energy consumption, the renewable hybrid energy system is a viable solution to create opportunities for prosperous and safer future. The Integration ofrenewable technology into existing system and new system designsoffers many advantages and solutions such as granting access to electricity in rural areas and underdeveloped countries to create or improve local industries and businesses. It can also promote convenience, comfort and advancements while decreasing the dependence on conventional energysources.The system utilizes the smart grid tied convertors that facilitate the transformation of the energy from the renewable energy resources into grid ready electricity. The system is also equipped with smart monitoring capabilities and switching that permits the management and control of the system. HOMER software was employed to determine the optimum design andsizing of the renewable hybrid energy system by calculating theannualized cost based on the systems components and loadprofile.

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