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A Review Modeling and Control Strategies for Renewable Based Energy

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ABSTRACT: Renewable energy sources also called non-conventional energy are sources that are incessantly restocked by natural processes. For example, hydropower, wind energy, bio-energy – bio fuels grown sustainably, solar energy etc., are some of the examples of renewable energy sources. Battery charging process is non-linear, time-varying with a substantial time delay so it is complicated to accomplish the preeminent energy management performance by using conventional control techniques. For modeling the renewable energy source, different control strategies have been used by researchers/ authors and presented in the literature. This paper presents the different problems related to grid integration of renewable energy sources (RES) and their control strategies.

Keywords: Battery Charging, Hydropower, Modeling, Optimization, Renewable Energy

I. INTRODUCTION

Under the pressure of limited available energy resources and environmental policies, electrical power generation using renewable energy has rapidly increased in recent years [1]. In China, a large number of remote rural or mountainous inhabitants have no access to the main electricity supply network so it is important to explore the local natural renewable energy resources such as wind or solar [2] for power generation, mainly for local consumptions. Due to the nature of intermittence of renewable energy, the use of the secondary energy storage such as batteries become inevitable which will be compensated in the fluctuations of power generation [3]. The use of a small size wind turbines could enable more households to have accesses to electricity. A block diagram for the energy conversion process in a small-scale renewable energy generation system is shown in Fig.1. First, the renewable resource such as wind or tidal energy is used to drive a turbine, translating its power to mechanical form, which then drives a generator. The AC power generated is generally with a variable frequency and unstable voltage so it will be converted to DC power. The DC power either is used to serve the load directly or converted to good quality AC power supply to AC loads. Due to uncertainties of the renewable energy availability, battery storage is adopted. So the electricity energy will be saved to the battery when the excessive electricity is generated and the stored energy will supply electricity to the load while there is no enough electrical power being generated. First, the renewable resource such as wind or tidal energy is used to drive a turbine, translating its power to mechanical form, which then drives a generator. The AC power generated is generally with a variable frequency and unstable voltage so it will be converted to DC power.

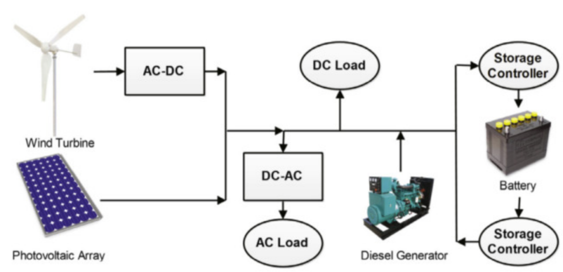

Fig. 1. A typical renewable energy generation system.

The DC power either is used to serve the load directly or converted to good quality AC power supply to AC loads. Due to uncertainties of the renewable energy availability, battery storage is adopted. So the electricity energy will be saved to the battery when the excessive electricity is generated and the stored energy will supply electricity to the load while there is no enough electrical power being generated. As we know, frequent charging and discharging will shorten the life time of a battery. With such a system, the problem is how to determine when the battery should be charged to provide the best energy efficiency and to prolong the life time.

Many works such as the modeling of the wind turbine, the control strategies for the three-phase generator and the optimization of the DC-DC converter etc., have been reported in many publications [4]. Various research papers identified with modeling and control method are accessible in literature. In this paper, renewable energy based half and half models and control systems are mulled over. What's more, different issues identified with half breed displaying are additionally tended to. It has been found that the specialists have attempted to accomplish two expansive results as specified previously. This paper is sorted out as follows: the methodologies and techniques embraced by various authors or researchers to accomplish an optimal hybrid design are discussed in Section 2. Literature work is presented in Section 3. Conclusion of the paper is given in Section 4.

II. CONTROL STRATEGY & OPTIMIZATION

In this section, renewable energy based hybrid models and control strategies are taken into consideration. In addition, various issues related to hybrid modeling are also addressed. It has been found that the researchers have worked to achieve two broad results as mentioned above.

Design Optimization

As discusses earlier, the researchers worked under two broad optimization objectives. One such category is the design of an optimal sizing of hybrid energy sources. This includes the selection of proper renewable energy sources with proper sizing, so that an optimized hybrid energy system could be developed, depending on the availability and feasibility of renewable energy power required of each source. Some of the key methodologies and approaches adopted are as follows:

A. Using Simulation Programs

Optimum sizing is necessary to obtain economical power output from an efficient renewable energy based system thereby reducing the investment with full utilization of the system component [5]. It has been found that simulation programs are the most common tools used for optimization of hybrid systems, among which, Hybrid Optimization Model for Electric Renewable (HOMER) has been used extensively [NREL: HOMER]. Later, researchers developed HYBRID2, with very precise simulation, as it can define time intervals ranging from 10 min to 1 hour. Similarly, HOGA is developed incorporating an optimization program by means of Genetic Algorithms. It is seen that all these simulation programs can only simulate one configuration at a time, but not designed to provide an optimized configuration.

B. Graphical Approach

Various graphical optimization techniques have been reported in the literature. Graphical construction technique to calculate the optimum combination has been presented using long-term data [6]. Another graphical technique is used to optimally design a hybrid solar–wind power generation system by considering the monthly-average solar and wind energy values. However, in both graphical methods, only two parameters are included in the optimization process, while some important factors are completely neglected.

C. Probabilistic Approach

Probabilistic approaches have also been opted for sizing hybrid system, as it accounted for the effect of renewable sources variability in the system design. Sizing method treating storage energy variation as a random walk and the probability density for daily increment or decrement of storage level approximated by a two-event probability distribution is presented [8]. The method is further extended to account for the effect of correlation between day to day radiations values, then modified, in whose works, the storage energy transitions were approximated by three-event probabilistic approach to overcome the limitations of conventional two-event approach in matching the actual distribution of the energy generated by hybrid systems. Probabilistic approach is based on the convolution technique to incorporate the fluctuating nature of the resources and the load, thus eliminating the need for time-series data, to assess the long-term performance of a hybrid solar wind system for both stand-alone and grid-connected applications. It has been noticed that the major limitation of this probabilistic approach is that it cannot represent the dynamic changing performance of the hybrid system.

D. Artificial Intelligence Approach

Artificial intelligence methods such as Genetic Algorithms, Artificial Neural Networks and Fuzzy Logic, have also been widely used to optimize a hybrid system. In such cases, Genetic Algorithm has been widely used as compared to other artificial intelligence techniques because of their capability to handle complex problems with linear or non-linear cost functions [9]. Genetic Algorithms address the problems of uncertain renewable energy supplies, load demand and the non-linear characteristics of some components by incorporating past and future demand. GA is also widely used in conjunction with artificial neural networks. New design variables/constraints including cost minimization, and both reliability and CO_2 emission are taken as constraints. Markov-based GA is introduced for the determination of optimal sizes of renewable energy sources units.

It is found that Markov-based GA can help to reduce CPU time greatly and provide competitive cost.

E. Operating Point Control

Effort has also been done in controlling the operating point of the system keeping the system to work at maximum power point. A cost-effective control technique for maximum power point tracking from the photovoltaic array and wind turbine under varying climatic conditions without measuring the irradiance of the photovoltaic or the wind speed has been developed. Predictive control has also been used to compute the operating points of the wind subsystem and of the solar subsystem together to generate enough energy to satisfy the load demand. In addition to this, supervisory controls have also been used to optimize the operating points so as to reduce the peak value of surge currents. Predictive control has also been extensively used by other researchers [7]. It is shown that the temperature profile can be predicted as a function of the cooling strategy for a solar-module. It is found that the I–V electrical characteristic of the whole module can be derived from this information, thereby identifying those average parameters that mainly affect the solar-module behaviour, thus facilitating the prediction on the current and voltage levels that can be sustained by the solar panel as well as the maximum sup pliable power. All of these aspects are a key to the proper design of the electronic control interface that tracks the maximum power point. Such control techniques have been applied to control different types of hybrid systems to maintain constant voltage, constant frequency, MPT, neutral-current compensation, harmonics elimination, load balancing and the highest efficiency optimization.

F. Hybrid Energy Storage System Control

Power quality can be increased by the proper selection and control of Hybrid Energy Storage System. A miniature flywheel energy storage system for energy storage with a pair of hybrid magnetic bearings (HMBs); consisting of both superconducting magnetic bearings (SMBs) and active magnetic bearings (AMBs) applied with H-infinity control method and zero bias method has also been developed. It is seen that by using the HMBs the radial displacement of the rotor is much smaller than that with SMBs thus improving the dynamics of the ESS. Hybrid power sources that combine advanced batteries with ultra capacitors can be operated for longer times. Peak power can be greatly enhanced, internal losses can be considerably reduced, and that discharge life of the battery is extended using ultra capacitors [10]. The greatest benefits can be seen when the load pulse rate is higher than the system eigen-frequency and when the pulse duty is small. Ultra capacitors are also increasing interest because of their high-energy density (compared to conventional capacitors) and high-power density (compared to batteries and fuel cells). The use of ultra capacitor in power distribution and in utility electronic apparatus has shown improvements in power quality, uninterrupted power supply, and memory backup .

Also, superconducting magnetic energy storage (SMES) has been utilized for better power quality by many researchers. With the appropriate topology of the power conditioning system (PCS) and its control system design, the SMES unit has been found capable of simultaneously performing both instantaneous active and reactive power flow control. Fuzzy control scheme has also been used for the optimized performance of a hybrid energy storage system composed of a superconducting magnet Due to the emergent technology of fuel cells, much amount of research has also been focused on it. PEMFC control strategy has been developed to produce the power, minimize the fuel consumption and also provide a regulated dc bus voltage to the load. This is done by controlling the voltage of air pump of FC for the control of fuel cell current through a dc/dc switching converter. The control results, fuel consumption, and fuel cell protect against oxygen starvation phenomenon. To incorporate some non linear structures, the development of an ANN based fuel-cell model within the hybrid model of a FC stack not only improves accuracy but also allows the model to adapt itself to operating conditions; giving a good estimate of the relationship between current and temperature and making the system work on maximum power condition . Other types of fuel cells have also been suggested in HESS for the minimization of hydrogen rate using the output dc current of the SOFC or the current magnitude of the ac load. The topology of ESS is also suggested by the researchers for better power quality. A two level ESS has been proposed, where the battery is paired with a fast-acting low-power -capacity ESS. The controller minimizes dump load, limits the intra-hour diesel ramp rates, and maximizes ESS utilization. In addition, the operation of charging and discharging of ESS can be managed by controlling the bidirectional converter operated under buck boost or shut down mode according to the operation condition of the fuel cell and battery. Fatness properties for a FC/super capacitor could also be used in designing a better control law.

III. LITERATURE SURVEY

Yong Yin, Xing Luo, Shen Guo, Zude Zhou and Jihong Wang, “A Battery Charging Control Strategy for Renewable Energy Generation Systems” [11]. Battery charging process is non-linear, time-varying with a considerable time delay so it is difficult to achieve the best energy management performance by using traditional control approaches. A fuzzy control strategy for battery charging or discharging used in a renewable power generation system is studied in the paper. Three working status of a battery in different energy transformation modes and the working principles of a re-chargeable battery are studied. To achieve the optimal charging and discharging status of the battery, a fuzzy control strategy is developed. The membership function database of the fuzzy sets, the fuzzification of the input and output variables and the evaluation of the fuzzy rules are studied to support the control strategy. Finally, the output defuzzification and the fuzzy control simulation is presented, which demonstrates that the satisfied system performance is achieved.

Xiangjun Li, Dong Hui, and Xiaokang Lai, “Battery Energy Storage Station (BESS)-Based Smoothing Control of Photovoltaic (PV) and Wind Power Generation Fluctuations”. [12] The battery energy storage station (BESS) is the current and typical means of smoothing wind- or solar-power generation fluctuations. Such BESS-based hybrid power systems require a suitable control strategy that can effectively regulate power output levels and battery state of charge (SOC). This paper presents the results of a wind/photovoltaic (PV)/BESS hybrid power system simulation analysis undertaken to improve the smoothing performance of wind/PV/BESS hybrid power generation and the effectiveness of battery SOC control. A smoothing control method for reducing wind/PV hybrid output power fluctuations and regulating battery SOC under the typical conditions is proposed. A novel real-time BESS-based power allocation method also is proposed. The effectiveness of these methods was verified using MATLAB/SIMULINK software.

A. Rabhi, J. Bosch, A. Elhajjaji, “Energy Management for an Autonomous Renewable Energy System”.[13] In this paper a controller and an management of production systems focusing on energy from renewable sources is presented. The main results are optimizing the energy extracted from renewable sources to and effectively control the charging and discharging of the battery. An algorithm based on fuzzy logic is developed to determine the degree of involvement of each source. Then we develop the controls in power converters installed in the system to properly manage and respond to instructions from the management algorithm. To validate this technique, simulation results are presented.

D.D. Budh and V.B. Virulkar, “Energy Management of Renewable Energy System with ESS”.[14] This paper discusses the effectiveness of BESS energy management method. Such BESS-based renewable energy systems require a suitable control strategy that can effectively regulate power output levels and battery state of charge (SOC) within a specified range. The control method can supervise the SOC to secure the charging level of the BESS by adjusting the target power for high and low SOC ranges. Considering the results of energy management and effectiveness of battery SOC control, regulation of battery SOC under typical conditions is proposed.

Amjed Hina Fathima and Kaliannan Palanisamy “Energy Storage Systems for Energy Management of Renewable in Distributed Generation Systems”[15] Distributed generation (DG) systems are the key for implementation of micro/smart grids of today, and energy storages are becoming an integral part of such systems. Advancement in technology now ensures power storage and delivery from few seconds to days/ months. But an effective management of the distributed energy resources and its storage systems is essential to ensure efficient operation and long service life. This chapter presents the issues faced in integrating renewables in DG and the growing necessity of energy storages. Types of energy storage systems (ESSs) and their applications have also been detailed. A brief literature study on energy management of ESSs in distributed microgrids has also been included. This is followed by a simple case study to illustrate the need and effect of management of ESSs in distributed systems.

Feng Gao, Lei Zhang, Qi Zhou, Mengxing Chen, Tao Xu and Shaogang Hu “State-of-Charge Balancing Control Strategy of Battery Energy Storage System Based on Modular Multilevel Converter”.[16] This paper proposed a novel battery energy storage system based on modular multilevel converter (MMC), which has several merits compared with two-level and cascaded multilevel battery energy storage systems. The proposed system can manage the state-of-charges (SOCs) of all batteries to be equal to avoid the overcharge or over discharge of single battery stack as traditional. Besides, the inherent power exchange characteristics using circulating current could increase the control flexibility for SOC balancing, and improve output waveform quality, maximize storage capacity and reduce internal losses. The key issues regarding injected dc current control, SOC balancing control and circulating current control are discussed in this paper.

Finally, the proposed system were verified through Matlab/Simulink simulation and a scaled down experiment prototype. Yan Zhang, Baolong Liu, Tao Zhang, Bo Guo "An Intelligent Control Strategy of Battery Energy Storage System for Microgrid Energy Management under Forecast Uncertainties[17]. This paper concerned on efficient energy management of microgrid with RER integration and battery energy storage system (BESS) and in real-time electricity price (RTP) markets. A model predictive control (MPC) based scheduling and operation strategy for microgrid operator to minimize the operation costs under different forecast uncertainty levels of load demand, electricity price, and renewable energy generation outputs is proposed. Three other strategies are also discussed for evaluating the performance of strategy presented in this paper. Simulation results show that the proposed MPC-based strategy has better performance and more robust than the other strategies facing different prediction uncertainty levels.

S. D. Saranya, S. Sathyamoorthi and R. Gandhiraj "A Fuzzy Logic Based Energy Management System for A Microgrid"[18] proposed an approach for the hybrid solar photovoltaic and wind power system in Battery management for stand-alone applications. Battery charging process is non-linear, time-varying with a considerable time delay so it is difficult to achieve the best energy management performance by using traditional control approaches. A fuzzy control strategy for battery charging or discharging used in a renewable power generation system is analyzed in the paper. To improve the life cycle of the battery, fuzzy control manages the desired state of charge (SOC). A fuzzy logic-based controller to be used for the Battery SOC control of the designed hybrid system is proposed and compared with a classical PI controller for the performance validation. The entire designed system is modeled and simulated using MATLAB/Simulink Environment.

Sathish Kumar Kollimalla, Mahesh Kumar Mishra, and N. Lakshmi Narasamma "Design and Analysis of Novel Control Strategy for Battery and Super capacitor Storage System"[19] In the proposed method, batteries are used to balance the slow changing power surges, whereas super capacitors (SC) are used to balance the fast changing power surges. The main advantage of the proposed control strategy is that, the slow response of battery system including dynamics of battery, controller, and converter operation, is overcome by diverting the power surges to the SC system. The proposed method inherits charge/discharge rate control to improve the life span and reduce the current stresses on battery. The proposed method features less computational burden as it uses simple control strategy. The detailed experimental results presented validate the proposed control strategy for sudden changes in photovoltaic (PV) generation and load demand.

Booma J., Arul Pragash I., Dhana Rega A.J. "A Novel Control Scheme for Standalone Hybrid Renewable Energy System".[20] This paper proposed an integrated control scheme for standalone hybrid renewable energy system with battery management. The Standalone Hybrid Renewable Energy System comprised of Photo Voltaic system and Wind Generation System can provide low cost, reliable green energy to the rural areas. In this paper, an integrated control logic of power flow management with voltage regulation for standalone hybrid renewable energy system is proposed to provide reliable and regulated power supply to residential loads (both DC and AC loads). The modeling of the proposed system consist of three power sources (Tata TB305LBZ solar panel model with maximum power of 3050 W, PMSG based Wind Generation System with 1500 W rating, and Nickel Metal Hydride battery with maximum capacity of 1000 AH) and three power sinks (DC load of 500 W, AC load of 2000 W and battery unit during charging conditions). The performance of the proposed standalone system is verified under different environmental conditions by using MATLAB/Simulink tool and results are effectively validated at different system conditions.

H S Shalini, Chandasree Das "Energy Management of Hybrid System with Efficient Control Strategy for Smoothing of the Power Fluctuation Using Battery Energy Storage System (BESS) - A Case Study"[21] Hybrid generation system plays a very important role in remote and isolated areas. A hybrid system is designed to operate independently as well as in grid connected mode, through power converter system (PCS). This paper presents suitable control strategies, which can regulate output power level of the hybrid system composed of Photo Voltaic (PV), Wind Turbine (WT) and Battery Energy Storage System (BESS). The proposed system has been carried out with case studies based on source and load priority which provides uninterruptable power to the loads. Sources are individually controlled to operate at Maximum Power Point using Maximum Power Point Tracking (MPPTIC algorithm) for PV system and Doubly Fed Induction Generator (DFIG) based Pitch control technique in WT system. State of Charging (SOC) in BESS put forward for smoothing of fluctuations based on charging and discharging of a battery. The effectiveness of the proposed technique is validated using MATLAB/SIMULINK software.

Linas Gelazˇanskas, Audrius Baranauskas, Kelum A.A. Gamage, Mindaugas Azˇubalis "Hybrid wind power balance control strategy using thermal power, hydro power and flow batteries"[22]. The increased number of renewable power plants pose threat to power system balance. Their intermittent nature makes it very difficult to predict power output, thus either additional reserve power plants or new storage and control technologies are required. Traditional spinning reserve cannot fully compensate sudden changes in renewable energy power generation. Using new storage technologies such as flow batteries, it is feasible to balance the variations in power and voltage within very short period of time. This paper summaries the controlled use of hybrid flow battery, thermal and hydro power plant system, to support wind power plants to reach near perfect balance, i.e. make the total power output as close as possible to the predicted value. It also investigates the possibility of such technology to take part in the balance of the Lithuanian power system. A dynamic model of flow battery is demonstrated where it evaluates the main parameters such as power, energy, reaction time and efficiency. The required battery size is tested based on range of thermal and hydro power plant reaction times. This work suggests that power and energy of a reasonable size flow battery is sufficient to correct the load and wind power imbalance.

IV. CONCLUSION

The control process of the battery charging and discharging is non-linear, time-varying with time delays. It is a multiple variable control problem with unexpected external disturbances. The control procedure of the battery charging and discharging is non-direct, time-differing with time delays. It is a multiple variable control issue with surprising outside disturbances. This paper gives an outline of available methodologies and these presently under research for most favorable control strategies and goals considered in the plan of half and half renewable vitality frameworks. Diverse methodologies and strategies for framework control of mixture frameworks are exhibited. Current status and future potential outcomes in framework control have been discussed. It is found that the huge amount of work done using conventional control approach or power convertor control. So in future work, this can be implemented using soft computing technique.

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