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Load Frequency Control of Hybrid power System using Classical PID Controller

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Abstract - This paper addresses the use of PID tuned by Particle Swarm Optimization for frequency control in the hybrid power system. The proposed system composed of renewable sources like wind turbine generation and photovoltaic system with diesel engine generator and storage systems such as the battery, aqua electrolyzer, and Fuel Cell. The stochastic nature of renewable sources causes dangerous fluctuations of frequency and power of the hybrid power system which can provoke the deterioration of electrical equipment. This issue requires an adequate control strategy. Classical PID controller is investigated to give better performance in terms of deviation reduction and elimination of the mismatch between generation and load. The results are shown and compared.

Keywords: Frequency Load control, PID controller, Renewable Energy, Particle Swarm Optimization

INTRODUCTION

Due to the increase of population around the world, the need for power and the greenhouse crisis lead towards the using o renewable energy sources as a distributed generation in isolated areas or interconnected with the main grid. The microgrid system plays an important role in the electrical system to prove the electricity in remote and isolated areas where is not the availability of the main grid (Souza Ribeiro et al., 2010). The use of a hybrid energy system presents a better solution to fossil depletion and greenhouse problems (Lee et al., 2008). The microgrid is wide consists of renewable energy sources along with storage devices and conventional sources. The better configuration of microgrid includes more than one renewable source such as wind and solar for ensuring the service continuity to supply the demand over time.

These renewable sources have a stochastic nature what is made the integration of energy storage devices like Battery, and Flywheel an important solution to reduce the imbalance between generations and loads (Dhillon et al., 2015, Venkataramanan and Marnay., 2008, Palma-Behnke et al., 2012 and Katiraei et al., 2006). The microgrid is interconnected of different distributed generation sources with loads to operate autonomously and supply power to their loads. The intermittent nature of renewable sources provokes frequency and power fluctuations which require an adequate control system (Favuzza et al., 2011).

Various control techniques such as the PID controller, Fuzzy Logic Controller, and PID fractional controller are used to control the frequency and power deviations (Favuzza et al., 2011, Palma-Behnke et al., 2012, Marei et al., 2002, Regad et al., 2019). The Classical PID controller is considered the simplest and easy to be implemented in the kind of system. It is also largely used in the industry process (Favuzza et al., 2011, Palma-Behnke et al., 2012). The main problem to apply this controller is to determine its optimal parameters. Recently some optimization techniques like Genetic algorithm and Particle Swarm Optimization are investigated to overcome this kind of problem (Pan and Das., 2014, Pan

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and Das., 2016). The PSO technique has not yet largely been reported to apply in the field of the hybrid energy system (Dhillon et al., 2015, Palma-Behnke et al., 2012). The present paper addresses the PID controller of frequency control in an isolated microgrid area. The control technique involves the PID controller tuned using the PSO algorithm. The results show the better robustness of PID-PSO in comparison with PID-GA.

LITERATURE REVIEW ON MICROGRID

Microgrids (MGs) could address significantly to both issues and may play an important role in the new decentralized power systems. A hierarchical organizational scheme of MGs with a clear distinction of the Microgrid is studied and analysed. One of the most advantages of Microgrid systems is of being installed at demands premises that make it to be considered as economical and environmentally friendly as the electricity is produced by renewables generations units like Wind turbine Generator, Photovoltaic system and fuel cell etc (Dhillon et al., 2015). To design a Microgrid system two or more renewable energy generations always combined with storage devices and conventional sources to deliver electricity to the connected load and ensure the service continuity (Senjyu et al., 2005).

The weather conditions based on solar irradiance and wind speed which are the input data to the Photovoltaic system and Wind turbine Generator system respectively; are stochastic along with the load demand which is intermittent and changes over time. The change in both generation powers according to the weather condition and in power demand because of human life conditions affects the stability and continuity of microgrid operation. These issues are discussed by some studies as in (Boden et al., 2013, Venkataramanan et Marnay., 2008), which show the utility of the combination of more than one renewables sources along with storage devices and supplementary sources' like a Diesel engine and Fuel Cell. Many configurations are shown to be the best configuration of a microgrid that ensure the electrical service continuity with less sensibility to the weather condition change and disturbances of loads. The use of energy storage system enhances the stability of microgrid by absorbing the surplus of power which can provoke the mismatch between generation and loads and they to release the stored power later when the power load is less than generation during the night or clouded days. On other hand, they are used to control the frequency and power deviations under the loads change and climate problems. The supplementary sources used to help the primary renewable sources to ensure system reliability (Venkataramanan et Marnay., 2008). The characteristics of different components model have been described in many works (Favuzza et al., 2011, Katiraei et al., 2006). Such an unbalancing act can be caused by the change in both the consumer loads as well as generating power from renewable sources. It is essential to maintaining the reliable operation of the microgrid system through the integration of energy storage system and conventional sources. They include Battery, flywheel, Fuel Cell, Aqua electrolyzer and Diesel Generator and so one.

From previous researches, the modern power system requires new microgrid technologies intelligent control strategies and optimization techniques to ensure the generation and load balance which cause serious disturbances. These problems become more important with the increase in microgrid based renewable energy production units that varying naturally. These challenges and uncertainties in power systems make the classical control strategies to be unable to provide better performances stability and reliability over a wide range of operating conditions of the microgrid (Marei et al., 2002, Regad et al., 2019).

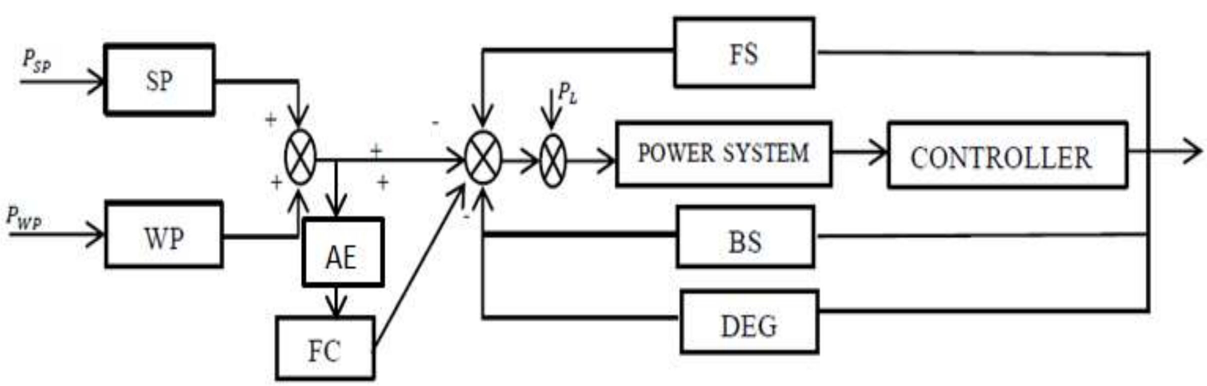

Figure 1: Bloc of a microgrid system

The proposed microgrid system is modelled by the first-order transfer function of energy generation and storage devices as shown in figure.1. The system is modelled for analysis of frequency and power behaviour. A control technique must be investigated to improve system performances and stability (Pan et Das., 2014., Regad et al, 2019, Das et al., 2012).

PID controller structure

Wang et al., (2008) give the transfer of proportional-integral-derivative (PID) controller.

$$TF_{PID} = K_P + \frac{K_I}{s} + K_D.s \qquad (1)$$

Where,K_P,K_I, and K_D are the proportional, integral and derivative gain of PID the controller. The structure of the PID controller is presented in the figure.2 (Wang et al., 2008).

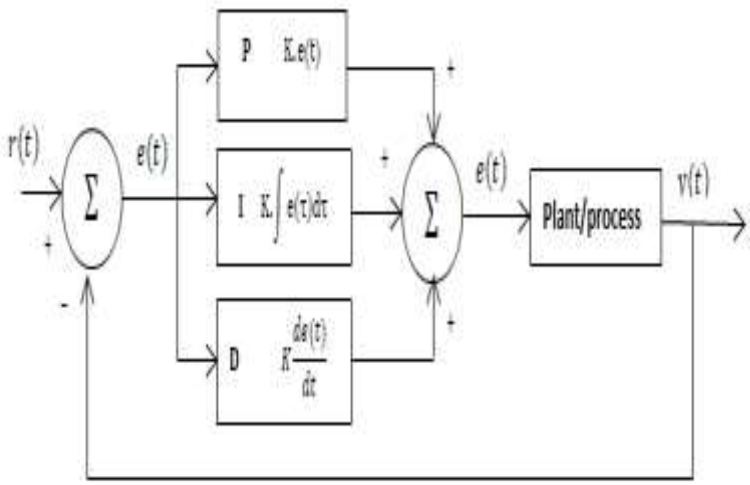

Figure 2: Structure of the PID controller

Parameters of the PID controller are optimally tuned by considering frequency and power deviations. Objective functions considered for solving any problem plays an important role to improve the dynamic response of the system. Hence integral square error (ISE) is considered as objective function J for tuning controller parameters (Kumari et Jha., 2014).

$$J = ISE = \int_0^{T_{sim}} (\Delta F^2) dt$$

Where ΔF is the system frequency deviation of the microgrid. The T_{sim} is the time simulation. This objective function will be resolved using PSO algorithm to determine the optimal parameters of the PID controller.

Overview of the Particle Swarm Optimization

One of the most optimization methods, the Particle Swarm Optimization algorithm is largely used to be applied in many fields of optimization problems. PSO is a stochastic optimization algorithm developed by Eberhart and Kennedy, inspired by the social behaviour and fish schooling of bird flocking. Each particle in the swarm is a different possible set of the unknown parameters of the objective function to be optimized [Pan et Das., 2016, Regad et al, 2019). The swarm consists of N particles moving around in a D-dimensional search space. Each particle is initialized with a random position and a random velocity. Steps for PSO based controllers' parameters optimization is explained in (Yang. 2011, Pandey et al., 2014).

RESULTS AND DISCUSSIONS

The given model in figure.1 is designed in Simulink using a first-order transfer function (Palma-Behnke et al., 2012, Lee et al., 2008 and Boden et al., 2013). The system is simulated under varying in generated power and load conditions as shown in followed figures. The generated power from renewable energy sources and load demand is presented in figure.3. The PID controller is tuned using the PSO algorithm which its fitness function is shown in figure.4 and has fast converging behaviour. Frequency and power deviations that demonstrate the robustness of the PSO optimized PID controller in terms of performance indices are presented in figure.5. Figure.6. presents different output power of DEG and Battery energy storage using GA and PSO. The results reflect good stability and reliability of proposed microgrid through the employment of a PID controller tuned by the PSO Algorithm.

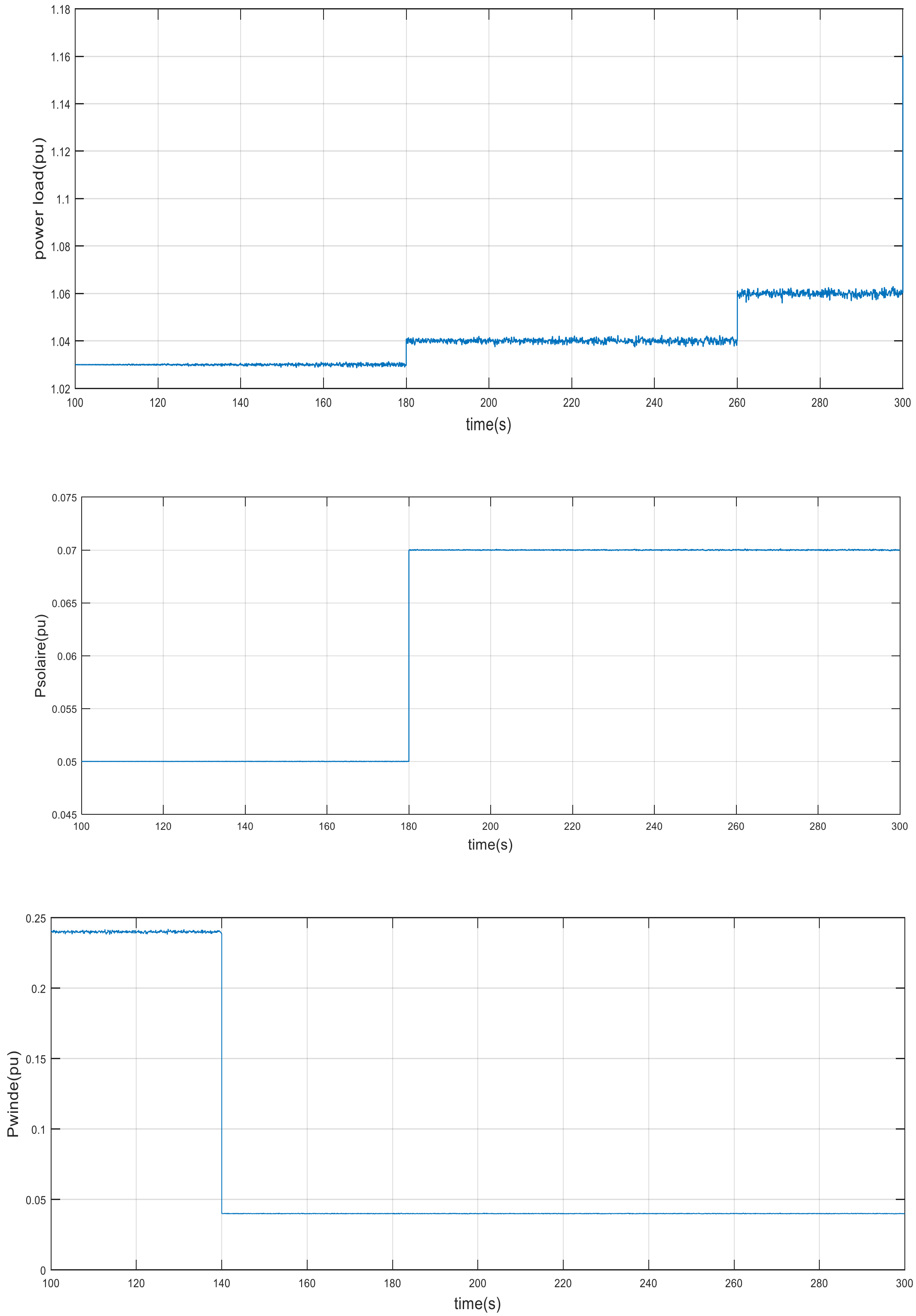

Figure 3: Load demand, the output power of WTG and SPV

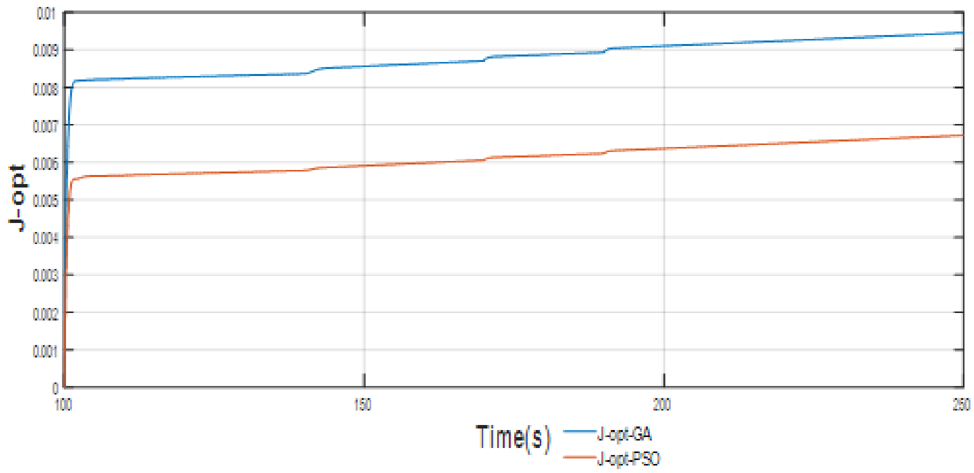

Figure 4: The plot of the fitness function of GA and PSO

Figure.4 shows the convergences of two optimization techniques such as Genetic Algorithm and Particle Swarm Optimization. The results show the fast convergence of the PSO to find the optimal controller parameters.

Time-domain analysis
In this subsection, a comparison between PSO and GA based PID is accomplished for frequency and power deviations.

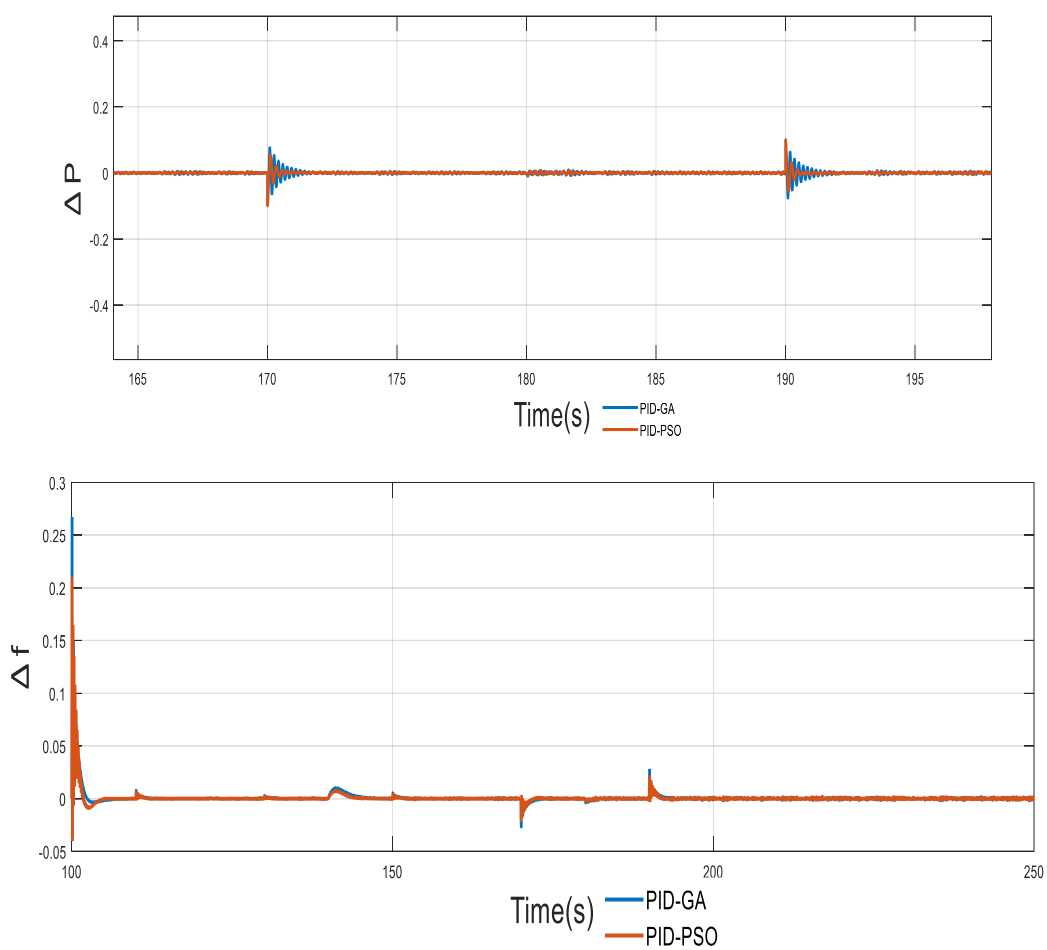

Figure 5: Frequency and power deviations with best PID controller based GA and PSO

The above figure.5 shows the frequency control in time domain analysis of microgrid. The best obtained PID controller parameters reduce the frequency and power fluctuation against the stochastic variations in power generation from the renewable sources and loads demand perturbations.

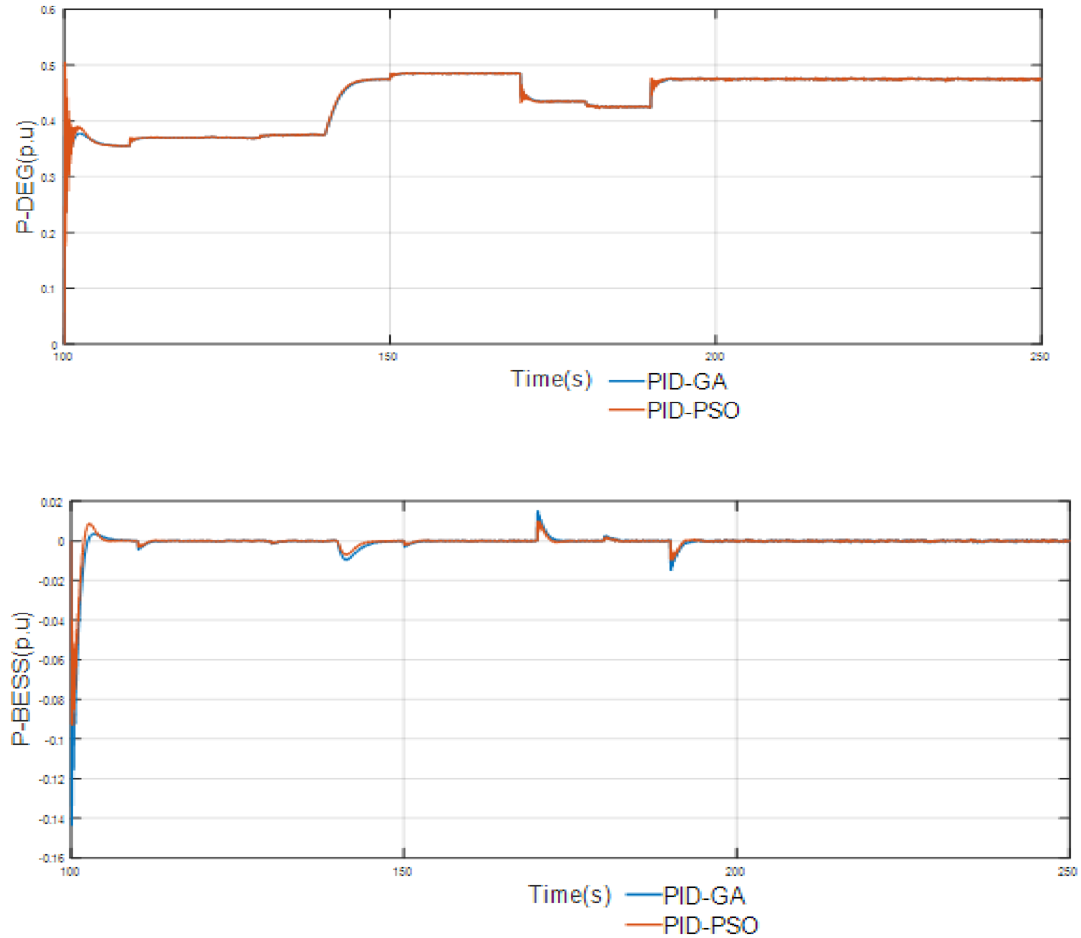

Figure 6: The output power of DEG and BESS using best PID controller

Figure 6 presents the outputs powers of microgrid components like BESS and DEG. The sudden change in generation and load affect the frequency and power stability and the controller work to reduce this effect by the feedback signal to the storage devices and secondary sources like the FC and DEG. The aforementioned results show up that the PSO algorithm enhances the system performances better than GA in term of reducing the frequency fluctuation and convergence to the optimal parameters of the proposed controller.

CONCLUSION

This paper presents the load frequency control of an isolated microgrid composed of a Wind Turbine Generator, Solar Power System, Battery, Flywheel, Aqua Electrolyser, Diesel Engine Generator, and Fuel Cell. The frequency and power fluctuation are controlled using PID controller connected in the feedback of Energy storage devices BESS and FESS along with the conventional sources like DEG and FC. The PID controller parameters are optimized using Particle Swarm Optimization Algorithm and Genetic algorithm through the minimizing of and objective function. The obtained results show better performances of the PID-PSO technique in terms of less oscillation and good system stability. The PID-PSO outperforms PID-GA to reduce the frequency and power deviations. This proposed method is a good choice for application in control of the hybrid energy system based on the renewable energy system in comparison with the Genetic Algorithm.

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