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Study of wind turbine based self-excited induction generator under nonlinear resistive loads as a step to solve the Egypt electricity crisis

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ABSTRACT

The crisis of electricity generation in Egypt requires the need to study the possibility of using renewable energy as a way to solve this problem. Also, renewable energy reduces pollution resulting from the use of traditional methods of electricity generation. The main objective of the paper is the dynamic study of a stand-alone wind turbine based self-excited induction generator (SEIG) under nonlinear resistive loads at fixed pitch angle and different wind speed. The approach is based on the dynamic equations for SEIG, turbine, and nonlinear resistive loads using MATLAB/SIMULINK. The dynamic study of the isolated wind turbine based SEIG under nonlinear resistive load, indicate that the system is reliable, dependable, and fulfillment. From the results the system can be used as a reflected source of the unified network as a step to solve the crisis of electricity generation in Egypt and also as a clean energy.

1. Introduction

The load from power station varies from time to time due to uncertain demand of consumers and is known as variable load on the station. A power station is designed to meet the load requirements of the consumers and to follow the quick nonlinearity of the load. An ideal load on the station, from stand point of equipment needed and operating routine, would be one of constant magnitude and steady duration. However, such a steady load on the station is never realized in actual practice. The consumers require their small or large block of power in accordance with the demand of their nonlinear activities. The load demand of one consumer at any time may be different from that consumer. The result is that load on the isolated wind power station varies nonlinearly from time to time [1].

Electricity generation crisis and environmental pollution effect motivate to study the availability of green renewable power. Wind is available in most Arab countries, on an average of 1400 h/year. The best wind power potential may be found in Egypt, Oman and Morocco where full load hours of appropriate wind reaches 2500 h/year with a speed ranging from 8 to 11 m/s [2]. For Egypt, the area of Suez Gulf is characterized with high average wind speed. Area from Ras Gharib north up to Elzyt Gulf has an excellent wind regime exceeding 10 m/s which would host 3000–4000 MW wind farms projects. The area in the west of Suez Gulf can host about 20,000 MW installed capacities of wind farms [3]. Because of the Egyptian electricity crisis, wind turbine based SEIG may be the first step to solve this problem, especially with respect to large areas

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Nomenclature

r_s, r_r, R_L	stator, rotor (referred to stator), and load resistive respectively
L_{1s}, L_{1r}, L_m	stator, rotor (referred to stator), and magnetizing inductance respectively
A	the area swept by the blades of the wind turbine, in m^2
C	terminal excitation capacitance
I_{dL}, I_{qL}	the load current along the d-axis and q-axis respectively
I_{ds}, I_{dr}	direct axis stator, rotor (referred to stator) current respectively
I_{qs}, I_{qr}	quadrature axis stator, rotor (referred to stator) current respectively
J	the inertia of the rotor in (Kg m^2)
K_d, K_q	constants representing initial induced voltages along the d-axis and q-axis respectively, due to the remaining magnetic flux in the core.
p	d/dt
P	the number of poles
P_t	the wind turbine power
R	the sweep diameter of the wind turbine.
T_t	the wind turbine torque in (Nm)
V_{cd}, V_{cq}	the capacitor voltage along the d-axis and q-axis respectively
V_m	the wind speed m/s
ω_m	the angular velocity of the wind turbine, rad/s.
ω_r	the electrical angular velocity of the rotor
ρ	air density $in\,Kg/m^3$
$\lambda_{qs}, \lambda_{qr}$	quadrature axis stator, rotor (referred to stator) flux linkage respectively
$\lambda_{ds}, \lambda_{dr}$	direct axis stator, rotor (referred to stator) flux linkage respectively
λ	tip speed ratio

that has suitable speed range for this technology [4]. For this purpose excessive study for the load nature should by taking into account like nonlinearity of loads with respect to time [5].

The self-excited induction generator mathematical model has been proposed to study the transient and steady state of operation. The d–q axes stator–rotor current are the functions of machine parameters. The solution of such equation has been obtained assuming all parameters are nonlinear [6]. In this paper, the study has been made for an analysis of fixed pitch angle and different wind speed based SEIG and its dynamic behavior under nonlinear resistive load. The residual magnetization in the machine is taken into account in simulation process as it is necessarily required for the generator to self -excite. Initial voltage in the capacitor is considered as 10 V for build-up of voltage for excitation of SEIG. The simulations have been carried out developing model in MATLAB/SIMULINK [7].

Several researchers in recent years have presented many techniques aimed for studying the response of wind based SEIG under different situations. Study of Wind Turbine based SEIG under Balanced/Unbalanced Loads and Excitation; the main objective of the paper is the dynamic study of SEIG under balanced R-L/R-C loads, balanced and unbalanced excitation, and fixed pitch angle wind turbine model has been considered for driving induction generator [8]. Wind driven induction generator study with static and dynamic loads; the main objective of the paper is study the performance of SEIG under balanced/unbalanced excitation with balanced RLC and dynamic load [9]. The proposed technique study the performance of wind turbine based SEIG under nonlinear load variation and the behavior of the system. This paper is organized as follows. The mathematical modeling of SEIG, wind turbine, and the nonlinear resistive load are described in Section 2. In Section 3, the Simulink model of the system is under study. The simulation results are explained in Section 4, and conclusions are drawn in Section 5.

2. The system mathematical model

This section include the d–q mathematical model of the self-excited induction generator, the wind mathematical model with fixed pitch angle turbine under different wind speed, and the nonlinear load model characteristics. The schematic diagram of the under testing standalone wind turbine based SEIG is shown in Fig. 1.

2.1. Modeling of the self-excited induction generator

The generated voltage in a self-excited induction generator grows and reaches a steady state value where the peak of the generated voltage remains at a constant peak value. Once steady state is attained a load can be connected to the SEIG. In a SEIG operating without load the stator current and the capacitor current are equal. However, in a loaded SEIG the stator current is divided into capacitor current and load current. With a good model and implementing the model using simulation software the dynamic characteristics of generated voltage, stator current, capacitor current, load current, magnetizing current, power, and electromagnetic torque can be studied with confidence. The standard model described in this paper utilizes