International Journal of Electrical and Electronics Engineers

Vol. No. 9, Issue No. 01, January-June 2017

ISSN (O) 2321-2055
ISSN (P) 2321-2045

REVIEW ANALYSIS OF SOLAR- FUEL CELL OF INTEGRATED ENERGY SYSTEM

Manish Khemariya[1], Arvind Mittal[2], Prashant Baredar[3], Anand Singh[4]

[1]Department of Electrical & Electronics, Lakshmi Narain College of Technology, Bhopal

[2,3,4]Department of Energy, Maulana Azad National Institute of Technology, Bhopal

ABSTRACT

Renewable energy integrated energy system have been proven through their ability to address the limitations of single renewable energy system in terms of power efficiency, stability, and reliability while operating at minimum cost. in this regards many research and practical experiences have been done. The present paper reviews the different hybrid solar PV–fuel cell integrated energy system used for electrical power generations. Dissimilar principles of sizing the different system components of integrated energy system at the most preferable logistical environmental and economic considerations have been discussed. Also, the paper discussed some of the optimization methods which are used to associate the energy making cost and presentation of different integrated energy system configurations using simulation techniques.

Keyword:-Solar PV, Fuel cell, HOMER,integrated energy system

I. INTRODUCTION

Renewable resources like solar energy or wind energy are essentially unpredictable and uncertain as far as their availability round the clock is concerned. Owing to their intermittent nature, the reliability and consistency of an energy system involving a single renewable energy source is very less. Also this would call for elaborate energy storage to ensure uninterrupted supply of power, especially when a stand-alone installation is considered. To address all these issues and to utilize the various renewable resources efficiently, two or more individual renewable energy sources can be combined together to function as an energy generation system. Such a system is called Integrated Energy Systems (IES) and can be deployed to meet the energy demand of rural areas, off-grid communities and remote applications. A mix of various sources such as solar PV panels, wind generators, micro hydro turbines, biomass, ocean wave, geothermal, tides, fuel cell and others sources of electrical energy can be utilized as required to meet the energy demand in a way that is appropriate to the local geography and other specifics[1]. When conventional sources are incorporated along with the renewable sources the systems are termed as Hybrid Energy Systems (HES). A complete IES may have various units other than the energy generating units, such as power condition units, energy storage units, controller units, backup power supply units etc.

An Integrated Energy System increases the reliability of supply and reduces the energy storage requirements (not requiring energy storage at all in some cases). It also reduces the overall costing and per unit cost of electricity, since many smaller units of sources can be put together to function in parallel with greater efficiency. Moreover, the incorporation and utilization of renewables present environmental advantages. Before developing an integrated energy system for a specific site, it is essential to know the particular energy demand and the

International Journal of Electrical and Electronics Engineers
Vol. No. 9, Issue No. 01, January-June 2017
ISSN (O) 2321-2055
ISSN (P) 2321-2045

resources available at that site. Therefore, energy planners must study the availability of solar energy, wind, and other potential resources at the site, in addition to the energy demand. This will allow them to design the suitable kind of integrated energy system that harvests the available energy effectively and meets the demands of the location at the best.

II. INTEGRATED ENERGY SYSTEMS

The high costs of commercially delivered electricity can be attributed to strong dependence on centralized energy systems which operate mostly on fossil fuels and require huge investments for establishing transmission and distribution grids. It would be even more uneconomical if the grid facilities are to penetrate remote regions making rural electrification relatively costlier compared to electrification of urban areas [2]. In order to tackle these problems there is a strong need for alternative systems of power generation and distribution. Unlike the centralized energy systems, decentralized energy systems are mostly based on renewable energy sources, operate at lower scales (of the order of few kW) both in the presence and absence of grid. They are easily accessible to remote locations because of the ability to function independently and generate power in the propinquity of demand site. Hence implementation of decentralized energy systems can handle the rural electrification imbroglio effectively by providing environmentally benign, sustainable and reliable energy supply [3]. Integrated Energy Systems (IES) possess many attractive features both technically and economically so that they are considered as the best representatives of decentralized energy systems. Although IES are more popularly used for off-grid applications, they may be employed for certain applications in areas where grid is available and is incorporated into the system. Therefore, IES are usually classified as Grid connected systems and Stand-alone systems.

The implementation of decentralized energy systems depends upon the extent of decentralization. In the case of a village decentralization, the system would be managed by local participation and specifically designed to cater to the local needs. In few cases, the excess power may be supplied to the grid. In the case of an industry level decentralization, the power generated would usually be from the by-product of industrial process (as in bagasse co-generation) and would be used mainly to meet its own needs with any surplus being fed into the grid. The extent of decentralization also determines whether the system operates in either grid-connected or stand-alone mode [4].

A grid connected integrated energy system is connected to the utility grid and feeds the generated power to the grid. Any local load connected to the system may derive power from the integrated system directly or through the grid. Such a system eliminates the requirement of a storage system since the load may be supplied from the grid when the integrated energy system is not operational and does not produce any power. In a grid-connected power system, the grid acts like a storage unit with unlimited capacity, which takes care of seasonal load variations and accommodates all fluctuations in the energy generation from the IES side [5]. However, a grid connected system may not be feasible in remote locations where the grid cannot penetrate and there may be no other sources of energy. In such cases, a standalone system may be employed giving priority to the needs and usage pattern of the local region with ample storage facilities. Stand-alone systems comprise the majority of Integrated Energy System installations in the remote regions of the world. In rural areas the electricity from such installations are usually utilized for irrigation, food preservation, crop processing, cooling and small-scale

International Journal of Electrical and Electronics Engineers
Vol. No. 9, Issue No. 01, January-June 2017
ISSN (O) 2321-2055
ISSN (P) 2321-2045

industries which in turn help in improving the living standard of the people [6]. They are often the most cost-effective choice for applications far from the utility grid such as lighthouses, remote weather stations, military applications etc. Stand-alone systems, however, require ample storage facilities (which has a major influence on the overall costing) to provide a reliable supply. In the rare cases when extra energy is generated at light load conditions and with no more storage possible, it would be forced to be discarded [5]. The economics associated with RET based systems may not be favourable in many cases, however, there has been a gradual decrease in the cost of such systems with respect to the maturing technology over time [7]. Smaller profitable units could be effectively deployed for sites or applications having a lower energy demand such as remote communities.

Certain barriers prevail with single source based RETs where the concept of integrated or hybrid RET systems is an ideal solution to overcome these barriers. For off-grid locations single technology approaches like stand-alone solar photovoltaics (SPV), wind turbines, small hydro power (SHP) or biomass resources do not meet the load demand continuously. Often these approaches lead to an over-sizing of the system and are not sustainable for longer periods due to high expenses [8]. In India, out of the RES available for decentralized electricity generation, SHP is the best suited option to combine with other RES in a hybrid system, with biomass based electricity generation as second-best. Modern technologies such as SPV systems and biomass based generation systems have made the use of RES an efficient option for decentralized, off-grid village electrification [9]. Yet, the one factor which is even more important than the environmental sustainability of these technologies and their suitability for off-grid locations, is cost. Eventually, only the most economic option of electricity generation will prevail. This is especially significant for renewable energy generation, where the costs and the RET employed usually depend on the specific location [10]. In the following section a brief description of different types of stand-alone integrated energy systems are presented.

2.1 Solar PV – Wind Generator and Battery Stand-alone Integrated Energy System

A block diagram of the integrated energy system with solar PV and wind power is shown in Figure 1. In order to extract the maximum available power from the wind and solar PV energy sources, lead-acid type battery is used to store the surplus energy and to supply the load during times of lean power production by the renewable resources [11]. The output of both the PV panels and the wind turbine is in the DC form. Both the sources along with the battery are connected together to a common DC bus. A DC-DC converter may be used to step up/down the DC level available from the bus. The DC-AC converter (inverter) is used to interface the DC bus voltage and the DC battery voltage to the AC load requirements. The energy produced from each PV or/and wind source is transferred to the consumer load through the DC-AC inverter, while the energy surplus is used to charge the batteries [12, 13].

International Journal of Electrical and Electronics Engineers
Vol. No. 9, Issue No. 01, January-June 2017
ISSN (O) 2321-2055
ISSN (P) 2321-2045

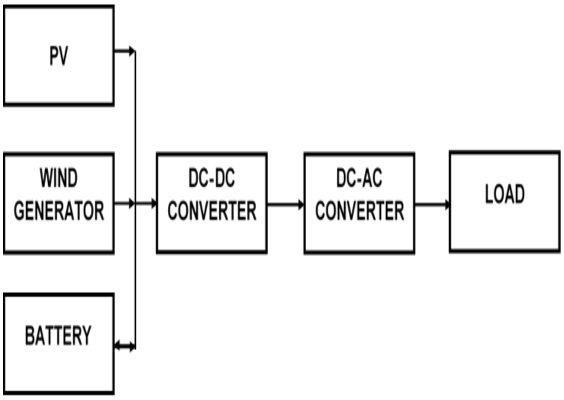

Figure **Error! No text of specified style in document.**: Block Diagram of Solar PV-Wind Generator and Battery Integrated Energy System

2.3 Wind Generator – Fuel cell and Battery Stand-alone Integrated Energy System

A block diagram of the integrated energy system with wind generator and fuel cell is shown in Figure 2. In this system, wind generator is main source of supply and fuel cell is a supplemented source of supply. This integrated energy system is combined with a battery bank and battery charger. When the wind generator is not operating, the fuel cell supplies the load as well as the battery charger to recharge the batteries (in case the batteries are low on charge). Batteries are used to provide backup when both the sources are non-operational. The DC-AC converter is used to interface the DC bus voltage and the DC battery voltage to the AC load requirements [13, 14].

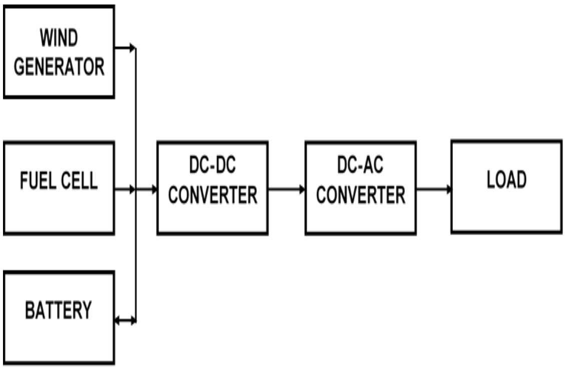

Figure 2: Block Diagram of Wind Generator–Fuel cell and Battery Integrated Energy System

2.4 Solar PV – Fuel Cell and Battery Stand-alone Integrated Energy System

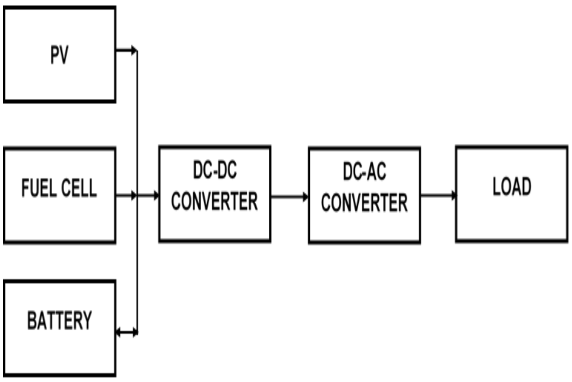

Figure 3: Block Diagram of Solar PV-Fuel cell and Battery Integrated Energy System

A block diagram of the integrated energy system with solar PV and fuel cell is shown in Figure 3. Here, the PV system is the main energy source of the system and fuel cell is used as a backup power source. During the day, the PV system feeds the load through the DC/AC converters. When the load is off-peak, surplus energy is stored in the battery bank. During the night or during periods in which the PV system cannot supply the full load, the fuel cell is operated to meet the demand. The battery bank supplies the load when both the PV system and fuel cell are non-operational [15].

III. REVIEW ANALYSIS

This section presents a study, design and optimization of complete integrated energy system. The commonly employed sources of energy are solar photovoltaic and PEM fuel cell system and storage systems like battery bank, hydrogen storage fuel cell system are used along with them. HOMER is usually used for the optimization of the integrated energy systems and it solves the optimization problem to minimize the total cost and provides the optimum sizing of the components.

K. Karakoulidis et al. modeled and optimized a renewable energy system that meets a known electric load with the combination of a photovoltaic (PV) array, a diesel generator and batteries [16]. They examined the replacement of the conventional technologies with hydrogen technologies. The modeling, optimization and simulation of the proposed system were performed using HOMER software. They indicated by the simulation results that the replacement of conventional technologies, namely diesel generators and batteries by hydrogen technologies is technologically feasible, reduces emissions, noise and fossil fuel dependence and increases renewable energy penetration.

Sowjan Kumar Kotte [17] optimized and compared three stand-alone renewable hybrid Wind Turbine Generator (WTG)-Battery, WTG-Fuel Cell (FC) and WTG-Fuel Cell (FC)-Battery power systems using HOMER software. Although this study shows that hydrogen energy storage system is economically less competitive with battery storage systems, there are other benefits to hydrogen storage system worth mentioning like environmental friendlier (no ecological cost is associated) and increase in storage size is cheaper compared to batteries. They concluded that among three WTG system configurations, WTG-FC-Battery hybrid system acquires the configuration with the lowest system cost as compared with either single storage system.

Ahmad Rohani et al. performed the simulation of a hybrid energy system composed of photovoltaic (PV) together with wind generators (WG), fuel cell (FC), and battery storage using optimization software HOMER and also designed a power management strategy [18]. They showed by the simulation results that a hybrid power system comprising of 150 kW peak photovoltaic system together with100 kW wind generator system, 25 kW fuel cell, and battery storage of 6 hours of autonomy (equivalent to 6 hours of average load), would be a feasible solution for distributed generation of electric power for stand-alone applications at remote locations.

BalachanderKalappan et al. presented a study and design of a stand-alone hybrid renewable power system [19] consisting of photovoltaic, wind turbine system, a battery bank and a hydrogen storage fuel cell model for day to day load demand of four metropolitan cities in India. They performed the sizing, optimization and economic estimation of the systems were using HOMER software. HOMER solves the optimization problem to minimize the total cost and provides the optimum photovoltaic, wind turbine, battery and fuel cell ratings. They suggested by the simulation results that this hybrid system is most suitable for all locations.

International Journal of Electrical and Electronics Engineers
Vol. No. 9, Issue No. 01, January-June 2017
ISSN (O) 2321-2055
ISSN (P) 2321-2045

G.P. Giatrakos et al. presented the sustainable planning of a renewable based energy system [20], which aims to fulfill the electric needs of Karpathos Island, Greece by replacing the existing diesel generators with new wind farms, photovoltaic installations and hydrogen production systems. The designing and planning of the system has been done using HOMER. They concluded by electric system design and least cost planning analysis that the system is best suited for the said island.

PrabodhBajpai et al. modeled, optimized and compared three stand-alone solar photovoltaic (SPV) power systems with different energy storage technologies i.e. SPV-Battery system, SPV-Fuel Cell (FC) system and SPV-FC-Battery system [21] .They have modeled and optimized the system using HOMER software and also analyzed the effect of using maximum power point tracker (MPPT) in all three SPV system configurations. They concluded that SPV-FC-Battery hybrid system with MPPT is most economic solution compared to single storage system.

Barsoum N .N. et al. investigated on the modeling of a stand- alone power system focusing on photovoltaic-hydrogen energy systems, which will be useful for remote users [22]. They have realized a complete simulation model in the software simulation environment and optimization is done using HOMER. They have concluded that remote systems, such as low-hydrogen-penetration systems could certainly become competitive in the near future, depending primarily on the fuel cell cost.

S.B. Silva et al. demonstrated the viability to produce hydrogen from the PV system in off-peak load and store it to provide power on demand using the local source, thus ensuring a continuous power flow [23]. They proposed a methodology to design of PV, batteries, electrolyzers and fuel cells analytically and the system is optimized using HOMER. They showed by the simulation results that the load management on the demand side allows better utilization of the hybrid system.

S.B. Silva et al. simulated a stand-alone photovoltaic-fuel cell-battery system for optimized sizing and costing using HOMER to supply electric power in a remote village [24]. They showed by simulation analysis that this hybrid system is not economically viable but by reducing the interest rates on the cost of electricity produced by this system, the cost of energy will be reduced, and the optimization showed that PV-battery combination is economically viable in this region.

IV. CONCLUSIONS

This paper discourses the ideas of off-grid forintegrated energy system power generation. Integrated energy systempermits high development in the power dependability, with high correctness and fast optimization techniques, high system efficiency, and reduce the schemesupplies for storages strategies. The paper has also presented different sizing techniques for off-grid Solar PV– Fuel Cellintegrated energy system. Accurate sizing of integrated energy system can significantly help to regulate the initial capital investment while maintaining system reliability at smallest cost. The optimization methods of the Solar PV– Fuel Cellintegrated energy systemwere also deliberated. The optimization techniques compare the performance and energy making cost of different system configurations and that will help to set up the optimum configuration of integrated energy system configuration using simulation techniques.

REFERENCES

[1.] Swati Negi and LiniMethew, "Hybrid Renewable Energy System: A Review", International Journal of Electronic and Electrical Engineering,2014,7(5), pp. 535-542.

[2.] Hiremath R, Shikha S, and Ravindranath N., "Decentralized energy planning; modeling and application—a review", Renewable and Sustainable Energy Reviews 2007,11(5),pp.729–752.

[3.] Renewable Energy Policy Network for the 21st Century, "Renewables 2005 Global StatusReport.",Washington,DC:WorldwatchInstitute.http://www.worldwatch.org/system/files/ren21-2.pdf. accessed on 12-01-15.

[4.] Kaundinya, D.P., Balachandra, P., and Ravindranath, N.H., "Grid-connected versus stand-alone energy systems for decentralized power—A review of literature", Renewable and Sustainable Energy Reviews ,2009, vol.13,pp. 2041–2050.

[5.] Kanase-Patil, A.B., Saini, R.P., and Sharma, M.P, "Integrated renewable energy systems for off grid rural electrification of remote area", Renewable Energy ,2010,vol.35,pp. 1342–1349.

[6.] Muneer T., Muhammad A., and SaimaM., "Sustainable production of solar electricity with particular reference to the Indian economy", Renewable and Sustainable Energy Reviews, 2005, 9(5), pp.444– 473.

[7.] Kanase-Patil, A.B., Saini, R.P., and Sharma, M.P., "Sizing of integrated renewable energy system based on load profiles and reliability index for the state of Uttarakhandin India", Renewable Energy, 2011,vol.36, pp.2809–2821.

[8.] Liming H., "Financing rural renewable energy: a comparison between China and India", Renewable and Sustainable Energy Reviews, 2009, 13(5), pp.1096-1103.

[9.] NouniM.R., MullickS.C., and Kandpal T.C., "Providing electricity access to remote areas in India: An approach towards identifying potential areas for decentralized electricity supply'", Renewable and Sustainable Energy Reviews, 2008, 12(5), pp.1187–1220.

[10.] June M. Lukuyu, and Judith B. Cardell, "Hybrid Power System Options for off grid rural electrification in Northern Kenya", Smart Grid and Renewable Energy, 2014, 5(5), pp. 89-106.

[11.] RachidBelfkira, Cristian Nichita and Georges Barakat, "Modeling and optimization of wind/PV system for stand-alone site", IEEE International conference on Electrical Machines, 2008, pp.1-6.

[12.] MaamarLaidi, Salah Hanini, BrahimAbbad, NachidaKasbadjiMezouk, and Mohamed Abbas, "Study of a Solar PV- Wind- Battery Hybrid Power System for a remotely located region in the Southern Algerian Sahara: Case of Refrigeration", Journal of Technology Innovation in Renewable Energy, 2012, 1(1), pp.30-38.

[13.] Mohamed A.H. El. Sayed and Adel M. Sharaf, "Hybrid Wind- Fuel Cell Renewable Energy Utilization Scheme for Village Electricity", International Middle East Power Systems Conference, 2010, pp.138-143.

[14.] M.T. Iqbal "Simulation of a small wind fuel cell hybrid energy system", Renewable Energy, 2003, vol. 28, pp. 511-522.

[15.] S.B. Silva, M.M. Severino, and M.A.G. de Oliveira, "A stand alone hybrid photovoltaic fuel cell and battery system: A Case study of Tocantins, Brazil", Renewable Energy, 2013,vol.57, pp. 384-389.

[16.] K. Karakoulidis, K. Mavridis, D.V. Bandekas, P. Adoniadis, C. Potolias,and N. Vordos,"Techno-economic analysis of a stand-alone hybrid photovoltaic-diesel-battery-fuel cell power system",RenewableEnergy,vol. 36,2011,pp.2238-2244.

[17.] Sowjan Kumar Kotte, Ravishankar, AbdullAhad,and Suresh Babu,"Dynamic Modeling and Simulation of a Wind Fuel Cell Hybrid Energy System for Standalone Systems with Hybrid Optimization Model For Electrical Renewable",Proceedings of International Colloquiums on Computer Electronics Electrical Mechanical and Civil,2011, pp.118-123.

[18.] Ahmad Rohani, KazemMazlumi,andHosseinKord, "Modeling of a Hybrid Power System for Economic Analysis and Environmental Impact in HOMER", IEEE Proceedings of Iranian Conference on Electrical Engineering,2010, pp.819-823.

[19.] BalachanderKalappan,andDr.VijayakumarPonnudsamy,"Modeling,Simulation and Optimization of Hybrid Renewable Power System for Daily Load demand of Metropolitan Cities in India", American Journal of Engineering Research,2013, vol.2(11), pp.174-184.

[20.] G.P. Giatrakos, T.D. Tsoutsos, P.G. Mouchtaropoulos, G.D. Naxakis,and G. Stavrakakis, "Sustainable energy planning based on a stand-alone hybrid renewable energy/hydrogen power system: Application in Karpathos island, Greece", Renewable Energy,vol. 34, 2009, pp.2562–2570.

[21.] PrabodhBajpai,Prakashan N.P, and N.K.Kishore,"Renewable Hybrid stand-alone Telecom Power Systems Modeling and Analysis",IEEE Region 10 Conference,TENCON,2009,pp.1-6.

[22.] Barsoum N.N. and VacentP.,"Balancing Cost, Operation and Performance in Integrated Hydrogen Hybrid Energy System", IEEE Proceedings of the First Asia International Conference on Modelling and Simulation (AMS'07), 2007,pp.14-18.

[23.] S.B.Silva,M.A.G.Oliveira and M.M.Severino,"Sizing and Optimization Photovoltaic, Fuel Cell and Battery Hybrid System",IEEE Latin America Transactions,9(1), March 2011, pp. 83-88.

[24.] S.B. Silva, M.M. Severino and M.A.G. de Oliveira,"A stand-alone hybrid photovoltaic, fuel cell and battery system: A case study of Tocantins, Brazil", Renewable Energy, vol.57, 2013, pp. 384-389.