

Research Paper

Effects of Rotor Resistance Value of SCIG on its Output Power and Efficiency

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Abstract: *Nowadays using from wind power plants in power system has increased so that in some countries thermal generation stations exchanged with wind power plants. SCIG generator is popular to use in power plants. Because it is cheap and does not need to extra maintain. Of course cause of working it in fix speed of wind, there is some limitation to use in it. Therefore in location by fix speed of wind, using from SCIG is economic. At this work, a SCIG simulated in MATLAB Simulink and then exercised different value for its rotor resistance and by taking its output power and electromagnetic torque, its results compared and its efficiency investigated.*

Keywords: *Wind Power, SCIG, Rotor Resistance*

1. Introduction

By knowing that nowadays renewable energy is popular to use, wind power plants use to generate electrical energy in most countries. SCIG and DFIG are two conventional generators that are used in power plants. SCIG generator works in location by fix speed of wind but DFIG generator can work in location by variable speed of wind. By attention to performance in wind speed, DFIG generator is so better than SCIG generator. But cause of having back to back system in rotor feed, DFIG generator is so expensive and cause of having brush to

connect rotor winding to back to back system, it needs to extra maintain. SCIG has a simple structure. It has not back to back system and its rotor is bars that are connected to each others. Therefore SCIG is so cheaper than DFIG and in location by fix speed of wind, using from SCIG generator in wind power plants is better and more economic than using from DFIG. By attention to use SCIG in power plants, investigation the performance and making better performance of it, is important. Nowadays, by developing in materials and metals alloy science, it can be use metals by special alloy in structure of rotor of SCIG. In SCIG generator, rotor is made up from bars (usually from aluminum alloy) that are connected together in two ends of terminals. This kind of rotor in induction machine is useful as mechanical strength and has less cost. By varying in wind speed, slip almost does not change and its variation has finited to 1%-2% and therefore torque-speed curve and power-speed curve of SCIG, result maximum torque and power only in one speed of wind. Therefore this kind of induction generator has been used in location by fix speed of wind. Because by varying in wind speed, generator fallout from its optimum point in power-speed curve and its output power will not be optimum and varying in wind speed will cause mechanical stress to generator [1, 2].

In the past at some times for making better performance and having good efficiency in wind power plants, two generators had used that one of them resulted optimum power in low speed of wind and the other one resulted optimum power in high speed of wind. By this work, the rang of wind speed that wind power plants could result optimum power increased. But nowadays, by varying in the number of pole of SCIG, two power-speed curve results that by this work, it will be have two synchronism speeds for SCIG and therefore efficiency will increase(by attention to fig. 1). At that rate, by varying in wind speed, performance factor (C_p) of this SCIG (by two speeds) will be more suitable than one speed SCIG. Therefore output power and efficiency of SCIG that works in two speeds is more than the kind of SCIG that works in one speed of wind [3, 4].

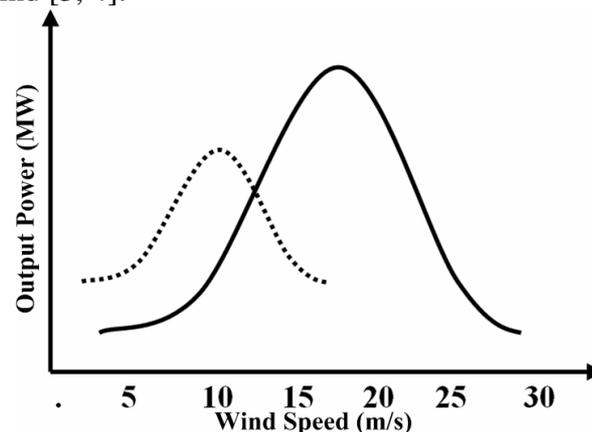


Fig. 1: power-speed curve of SCIG with two synchronism speed

At this work, a SCIG generator simulated in MATLAB Simulink and different values exercised for its rotor resistance at same situation and then rotor speed, output power and output torque of it compared in that changes. It is shown that how changing in rotor alloy and therefore changing in its rotor resistance can change rotor speed, output power, output torque

and efficiency of it. Therefore selection a suitable alloy in the structure of SCIG is so important.

2. Details of Simulated SCIG:

Main relations of induction machines has used for simulation SCIG generator. These equations are formulated in (1)-(4):

$$v_{ds} = R_s i_{ds} + \omega \psi_{qs} + \frac{d\psi_{ds}}{dt} \tag{1}$$

$$v_{qs} = R_s i_{qs} + \omega \psi_{ds} + \frac{d\psi_{qs}}{dt} \tag{2}$$

$$v_{dr} = R_r i_{dr} - (\omega - \omega_r) \psi_{qr} + \frac{d\psi_{dr}}{dt} \tag{3}$$

$$v_{qr} = R_r i_{qr} + (\omega - \omega_r) \psi_{dr} + \frac{d\psi_{qr}}{dt} \tag{4}$$

Where V_{ds} , V_{qs} , V_{dr} , V_{qr} , R_s , R_r , L_m , Ψ_{ds} , Ψ_{qs} , i_{ds} , i_{qs} , i_{dr} , i_{qr} , ω and ω_r are stator voltage in direct axis, stator voltage in quadrature axis, rotor voltage in direct axis, rotor voltage in quadrature axis, stator resistance, rotor resistance, mutual inductance, stator flux linkage in direct axis, stator flux linkage in quadrature axis, stator current in direct axis, stator current in quadrature axis, rotor current in direct axis, rotor current in quadrature axis, reference frame angular velocity and rotor electrical angular velocity respectively.

The stator and rotor currents can be expressed in terms of the dq flux linkages as equation (5).

$$\begin{bmatrix} i_{ds} \\ i_{qs} \\ i_{dr} \\ i_{qr} \end{bmatrix} = \begin{bmatrix} -\frac{l_r}{l_\alpha} & 0 & \frac{l_m}{l_\alpha} & 0 \\ 0 & -\frac{l_r}{l_\alpha} & 0 & \frac{l_m}{l_\alpha} \\ \frac{l_m}{l_\alpha} & 0 & -\frac{l_s}{l_\alpha} & 0 \\ 0 & \frac{l_m}{l_\alpha} & 0 & -\frac{l_s}{l_\alpha} \end{bmatrix} \begin{bmatrix} \psi_{ds} \\ \psi_{qs} \\ \psi_{dr} \\ \psi_{qr} \end{bmatrix} \tag{5}$$

$$l_\alpha = l_m^2 - l_r \cdot l_s \tag{6}$$

Where, L_s and L_r are stator inductance and rotor inductance respectively.

By locating relations (5) and (6) to (1)-(4), equations (7)-(10) are result.

$$v_{ds} = \left[\frac{d}{dt} + \frac{R_s}{l_s} \right] \psi_{ds} - \omega \psi_{qs} - \frac{R_s \cdot l_m}{l_s} \cdot i_{dr} \tag{7}$$

$$v_{qs} = \omega \psi_{ds} + \left[\frac{d}{dt} + \frac{R_s}{l_s} \right] \psi_{qs} - \frac{R_s \cdot l_m}{l_s} \cdot i_{qr} \tag{8}$$

$$v_{dr} = \frac{l}{l_s} \frac{d}{dt} \psi_{ds} - (\omega - \omega_r) \frac{l}{l_s} \psi_{qs} + (R_r - \frac{l}{l_s} \frac{d}{dt}) i_{dr} + (\omega - \omega_r) \frac{l}{l_s} i_{qr} \tag{9}$$

$$v_{qr} = (\omega - \omega_r) \frac{l}{l_s} \psi_{ds} - \frac{l}{l_s} \frac{d}{dt} \psi_{qs} - (\omega - \omega_r) \frac{l}{l_s} i_{dr} + (R_r - \frac{l}{l_s} \frac{d}{dt}) i_{qr} \tag{10}$$

Of course in SCIG, rotor voltages in direct and quadrature axis are zero.

Simulated SCIG in its original value of rotor resistance delivers 2 MW to infinite bus. Wind speed and therefore aerodynamic input torque assumed constant [5]. System frequency assumed constant in 50 HZ. Values of other assumed parameters have shown in table 1.

Table 1: Values of SCIG parameters [6]

Parameter	Value	Unit
P _{out} (rated power)	2×10 ⁶	W
R _s (stator resistance)	1.748×10 ⁻³	Ω
R _r (rotor resistance)	6.28×10 ⁻³	Ω
L _s (stator inductance)	2.589×10 ⁻³	H
L _r (rotor inductance)	2.604×10 ⁻³	H
L _m (mutual inductance)	2.492×10 ⁻³	H
V _s (generator output voltage)	690	V
j(moment of inertia)	1.39×10 ³	Kg/m
T _{in} (input mechanical torque)	2×10 ⁴	N.m
P(number of pole)	6	----
f _s (frequency)	50	Hz

3. Results and Discussion:

Equation of converted power from rotor to stator (P_{conv}) in induction generator is given in (11).

$$P_{conv} = \frac{3V_{th}^2}{R_r} S(1-S) \tag{11}$$

Where V_{th} and S are thevenin equal voltage and slip of generator respectively. It can be understand from this equation that by decreasing in rotor resistance, converted power and therefore output power increases [7]. By attention to mechanical equation (12), in steady state situation, electromagnetic torque of generator will equal to input mechanical torque of generator. In decreasing of rotor resistance value, input mechanical torque is constant and therefore at this change electromagnetic torque of generator is constant. According to equation (13) and by attention to be constant electromagnetic torque and increasing output power in decreasing of rotor resistance, rotor electrical angular velocity will increase. This

process can be observed in results of simulation. Of course, against this process will happen in increasing of rotor resistance.

$$T_{in} - T_e = j \cdot \frac{d\omega_r}{dt} \tag{12}$$

$$P_{out} = T_e \cdot \omega_r \tag{13}$$

In which T_{in} , T_e , j and P_{out} are input mechanical torque, electromagnetic torque, moment of inertia and output power of generator respectively.

When rotor resistance forced $6.28 \times 10^{-3} \Omega$, rotor speed was 100 rad/s and by attention to be electromagnetic torque 20 KN.m, output power was 2 MW.

By decreasing rotor resistance to 0.9 and 0.8 of main value, as can be seen in fig. 2, rotor speed increased from 100 rad/s to 100.5 and 100.9 rad/s. Therefore, Output power, as can be seen in fig. 3, increased from 2 MW to 2.0095 and 2.019 MW respectively. It can be observed from this work, in SCIG generator by assumed parameters, by 10% and 20% decreasing in rotor resistance, output power will increase as 0.475% and 0.95% to main value respectively.

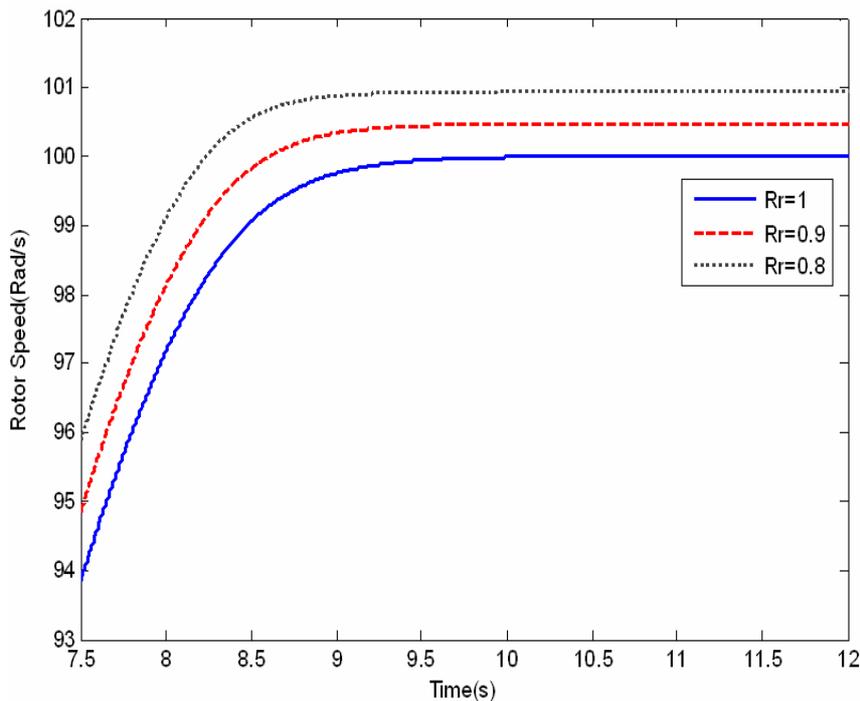


Fig. 2: rotor speed in decreasing of rotor resistance

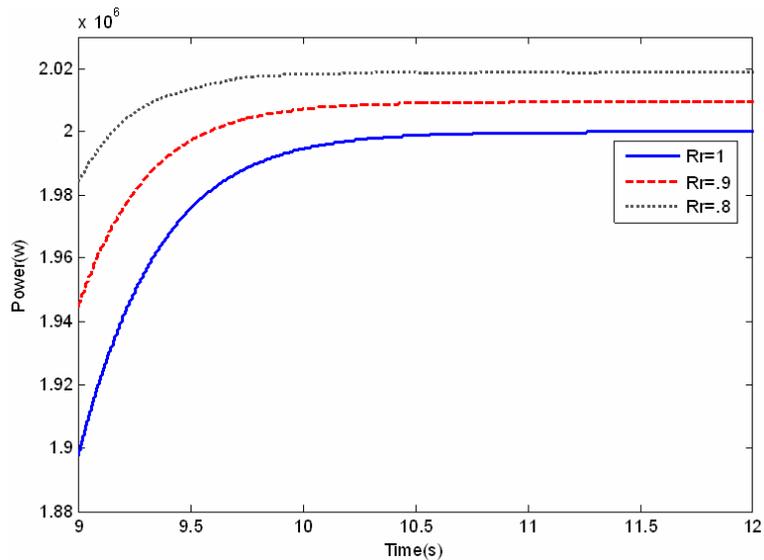


Fig. 3: output power in decreasing of rotor resistance

On the other hand, by increasing rotor resistance to 1.1 and 1.2 of its main value, as can be seen in fig .4, rotor speed decreased from 100 rad/s to 99.53 and 99.06 rad/s respectively and Output power, as can be seen in fig .5, decreased from 2 MW to 1.991 and 1.981 MW. Therefore, by 10% and 20% increasing in rotor resistance, output power will decrease as 0.45% and 0.95% to main value respectively.

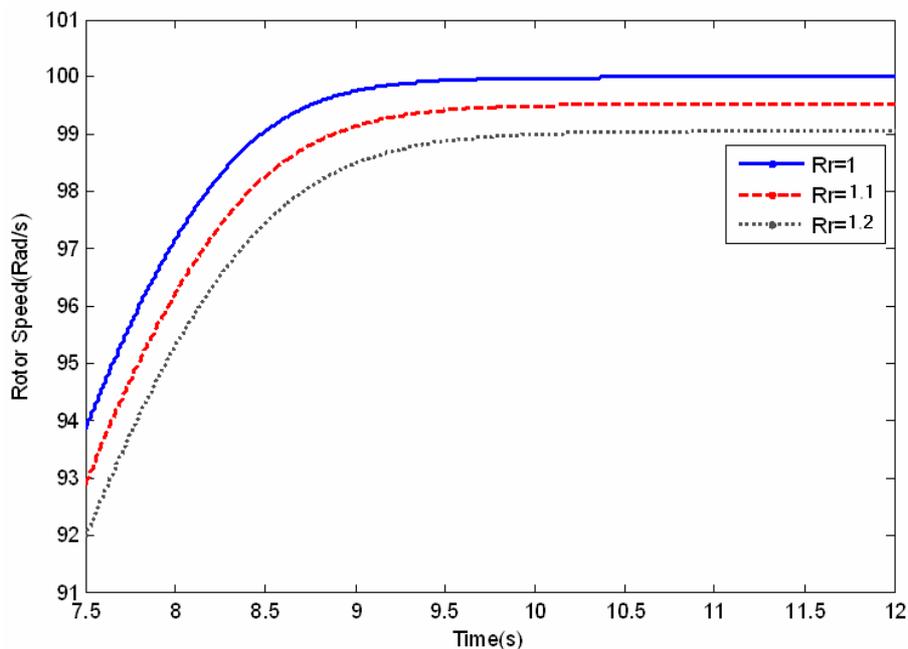


Fig. 4: rotor speed in increasing of rotor resistance

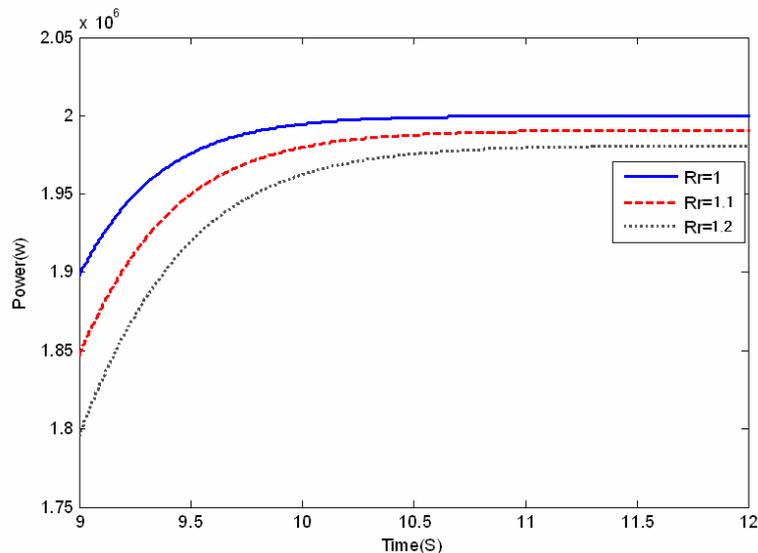


Fig. 5: output power in increasing of rotor resistance

4. Conclusions:

Nowadays renewable energy is popular to use. Therefore wind power plants are used to generate electrical energy in most countries. SCIG generator is popular to use in power plants. Because it is cheap and it does not need extra maintenance. Today's by developing in materials and metals alloy science, it can be used by special alloys in the structure of the rotor of SCIG. In SCIG generator, the rotor is made up of bars (usually from aluminum alloy) that are connected together at two ends of terminals. In this work, a SCIG was simulated in MATLAB Simulink and then exercised with different values for rotor resistance and its output power was compared. It can be seen from this work that using an alloy with less resistance in the rotor structure of SCIG generator causes an increase in its output power and therefore its efficiency increases.

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