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GRID-INDEPENDENT INTEGRATED RENEWABLE ENERGY SYSTEM (IRES) FOR RURAL ELECTRIFICATION: A REVIEW

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Abstract

A mammoth transformation in energy systems and policy making models are required to meet the essentials of communities living in rural and remote areas and specifically for those that are subject to energy as well as economic poverty. Novel models must be reflexive to global concerns on climatic changes, parallel with social, economic and environmental agendas of national, state, as well as local governments. The methods also have to be compatible with embedded energy infrastructure. Decentralized solar power plants are a resilient technology which efficiently supports energy transformation to economically and socially deprived communities yet the deployment of this technology is conned by path dependencies including policies, business models and set-ups.

The multi-dimensional perspective can be used to test energy transformation within rural and remote communities in India and other countries, through interviews with regime and top level actors. Identification of various stumbling blocks impeding successful deployment of Integrated Renewable Energy Resources including a aloofness between policy makers and implementers, poor coordination within and between actors, and limited institutional focus. To support a successful transition to stand alone -grid Renewable Energy based regimes for rural and remote communities; actors suggest strong political determination, setting enabling policy frameworks, and implementing a collaborative ecosystem with businesses, financial intermediaries, distribution companies, civic societies and end players.

Keywords: Renewable Energy, financial intermediaries, collaborative ecosystem, environmental agendas

Introduction:

The off grid electrification by use of Integrated Renewable Energy System (IRES) is suggested to satisfy the electrical as well as cooking needs of the un-electrified villages. Many community based scenes are considered during creation of model and optimization of IRES to ensure reliability such as energy index ratio (EIR) and expected energy not supplied (EENS). The optimised system reliability, total system cost (TSC) and cost of energy (COE) can also be calculated by introducing the customer interruption cost (CIC). The four different renewable energy scenarios can be compared. The fourth renewable energy scenario summing up to 44.99% micro hydropower (MHP), 30.07% biomass, 5.19% biogas and 4.16% solar energy along with the non-renewable resources of wind (1.27%) and energy plantation (12.33%) has been found to be the most suitable among the different options considered. Furthermore, EIR of the fourth IRES system has been found to be 0.95 at the optimized cost of around 19 lakhs with estimated COE of Rs 3.36 per kWh. The Cost of Energy obtained using LINGO software and HOMER software can also been compared. In order to verify feasibility and cost of system for different biomass fuel prices, a sensitivity analysis has also been carried out and it has been found that the fourth scenario is more sustainable than the other considered options.

Extension of the grid has led to generation of electric power at the end user facility and has been proved to be cost efficient and to an extent efficient, which is uneconomic. With added significance on eco-friendly technologies the use of micro-hydro, wind, solar, biomass and mini non-renewable power plants is being explored. This paper presents an extensive review on various issues related to Integrated Renewable Energy System (IRES) based power generation. Issues related to binding-up configurations, storage options, sizing techniques and system control for energy flow management for suitable demands is discussed. For off-grid applications integration of renewable energy sources, performed through DC coupled, AC coupled or DC–AC coupled configurations which can be hybrids, are studied in detail. Based on the requirement of batteries in isolated areas, storage technology options can be selected for integrated systems. Uncertainties and intermittencies involved in designing an effective IRES based power generation system for stand-alone areas is accounted due to highly non-static nature of availability of sources and the demand at site. Different types of methodologies have been implemented and reported in literature for sizing down of the system components are presented. Distributed control with stand alone grids, centralized as well as hybrid control schemes for energy flow management in IRES can also be discussed.

Methodology

The premier to IRES was Ramakumar [1–5] who evaluated the techno-economic calculationsof small-scale decentralized IRES for already available renewable energy sources in the rural areas of developing countries. Studies were carried on the basis of the broad aspects of energy demands like cooking, small-scale industries, irrigation and electricity using Cascaded approaches. Ahmed and Cohen [6] have found that Integrated Renewable Energy Planning (IREP) requires consideration of utility systems like supply side, demand side, transmission and distribution. A knowledgeable approach was suggested by Ramakumar et al. [7,8] to zero down to a minimum, the capital cost using the concept of Loss of Power Supply Probability (LPSP). Gavanidou and Bakirtzis [9] used a trade risk method to compute the optimal sizes of solar photovoltaic (SPV) array and battery to get to minimum, capital investment as well as for the minimum Loss of Load Probability (LOLP) requirement. Ramanathan and Ganesh [10] used almostseven energy sources to provide lighting in households using an integrated goal programming (GP) - Analytic Hierarchy Process (AHP) model. Ramakumar et al. [11,12] further employed a Linear Programming (LP) approach to design IRES, which involved the finding out of various resources required for sizing of the devices. The objective functions of the optimization were to bring to a minimum the total annual cost per year subject to energy constraints.

An Optimum Renewable Energy Model (OREM) was proposed by Iniyanet al. [13,14] for the maximum utilization of renewable energy sources for lighting, cooking, pumping, heating, cooling and transportation in India for the period 2020–2021. A mathematical model was developed by Ramakumar and Chiradeja [15] for renewable energy system with distribution system models as well as power flow calculations. It was found that injection of diesel generator can improve the system voltage profile and reduce the losses in electrical transmission line. Nakata et al. [16] used hybrid optimization modeling for combining renewable energy systems to supply electricity and heat in rural Japan. A hybrid energy system using various system components was developed by Ashok [17] to find an optimal combination of components for a typical remote village of Western Ghats in Kerala state. The optimization model can be solved using non-linear constrained optimization techniques to get the combination of optimum sizes of components on the basis of minimized total life cycle cost. Katti and Khedkar [18] have presented a decision support technique to optimize generation capacity of wind only, Solar Photo Voltaic only and integrated-Solar Photo Voltaic-wind power systems for off-grid application using weather based model and a simple numerical algorithm. Fernandez et al. [19] used the optimal mix of renewable as well as conventional resources to fulfil the energy needs like lighting, cooking and space heating of a rural area of Kanvashram, located in PauriGarhwal district of Uttarakhand state, India.

Akella et al. [20] modeled and optimized IRES model for Jaunpur block of Uttarakhand state, India. Electric Power Delivery Factor (EPDF) has been used for the optimization of the system that uses micro hydropower (MHP), biomass, solar and wind energy resources. It has been found that the optimal modeled IRES could provide cost -efficient solution having EPDF range from 1.0 to 0.75. A deficit of EPDF less than 0.75 is the indication of a unsuitable and non-feasible model. Diaf et al.[21] developed an optimum sizing model with a new concept to supplying wind power via uninterrupted power supply to Hybrid Photovoltaic/ Wind System (HPWS). This model consists of sub-models of system components, technical sub-model based on LPSP and economical sub-model based on equalized Cost of Energy (LCE). Lagorse et al. [22] applied a new concept to supply electricity using a hydrogen fuel cell in combination with Solar Photo Voltaic battery stand-alone system throughout the year. They validated the suggested model with different optimization techniques such as genetic algorithm and obtained the optimal solution.

Kaldellis [23] formulated a methodology to maximize Solar Photo Voltaic contribution and minimize the cost of electricity generation along with the most suitable storage devices available to the south- east Mediterranean Sea islands. The results clearly state that the proposed system is more cost effective and feasible in terms of real-life implementation than the existing thermal power stations. In view of the above literature review, it is revealed that very lesswork is available on the supply-demand models and the main motive has been on energizing rural areas but not the individual village/cluster of villages. Further, no attempts have been made to extend the usage of IRES to supply electricity to a community cold storage for processing the perishable vegetables and fruits apart from meeting power needs for domestic purposes. The present paper deals with the optimization Iterative approaches of different options available in the study area considering the reliability worth and COE.

Available Iterative approaches

Author Zang et al[56] has considered PV, diesel Generator and Battery with COE Indicator and Design Constraints involving Generator output power, battery SOC. The outcome achieved here that, the author has proposed an algorithm for component sizing using linear programming.

Gupta et al [57] has considered Solar Photo Voltaic, micro-hydro, biogas and biomass with Total Cost optimized indicator. Design Constraints involve units generation limits, individual capacity limits and battery capacity limits. They have developed a mixed integer linear mathematical programming model (time-series) to determine optimal resource allocation that resources with lesser unit cost.

Ekren, and Ekren [58] PV, wind, battery with Hybrid system cost Design constraints that have Loss of load probability (LLP), autonomy, auxiliary energy unit cost . The outcome achieved is Optimizing the sizing of PV area, battery capacity and wind turbine rotor swept area using the OptQuest tool in ARENA software.

Yang et al. [59] has considered Solar, wind, and battery bank energy sources. Design constraints is Annualized system cost LPSP. For calculation of the outcome, during cost optimization process, five decision variables were considered: PV module number, PV module slope angle, wind turbine number, wind turbine installation height and battery capacity.

Kellogg et al. [63] has considered Wind, PV and Indicator Optimized is Total cost with Design Constraint Price per kWh and break even distance The outcome has justified the installation of stand-alone hybrid system by comparison with the line extension, supplying the load with conventional utility power.

Ashok et al. [64] has considered the Resources of Solar, wind, and micro-hydro; Indicator optimized is Total capital cost with Design Constraints of Resource availability and equipment; the outcome developed a decision support system for the hardware design of integrated energy system

Challenges and future scope

Although power generation using renewable energy sources is sustainable and green, however several challenges are still existent in IRES based power generation such as

1. Capital cost of renewable energy products is very high as compared to the conventional power generation technologies.
2. Poor efficiency of solar panels is the major barrier in its use and a lot of research is in process in this direction and Space based Solar Power is one option which is a breakthrough.
3. Significant amount of energy is lost in energy conversion process using power converters.
4. A persistent need to increase the life cycle of storage technologies using novel materials.
5. Load transients have to be dealt with.
6. Meeting the peak demands with renewable energy resources.
7. A major concern for the consumer and manufacturer is the disposal of storage systems.

References

[1] Ramakumar R. Integrated renewable energy systems: power engineering review. IEEE 1995;15(2):10–3.

[2] Ramakumar R, Abouzahr I, Ashenay KA. Knowledge-based approach to the design of integrated renewable energy systems. IEEE Trans Energy Convers 1995;10:736–46.

[3] Ramakumar R, Shetty PS, Ashenayi K. A linear programming approach to the design of integrated renewable energy systems for developing countries. IEEE Trans Energy Convers 1986;EC-1:18–24.

[4] KanasePatil AB, Saini RP, Sharma MP. Integrated renewable energy systems for off grid rural electrification of remote area. Renew Energy 2013;5:1342–9.
[5] Ashenayi K, Ramakumar R. IRES a program to design integrated renewable energy systems. Energy 1990;15:1143–52.
[6] Ramakumar R, Abouzahr I, Krishnan K, Ashenayi K. Design scenarios for integrated renewable energy systems. IEEE Trans Energy Convers 1995;10: 736–46.
[7] Lasseter R, Abbas A, Marnay C, Stevens J, Dagle J, Guttromson R, et al. Integration of distributed energy resources: the CERTS Microgrid Concept California Energy Commission. P500-03-089F; October 2003.
[8] Farret FA, Simões MG. Integration of Alternative Sources of Energy. Hoboken, NJ: Wiley; 2006.
[9] Sao CK, Lehn PW. A transformerless energy storage system based on a cascade multilevel PWM converter with star configuration. IEEE Trans IndAppl 2008;44(5):1621–30.
[10] Sood PK, Lipo TA, Hansen IG.A versatile power converter for high-frequency link systems. IEEE Trans Power Electron 1988;3(4):383–90.

[11] Barton JP, Infield DG. Energy storage and its use with intermittent renewable energy. IEEE Trans Energy Convers 2004;19:441–8.
[12] Makansi J, Abboud A. Energy storage. The missing link in the electricity value chain. Saint Louis, USA: Energy Storage Council; 2002.
[13] Abbey C, Robinson J, Joós G. Integrating renewable energy sources and storage into isolated diesel generator supplied electric power systems. In: Proceedings of the 13th international power electronics and motion control conference (EPE-PEMC); 2008.
[14] Chen H, Cong TN, Yang W, Tan C, Li Y, Ding Y. Progress in electrical energy storage system: a critical review. Prog Nat Sci 2009;19:291–312.
[15] Karpinski AP, Makovetski B, Russell SJ, Serenyi JR, Williams DC. Silver-zinc: status of technology and applications. J Power Sources 1999;80:53–60.
[16] Moore T, Douglas J. Energy storage, big opportunities on a smaller scale. EPRI J 2006;Spring Issue:16–23.
[17] Rahman F, Rehman S, Arif M, Majeed A. Overview of energy storage systems for storing electricity from renewable energy sources in Saudi Arabia. Renew Sustain Energy Rev 2012;16:274–83.
[18] Katti PK, Khedkar MK. Alternative energy facilities based on site matching and generation unit sizing for remote area power supply. Renewable Energy 2007;32:1346–62.
[19] Fernandez E, Saini RP, Devdas V. Relative inequality in energy resource consumption: a case of Kanvashram village, PauriGarhwaldist, Uttaranchal (India). Renewable Energy 2005;30:763–72.
[20] Akella AK, Sharma MP, Saini RP. Optimum utilization of renewable energy sources in a remote area. Renew Sustain Energy Rev 2007;11:894–908.
[21] Diaf S, Belhamel M, Haddadi M, Louche A. Technical and economic assessment of hybrid photovoltaic/wind system with battery storage in Corsica Island. Energy Policy. 2008;36:743–54.
[22] Lagorse J, Paire D, Miraoui A. Sizing optimization of a stand-alone street lighting system powered by a hybrid system using fuel cell, PV and battery. Renewable Energy 2009;34:683–91.
[23] Kaldellis JK, Zafirakis D, Kaldelli EL, Kavadias K. Cost benefit analysis of a photovoltaic-energy storage electrification solution for remote islands. Renewable Energy 2009;34:1299–311.
[24] Economic and Statistics Department. Government of Uttarakhand, JanpathEkDrusti Main - Almora, Almora; 2007.
[25] Ministry of New and Renewable Energy (MNRE). Government of India, Annual Report 2007-2008, .
[26] Mani A, Rangarajan S. Solar radiation over India. New Delhi: Allied Publication; 1992.
[27] Ashari M, Nayar CV, Keerthipala WWL. Optimum operation strategy and economic analysis of a photovoltaic-diesel-battery-mains hybrid uninterruptible power supply. Renewable Energy 2001;22:247–54.
[28] Markvart T. Sizing of hybrid photovoltaic-wind energy systems. Sol Energy 1996;57:277–81.
[29] Karaki SH, Chedid RB, Ramadan R. Probabilistic performance assessment of autonomous solar-wind energy conversion systems. IEEE Trans Energy Convers 1999;14:766–72.
[30] Stojkov M, Nikolovski S, Mikulicic V. Estimation of electrical energy not supplied in reliability analysis of distribution networks. Dubrovnik, Croatia: IEEE MELCON; 2004. p. 967–970.
[31] Tina G, Gagliano S, Raiti S. Hybrid solar/wind power system probabilistic modeling for long – term performance assessment. Sol Energy 2006;80: 578–88.

[32] Billinton R, Allan RN. Reliability evaluation of power systems. Delhi: Springer Indian Edition; 2006.
[33] El-Shater TF, Eskander M, El-Hagry M. Hybrid PV/fuel cell system design and simulation. Renew Energy 2002;27:479–85.
[34] Chedid R, Rahman S. Unit sizing and control of hybrid wind–solar power systems. IEEE Trans Energy Convers 1997;12(1):79–85.
[35] Chedid RB, Karaki SH, El-Chamali C. Adaptive fuzzy control for wind–diesel weak power system. IEEE Trans Energy Convers 2000;15(1):71–8.
[36] Bajpai P, Dash V. Hybrid renewable energy systems for power generation in stand-alone applications: a review. Renew Sustain Energy Rev 2012;16: 2926–36.
[37] Hakimi SM, Moghaddas-Tafreshi SM. Optimal sizing of a stand-alone hybrid power system via particle swarm optimization for Kahnouj area in southeast of Iran. Renew Energy 2009;34:1855–62.
[38] Yang H, Zhou W, Lu L, Fang Z. Optimal sizing method for stand-alone hybrid solar–wind system with LPSP technology by using genetic algorithm. Sol Energy 2008;82:354–67.
[39] Ekren O, Ekren BY. Size optimization of a PV/wind hybrid energy conversion system with battery storage using response surface methodology.Appl Energy 2008;85:1086–101.
[40] Xu D, Kang L, Chang L, Cao B. Optimal sizing of standalone hybrid wind/PV power systems using genetic algorithms. In: Proceedings of the Canadian conference on electrical and computer engineering; 2005. p. 1722–5.
[41] Mellit A, Benghanem M, Hadj Arab A, Guessoum A. An adaptative artificial neural network model for sizing stand-alone photovoltaic systems: application for isolated sites in Algeria. Renew Energy 2005;30(10):1501–24.
[42] Fadaee M, Radzi MAM. Multi-objective optimization of a stand-alone hybrid renewable energy system by using evolutionary algorithms: a review. Renew Sustain Energy Rev 2012;16:3364–9.
[43] Maheri A. Multi-objective design optimisation of standalone hybrid wind– PV–diesel systems under uncertainties. Renew Energy 2014;66:650–61.
[44] Ippolitoa MG, Di Silvestre ML, Sanseverino ER, Zizzo G, Graditi G. Multiobjective optimized management of electrical energy storage systems in an islanded network with renewable energy sources under different design scenarios. Energy 2014;64:648–62.
[45] Sharafi M, ELMekkawy TY. Multi-objective optimal design of hybrid renewable energy systems using PSO-simulation based approach. Renew Energy 2014;68:67–79.
[46] Abbes D, Martineza A, Champenois G. Life cycle cost, embodied energy and loss of power supply probability for the optimal design of hybrid power systems. Math Comput Simul 2014;98:46–62.
[47] Tant J, Geth F, Six D, Tant P, Driesen J. Multiobjective battery storage to improve PV integration in residential distribution grids. IEEE Trans Sustain Energy 2013;4:182–91.
[48] Arnette A, Zobel CW. An optimization model for regional renewable energy development. Renew Sustain Energy Rev 2012;16:4606–15.
[49] Abedi S, Alimardani A, Gharehpetian GB, Riahy GH, Hosseinian SH. Comprehensive method for optimal power management and design of hybrid RESbased autonomous energy systems. Renew Sustain Energy Rev 2012;16 (3):31577–87.
[50] Moura PS, DeAlmeida AT. Multi-objective optimization of a mixed renewable system with demand-side management. Renew Sustain Energy Rev 2010;14 (5):1461–8.
[51] Ould B, Sambou V, Ndiaye PA, Kébé CMF, Ndongo M. Optimal design of a hybrid solar–wind–battery system using the minimization of the annualized cost system and the minimization of the loss of power supply probability (LPSP). Renew Energy 2010;35(10):2388–90.
[52] Katsigiannis YA, Georgilakis PS, Karapidakis ES. Multiobjective genetic algorithm solution to the optimum economic and environmental performance problem of small autonomous hybrid power systems with renewables. IEEE Trans Renew Power Gener 2010;4(5):404–19.
[53] Dufo-López R, Bernal-Agustín JL. Multi-objective design of PV–wind–diesel– hydrogen–battery systems. Renew Energy 2008;33(12):2559–72.
[54] Diaf S, Belhamel M, Haddadi M, Louche A. Technical and economical assessment of hybrid photovoltaic/wind system with battery storage in Corsica island. Energy Policy 2008;36:743–54.
[55] Bernal-Agustín JL, Dufo-López R, Rivas-Ascaso DM. Design of isolated hybrid systems minimizing costs and pollutant emissions. Renew Energy 2006;31 (14):2227–44.
[56] Zhang X, Tan SC, Li G, Li J, Fang Z. Components sizing of hybrid energy systems via the optimization of power dispatch simulations. Energy 2013;52:165–72.
[57] Gupta A, Saini RP, Sharma MP. Steady-state modelling of hybrid energy system for off grid

electrification of cluster of villages. Renew Energy 2010;35:520–35.

[58] Ekren BY, Ekren O. Simulation based size optimization of a PV/wind hybrid energy conversion system with battery storage under various load and auxiliary energy conditions. Appl Energy 2009;86(9):1387–94.

[59] Yang H, Zhou W, Lou C. Optimal design and techno-economic analysis of a hybrid solar–wind power generation system. Appl Energy 2009;86(2):163–9.

[60] Li C-H, Zhu X-J, Cao G-Y, Sui S, Hu MR. Dynamic modeling and sizing optimization of stand-alone photovoltaic power systems using hybrid energy storage technology. Renew Energy 2009;32(3):815–26.

[61] Yang HX, Lu L, Zhou W. A novel optimization sizing model for hybrid solar– wind power generation system. Sol Energy 2007;81(1):76–84.

[62] Prasad AR, Natarajan E. Optimization of integrated photovoltaic–wind power generation systems with battery storage. Energy 2006;31:1943–54.

[63] Kellogg WD, Nehrir MH, Venkataramanan G, Gerez V. Generation unit sizing and cost analysis for stand-alone wind, photovoltaic and hybrid wind/PV systems. IEEE Trans Energy Convers 1998;13(1):70–5. [64] Ashok S. Optimised model for community-based hybrid energy system. Renew Energy 2007;32(7):1155–64.

[65] Khatod D, Pant VK, Sharma J. Analytical approach for well-being assessment of small autonomous power system with solar and wind energy sources. IEEE Trans Energy Convers 2010;25(2):535–45.

[66] Kaldellis JK, Zafirakis D, Kondili E. Optimum autonomous stand-alone photovoltaic system design on the basis of energy pay-back analysis. Energy 2009;34(9):1187–98.

[67] Dufo-Lo´pez R, Bernal-Agustı´n JL, Mendoza F. Design and economical analysis of hybrid PV–wind systems connected to the grid for the intermittent production of hydrogen. Energy Policy 2009;37(8):3082–95.

[68] Lujano-Rojas JM, Dufo-López R, Bernal-Agustín JL. Probabilistic modelling and analysis of stand-alone hybrid power systems. Energy 2013;63:19–27.

[69] Tina G, Gagliano S. Probabilistic analysis of weather data for a hybrid solar/ wind energy system. Int J Energy Res 2011;35(3):221–32.

[70] Tina G, Gagliano S, Raiti S. Hybrid solar/wind power system probabilistic modeling for long-term performance assessment. Sol Energy 2006;80 (5):578–88.

[71] Yang HX, Lu L, Burnett J. Weather data and probability analysis of hybrid photovoltaic–wind power generation systems in Hong Kong. Renew Energy 2003;28(11):1813–24.

[72] Karaki SH, Chedid RB, Ramadan R. Probabilistic performance assessment of autonomous solar–wind energy conversion systems. IEEE Trans Energy Convers 1999;14:766–72.

[73] Bagul AD, Salameh ZM, Borowy B. Sizing of a stand-alone hybrid wind photovoltaic system using a three-event probability density approximation. Sol Energy 1996;56(4):323–35.

[74] Borowy BS, Salameh ZM. Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system. IEEE Trans Energy Convers 1996;11(2):367–73.

[75] Markvart T. Sizing of hybrid PV–wind energy systems. Sol Energy 1996;59 (4):277–81.

[76] ⟨http://www.homerenergy.com⟩ [accessed 20.02.14].

[77] Rehman S, El-Amin IM, Ahmad F, Shaahid SM, Al-Shehri AM, Bakhashwain JM. Feasibility study of hybrid retrofits to an isolated off-grid diesel power plant. Renew Sustain Energy Rev 2007;11(4):635–53.

[78] Shaahid SM, Elhadidy MA. Technical and economic assessment of gridindependent hybrid photovoltaic–diesel–battery power systems for commercial loads in desert environments. Renew Sustain Energy Rev 2007;11 (8):1794–810.

[79] Silva SB, Oliveira MAG, Severino MM. Economic evaluation and optimization of a photovoltaic–fuel cell–batteries hybrid system for use in the Brazilian Amazon. Energy Policy 2010;38(11):6713–23.

[80] Bekele G, Palm B. Feasibility study for a standalone solar–wind-based hybrid energy system for application in Ethiopia. Appl Energy 2010;87(2):487–95.

[81] Lau KY, Yousof MFM, Arshad SNM, Anwari M, Yatim AHM. Performance analysis of hybrid photovoltaic/diesel energy system under Malaysian conditions. Energy 2010;35(8):3245–55.

[82] Prodromidis GN, Coutelieris FA. Simulation and optimization of a standalone power plant based on renewable energy sources. Int J Hydrog Energy 2010;35(19):10599–603.

[83] Rehman S, Hadhrami LMA. Study of a solar PV–diesel–battery hybrid power system for a remotely located population near Rafha, Saudi Arabia. Energy 2010;35(12):4986–95.
[84] Nandi SK, Ghosh HR. Techno-economical analysis of off-grid hybrid systems at Kutubdia Island, Bangladesh. Energy Policy 2010;38(2):976–80.
[85] Haidar AMA, John PN, Shawal M. Optimal configuration assessment of renewable energy in Malaysia. Renew Energy 2011;36(2):881–8.
[86] Tzamalis G, Zoulias EI, Stamatakis E, Varkaraki E, Lois E, Zannikos F. Technoeconomic analysis of an autonomous power system integrating hydrogen technology as energy storage medium. Renew Energy 2011;36(1):118–24.
[87] Shaahid SM, Elhadidy MA. Economic analysis of hybrid photovoltaic–diesel– battery power systems for residential loads in hot regions – a step to clean future. Renew Sustain Energy Rev 2008;12(2):488–503.
[88] Beccali M, Brunone S, Cellura M, Franzitta V. Energy economic and environmental analysis on RET–hydrogen systems in residential buildings. Renew Energy 2008;33(3)366–82.