Research Article

Current Status of Research on Hybrid Power Generation Systems

[1]Madan A. Sendhil, [2]S. Balasubramanian and [3]G. Arunkumar
[1]Rathinam Technical Campus,
[2]Depertment of Mechanical Engineering,
[3]Depertment of ECE, Rathinam Technical Campus, Postal Code 641021, Coimbatore, India

Abstract: The main aim of this paper is a detailed study of recent developments in hybrid power generation systems. Renewable energy sources nowadays play a vital role in efficient and pollution free electric power generation systems as a recent trend. Solar energy and wind energy are the most popular sources of power generation in many developing countries. This study presents a detailed analysis of recent research works that are made in the field of renewable power generation systems and a study of various hybridization methodologies of electric power generation schemes and electrical energy utilization from solar, wind, diesel, biomass and thermal power generating systems. In this study various IEEE journals, magazines and conference proceedings has been analyzed and are concluded.

Keywords: Distributed generation, hybrid power generation, microgrid, non-conventional energy sources, solar photo-voltaic system, wind energy conversion systems

INTRODUCTION

One of the primary needs for socio-economic development in any nation in the world is the provision of reliable electricity supply systems with lower carbon footprint levels. Most of the present energy demands are met by fossil fuel plants and nuclear power plants. A small part of the demand is met with renewable energy technologies such as the wind, solar, biomass, geothermal etc. The development of Solar-Wind hybrid Power generation system that harnesses the renewable energies from sun and wind to generate electricity.

Most of the research works are about how to conserve the energy and how to utilize the energy from various sources and also been into the development of reliable and robust systems to harness energy from non-conventional energy resources. Among them, the wind and solar power sources have experienced a remarkably rapid growth in the last decades. Both are pollution free sources with abundant power.

Wind energy: Wind energy is the kinetic energy associated with atmospheric air. It has been utilized for sailing, grinding grains and for irrigation purposes for the past hundred years. Windmills for water pumping have been installed in many countries particularly in the rural areas. Wind turbine transforms the energy from the wind into mechanical power, which can be used directly for the production of electric power to generate electricity. Several wind turbines are grouped together called wind farms.

Solar energy: Solar energy is the energy from the radiation of sun shine. It is a renewable, inexhaustible and environmental pollution free source of power. Solar Photovoltaic (PV) systems are used to convert the solar energy into electrical energy and are stored in storage batteries. Solar PV systems provide power during the period of solar radiations and are able supply for complete 24 h a day by storing the energy through storage batteries. By adopting appropriate technology for the concerned geographical locations, we can extract a large amount of electrical power from solar radiations and more over the solar energy is expected to be the most promising alternate source for the production of electrical energy.

Diesel generators which are often used as an alternative to conventional power supply systems and are run only during certain hours of the day and their fuel cost are considerably very high. So they are very expensive if it is used for commercial purposes. There is a growing awareness that renewable energy sources such as solar PV systems and Wind Energy Conversion Systems (WECS) will play an important role in modern power generation schemes.

Hybrid Power Generation (HPG) system consist of a combination of renewable energy sources such as WECS, solar PV systems etc., provide power to meet the energy demand. Most of the non-conventional energy systems are not connected to the main utility grid and are used as stand-alone applications and are operated independently. The best applications for these types of systems are in remote places, such
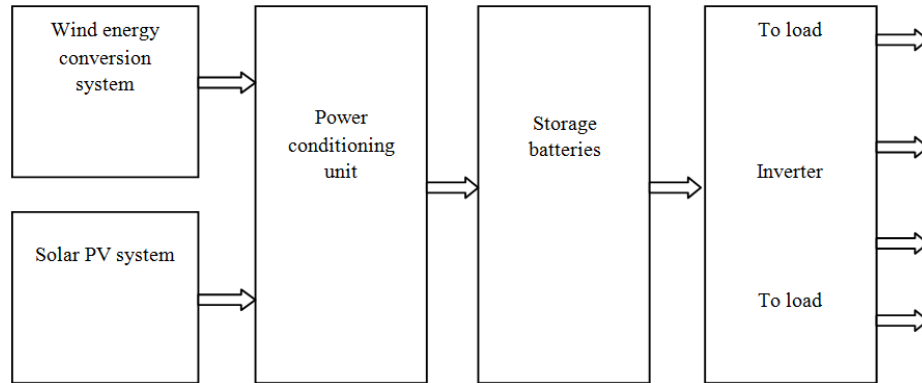
Fig. 1: Block diagram for hybrid power generation system incorporating wind and solar systems

as rural village electrification, street lighting and telecommunication systems. Hybrid systems are grown faster as they appear to be the right solution for clean and distributed production of electrical energy.

METHODOLOGY

Hybrid power generation systems: Nowadays wind and solar energy systems are integrated along with conventional power generating systems. The main advantages of the HPG systems are reliable, pollution free and to meet the required power demand throughout the year. Figure 1 shows a basic block diagram for a typical hybrid power generation system incorporating both the wind and solar systems.

REVIEW ON CURRENT STATUS OF RESEARCH IN HPG SYSTEMS

Som and Chakraborty (2014) developed a Real Valued Cultural Algorithm (RVCA) for an economic evaluation of a power system network for Distributed Energy Resources (DERs) by forming an autonomous power delivery system in an Indian scenario. The RVCA-evaluated total annual costs for the autonomous microgrid system utilizing both solar module and fuel cells as DERs and solar module and bio-mass gassifier unit as DERs and were compared. Different types of consumers together form a microgrid with the optimal supply of power from DERs. The optimal power generation conditions have been obtained for the minimum cost of microgrid system operation. The results were compared for different loading scenarios, using hybrid solar-biomass gassifier unit and found to be cost effective. From their results, a reduction of 8.1% in the annual cost was obtained using solar module-biomass gassifier unit to that of using solar module-fuel cell for the same load demand in microgrid operation.

Aien *et al*. (2014) developed a new methodology for Probabilistic Optimal Power Flow (P-OPF) studies for the unprecedented ascending penetration of Distributed Energy Resources (DERs) by modifying the Two Point Estimation Method (2PEM). The original 2PEM cannot handle correlated uncertain variables but the proposed method has been equipped with an ability to handle the uncertainty. For the justification of the impressiveness of the proposed method, two case studies namely the Wood and Woollenberg 6-bus and the Mathpower 30-bus test systems were examined and results obtained from the proposed methods were compared with the Monte Carlo Simulation (MCS) results. The comparison of the results from the proposed system shows the effectiveness of the method in the respected area regards to accuracy and execution time.

Iqbal and Sharma (2014) analyzed the reliability and optimization problem associated with Hybrid Power Supply System (HPSS) and several models of various techniques have been used to solve these problems. Several approaches, like multi-agent system, Supervisory model predictive control method, Unit sizing optimization; Maximum Power Point Tracking techniques and Dynamic modeling method were utilized to find out the optimal solution of non-linear problem. The main aim of the proposed study finds out the advantages and application of the evolutionary computing techniques in particular to the reliability and optimization problem by analysis and by comparing various control strategies.

Biswas *et al*. (2014) presented an optimal load flow model in conventional thermal power system to minimize the generation cost, active power losses and reactive power losses by introducing an additional wind generator in the existing system. To satisfy the need of future demand, in view of the non conventional energy perspective as well as to preserve the conventional asset for future they introduced a wind power generator in the system and a study was carried out regarded with the reliability as well as the voltage profile of the proposed system. They proposed a system to decrease the total loss by using hybrid thermal-wind power system. The Voltage profile of the proposed system had been tested. The implementation of the proposed

methodology can offer a net saving of generation cost. The proposed algorithm has been tested on standard IEEE 30 bus test system and the results were compared with earlier methods.

Colson *et al*. (2014) explored the formulations of storage system round-trip efficiency and operational cost, along with a model that can be determined from manufacturer data sheets and used in a real-time simulation environment for the evaluation of Storage systems. A battery model was used for real-time power management study for hybrid systems where a decentralized Multiagent System (MAS) was developed and which addresses the multi objective tradeoff optimization for the proposed hybrid system.

Rao *et al*. (2014) presented an alternate power generation, which is clean and economical for the future generation. The two sources which are used for power generation was solar and wind energy systems. DC output of photovoltaic panel and rectified dc output of Wind Energy Conversion System (WECS) was fed to a boost converter which is operating at closed loop in-order to maintain constant output power in all environmental conditions. The WECS consists of wind turbines with Permanent Magnet Synchronous Generator (PMSG) and the output of boost converter was fed to a common dc link which was connected to a 3 phase Sinusoidal Pulse Width Modulation (SPWM) inverter, which converts dc input to 3 phase AC output. A simulation was carried out for the rating of 2 KW solar and 3.2 KW wind hybrid system. The simulation model entire system was done in MATLAB/ SIMULINK.

Prema and Rao (2014) proposed a Predictive Power Management scheme which incorporates a forecast of the power generation capability of each generator, the load demand and other site-specific parameters is vital to extract the best from a hybrid power generation system. Such a management system, makes a long term forecast to minimize the errors on the behavioral patterns of wind and solar energy, has become a major subject matter of study for researchers across the globe. This paper gave an overview of the power management strategies and different predictive power management topologies and their advantages and challenges were discussed in that study.

Pirhaghshenasvali and Asaei (2014) proposed hybrid generation system for a practical stand-alone application in Iran. The proposed system consists of Wind-Turbine Generators (WTG), Photovoltaic (PV) systems, battery banks and diesel generator as power sources. The investment costs and fuel cost were minimized in the proposed system. The presented generation scheme should be able to produce sufficient power to cover the peak load. PV and WTG as well as battery banks are utilized as primary power sources and a diesel generator as a backup power for the system. The stand-alone system is designed based on the local data of solar radiation and wind speed along with operation states for system load in 24 h. Particle Swarm Optimization (PSO) algorithm was used to obtain the optimal sizes for WTG, PV, battery banks and the diesel generator.

Tlili *et al*. (2014) focused on the integration of a Photovoltaic Generator (GPV), a PEM Fuel Cell (PEMFC), an electrolyzer and a hydrogen storage tank for sustained power generation. In the proposed PV-FC hybrid system, the PV generator feeds a variable load through a DC-DC converter controlled by an MPPT (maximum power point tracking) control and transfers energy to the electrolyzer side if possible to produce hydrogen which will be stored in a tank for a later use in the Fuel Cell (PEMFC). When the PV system cannot completely meet the load demands, the FC system provides the lack of power. A MATLAB-SIMULINK simulation was developed for the simulation of the proposed PV-FC hybrid system. Simulation results were presented in order to highlight the performances of proposed hybrid system.

Zhang *et al*. (2014) analyzed the problem of dynamic diesel generators reconfiguration for an intelligent hybrid energy micro-grid system which integrates wind generators, solar photovoltaic panels and diesel generators. They were created a strategy for adjusting the number of the active diesel generators dynamically in order to minimize the total fuel cost while keeping a given Quality-of-Service (QoS) in terms of shortage probability. By the application of Hoeffding Theorem, they proposed a dynamic diesel generators reconfiguration algorithm which was capable of calculating the minimum number of active diesel generators subject to the shortage probability below a desired threshold and a the simulation study was carried out and the simulation results shows the reduction of the fuel cost.

Kollimalla *et al*. (2014) proposed a Hybrid Energy Storage System (HESS) for remote area power supply system consisting of PV, battery, Super Capacitor (SC) and load. PV generation and load demand varies continuously; batteries can undergo irregular, partial charge/discharge cycles. In the proposed method, batteries were used to balance the low frequency power surges, because of its low power density and low charge/discharge rates. Whereas SCs are used to balance the high frequency power surges, because of its high power density and high charge/discharge rates. The control of the battery system is coordinated with SC to improve the life span and reduce the stress on battery. The proposed control strategy is compared with the conventional strategy and validated for sudden changes in PV generation and load demand through digital simulation.

Zahboune *et al*. (2014) analyzed the system with hybrid power supply, harvesting PV and wind power in combination, integrated with battery storage with the

objective of satisfying the electricity demand and optimizing the cost. The proposed algorithm results a new Electricity System Cascade Analysis (ESCA) were demonstrated by a case of study of a house and three water pumps. The daily energy consumption of the system was 44.235 kWh. The size of the installed PVP, wind turbine capacity and the inverter has been minimized using a modified procedure.

Marshal and Deepa (2014) presented an innovative Switching logic for hybrid Distributed Energy Generators (DEG) by using a Single Input Buck-Boost (SIBB) converter and DSP controller based on their availability. With this proposed logic maximum amount of energy is extracted from the renewable energy resources depend on their availability. The combination of suggested switching logic and circuit configuration allows two renewable energy resources, to supply the load individually or simultaneously. The fast operation and reliability a DSP controller was utilized to increase the efficiency of the proposed system. To achieve extreme system efficiency three different modes of operations were projected. To analyze the real time feasibility of the proposed logic the system a simulation was carried out in MATLAB/SIMULINK environment and the results were compared with various methods. A hardware model of the system was developed along with integration of switching logic proposed for the learning of system in contradiction of the real time situations.

Thushar and Surya (2014) proposed a new autonomous wind-hydro hybrid generation system consists of one Squirrel-Cage Induction Generator (SCIG) driven by a variable-speed wind turbine and another SCIG driven by a constant-power hydro turbine feeding three-phase four-wire medium loads. The proposed system consists of two back-to-back-connected Pulse Width Modulation (PWM) controlled Insulated-Gate-Bipolar-Transistor (IGBT) based Voltage Source Converters (VSCs) with a efficient battery energy storage system at their dc link. The main purpose of the proposed control algorithm for the VSCs were to acquire Maximum Power Tracking (MPT) by rotor speed control of a wind turbine driven SCIG under varying wind speeds and control of the frequency and magnitude the of the load voltage. The proposed wind hydro hybrid system had the ability of bidirectional reactive and active power flow, by which it controls the magnitude and the frequency for voltage. The proposed system using cage generators, MPT controller and a voltage and a frequency controller were studied and were simulated in MATLAB using SIMULINK and SimPower System toolboxes and the proposed system was analyzed for various types of linear and nonlinear, under balanced and unbalanced load conditions. The performance of the proposed system was presented to demonstrate its Voltage and Frequency Control (VFC), harmonic elimination and load balancing.

Mishra *et al*. (2014) proposed architecture of a hybrid system which is based on solar photo-voltaic and wind energy systems. Depending upon availability and requirement these sources deliver the load together or independently. The proposed architecture consists of solar PV and wind energy system. In solar PV system MPPT technique was applied to maximize power output and a boost converter was employed to raise DC voltage and its output was fed to a three phase PWM inverter for converting DC voltage into AC at 50Hz frequency. In wind energy conversion system PMSG was driven by two masse drive train based wind turbine with zero pitch angles and both the systems supplying individual and combined load of 1 kW. A simulation study of the proposed system was carried out with MATLAB SIMULINK and simulation results were provided in that study.

Ma *et al*. (2014) proposed a novel power flow control method for a hybrid AC-DC microgrid with solar energy and energy storage for the integration of a pulse load. This micro grid works in islanding mode with a synchronous generator and PV farm supplying power to the systems in both AC and DC sides, respectively. A bidirectional AC-DC inverter was used to link the AC and DC sides by controlling the active and reactive power flow between them. The PV farm is connected to the DC bus through a DC-DC boost converter with Maximum Power Point Tracking (MPPT) functionality and a Battery bank was connected to the DC bus through a bidirectional DC-DC converter. The proposed system was tested with a pulse load connected in the AC side. Simulation results show that the proposed topology was coordinated for power management in both the AC and DC sides under critical loads with high efficiency, reliability and robustness in islanding modes.

Twaha *et al*. (2014) analyzed to determine the optimal hybrid renewable-based Distributed Generation (DG) system with feed-in tariffs. They compared grid-connected wind/hydro/diesel with storage, grid-connected wind/hydro/PV with storage, grid-connected hydro/PV with storage and grid-only systems. A new transmission capacity burden index has been introduced to indicate the extent at which the transmission line was loaded in the DG environment. HOMER software has been employed as an optimization tool and an optimality ranking technique has been used as a second method to determine the best optimal hybrid DG system. The simulation results indicate that a purely renewable based DG system is concluded as a best optimal system, such systems are very paramount to the Kingdom of Saudi Arabia (KSA) whose energy supply is dominated by fossil fuels. If such systems were implemented, KSA can contribute to the world's call to reduce greenhouse gasses in addition to reduce the dependence on conventional energy resources.

Feng *et al*. (2014) proposed a Hybrid Energy Storage (HES) composed of lithium-ion batteries and

ultra capacitors that can be incorporated in the PV-based system to complement the supply-demand mismatches by using a multimode fuzzy-logic power allocator. The battery used in the HES was modeled based on the experimental data and can accurately reflect the battery dynamics under varying conditions. The power allocator optimally adjusts the power contributions of the batteries and ultra capacitors and exchanges energy between them, thus compensating the supply-demand mismatches without accidentally depleting or saturating the two components. The proposed HES were evaluated in both short-and long-term scenarios. A good ac-side performance in the short-term scenario is observed due to the instant response of the ultra capacitors to the high-frequency requests. In the long-term scenario, the power allocator restrains the frequency fluctuations caused by the supply-demand mismatches within ±0.2 Hz, while maintaining the batteries and ultra-capacitors in a safe working region. Additionally, the participation of ultra-capacitors in supplying high-frequency power is beneficial for relaxing the stress on batteries and the simulation results show that the lifetime of batteries in the HES can be extended.

Wang *et al*. (2014) analyzed the wind power fluctuations and proposed a Hybrid Energy Storage System (HESS) consisting of a Battery Energy Storage System (BESS) and a super capacitor. A probabilistic approach for economically determining the power capacity specification for the HESS was proposed. This method would allow the capacities of the BESS and the super capacitor to be properly designed to optimize the characteristics of high energy density of the BESS and high power density of the super capacitor. Results show that the super capacitor within the HESS helps to process the high frequency fluctuations, which contributes to the extension of the BESS lifetime. In addition, the super capacitor helps to address the peaks in wind power fluctuations without severe penalty of round-trip losses associated with a BESS. The proposed approach has been simulated using real wind data from an existing wind power plant in Iowa.

Zhou and Sun (2014) developed a mathematical model of wind/solar generation systems, battery and super capacitor are built and the capacity of the system was considered as an optimization function for the proposed Hybrid Energy Storage Station (HESS) and various constraints were considered. To solve the optimization problem, an improved simulated annealing particle swarm optimization algorithm was proposed by introducing Simulated Annealing (SA) idea into Particle Swarm algorithm (PSO). The new algorithm enhances the ability to escape from local optimum and improve the diversity of particle swarm and to avoid prematurity. With an example system, the optimization results show that the convergence of new algorithm was faster than the traditional PSO algorithm and its cost

optimization was better, which demonstrated the correctness and validity of the proposed model and algorithms. This method provides a reference for the capacity optimization of HESS in wind/solar generation system.

Wan *et al*. (2014) proposed a novel hybrid intelligent algorithm approach to directly formulate optimal prediction intervals of wind power generation based on Extreme Learning Machine (ELM) and Particle Swarm Optimization (PSO). Prediction intervals with associated confidence levels were generated through direct optimization of both the coverage probability and sharpness to ensure the quality. The proposed method does not involve the statistical inference or distribution assumption of forecasting errors needed in most existing methods. A case study has been conducted using real wind farm data from Australian country. Comparing with benchmarks an experimental result was demonstrated for high efficiency and reliability of the developed approach. It is therefore convinced that the proposed method provide a new generalized framework for probabilistic wind power forecasting with high reliability and flexibility and has a high potential of practical applications in power systems.

Terciyanli *et al*. (2014) described an enhanced monitoring and forecast system for the electrical power generated from wind energy in Turkey. Wind Power Plant (WPP) owners, transmission system operator, distribution system operators and renewable energy experts are the shareholders of this system. The developed monitoring and forecast system was composed of wind electricity analyzers and reference wind masts, one for each WPP, a Wind-electric Power Monitoring and Forecast Center (WPMFC) equipped with database, data processing and application servers and forecast software. In this system all shareholders can communicate with the developed WPMFC in order to retrieve preprocessed wind-electric power forecast data and power quality data, through the IP network according to their authorization level. The electrical and meteorological raw data can also be retrieved for post-processing. The developed system was based on Global Positioning System (GPS) synchronized with real-time field measurements taken from each WPP, in addition to the use of mesoscale numerical weather prediction models. Instantaneous electrical and meteorological quantities of each WPP can be monitored continuously through the WPMFC. The forecast system employs physical, statistical and hybrid models combining both approaches. Some sample monitoring and forecast results are given in that study to illustrate the benefits and abilities of the developed system.

Satpathy *et al*. (2014) presented the sustainability of a 4-kW hybrid of wind and battery system was investigated for meeting the requirements of a 3-kW stand-alone dc load representing a base telecom station.

A charge controller for battery bank based on turbine maximum power point tracking and battery state of charge was developed to ensure controlled charging and discharging of batteries. The mechanical safety of the WECS is assured by means of pitch control technique. Both the control schemes were integrated and the efficacy was validated by testing it with various loads and wind profile was simulated in MATLAB/SIMULNIK.

He *et al.* (2014) proposed method named as adaptive Hybrid voltage and current Controlled Method (HCM) method to accomplish superior harmonic compensation performance using Distributed Generation (DG) unit. It shows that the proposed adaptive HCM can reduce the numbers of low-pass/bandpass filters in the DG unit digital controller. Moreover, phase-locked loops are not necessary as the microgrid frequency deviation can be automatically identified by the power control loop. Consequently, the proposed control method provides opportunities to reduce DG control complexity, without affecting the harmonic compensation performance. Comprehensive simulated and experimental results from a single-phase microgrid were provided to verify the feasibility of the proposed adaptive HCM approach.

Mendis *et al.* (2014) presented a control strategy for managing the demand-generation fluctuations using a hybrid energy storage system in a wind-dominated Remote Area Power Supply system (RAPS) consisting of a Doubly Fed Induction Generator (DFIG), a battery storage system, a super capacitor, a dump load and main loads. The operation of battery storage system was coordinated with a super capacitor with a view to improving the performance of the battery. In this regard, the battery storage system is connected to the load side of the RAPS system, whereas the super capacitor is connected to the dc bus of the back-to-back converter of the DFIG. The operation of the hybrid energy storage system was coordinated through the implementation of a power management algorithm, which was developed with a view to reducing the depth of discharge and ripple content of the battery current. In addition, a dump load was connected to the load side of the RAPS system, which utilizes the power in situations that cannot be handled via an energy storage system and a coordination method has been developed and proposed to coordinate the power flows among all system components with a view to regulating the power flow and thereby ensuring the robust voltage and frequency control on the load side while capturing the maximum power from wind.

CONCLUSION

In this study several hybrid power generation systems are analyzed and a detailed study is carried out for various control strategies and optimization algorithms which are incorporated with the production of electrical energy from various non conventional energy sources. Many of the researchers proposed both simulation and real time implementation for hybrid power generation systems. Finally we can conclude that integration renewable energy sources, Hybrid power generation systems and distributed generation systems provides an alternate strategy for reliable, economical and efficient power generation systems along with conventional power generation schemes to meet the required power demand and are very useful to power engineering society.

REFERENCES

Aien, M., M. Fotuhi-Firuzabad and M. Rashidinejad, 2014. Probabilistic optimal power flow in correlated hybrid wind-photovoltaic power systems. IEEE T. Smart Grid, 5(1): 130-138.

Biswas, S., R. Chatterjee and R. Pramanik, 2014. Optimization of electrical power networks with wind generator integration. Proceeding of the 1st International Conference on Non Conventional Energy (ICONCE, 2014), pp: 148-153.

Colson, C.M., M.H. Nehrir, R.K. Sharma and B. Asghari, 2014. Improving sustainability of hybrid energy systems Part I: Incorporating battery round-trip efficiency and operational cost factors. IEEE T. Sust. Energ., 5(1): 37-45.

Feng, X., H.B. Gooi and S.X. Chen, 2014. Hybrid energy storage with multimode fuzzy power allocator for PV systems. IEEE T. Sust. Energ., 5(2): 389-397.

He, J., Y.W. Li and F. Blaabjerg, 2014. Flexible microgrid power quality enhancement using adaptive hybrid voltage and current controller. IEEE T. Ind. Electron., 61(6): 2784-2794.

Iqbal, M.A. and S. Sharma, 2014. Analysis and comparison of various control strategy of hybrid power generation a review. Proceeding of 1st International Conference on, Non Conventional Energy (ICONCE, 2014), pp: 184-189.

Kollimalla, S.K., M.K. Mishra and N. Lakshmi Narasamma, 2014. A new control strategy for interfacing battery supercapacitor storage systems for PV system. Proceeding of IEEE Students' Conference on Electrical, Electronics and Computer Science (SCEECS, 2014), pp: 1-6.

Ma, T., B. Serrano and O. Mohammed, 2014. Distributed control of hybrid AC-DC microgrid with solar energy, energy storage and critical load. Proceeding of 2014 Clemson University and Power Systems Conference (PSC, 2014), pp: 1-6.

Marshal, T.P.J. and K. Deepa, 2014. Hybrid renewable energy system: Optimum design, control and maximum utilization with SIBB converter using DSP controller. Proceeding of Power and Energy Systems Conference: Towards Sustainable Energy, pp: 1-4.

Mendis, N., K.M. Muttaqi and S. Perera, 2014. Management of low-and high-frequency power components in demand-generation fluctuations of a DFIG-based wind-dominated RAPS system using hybrid energy storage. IEEE T. Ind. Appl., 50(3): 2258-2268.

Mishra, S., M. Gupta, A. Garg, R. Goel and V.K. Mishra, 2014. Modeling and simulation of solar photo-.,taic and PMSG based wind hybrid system. Proceeding of IEEE Students' Conference on Electrical, Electronics and Computer Science (SCEECS, 2014), pp: 1-6.

Pirhaghshenasvali, M. and B. Asaei, 2014. Optimal modeling and sizing of a practical hybrid wind/PV/diesel generation system. Proceeding of Power Electronics, Drive Systems and Technologies Conference (PEDSTC, 2014), pp: 506-511.

Prema, V. and K.U. Rao, 2014. Predictive models for power management of a hybrid microgrid-a review. Proceeding of International Conference on Advances in Energy Conversion Technologies (ICAECT, 2014), pp: 7-12.

Rao, S.P.L., C.P. Kurian, B.K. Singh, K. Abhinav and G. Nandy, 2014. Design and simulation of grid connected hybrid solar-WECS using SIMULINK/ MATLAB. Proceeding of International Conference on Advances in Energy Conversion Technologies (ICAECT, 2014), pp: 241-247.

Satpathy, A.S., N.K. Kishore, D. Kastha and N.C. Sahoo, 2014. Control scheme for a stand-alone wind energy conversion system. IEEE T. Energy Conver., 29(2): 418-425.

Som, T. and N. Chakraborty, 2014. Studies on economic feasibility of an autonomous power delivery system utilizing alternative hybrid distributed energy resources. IEEE T. Power Syst., 29(1): 172-181.

Terciyanli, E., T. Demirci, D. Kucuk, M. Sarac, I. Cadirci and M. Ermis, 2014. Enhanced nationwide wind-electric power monitoring and forecast system. IEEE T. Ind. Inform., 10(2): 1171-1184.

Thushar, A. and P.R. Surya, 2014. Autonomous wind-Hydro hybrid system using cage generators and battery storage. Proceeding of Power and Energy Systems Conference: Towards Sustainable Energy, pp: 1-6.

Tlili, N., B. Neily and F. Ben Salem, 2014. Modeling and simulation of hybrid system coupling a photo voltaic generator, a PEM fuel cell and an electrolyzer (Part II). Proceeding of 11th International Multi-Conference on Systems, Signals and Devices (SSD), pp: 1-7.

Twaha, S., Z. Al-Hamouz and M.U. Mukhtiar, 2014. Optimal hybrid renewable-based distributed generation system with feed-in tariffs and ranking technique. Proceeding of 8th International IEEE Power Engineering and Optimization Conference (PEOCO, 2014), pp: 115-120.

Wan, C., Z. Xu, P. Pinson and Z.Y. Dong, 2014. Optimal prediction intervals of wind power generation. IEEE T. Power Syst., 29(3): 1166-1174.

Wang, X., M. Yue, E. Muljadi and W. Gao, 2014. Probabilistic approach for power capacity specification of wind energy storage systems. IEEE T. Ind. Appl., 50(2): 1215-1224.

Zahboune, H., F.Z. Kadda, S. Zouggar, E. Ziani, J. Klemes, P.S. Varbanov and Y. Zarhloule, 2014. The new electricity system cascade analysis method for optimal sizing of an autonomous hybrid PV/wind energy system with battery storage. Proceeding of the 5th International Renewable Energy Congress (IREC, 2014), pp: 1-6.

Zhang, S., J. Yang, X. Wu and R. Zhu, 2014. Dynamic power provisioning for cost minimization in islanding micro-grid with renewable energy. Proceeding of IEEE PES Innovative Smart Grid Technologies Conference (ISGT, 2014), pp: 1-5.

Zhou, T. and W. Sun, 2014. Optimization of battery-supercapacitor hybrid energy storage station in wind/solar generation system. IEEE T. Sust. Energ., 5(2): 408-415.