ISSN 2229-5518

Transient stability enhancement of induction generator using rotor resistance

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Abstract—Transient stability enhancement of induction generator is one of the main issues in wind power generator. During the fault in power system, rotor speed instability and voltage instability may occur. This paper investigates for transient stability improvement of induction generator after fault. Simulation result shows instability in rotor speed due to fault and by increasing rotor resistance how rotor returns from further acceleration.

Index Terms— Active power, Induction Generator, reactive power, rotor resistance, rotor speed stability, transient stability, torque slip characteristics.

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1 Introduction

AN induction generator or asynchronous generator is a type of AC electrical generator that uses the principles of induction motors to produce power. Induction generators operate by mechanically turning their rotor in generator mode, giving negative slip. Induction generators produce electrical power when their rotor is rotated faster than the synchronous frequency. Induction generator cannot produce reactive power but it consumes reactive power from external source or grid to maintain the stator magnetic field and must control terminal voltage of the generator [1]. Faults that occur on transmission line that lead to over speed and instability of network voltage [2]. After fault clearance and voltage recovery, the speed rotor of induction generator is so high that it does not return to stable value easily. It accelerates to high speed and takes more time to stable [3].

In [4] and [5], using the braking resistor is introduced as a solution for improving transient stability of IGs. The braking resistor decreases the rotor speed and hence improves transient stability. Braking resistors that are connected to the IGs absorb less electrical power in comparison with the braking resistors that connect to synchronous generator and it shows that the braking resistor is less effective in improving the IGs stability than that of the synchronous generators. In this method, rotor resistance increase after fault so that stable operating region increases and accelerated speed of rotor also reduces to stable value. As we increases the rotor resistance of induction generator so that the speed of induction generator is reduced to initial or nearby it stable value and real and reactive power of induction generator is also stabilize.

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2 Transient Stability Of Induction Generator

The equal area criterion was originally developed for synchronous generators and is not a suitable method for evaluation of the IGs transient stability because the operation of an IG is significantly different from that of a synchronous generator due to the nature of its asynchronous operation. IG's stability can be analyzed using the torque–slip curve.

2.1Stable Operation

During stable operation electrical generator torque and the mechanical turbine torque are balanced. At this point IG operate at steady state. When system fault occur there is sudden drop in ac voltage as well as electric torque and reactive power. As mechanical torque is greater than electric torque, the IG will begin to accelerate and speed increases. Suppose fault is clear after small time, ac voltage start to recover and IG absorb large reactive power. When electric torque is greater than mechanical torque then it acts as breaking torque and it reduce the speed of rotor and slip also decreases. Deceleration of the IG and decline of rotor slip means a reduction in the reactive power absorbed by the IG. This reduction in the absorbed reactive power, cause to a rise in ac voltage. Stable operation of induction machine in motoring and generating mode is shown by torque-slip curve in fig.1.

The generalized torque equation for induction machine is given as:

$$T_{em} = \frac{(3 * V_{th}^2 * \frac{R_r}{S})}{(\frac{N_s * 2 * pi}{60} * (R_{th} + \frac{R_r}{S})^2 + (X_{th} + X_2)^2)} \qquad (1)$$

T_{em}: Electromagnetic Torque
V_{th}: Thevenin equivalent voltage
R_{th}: Thevenin equivalent resistance
N_s: Synchronous Speed

ISSN 2229-5518

R: Rotor Resistance
S: Slip

2.2 Unstable Operation

If fault is ON for longer time rotor speed goes on increasing, slip also increases to higher value. Electric torque is less than the mechanical torque therefore rotor slip increases and making the system unstable. If the slip is less than (note that the slip in the generating mode is negative) critical slip or rotor speed is higher than critical speed, the machine will be unstable. Therefore, transient stability can be improved by decreasing the critical slip of the IG. This can be achieved by

1) Decreasing the value of stator resistance, stator reactance, mutual inductance, and rotor reactance, and
2) Increasing the value of rotor resistance.

The most effective parameter is rotor resistance. Transient stability improvement by increasing the rotor resistance is shown in Fig.2. With the rotor resistance R_1, the stable operating slip varies from its initial value S_1 to the critical slip Sc_1. When the rotor resistance is increased to R_2, the stable operating range is expanded as from S_2 to Sc_2.Therefore, by increasing the rotor resistance there is a significant expansion in the stable operating range.

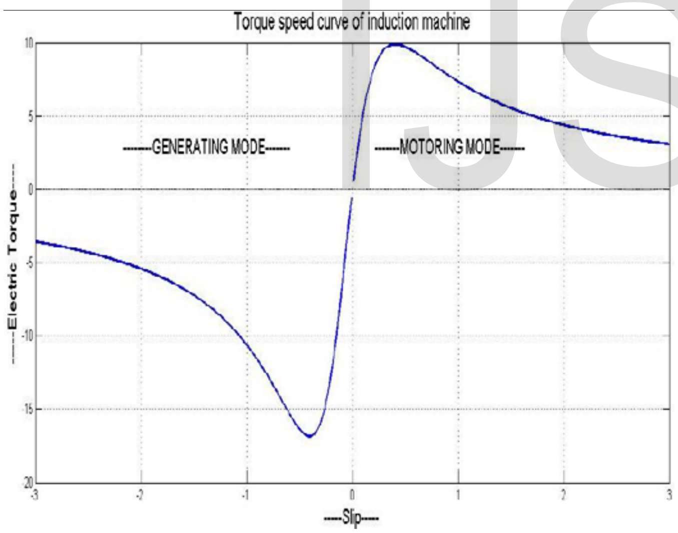


Fig.1. Steady-state torque-slip curve of induction machine.

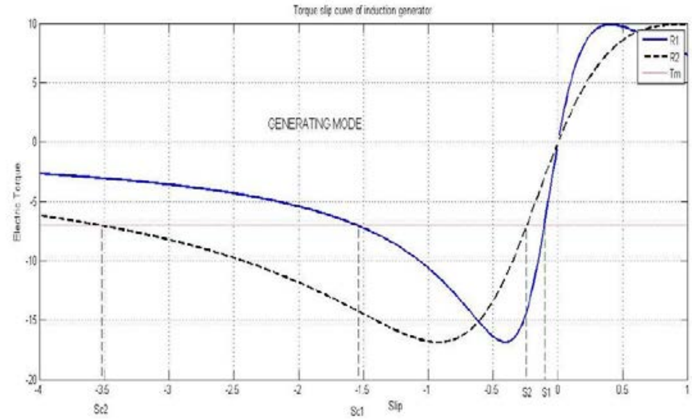


Fig.2. Transient stability improvement by increasing rotor resistance.

3 Simulation results

Transient stability simulations were employed to verify the effectiveness of increasing rotor resistance of IG. The test system utilized is shown fig.3. consist of induction generator injecting power of MW through the transmission line to the grid.

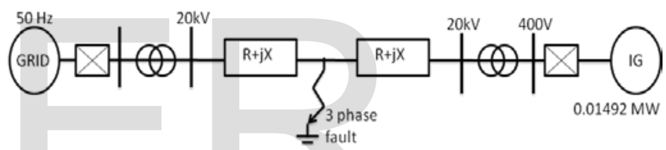
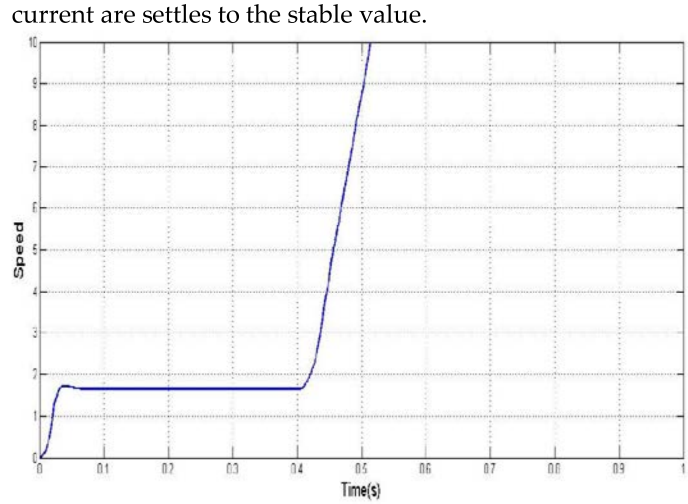


Fig.3. Schematic diagram of simulated system.

3.1 Case (a)

In this case generator supplying power of 0.01492 MW in the transmission network, a three-phase-to-ground short circuit is applied on the transmission line from 0.4 to 0.45 s. for rotor resistance of say R_3 ohms. During fault, rotor gets accelerated, voltage decreases to zero and current increases suddenly to a large value. After fault clearance at 0.45 s. still rotor speed goes on increasing for long time while voltage and current are settles to the stable value.



ISSN 2229-5518

Fig.4. Behavior of IG before and after fault for resistance R_3.

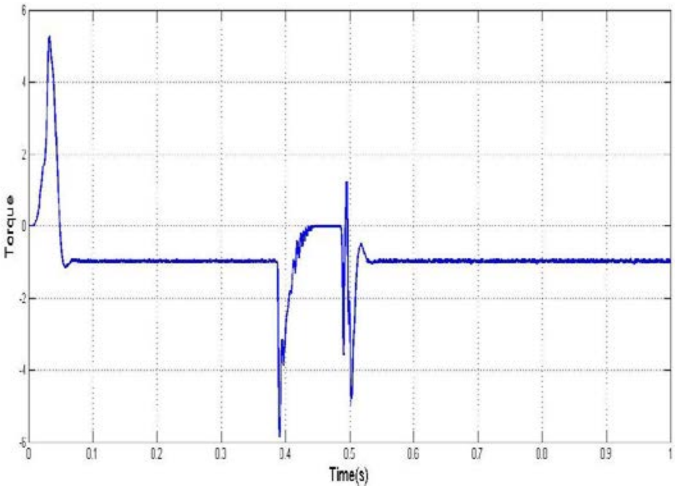


Fig.5. Behavior of torque before and after fault for resistance R_3.

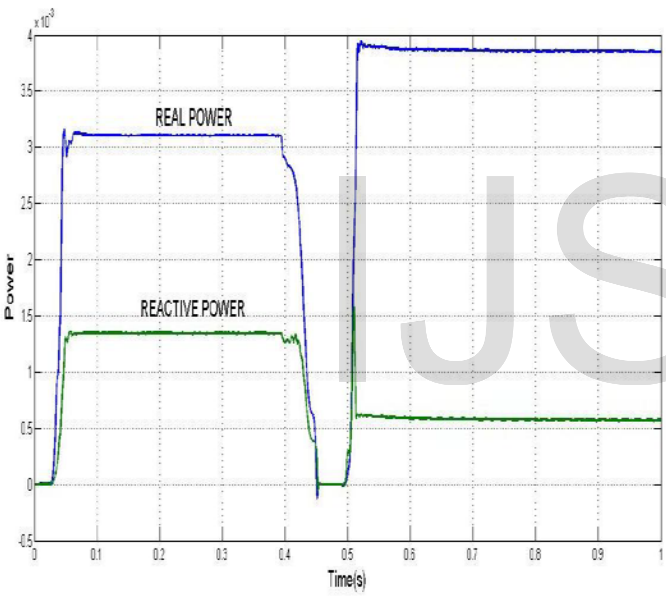


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Fig.6. Power during and after fault for resistance R_3.

3.2 CASE (B)

In this case on the same system if rotor resistance increases to R_4 which is multiple of resistance R_3 ohms. After fault clearance at 0.45 s. speed of rotor decelerates and sets to stable value as before fault shown in fig.7. where speed is in p.u. In IG when electromagnetic torque is equal to mechanical torque then system is stable. Torque of IG settles to the stable value as before the fault to the -1 p.u. shown in fig.8. After fault clearance IG draws more reactive power from grid for very short time to brings stability as shown in fig.9. for resistance R_4.

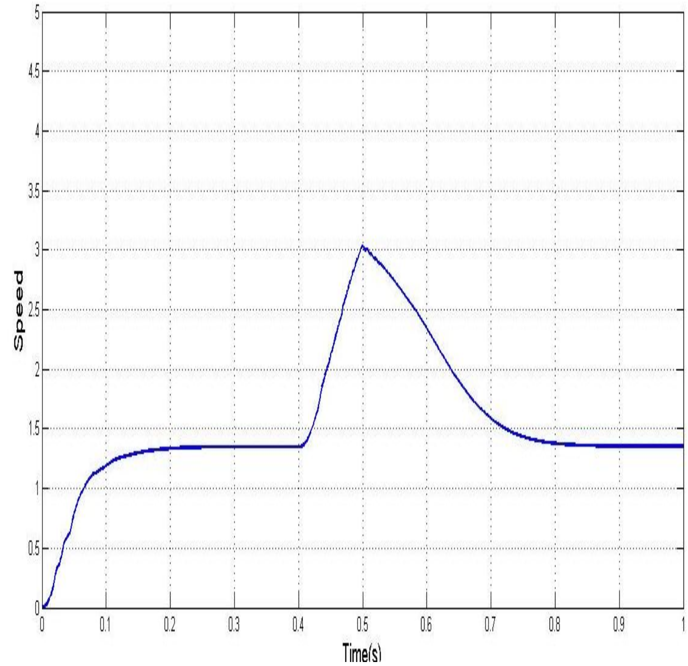

Fig.7. Behavior if IG using resistance R_4 (fault applied from 0.4 to 0.45 s).

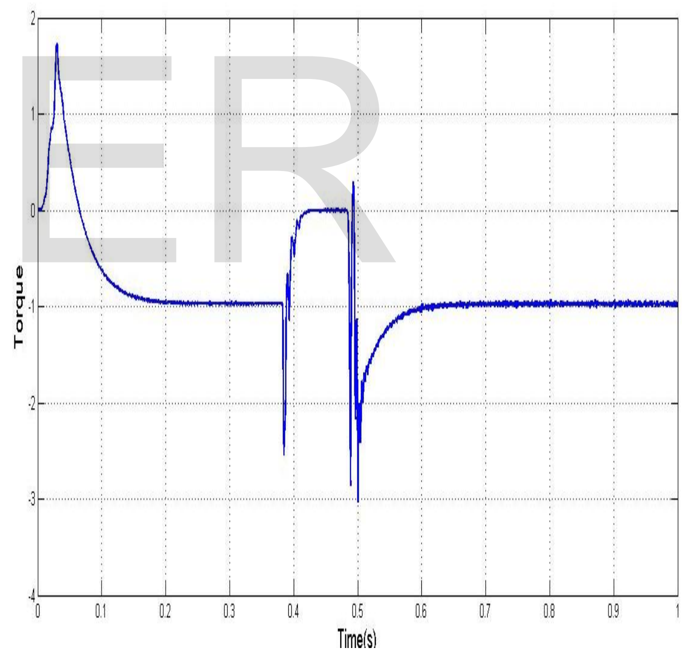

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Fig.8. Electric torque fluctuating behavior for resistance R_4 (fault applied from 0.40 to 0.45).

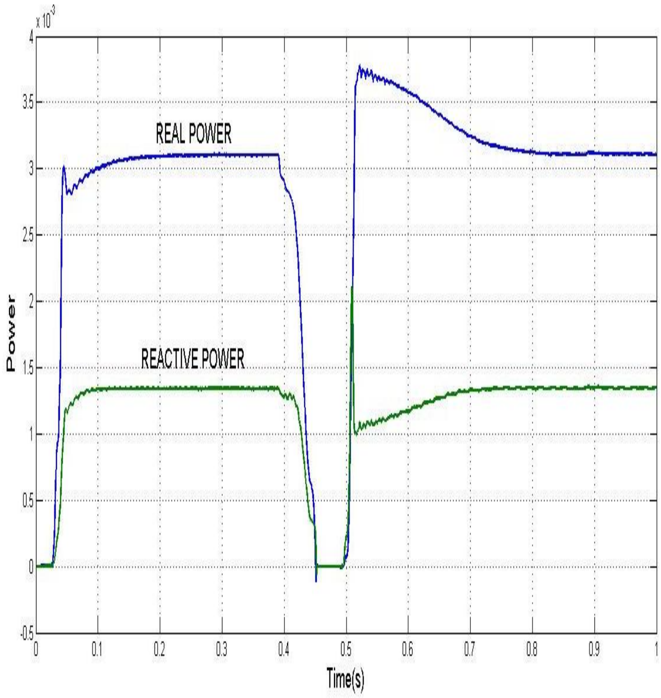

Fig.9. Power during and after fault for resistance R_4.

4 Conclusion

Transient stability can be improved more effectively by increasing rotor resistance instead of decreasing the value of stator resistance, stator reactance, mutual inductance, and rotor reactance of induction generator. In this method, after increasing rotor resistance, suddenly increased speed of IG slows down to near stable value. This approach is simple and of low cost. For future work and for more effectiveness FACTS devices, plugging mode methods are used.

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