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A meta-heuristic firefly algorithm based smart control strategy and analysis of a grid connected hybrid photovoltaic/wind distributed generation system

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ABSTRACT

An integrating distributed generation to power systems causes several technical issues, especially system stability like voltage at point of common coupling (PCC) and system. Therefore, to fully address the issue, current exiting power systems should be upgraded to the advanced power grid. To make the power grid become 'advanced', particularly in terms of stability and flexibility, one must need to make a controller which capable to control the above issue after integration of hybrid distribution generation system into the utility grid. All the issues have been attempted to address in this paper.

Dynamic model for the main system components, namely, wind energy conversion system (WECS), PV energy conversion system (PVECS) and control for PVECS and the power electronics devices are addressed in this paper. The overall control strategy for grid connected hybrid wind/PV distributed generation system has also been presented. Different energy sources in the system are integrated through a DC bus into the utility grid. Based on the dynamic component models, a simulation model for the hybrid distributed generation system connected with utility grid has been developed using MATLAB/Simulink. Hybrid system comprises of Wind Turbine (WT) and solar Photovoltaic (SPV). For control the voltage and frequency at PCC Firefly based controller is used. Performance of several controllers such as Proportional Integral (PI), and Proportional Integral Derivatives (PID) are evaluated to control the frequency of the system. The controller gains are simultaneously optimized by powerful meta-heuristic firefly algorithm. Comparison of the dynamic responses reveals better performance of the PID controller. Here, it has been observed that the values of gain designed by firefly algorithm are robust which is verified and validated by case studies. Investigations reveal that the FA is successfully applied for simulation studies and it has been carried out to verify the controller and system performance under different scenarios which reveals that overall control strategy are robust and perform well.

1. Introduction

Currently the main source of electrical power generation is fossil fuel producing carbon dioxide (CO_2) emission and other gases, which lead to global warming. Due to the environmental issues in reducing green house gases (GHG), the utilization of renewable energy sources (RES) in now growing rapidly and is being widely accepted as an alternative power supply (Lopes et al., 2000; Momoh, 2009; Katz, 2008). An important phenomenon in this regard for further electric power generation is distributed generation, which is also known as embedded generation, dispersed generation or decentralized generation (Katz, 2008; DeBlasio and Tom, 2008).

In order to meet the rising electrical power demand and increasing service quality demands, as well as reduce pollution, the existing power grid infrastructure should be developed into an advanced grid. This advanced grid is flexible for interconnectivity with distributed generation, such as wind turbines and solar power (DeBlasio and Tom, 2008; Hammons, 2007). However, integrating this concept of distributed generation into utility grid systems will increase many complex issues on real time operation (Chiradeja, 2005; Barker and de Mello, 2000). Previous research shows that distributed generation has an immediate impact when

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it is connected into distribution systems (DS), such as on power flow direction, protection, voltage profile, power quality and stability (Hammons, 2007; Barker and de Mello, 2000; Mahadanaarachchi and Ramakuma, 2008). Therefore, more research needs to be performed systematically in order to analyze and minimize the impact of distributed generation on power systems; not only on distribution systems but also on utility grid (Lopes et al., 2000; Mahadanaarachchi and Ramakuma, 2008; Agbossou et al., 2004; Agbossou et al., 2001; Lasseter, 2001; Lai, 2007). Moreover, this is tried to perform in this work. It is expected in the near future that the utilization of distributed generation will increase and currently utility grid connected with hybrid system is regarded as vital infrastructure for the development of the industrial and business nations worldwide (Sharma et al., 2000; Delmerico et al., 2003; Vlatkovic, 2004; Raju et al., 2003; Muljadi and Butterfield, 2001; Lai and Peng, 1996).

In view of the above literature review, it can be concluded that many previous works have investigated different aspects of PV systems, including the energy production and economics (Mei and Pal, 2007; Hammons, 2007; Hua et al., 1998). The most widely addressed technical issue regarding PV systems is the so-called maximum power-point tracking (MPPT) (Hua and Shen, 1998; Hollmuller et al., 2000; Masoum et al., 2002; Kundur et al., 1994; Ulleberg and Mørner, 1997; Ulleberg, 1998). Lin and Liu (2006) reviews 19 different MPPT methods introduced since1968. However PV system in standalone mode is good for low power application. But the major drawback with PV system is that without a good and robust power management system, the power supplied to the consumers would be very unstable (Hua and Shen, 1998; Hollmuller et al., 2000; Masoum et al., 2002; Esram and Chapman, 2007; Karki and Billinton, 2001). The power management technique will be very complex when we used different renewable energy sources.

In wind energy application, variable speed wind turbines are popular mainly because of their capability to capture more power from the wind using the maximum power point tracking (MPPT) algorithm and improved efficiency (Raju et al., 2003; Muljadi and Butterfield, 2001). In case of DFIG, gear box many times suffers from faults and requires regular maintenance (Yang, 2009), making the system unreliable. However PMSG has removed the reliability problem & has received much attention in wind energy applications because of its self-excitation capability, leading to a high power factor and high efficiency operation (Lukasik and Zak, 2009). From literature survey it is found that Wind and solar energy have too many limitations if it can be used separately as a single source in standalone mode because we know that wind and solar both are unpredictable so it is not reliable.

The limitation of the above can be removed by making the hybrid system in standalone mode. Multi source hybrid alternative energy systems (with proper control) in standalone mode have great potential to provide higher quality and more reliable power to customers than a system based on a single resource (Rahman and Tam, 1988; DeBlasio and Tom, 2008; Sharma et al., 2000; Calais and Agelidis, 1998; Masoum et al., 2002; Santarelli et al., 2004; Valenciaga and Puleston, 2005). Because of this feature, hybrid energy systems have caught worldwide research attention. Because of the intermittent nature of wind and solar energy, standalone wind and PV energy systems normally require energy storage devices or some other generation sources to form a hybrid system. A battery bank is also used in the system for short-time backup (Valenciaga and Puleston, 2005; Dufo-López and Bernal-Agustín, 2008; Giannakoudis et al., 2010; Ziogou et al., 2011).

In case of a long-term no-wind or low-wind condition, no availability of sun rays, the battery alone may not cater to the load demand in standalone mode (Marnay et al., 2008; Colson and Nehrir, 2011; Dimeas and Hatziargyriou, 2005; Venkataramanan and Marnay, 2008; Khoan and Vaziri, 2005; Prata, 2006; Bastiao et al., 2008). However this problem is removed by making the hybrid system connected with utility grid. But Due to the integration of distributed generation, voltage variation and violation and frequency deviation can still happen at the Point of Common coupling PCC. Therefore, the limit of power injection to the system must be verified before installing distributed generation on the system. In addition, voltage variation levels should also be considered and should not vary more than ±5 percent (PU) (Khoan and Vaziri, 2005; Prata, 2006; Bastiao et al., 2008). To maintain balanced line voltage at PCC it is necessary to compensate the voltage unbalance at PCC. Hybrid systems, such as wind power and solar power systems use power electronic converters in order to feed the produced energy into the utility grid (Bastiao et al., 2008; Singh and Kasal, 2008; Malla and Bhende, 2014; Ackermann, 2005; Raiambal and Chellamuthu, 2002; Mei and Pal, 2007; González - Longatt et al., 2011). The Converter of the grid side is the one which is responsible for the grid synchronization (Lai, 2007; Bastiao et al., 2008; Singh and Kasal, 2008; Malla and Bhende, 2014; Ackermann, 2005; Raiambal and Chellamuthu, 2002; Mei and Pal, 2007; González - Longatt et al., 2011) and should not only control the power delivered to the network, but also contribute to the grid stability, supporting the grid services (voltage/frequency) under generic conditions, even under grid faults (Sharma et al., 2000). A phase-locked loop (PLL) algorithm is used in order to obtain the synchronization (Kaura and Blasko, 1997; Arruda et al., 2001; Lee et al., 1999; Arruda et al., 2000). In PLL algorithm the most important synchronization variable is the frequency of the grid voltage. In PLL algorithm, for the detection of frequency detection is done (Delmerico et al., 2003; Vlatkovic, 2004), to estimate the grid frequency that will be used in the PID controller. But from the above investigation we surprise nobody used a soft computing based optimization technique to find the optimum gain of controller which used in frequency control. This is tried to overcome in this work. In this work it is simultaneously optimized the gain of various controllers which is used for voltage control.

So this work focuses on the performance a devaluation of different controller which is used for control the frequency (Pathak et al., 2016; Abdullah et al., 2011; Xia et al., 2013; Carrasco et al., 2015). In view of the above discussion, the following works have been included in the present work-

1. To develop a model of a grid connected Hybrid (solar & wind) distribution generation system with necessary control.
2. To apply Firefly Algorithm for simultaneous optimization of controller gains of several classical controllers such as Proportional–Integral (PI), and Proportional–Integral–Derivative (PID) in the model of hybrid system connected with utility grid.

2. System investigation

Investigation have been carried out on a grid connected hybrid Wind/PV distributed generation system (shown in Fig. 1) consists of a permanent magnet synchronous generator (PMSG) based variable speed wind energy conversion of a 6 KW, PV array 1 KW & utility grid. Hybrid system connected through utility grid & load through command dc link and DC-AC convertor. A single switch three-phase switch-mode rectifier is used here, which is controlled to extract maximum power from the fluctuating wind. Individual dc–dc boost converters are used to control the power flow to the load through dc link in PV system. A simple and effective control with dc–dc converters is used for maximum power point tracking and hence maximum power extracting from and the solar photo voltaic systems. Here for controlling voltage at PCC & for controlling system frequency and make a system stable