Modified Neural Network for Dynamic Control and Operation of a Hybrid Generation Systems

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ABSTRACT
This paper presents modified neural network for dynamic control and operation of a hybrid generation systems. PV and wind power are the primary power sources of the system to take full advantages of renewable energy, and the diesel-engine is used as a backup system. The simulation model of the hybrid system was developed using MATLAB Simulink. To achieve a fast and stable response for the real power control, the intelligent controller consists of a Radial Basis Function Network (RBFN) and an modified Elman Neural Network (ENN) for maximum power point tracking (MPPT). The pitch angle of wind turbine is controlled by ENN, and the PV system uses RBFN, where the output signal is used to control the DC / DC boost converters to achieve the MPPT. And the results show the hybrid generation system can effectively extract the maximum power from the PV and wind energy sources.

Keywords: Photovoltaic system, radial basis function network, Elman neural network, maximum power point tracking, diesel-engine.

1. Introduction

Wind and solar power generation are two of the most promising renewable power generation technologies. Variable-speed wind turbines have many advantages that are well documented in the literature [1], [2]. The wind turbine can operate with maximum aerodynamic efficiency, and the power fluctuations can be absorbed as an inertial energy in the blades. In some applications, the wind turbine may be augmented by an additional power source, usually a diesel generator. These systems are called wind–diesel systems [3], [4] and may be used to supply electricity energy to stand-alone loads, e.g., small villages that are not connected to the main utility. Most diesel generation systems operate at a constant speed due to the restriction of constant frequency at the generator terminals. However, diesel engines have high fuel consumption when operating with light load and constant speed. In order to improve the efficiency and avoid wetstacking, a minimum load of about 30% to 40% is usually recommended by the manufacturers [5]. Variable-speed operation can increase the efficiency, where the fuel consumption can be reduced up to 40% [5], especially when operating with a light load. Moreover, the life expectancy can increase with a lower thermal signature. To avoid the frequent start/stop of the diesel generator, an energy storage system is often used.

Topologies of the power electronic converter for Maximum Power Point Tracking (MPPT) [6] and voltage conversion are studied in this paper. The maximum power point of photovoltaic array is variational, so a search algorithm is needed according to the current-voltage (I-V) and power-voltage (P-V) characteristics of the solar cell. The Perturbation and Observation (P&O) MPPT algorithm is commonly used, due to its ease of implementation. It is based on the observation that if the operating voltage of the PV array is perturbed in a given direction and the power drawn from the photovoltaic (PV) array increases, which means that the operating point is moving toward the MPP, so the operating voltage must be further perturbed in the same direction. Otherwise, with the operating point moving away from the MPP, the direction of the operating voltage perturbation must be reversed. By using P&O method, impedance matching is conducted between boost converter and photovoltaic array in order to realize the MPPT function [7], [8].

The general requirements of MPPT are: simple, low cost, quick tracking when condition changes and small output power fluctuation. The traditional methods are simple and low cost without good tracking performance, such as hill climbing, P&O, and incremental conductance, etc. Novel methods are developed with higher accuracy but complex process, such as optimum gradient method, fuzzy logic control (FLC) and neural networks (NN). These technique could also be costly, difficult to implement, and may not be stable enough [7], [8]. RBFN has a faster convergence property than common multiplayer-perceptron (MLP) neural networks, but with a simpler network structure. RBFN also has a similar feature as the fuzzy-logic system, where the output value is calculated using the weighted-sum method, and the number of nodes in the hidden layer is the same as that of the “if-then” rules of the fuzzy system. The receptive field functions of the RBFN are also similar to the membership functions of the premise part of the fuzzy-logic system. With advantages of multiple facets and the self-adapting capabilities, RBFN is very useful for controlling nonlinear and time-varying dynamic systems where uncertainties and parameter variations need extra attention [9].

2. Analysis of system overview

The proposed PV and diesel-wind hybrid system is shown in Figure 1. Dynamic models of the main components were developed using MATLAB/Simulink, consisting of

(1) wind energy conversion system (WECS) ,

(2) diesel generator system,

(3) PV generation system.

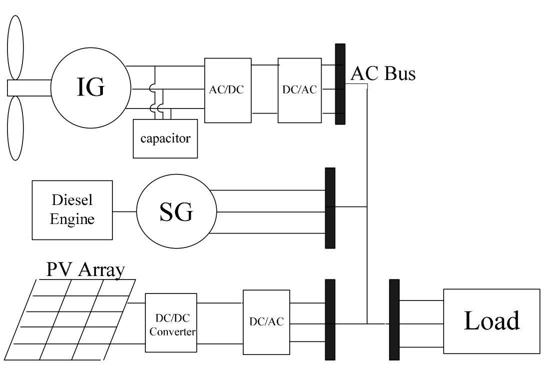

Figure 1. The proposed hybrid system.

2.1 Wind Energy Conversion System

In order to capture the maximal wind energy, it is necessary to install the power electronic devices between the WTG and the grid where the frequency is constant. The input of a wind turbine is the wind and the output is the mechanical power turning the generator rotor [6]. For a variable speed wind turbine, the output mechanical power available from a wind turbine could be expressed as

$$P_m = \frac{1}{2}\rho A C_p(\lambda,\beta)V_\omega^3 \quad (1)$$

where ρ and A are air density and the area swept by blades, respectively. V_ω is the wind velocity (m/sec), and C_p is called the power coefficient, and is given as a nonlinear function of the tip speed ratio (TSR) λ with

$$\lambda = \frac{\omega_r r}{V_\omega} \quad (2)$$

where r is wind turbine blade radius, and ω_r is the turbine speed. C_p is a function of λ and the blade pitch angle β.

2.2 Diesel-Generator Set Model and Excitation System

The Diesel generator set (DGS) model is made of combustion, drive train, and synchronous generator models. A common governor model is used in this paper; the essential features can be described by the transfer function described in [3].The excitation system used in diesel generator is Type-1 excitation model taken from IEEE standard 421.5 [10].

2.3 Photovoltaic Array Model

PV cell is a p-n junction, with characteristics similar to diodes. Parameters of the PV cell are shown in Figure 2. The relation between the array terminal current and voltage is [7].

$$V_{PV} = \frac{nKT}{q}\ln\left(\frac{I_{SC}}{I_{PV}}+1\right) \quad (3)$$