Advances and Applications in Mathematical Sciences
Volume 19, Issue 10, August 2020, Pages 1075-1087

A REVIEW OF ADVANCEMENT IN RELIABILITY TECHNIQUES USED FOR INTEGRATED RENEWABLE ENERGY SYSTEMS (IRES) COMPRISING HYDRO, WIND AND SOLAR ENERGY SYSTEMS

NITIN KUMAR SHARMA and SACHIN KUMAR

Department of Mathematics
R. D. Engineering College, Delhi-NCR
Ghaziabad-201206, U.P., India
E-mail: nitmaths@yahoo.co.in

Department of Mathematics
KIET Group of Institutions, Delhi-NCR
Ghaziabad-201206, U.P., India
E-mail: sachin.kumar@kiet.edu

Abstract

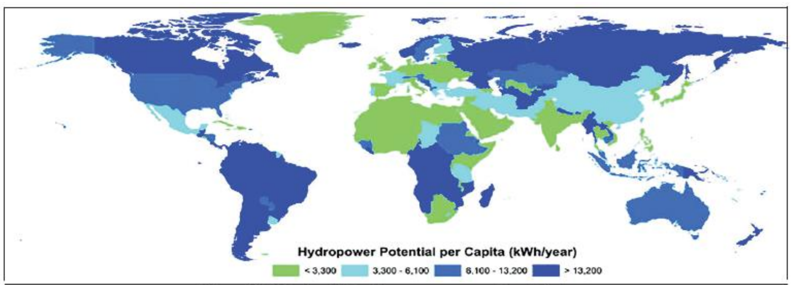
In current scenario, the conventional energy resources are exhausting and availability is reducing every day. Their production mechanism and residual of these fuels are very harmful for global environment due to their use at large level. On other hand if we take a look on previous data then we found that the technology for green energy sources are still costlier and have frequent breakdown in energy supply. That is why their use is not so popular in our society. So there is a necessity of new environment friendly and economic technology reforms in this sector. Many of the researchers introduced the concept of integrated renewable energy system. An IRES is the set of conventional and green energy system and involve complexity in their operation. Therefore reliability in their overall operation has become the need of the time. To achieve adequate level of reliability the researchers has presented their work by using various tools and techniques like ANN, Fuzzy logic, Genetic algorithm and other nature inspired techniques. In this paper authors have tried to review the work reported by different researchers and a comparative study between various techniques has been carried out. At last future scope of study has been highlighted.

2010 Mathematics Subject Classification: 90B25.
Keywords: IRES, reliability, genetic algorithm, wind/ PV energy, PSO.
Received November 9, 2019; Accepted August 2, 2020

1. Introduction

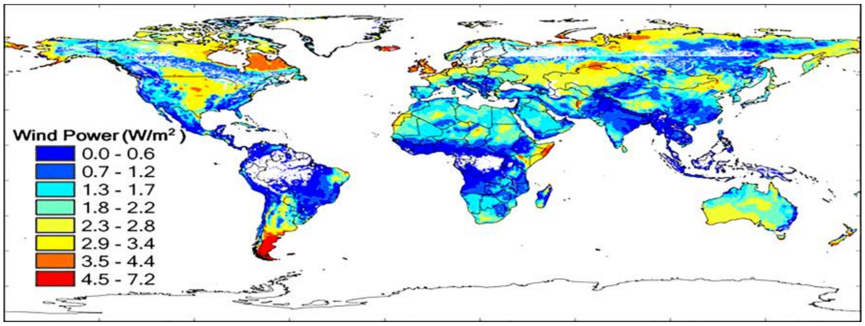
It can be observed that an RES with only one non-conventional source suffer from too much interrupted electrical energy output due to their inherent natural reasons and other technical failures during operations. Therefore integrated systems are needed to compensate the requirement of seamless power supply. Financial data shows that a large amount from economy is spent on energy sector to import raw material of the conventional energy.

It could be reduced by establishment of a non-conventional, pollution-free system which generate energy and is accessible to all at reasonable price. It may also contribute in globally socio-economical growth of a country.



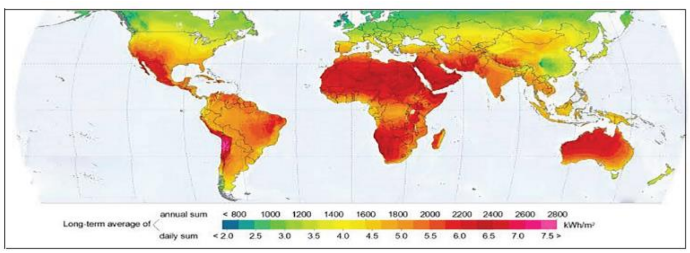
Map 1. Global Hydropower potential.

In a remote location, the unit price and load requirements of conventional power feed reduces when the grid system is connected with a standalone IRES technologies. If we talk about the natural contribution, Cho [6] stated in their paper that using the available technologies, Earth and other natural sources are capable to compensate World's requirements for electrical power (15 TW). Now, due to technical advancements and researches, it has become possible to meet the current energy demand, now its feasible to produce 3.8 TW from geothermal, 9 TW from biomass, 20 TW from wind, 1.6 TW from hydro and more than 50 TW from solar power. The map 1, 2, 3 show the global availability of Hydro, Wind, solar energy potential.



Map 2. Global Wind Energy Potential.

Till today, lot of work and investigations are reported by active researchers based on design, reliability and maximum output at low input cost for an off-grid integrated renewable energy system (IRESs). While a single source can generate electric power but it may suffer from voltage fluctuations and unstable power supply due to unavailability of source and technical breakdowns. It provide base for the concept of integrated renewable energy systems (IRES).



Map 3. Global solar radiation potential.

Eroglu et al. [7] analyzed the operational behavior of an off-grid integrated power system with solar/ wind/FC/electrolyzer with storage facility for a mobile house, it is capable to meet the demand by generating enough electric energy. Gothwal et al. [12] have reviewed different possibilities of decentralized power generation using renewable energy resources, as per availability and demand.

2. Architectures of Integrated Renewable Energy System (IRES)

As discussed earlier that Most preferable arrangements for IRES are wind-DG, Solar-wind, solar-wind-DG, PV-FC, with and without battery bank.

Schmitt et al. [27] worked on different sized Solar-Diesel integrated system between 10 kW to 30 kW. It is evident from their work that upto 90% rural areas of developing countries are now connected with conventional grid power supply. Studies also demonstrate that availability of solar and wind resources are stochastic in nature. Therefore to integration of these two with batteries not only increases the reliability of the IRES but also cost effective in comparison of DG and it works for long term. In a study, Luna-Rubio et al. [21] suggested that it is better to add an additional energy generating or storage source for uninterrupted power supply and reliability of IRES in place of expanding hardware of any single source only.

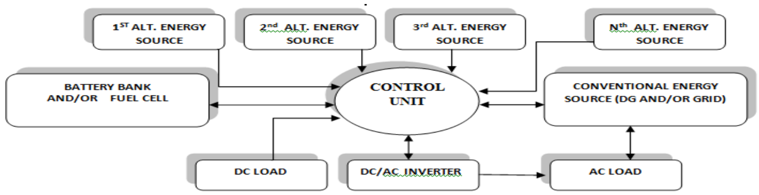


Figure 1. Architectures of general integrated energy system.

Generally, an integrated electric power system may be arranged as shown in Figure 1 we can call it “Integrated” because these are combinations of many power generating systems to meet the predecided electrical load or energy demand, which is usually AC power demand but may be DC or some time combination of both type of load. Power generating systems may be conventional systems (Power grid, Diesel powered gensets), Non-conventional (alternative sources like PV, Wind, Hydro power etc.) systems or energy storage components (batteries, fuel cells).

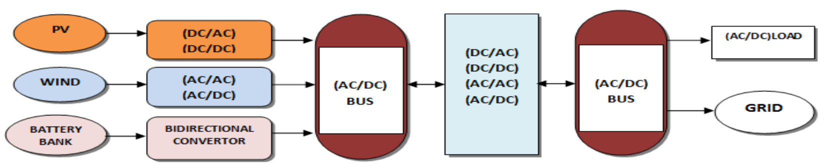


Figure 2. Solar-Wind-Battery integrated renewable energy system.

An integrated system is designed in such a way that shortfall of power supply from any subsystem is compensated by high capability of another subsystem during the operation using automatic or manual controls. We can understand it as, we know that the availability of renewable energy sources i.e. solar and wind etc. is unpredictable, generally, these sources demonstrate complementary patterns (Tina and Gagliano, [30]). Integrated systems can work either in grid-connected mode or in Off-grid (standalone) mode, In a grid-connected mode the objective is to fulfill the local energy demand and when there is a surplus energy then supply it to the grid, In case an Off-grid (stand-alone) system, it generate all of its energy itself and is not connected with grid, this is why, it is used in remote locations where grid supply is not possible. When an IRES includes wind or PV power generating system, then to overcome the stochastic availability of sunlight and wind energy, a power backup/storage source (batteries, FC, grid supply) is required. As per the complexity of IRES and availability of an energy source, there is a need of a controlling system which can decide supply/demand and stabilize the equilibrium in the system. Therefore, to analyze the performance of an IRES several indices are available and discussed ahead.

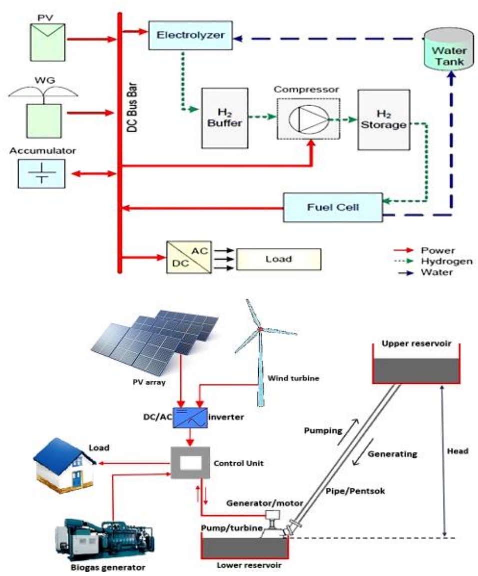


Figure 4. Solar-Wind-Hydro-Generator (biogas) integrated renewable energy system.

Gangwar et al. [8] presented four types of IRES, which are designed for a building which has low load factor condition, as

(a) Solar with battery system, (b) Solar, Fuel Cell, Electrolyzer with battery system (Figure 3),

(c) Solar and Wind with battery system, (d) Fuel Cell, solar, Electrolyzer, wind with battery system.

Out of these combinations of IRES, (d) type is not so popular among researcher. Because it is a combination of various sources, (d) type of IRES may be a costly set up but it is more reliable than (a), (b), (c) for a long time period and is highly recommended for the remote areas which are not connected with any conventional power supply. Goel and Sharma [11] suggested that hydro storage based IRES could be better system for remote areas and PV-wind IRES is more economical for area, more than 50 km from grid.

3. Reliability in IRES

Reliability can be termed as probability of a component or system performing its task/purpose successfully during intended operating period of time under the stated operating conditions or environment. When we are considering IRES, It can be defined as the ability of supplying continuous and quality power, with backup during any failure, to the load. Several performance indicators for integrated energy system are available for the assessment of reliability and/or feasibility analysis. Bhushan and Shivprakash [5] presented a review on the Hybrid (Wind/hydro/solar) system and found more economical, environmental friendly. The review also suggest that capability of a hybrid system for generating electric power is higher than that of the system with individual source and utility of battery bank makes system more reliable. The data was collected for a period of five years from 2010 to 2015 from Metrological Station and results were based on comparative study held between the different integrated systems. Patel and Singal [24] developed and validated the IRES model based on locally available sources. They also suggested that component size and distribution losses significantly affect the system reliability. Gangwar et al. [8] evaluated the cost and reliability of a standalone HRES used for a technical institute with low load factor. This study involves various arrangements of Hybrid RES with horizontal axis wind turbine, PV, fuel cell with electrolyzer and battery storage. Monte-Carlo simulation used by Kishore and Farnandez [20] for assessment of reliability in solar-wind system. In this paper they discussed various components of IRES comprising solar and wind energy generation system and models were analyzed for reliability. In this study, they also reported many procedures for evaluation of system reliability. Zhao et al. [34] focused on the comprehensive objective functions which include the reliability and optimization of operations of the system. The objective function, involving various cost indices, was estimated by reliability. Kekezoglu et al. [18] investigated for reliability of an IRES established at Davutpasa campus, Yildiz Tech. University, Istanbul and important indicators for Reliability were estimated. This study proves that the Reliability of IRES can be increased by designing different combinations of RES, as per need and availability, with suitable battery back-up. S. Nirmal and R. Scaria [23] worked with isolated wind solar and wind hydro integrated RES. The squirrel cage induction generator (SCIG) is used in solar wind integrated energy system, with the high power solar system and a variable speed wind turbine. The same is used again in another combination of IRES, having wind and hydro integrated system, here the SCIG is driven by a variable speed wind turbine and another SCIG driven by a constant power hydro turbine. An optimum HRES design was developed by Ardakani et al. [3]. They established an optimal design for IRES considering reliability indicators which were estimated with financial and scientific constraints. System reliability related constraints were expressed in terms of equivalent loss factor. The reliability was estimated with consideration of failure in different components involved in IRES. Effects of renewable energy on reliability in deregulated power system were addressed by Zhao and Wang [34]. A pool co-market operation was considered for the reliability analysis of wind and PV energy. The procedure incorporates the time sequential performance of enumeration reliability analysis. Pradhan and Karki [25] gave a probabilistic reliability assessment of a standalone small hybrid PV-Wind electric energy system for electrification in the village area of Nepal. This demonstrates the investigations for reliability of integrated system including various reliability indicators such that:

(a) Loss of load expectation (LOLE),

(b) Expected energy not served (EENS),

(c) Energy index of reliability (EIR),

(d) Expected customer interruption cost (ECOST)

The analytical and probabilistic approach is considered in estimation of these indicators.

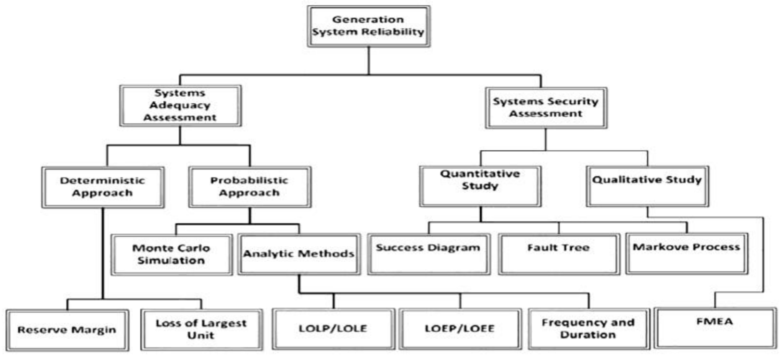


Figure 5. Assessment of various System reliabilty indiators.

Z. Tian and A. A. Saifi [29] developed a method for analysis of reliability to address the problem arising in the renewable energy sources over the passage of time and demand of energy in a period of one year. A simulation approach is used to evaluate reliability of HRES. The two popular indices, used to measure the reliability of a power system are Loss of Load Probability (LOLP) and Loss of Load Expectation (LOLE). Where LOLE can be defined as the count of days when the max. Demand crosses supply capability in a duration of one year, and LOLP is aggregate probability of occurring a shortage of power.

$$\text{LOLE} = \text{LOLP} \times T$$

Where Y = Total power output from subsystems. D = Demand level, (taken as a constant).

The relationship between these two is given as follows:

$$\text{LOLE} = P \times T.$$

Haying et al. [14] worked on solar and wind energy system, models of reliability assessment applied in sequential Monte-Carlo simulation and assessed adequacy of IRES. Nagarajan et al. [22] evaluated reliability and analyzed cost of an IRES with solar and wind subsystems. The variables, considered in this study, to optimize the hybrid system are solar radiation, speed of wind, load etc.

4. Advanced Techniques in IRES reliability

Khare et al. [19] incorporated PSO, CPSO, HOMER. The pattern of load consumption was analyzed and it was optimized for power requirements of RES of a police control room. Arabali et al. [2] used GA for Optimization of energy management. Arabali proposed a new scheme to fulfill the controllable Heating, Ventilation and Air-conditioning with a PV wind IRES. Kaabeche et al. [16] presented an Economical analysis for reliability indicators such that Deficiency of power supply probability, Life cycle cost. They suggested a design of the IRES in terms of expected requirement of system reliability, which is much supportive. Goel and Sharma [11] suggested that efficiency of PV based system can be increased by controlling temperature, tilt angle and array spacing. Ricalde [26] suggested a design of a smart grid management system with renewable energy generation based on neural network technique. It was system based on multi-agents which is arranged to control and measure the loads in a building. Alam and Gao [1] worked on modeling and analysis of a system with solar/ Wind/Fuel cell. The simulation results (using Fuzzy and HOMER) of this study suggested that a standalone renewable energy system is feasible option for power generation in remote areas. Ardakani [3] analysed different designs of hybrid power generation systems for the optimal system design using PSO. Berrazouane and Mohammedi [4] resolved the problems related to quality of power. They used fuzzy logic in management and supervision of energy and discussed real power imbalance fluctuations occurring in renewable energy from IRES. Shahirinia et al. [28] applied Genetic Algorithm (GA) to analyze optimal sizing of RES and determined the optimal cost value for the construction of integrated energy generation system. Xu et al. (2005) also used Genetic Algorithm(GA) and discussed the reliability criteria and problems related to probability of loss of power supply . Yang et al. [32] explained by using Genetic Algorithm (GA) Probability of loss of power supply. Ghada et al. [9] incorporated Genetic Algorithm (GA) analysed the Sensitivity of a standalone RES with battery and not connected with grid. This analysis was done for cost of carbon emission, different battery prices and interest rate. Jifang et al. [15] worked on Control strategy for multi-energy common DC bus hybrid power supply. In this study, it was shown by neural network and simulation that strategy is suitable for stabilization and continuity in voltage. Ghareeb et al. [10] used neural network approach in their work for RES for continuous power supply in micro grid application. They investigated the use of solar–wind hybrid power generation system with high penetration of renewable energy sources under dominant weather condition. Zhao et al. [35] aimed to optimize capacity configuration of a supply system using PSO approach. The technique was applied on a off grid RES and the feasibility and effectiveness is evident from analysis of conclusion of study. Wang et al. [31] presented a control scheme in their paper to improve the power factor and voltage of a hybrid Wind/soler system using programmable logical controller (PLC)'s new fuzzy module. Kaviani et al. [17] discussed the impact of component outages and equivalent loss factor on the reliability performance analysis of system. Hakimi [13] studied the net present value based on PSO approach. In their study, surplus energy transmitted to the electrolyzer and shortfall in power is compensated by fuel cell.

5. Conclusion

In Renewable energy generation sector, a tremendous growth has been recorded during last few years. It’s become possible due to increasing reliability, better output and decreasing cost of the sustainable IRES. As the development and economy of countries in the world depend on their energy generation capability. To balance demand and supply in this sector, application of new technologies is required and it give a rise to new problems which redirect us for lot of future research in this field. Many studies suggest that improvement in the reliability of IRES is possible if we analyze sizing and designing carefully in planning stage.

There are many constraints in designing and establishments of IRES, like location, climate, sizing, supply/demand equilibrium, availability of desired source and operational problems. There should be some procedures to locate best location to erect an integrated renewable energy system. A dedicated software/program is required to search the precise location and weather data which provide full data support from erection to operations. It will be very helpful in case of remote sites especially where electricity grid is not available. Hence it is necessary to develop an accurate optimization technique and geographical software for the assessment of the potential of solar radiation and wind velocity. Researchers are using several types of sizing methods like Hybrid, Multi-objective, Analytical, probabilistic, iterative methods and ANN, but none of these methods demonstrate operational dynamics of IRES. An advanced method is required for optimal sizing which can meet the demand and dynamic performance criteria. Recently some methods of Game theory are also used by researchers in their work on IRES. It is essential to apply concept of "Cournot compition, Bertrand duopoly Stackelberg duopoly" for the estimation of accurate system cost and salvage value of integrated systems daily increasing installation of IRES.

References

[1] M. A. Alam and D. W. Gao, Modeling and analysis of a wind/pv/fuel cell hybrid system in HOMER, In Proceedings of ICIEA-IEEE; 2007. p. 1594-1599.

[2] A. Arabali, M. Ghofrani, A. M. Etezadi and M. S. Fadali, Genetic algorithm based optimization approach for energy management, IEEE Trans. 28 (2013), 162-170.

[3] F. J. Ardakani, G. Riahy and M. Abedi, Design of an optimum hybrid renewable energy system considering reliability indices, In: Proceedings of ICEE; 2010. p. 842-7

[4] S. Berrazouane and K. Mohammedi, Hybrid system energy management and supervision based on fuzzy logic approach for electricity production in remote areas, In Proceedings of ICREVT-IEEE; 2012. p. 324-9.

[5] Bhushan D. Agarkar and Shivprakash B. Barve, A Review on Hybrid solar/wind/ hydro power generation system, International Journal of Current Engineering and Technology Special Issue-4 (March 2016).

[6] A. Cho, Energys tricky tradeoffs, Science 329(5993), 2010, p.786-787.

[7] M. Eroglu, E. Dursun, S. Sevencan, J. Song, S. Yazici and O. Kilic, A mobile renewable house using PV/wind/fuel cell hybrid power system, Int. J. Hydrogen Energy 36(13) (2011), 7985-7992.

[8] S. Gangwar, D. Bhaneja and A. Biswas, Cost, reliability and sensitivity of a stand-alone hybrid renewable energy system-A case study on a lecture building with low load factor, Journal of Renewable and Sustainable Energy 7, 013109 (2015), p.1-13.

[9] M. Ghada, M. Leuthold and S. Dirk Uwe, Optimization of an Off-grid hybrid PV Wind-Diesel system with different battery technologies sensitivity analysis, In: Proceedings of IEEE-INTELEC; 2013. p. 1-6.

[10] A. T. Ghareeb and O. A. Mohammed, Wavelet adaptive ANN forecaster for renewable energy sources for continuous supply in microgrid applications, In: Proceedings of PES-IEEE; 2013, p. 1-6.

[11] S. Goel and R. Sharma, Evaluation of stand alone, grid connected and hybrid renewable energy systems for rural application: A comparative review, Renewable and Sustainable Energy Reviews 78 (2017), 1378-1389.

[12] N. Gothwal, T. Mangalani and D. K. Doda, Importance of Off-Grid Power Generation using Renewable Energy Resources - A Review, International Journal of Computer Applications 179(28) (2018).

[13] S. M. Hakimi and S. M. Moghaddas-Tafreshi, Optimal sizing of a stand-alone hybrid power system via particle swarm optimization for Kahnouj area in south-east of Iran, Renew Energy 34 (2009), 1855-1862.

[14] W. Haying and B. Xiaomin, Adequacy assessment of generating system incorporating wind, pv, and energy storage, In Proceedings of ISGA Asia; (2012), 1-6.

[15] L. Jifang, T. Tianhao and H. Jiuhang, A neural network control strategy for multi energy common dc bus hybrid power supply, In Proceedings of SPEEDAMIEEE; 2010. p. 1827-1831.

[16] A. Kaabeche, M. Belharnel and R. Ibtiouen, Sizing optimization of grid independent hybrid PV/Wind power generation system, Energy 36 (2011), 1214-1222.

[17] A. K. Kaviani, G. H. Riahy and S. H. M. Kouhsari; Optimal design of a reliable hydrogen based stand-alone wind/PV generating system, considering component outages, Renew Energy 34 (2009), 2380-2890.

[18] B. Kekezoglu, O. Arikan, A. Erduman, E. Isen, A. Durusu and A. Bozkurt, Reliability analysis of hybrid energy system: case study of avutpasa campus, In: Proceedings of EUROCON; 2013, p. 1141-4.

[19] Khare Vikas, Nema Savita and Baredar Prashant, Optimization of the hybrid renewable energy system by HOMER, PSO and CPSO for the study area, Int. J. Sustain Energy 34 (2015), 1-18.

[20] L. N. Kishore and E. Fernandez, Reliability well being assessment of *pv* wind hybrid system using Monte Carlo simulation, In: Proceedings of ICETECT; 2011. p. 63-8.

[21] R. Luna-Rubio, M. Trejo-Perea, D. Vargas-Vazquez, G. J. Rıos-Moreno, Optimal sizing of renewable hybrids energy systems: A review of methodologies, Solar Energy 86 (2012), 1077-1088.

[22] T. Nagarajan, S. Vijiyasamundiswary and P. Sasilkumar, Reliability and cost analysis of hybrid renewable energy system, Int. Con. on Computation of Power, Energy, Info. and Communication 2013 (84-88).

[23] S. Nirmal and R. Scaria, Hybrid Systems: Wind Solar And Wind Hydro Hybrid Systems With Battery Storage, Int. J. of Advances in Science, Engg. and Technology, Volume 2, Issue-4, Oct.-2014.

[24] A. M. Patel and S. K. Singal, Economic Analysis of Integrated Renewable Energy System for Electrification of Remote Rural Area having Scattered Population, Int. J. of Renewable Energy Research 8(1) (2018).

[25] N. Pradhan and N. R. Karki, Probabilistic reliability evaluation of off-grid small hybrid solar pv wind power system for the rural electrification in Nepal, In: Proceedings of NAPS-IEEE; 2012. p. 1-6.

[26] J. L. Ricalde, E. Ordonez, M. Gamez and E. N. Sanchez, Design of a smart grid management system with renewable energy generation, In Proceedings of CIASG-IEEE; 2011, p. 1-5.

[27] Schmitt, G. Huard, and G. Kwiatkowski; PV-hybrid micro plants and mini-grids for decentralized rural electrification in developing countries, EDF Research and Development, France, 2006.

[28] A. H. Shahirinia, S. M. M. Tafreshi, A. H. Gastej and A. R. Moghaddomjoo; Optimal sizing of hybrid power system using genetic algorithm, In Proceedings of FPS-IEEE; 2005. p. 1-5. Renewable Energy System, In: Proceedings of ICCPEIC; 2013, p. 84-8.

[29] Z. Tian and A. A. Saifi, Reliability analysis of hybrid system, Int. J. of Reliability, Quality and Safety Engineering 21(3), 1450011, 1-12.

[30] G. M. Tina and S. Gagliano, Probabilistic modeling of hybrid solar/wind power system, Renew Energy 36 (2011), 1719-1727.

[31] Wang Li and Kuo Hua Liu, Implementation of a web based real time monitoring and control system for a hybrid wind-pv-battery renewable energy system, In Proceedings of ISAP; (2007), 9-16.

[32] H. Yang, L. Lu and W. Zhou, A novel optimization sizing model for hybrid solar-wind power generation system, Solar Energy 81 (2007), 76-84.

[33] H. Yang, W. Zhou and C. Lou, Optimal design and techno-economic analysis of a hybrid solar-wind power generating system, Appl. Energy 86 (2009), 163-169.

[34] Q. Zhao, P. Wang, L. Goel and Y. Ding, Impacts of renewable energy penetration on nodal price and nodal reliability in deregulated power system, In Proceedings of IEEE-PES; 2011, p. 1-6.

[35] Y. S. Zhao, J. Zhan, Y. Zhang, D. P. Wang and B. G. Zou, The optimal capacity configuration of an independent wind/PV hybrid power supply system based on improved PSO algorithm, In Proceedings of APSCOM-IEEE; 2009, p. 1-7.