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A review of frequency control of hybrid renewable energy system with hybrid control model

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Abstract

This paper presents a review of a frequency control of hybrid renewable energy system (HRES) with hybrid control model. Stand alone and grid-connected hybrid renewable energy system (HRES) to supply AC masses. The configuration of the frequency control based HRESs and interfacing power converters for connecting the energy sources to the AC bus is lengthily elaborated. In this paper, the summary of the control concepts in an HRES and the application of the appropriate control schemes for system stabilization, effective injection of high-quality power and proper load sharing are discussed. The different approaches for HRES design and control strategies for power converters in the recently published literature are also briefly addressed. This paper specially addressed various control strategy in the hybrid renewable energy system.

Keywords: Hybrid Renewable Energy System (HRES), Hybrid Controller, Power Converter

Introduction

Rapid exhaustion of non renewable resources on a worldwide and release of greenhouse gases to the atmosphere has contributed to global warming which has necessitated an urgent search for substitute energy sources to cater to the present day's demand [1-3]. More significantly, these non-renewable energy resources are quickly decreasing and will no longer be available in the near future due to speedy utilization [4]. Alternative energy technologies, like wind- and solar based energy generation systems, are receiving national and worldwide attention owing to the rising rate of utilization of nuclear and fossil fuels [5]. Renewable energy has the potential for endless use by end users with improved control devices and techniques [6]. With their advantages of being abundant in nature and nearly nonpolluting, renewable energy sources have attracted wide attention [7] [8]. These renewable energies are motivated by a will to decrease green-house gases (GHG) emissions and the increase of fuel prices that drives up the prices of energy [9]. There are numerous ways by which electricity can be generated locally using renewable sources such as solar, wind, biogas, etc [10].

Hybrid Renewable Energy Systems (HRES), combine two or more balancing renewable sources like wind and solar and one or more conservative sources like diesel generator [11], and equipment for the storage of energy [12]. Hybrid Renewable Energy System are usually more reliable and less costly than other type of renewable systems that rely on a single source of energy [13-15]. HRES is becoming popular for stand-alone power generation in lonely sites due to the advances in renewable energy technologies and power electronic converters which are used to convert the unfettered power generated from renewable sources into useful power at the load end [16]. One of the most promising applications of renewable energy technology is the installation of hybrid energy systems in remote areas, where the grid extension is costly and the cost of fuel increases significantly with the remoteness of the location [17].

A hybrid system can supply power AC or DC or both. Component or system control or both is used to regulate the overall system operation [18]. The appropriate selection of the hybrid system's components, its optimal sizing and operation control are essential and challenging steps in hybrid energy systems and minimizing the equivalent pollutant emissions of the hybrid system is one more objective [19]. There are many optimization algorithms applied to calculate the capacity allocation for the renewable energy based hybrid power system. In addition, more control models are used to control the frequency deviation and optimal operation [20].

Recent Research Works: A Brief Review

Assortments of related works are already existed in literature which is based on control of hybrid renewable energy system with different control methods. Among them, few works are reviewed here.

Dulal Ch. Das *et al.* [21] have proposed the simulation studies of autonomous hybrid generation systems consisting of wind turbine generators (WTGs), solar thermal power system (STPS), solar photovoltaic (PV), diesel engine generators (DEGs), fuel cells (FCs), battery energy storage system (BESS), flywheel (FW), ultra capacitors (UCs) and aqua electrolyzer (AE). The power system frequency deviates for sudden changes in load or generation or the both. The comparative performance of the controllers installed to alleviate this frequency deviation for different hybrid systems, was carried out using time domain simulation. Traditional controllers were tuned manually which was difficult and time consuming. Here, GA was used for optimization of controller's gains of the proposed hybrid systems.

S.G. Malla *et al.* [22] have proposed the wind and solar based stand-alone hybrid energy system for the remote area power system applications. The wind, solar, battery, fuel cell and dump load were connected to the common dc bus. An ac load was connected to dc bus through a pulse width modulation (PWM) based inverter. Ac voltage at load bus can be maintained at rated value by regulating dc-link voltage (V_{dc}) at its reference value and by controlling modulation index of PWM inverter. Novel control algorithms are developed to maintain V_{dc} at its reference voltage irrespective of variations in wind speed, solar irradiance and load. Along with the regulation of V_{dc}, dc–dc converter (connected between battery and dc-link) acts as a maximum power point tracker (MPPT) for photovoltaic (PV) array. Hence an extra dedicated MPPT circuit is not required to extract maximum power from PV. Control technique for the PWM inverter has been developed to make the line voltages balanced at the point of common coupling when the load was unbalanced. Hence, efforts were made to supply quality voltage to the consumers through the stand-alone power system.

J.E. Paiva *et al.* [23] have analyzed and proposed a different role for small distributed generation (DG) systems based on renewable sources, in the context of modern electrical grids. The main purpose of the system was to act as a grid services provider and not as a stochastic and dynamically unpredictable energy generator. Being a small system with a production cost higher than a conventional one, its operation as a grid services provider, rather than only an energy generator, was proposed and analyzed.

Yasuhiro Hamada *et al*. [24] have proposed the field experiments and numerical simulations on hybrid utilization of renewable energy and fuel cells for a residential energy system. They presented results of empirical testing and evaluation of hybrid utilization involving solar energy. First, field experiments were conducted on an electric power and domestic hot water supply system that uses both solar energy and fuel cells. The system achieved a large amount of reduction in primary energy consumption compared with conventional systems. Secondly, a simulation was performed on the optimum scale and effect of introduction of the system.

Lin Xu *et al*. [25] have proposed an improved optimal sizing method for wind-solar-battery hybrid power system (WSB-HPS), considering the system working in stand-alone and grid-connected modes. The proposed method was based on the following principles: a) high power supply reliability; b) full utilization of the complementary characteristics of wind and solar; c) small fluctuation of power injected into the grid; d) optimization of the battery's charge and discharge state; e) minimization of the total cost of system.

Compared with the traditional methods, the proposed method can achieve a higher power supply reliability while require less battery capacity in stand-alone mode. And in grid-connected mode, the optimization strategy based on energy filter is further utilized to achieve the optimal battery capacity. Thus, the proposed method can achieve a much smaller fluctuation of power injected into the grid.

Motivation for the Research Work

The review of the resent research work shows that, the renewable energy plays an important role for clean and sustainable energy sources. To meet the required power demand, smooth the changeability of primary energy and the need of storage hybrid energy systems used. Under hybrid energy operation, suitable energy management and control technique is essential for distributing the captured power in the form of AC or DC or both. Various approaches have been used in literature to control the hybrid energy system by effectively. Proportional Integral (PI) controller is one of the basic controllers which used to perform quick control operation. But, the effectiveness of the controller is depends on the controller gains and the controller gain tuning is complex problem. Therefore, traditionally Ziegler and Nichols method have been described to tune the conventional PI controller. The controller gains one time tuned for a given operating point are just suitable for restricted operating point changes. As a result, the use of the traditional PI controller does not meet the requirements of the robust performance. Furthermore, while the number of parameters to be optimized is large, traditional technique for optimization is definitely not favoured one. For tuning the controller gains and improve the performance of traditional tuning methods, the optimization algorithms are introduced such as, genetic algorithm, particle swam optimization, artificial neural network are applied to optimize the gains of the controller. The demerits of above techniques are overcome by the investigation new optimization algorithms. In literature very few works are presented to solve this problem and the drawbacks of the presented works have motivated to do this research work.

Proposed Methodology

Here, I have intended to propose a hybrid control model based frequency controller for hybrid energy system. The proposed hybrid control model will be combination of traditional control method with optimization algorithm. Initially, the source of the hybrid energy system will be considered for modelling the proposed control model. Then, the mathematical model of the energy sources will be derived by first order transfer function equations. The transfer function model will be formed by the gain and the time constant of the respective sources. The proposed hybrid control model will tune the optimal frequency control parameters and the frequency variation will be reduced by minimize the fluctuation. The proposed control model will be simulated in MATLAB/Simulink platform and the performance will be examined in time domain simulation.

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