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Reactive power control of isolated wind-diesel hybrid power system using grey wolf optimization technique

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Abstract

In this paper reactive-power control of an isolated wind–diesel hybrid power system is presented. The system generates electrical power from wind by an induction generator (IG) and a synchronous generator (SG) is present for a diesel-generator (DG) set. The mathematical model of the reactive-power balance is presented. In an isolated system IG consumes reactive power which is supplied by the static var compensator (SVC). It also provides reactive power support for load variations. In the type III SVC used here, the proportional integral (PI) controller gains are optimized using Grey Wolf Optimization (GWO) algorithm. Three objective functions namely Integral Time Absolute Error (ITAE), Integral Square Error (ISE) and Integral Time Square Error (ITSE) are considered and their performance is compared in a hybrid system and with earlier work.

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Keywords: Static var compensator (SVC);isolated wind–diesel hybrid power system; Grey Wolf Optimization (GWO); PI controller; ITSE; PSO

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1. Introduction

To maintain generation- load balance and limited life of conventional sources with high pollution rate, research on alternative sources of energy are focused. The renewable sources such as wind, solar, mini/micro hydro, etc. are in geographically dispersed locations close to loads. Such system is termed as distributed or dispersed power system[1]. If it delivers to a local load it is an isolated hybrid power systems[2]. Examples of such are the wind–diesel, wind–diesel–micro hydro systems, wind-diesel- Photo Voltaic system etc. Generators with wind turbine are generally asynchronous or induction generator for variable speed operation. The advantages of such generator over synchronous generator are: reduced unit cost, ruggedness, absence of separate dc source, ease of maintenance, self-protection against severe overloads and short circuits[3]. But the disadvantage of an Induction Generator (IG) lies in its requirement of reactive power to maintain flux. Reactive power can be met by capacitor banks/Synchronous Generator (SG)[4] in an isolated system. Majority of the loads are also inductive. The unequal generation and demand of the reactive power can cause a large voltage variation at generator terminals. Thus, the reactive-power-control strategy of the autonomous wind-diesel hybrid power system needs great improvement to maintain the voltage within the specified limits[5].

Static var compensator (SVC)[6-9] is commonly used for reactive-power control in the transmission system[11]. It is one of the flexible ac transmission systems (FACTS) devices. Though it is primarily concerned with transmission system, it can be used as a source of reactive power in isolated system to improve undesirable voltage fluctuation.

Optimal controller design using swarm optimizations have performed satisfactorily in many areas. Recently, a swarm based optimization- Grey Wolf Optimizer (GWO) has been proposed[12]. This optimization mimics the social behavior of a pack of wolves. Mirjalili et al. have shown superiority of this technique compared to its contemporaries such as Particle Swarm Optimization (PSO), Differential Evolution (DE) and Gravitational Search Algorithm (GSA) in solving the benchmark problems and some of the engineering applications. The SVC used here is type III which consists of a PI controller which signals the firing of SVC. The gains of this controller, Proportional gain K_p and Integral gain K_i are optimized using Grey Wolf Optimization technique.

The paper is organized as follows, Section 2 describes of the modeling equations concisely and Section 3 includes the algorithm of the optimization techniques. Section 4 shows the dynamic responses of the hybrid power systems with the optimal gain obtained followed by the concluding remarks.

2. Modeling Equations

The system taken in this work consists of a diesel generator (DG) set, IG, SVC and consumer loads as shown in Fig.1. The synchronous generator (SG) in DG acts as a reference grid for the IG connected on the wind energy-conversion system. The excitation system in the SG connected on the DG set is IEEE type-I excitation system. The SVC supplies the reactive power deficit apart from the reactive power generated by the SG[8]. The SVC used here is type III as shown in Fig.2.

Frequency is affected by deviation in the real power where as the voltage by reactive power. Here, the prime-mover time constant is greater than excitation time constant, so cross coupling between the load frequency control (LFC) and the automatic-voltage-regulator (AVR) loop is negligible. Thus under steady-state, the reactive-power balance is given by:

$$Q_{SG} + Q_{SVC} = Q_L + Q_{IG} \tag{1}$$

where Q_{SG} = Generated reactive power by SG (pu KVAR); Q_{SVC} = generated reactive power by SVC (pu KVAR); Q_L = load reactive power demand (pu KVAR) and Q_{IG} = reactive power consumed by IG (pu KVAR).