TRANSIENT ANALYSIS OF INDUCTION GENERATOR JOINTED TO NETWORK AT BALANCED AND UNBALANCED SHORT CIRCUIT FAULTS

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ABSTRACT

In wind power stations, induction machines are used as induction generators. Transient stability analysis of induction generator used in wind power station, jointed to infinite bus, before and after balanced and unbalanced short circuit faults is one of the main issues in power system security and operation. It is necessary to know the transient behavior of induction generator, when joint to network, in usual faults. In this paper, active power, torque and speed of induction generator at balanced and unbalanced short circuit faults with dynamic equation of induction machine are studied. With single equation of induction machine, transient active power, torque and speed are measured. Induction generators used in wind power system before and after three phase fault, two phase fault, single phase fault and two phase to earth fault conditions are analyzed. The natural approximation to derive analytical formulas for transient conditions is proposed and the transient behavior of induction generator is analyzed by the single equations. This paper includes three parts: modeling, simulation and analysis of results.

Keywords: induction generator, transient analysis, symmetrical sequence, short circuit fault.

1. INTRODUCTION

In recent years, renewable energy generation is coming up for effective use of natural energy, such as wind energy. Induction generators consisting squirrel-cage rotors are widely used as wind generators because of their salient features like robust rotor design, simple in the construction, maintenance free operation etc. However, these induction generators will draw large transient currents, several times as large as the machine rated current, when they are connected to utility grid [1-2] or occurred various disturbances such as earth fault.

Under such situations, there will be severe voltage fluctuations in the power system. Therefore, these systems influence brought to a power system becomes one of main issue for wind power generating system. From such a background, the transient condition connected to utility grid is examined by good many papers [1-5], however, there are few examples of analysis about transient condition for various disturbances such as earth fault.

In this paper we present active power, torque and speed of induction generator at balanced and unbalanced short circuit faults with dynamic equation of induction machine. With single equation of induction machine we present transient active power, torque and speed. Analysis of induction generators used in wind power system before and after three phase fault, two phase fault, single phase fault and two phase to earth fault conditions. The natural approximation to derive analytical formulas for transient conditions is proposed, and the transient behavior of induction generator is analyzed by the single equations. This paper includes three parts: modeling, simulation and analysis result

The simulation block diagram in MATLAB/SIMULINK is constituted using the system equation in consideration of the nonlinearity nature of the induction generator.

Furthermore, theoretical discussion also developed to determine the fault conditions and the time at which maximum transient currents flow in the system. These equations can be used to study the dynamic behavior of the induction generator under balanced and unbalanced fault conditions.

2. INDUCTION GENERATOR SIMULATION

We have used old formulation and equations to simulate that in this part fluxes are state changeable and voltages, mechanical torques are input data while power, speed and current are output data. Equation (1) presents theoretical equation of electromechanical torque for induction generator.

$$T_{em} = \frac{3}{2}\frac{p}{2}(I_{ds}I_{qs} - I_{qs}I_{ds}) = \frac{3}{2}\frac{p}{2}l_m(I'_{dr}I_{qs} \pm I'_{qr}I_{ds}) \quad (1)$$

Equations 2 and 3 present communication of torque with speed and Inersy and equation (4) present power with torque and speed.

$$T_{mech} - T_{em} - T_f = j\frac{dw_r}{dt} \quad (2)$$

$$w_r = \frac{1}{j}\int(T_{mech} - T_{em} - T_f)dt \quad (3)$$

$$\mathrm{P} = \mathrm{T} * \omega \quad (4)$$

All of equations that result simulated in reference ($\omega = 0$). For Induction Generator modeling, first simulated Induction motor then with negative of mechanical Torque in this motor, speed more than synchronous speed and slip is Negative. In this part machine performance is Generator. All of different parts of this system are simulated in Matlab.

3. ANALYSIS AND RESULT INDUCTION GENERATOR JOINTED TO NETWORK IN BALANCED & UNBALANCED FAULT

3.1. Three phase short circuit fault (balanced fault)

Single line Network for study, show in below, in Figure-1 and system information in Table-1 show in Appendix-1, also showing connection facts generator to Network and happen facts fault.

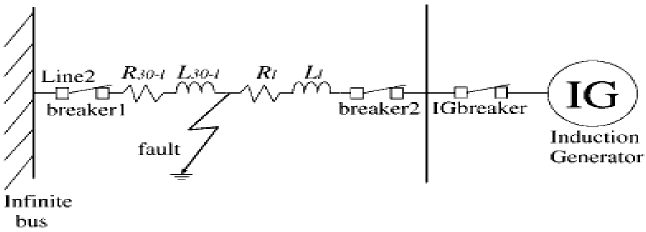

Fig. 1. Infinite bus system.

In this fault, we can that analysis with one of circuits of positive sequence (P.S) or negative sequence (N.S) or zero sequence;(Z.S) that parallel with load Impedance. in this part P.S model selected. Figure-2 shows equivalent circuit of q axis of P.S model of network with short circuit.
Equation (5) present voltage in q axis stator

$$V_{qs} = -(R_l I_{qs} - L_l \frac{dI_{qs}}{dt}) \qquad (5)$$

In this part, three phase fault on Induction Generator jointed to network simulated that results show in Figures 3 and 4.
With attention to results show speed rise in fault Time with positive slope because T_{em} next of fault time is zero and only that have T_{mech} this means there are no have inconvenience.
Torque and speed rising very fast. also in fault Time current increase because $I = \frac{V}{Z}$ and in fault Time load Impedance is short circuit and Z decrease and current increase. But in final machine fluxes decrease then V decreases the current decrease until zero. Figure-3 show active micspower generated power in fault time have dyna violent changes and next of ten cycle decrease to zero.

3.2. Unbalanced fault analysis

In this part, first input voltages with fortsq conversion (equation 6) then result three voltage P.S,N.S.Z,S then each of voltages jointed to oneself Efficient machine

$$f_{abc} = T * f_{a1a2a0} \qquad (6)$$

$$T = \begin{bmatrix} 1 & 1 & 1 \\ a & a^2 & 1 \\ a^2 & a & 1 \end{bmatrix} \quad a=1<120 \qquad (7)$$

a_1 : P.S
a_2 : N.S
a_3 : Z.S

Now, there are there induction machines.

3.2.1. Single phase analysis

System seems with P.S, N.S, and Z.S blocks. Now we have there induction machine P.S, N.S, Z.S that each of machine result I_{qd0s} , I'_{qd0r} .
With attention to current example q axis in P.S, N.S, Z.S three current, $I_{qs_{ps}}$, $I_{qs_{ns}}$, $I_{qs_{zs}}$ with sum this three current , we produce current of Q axis and so for D axis , O.
In Figure-5 showed results of single phase speed in fault Time a little increase because each of there phase create one T_{em} then time of single phase fault one T_{em} was zero, but another two phase are T_{em} .
Current of two phases is in crease then T_{em} then there are increase then cause speed a few increases then constant.
Active Power is multiple of speed & Torque then, with attention to speed this part, active power behavior is simple of Torque behavior.

3.2.2. Two phase fault to earth

In this part produce equivalent circuit, with parallel of circuits of P.S, N.S, Z.S. now we have, for all axis example q axis three circuit simple Figure-2 that series with another circuits. Difference of circuits is in ω because in circuits give
P.S $\longrightarrow \omega$, N.S $\longrightarrow \omega$, Z.S $\longrightarrow$ o.
Of each generated I_{qdos}, I'_{qd0r} . With attention to this current can having currents of Q,D,O with equation (8) figure 6 show results of two phase Fault to earth with attention to results, speed in fault time ω in positive slope increase but less than balanced fault because T_{em} is little.
Active power is multiple of torque and speed.

$$\begin{aligned} I_{Qs} &= I_{qs_{P.S}} + I_{qs_{N.s}} + I_{qs_{Z.s}} \\ I_{Ds} &= I_{ds_{P.S}} + I_{ds_{N.s}} + I_{ds_{Z.s}} \\ I_{Zs} &= I_{zs_{P.S}} + I_{zs_{N.s}} + I_{zs_{Z.s}} \end{aligned} \qquad (8)$$

3.2.3. Two phase fault

Equivalent circuit is parallel of P.S and N.S Circuits. Now we have, for all axis example q axis, two circuit Simple Figure-2 that's parallel with difference:

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In P.S circuit ω $+\omega$
In N.S circuit ω $-\omega$
Next of forts q conversion we have two machine of P.S and N.S that each of these have I_{qdos}, I'_{qd0r} . we attention to current example q axis in P.S , N.S have two Current $I_{qs_{ps}}$, $I_{qs_{ns}}$ then sum these produce current of Q axis and of course for D axis .

Figure-7 Showed output results of two phase fault.

With a little swing start, then in a few duration time speed increasing with styloid curve.

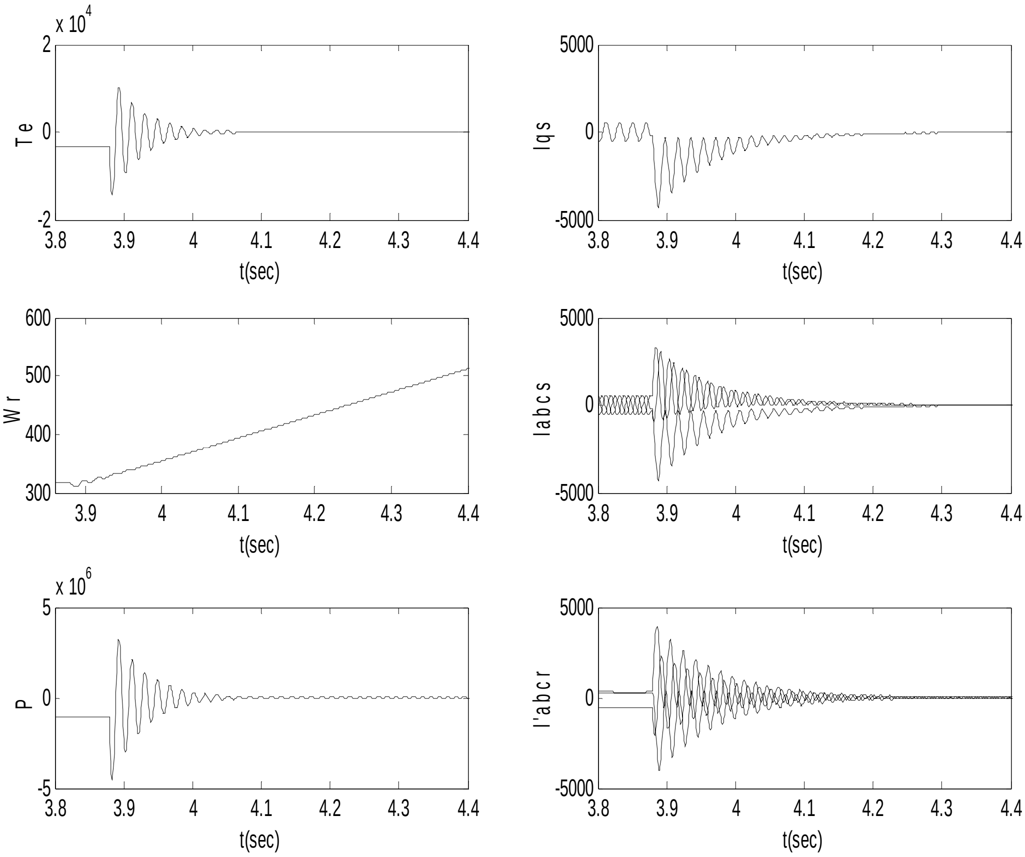

Figure-3. Curves of torque, speed and power in next of fault time in 3.88s.

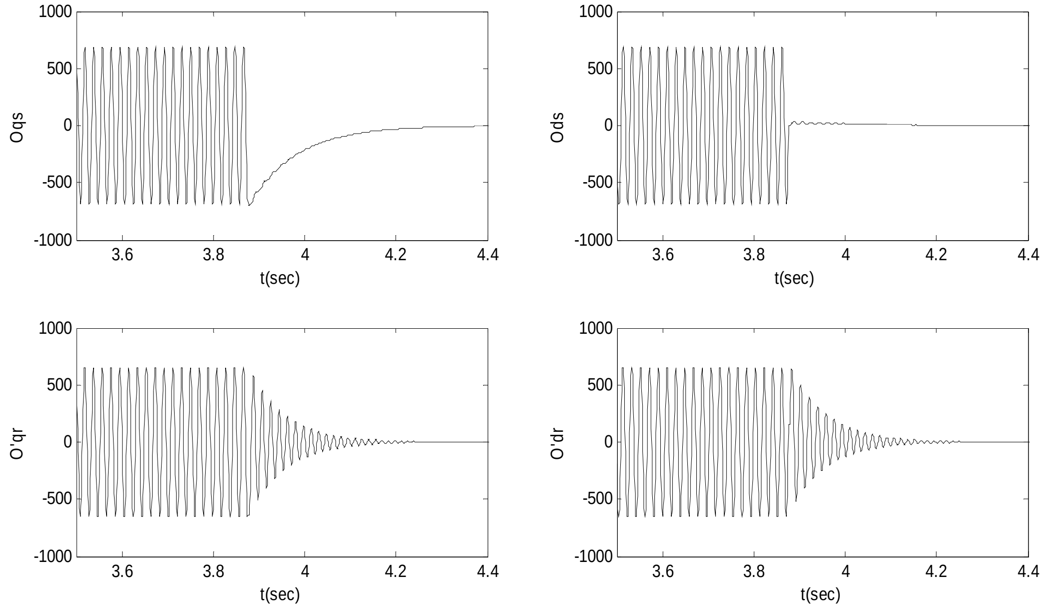

Figure-4. Curves of fluxes of q, d axis of stator and rotor in next of fault time in 3.88s.

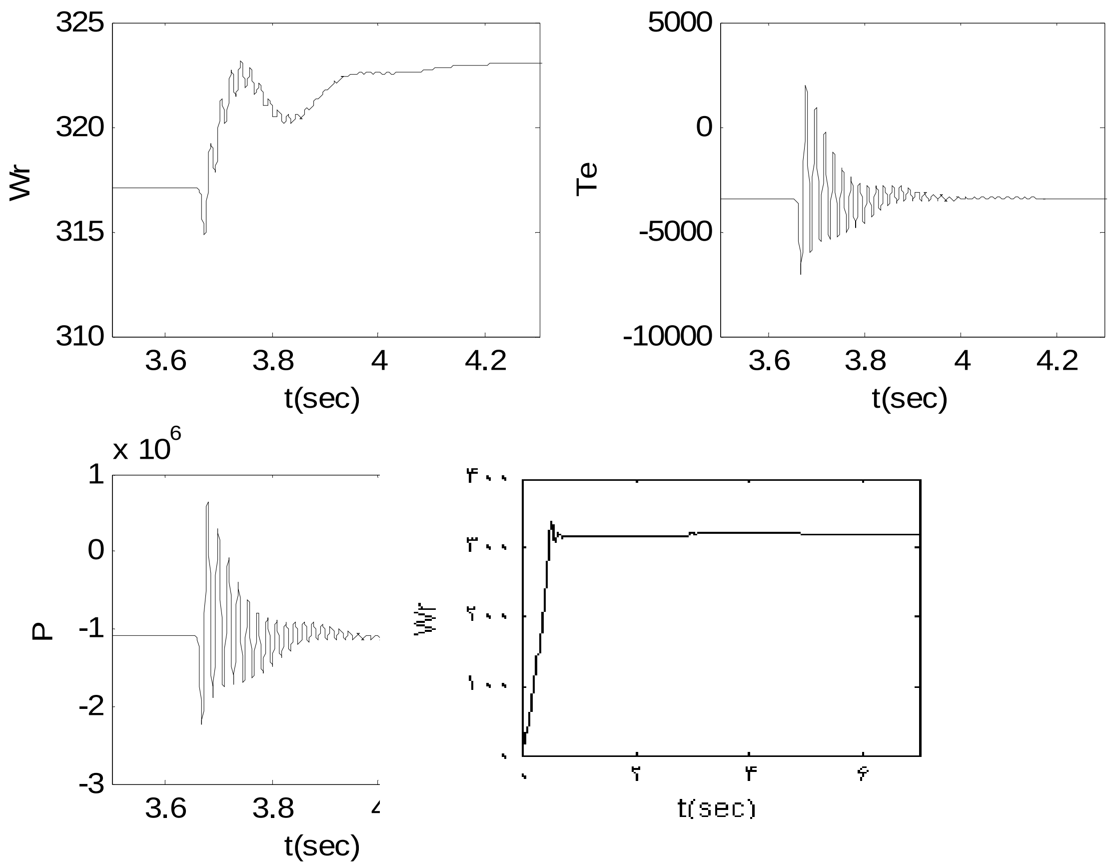

Figure-5. Curves of torque and speed (single phase fault).

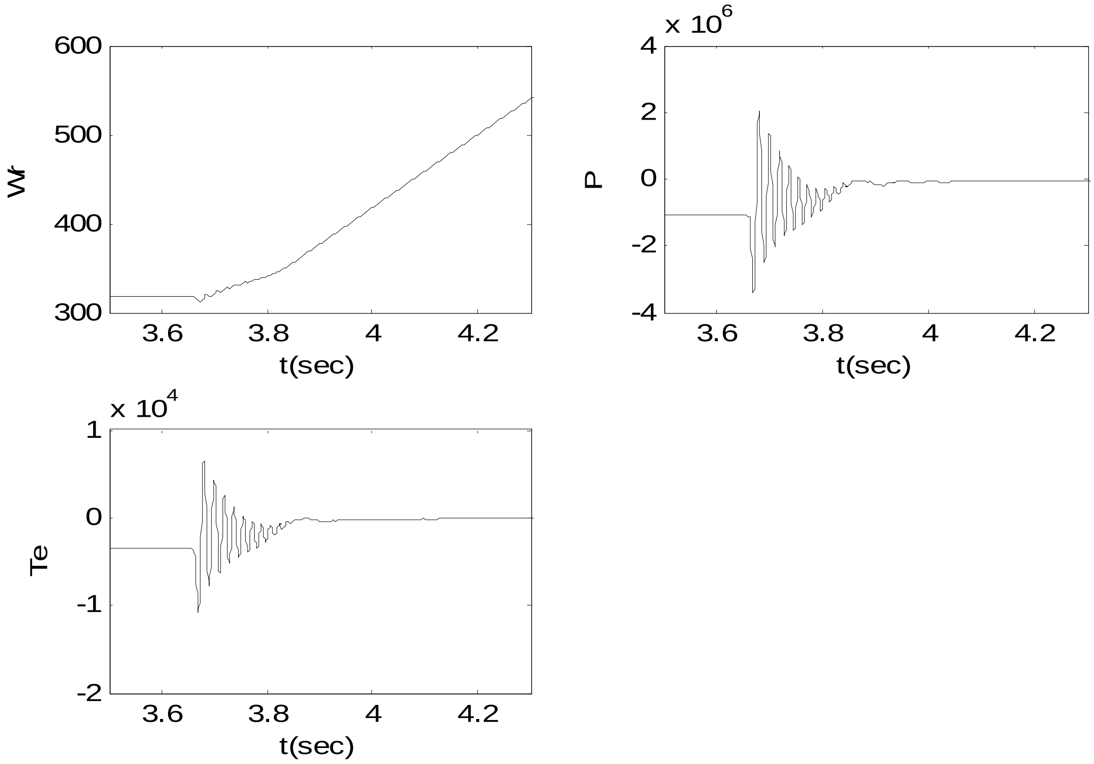

Figure-6. Curves of torque, active power and speed (two phase fault to earth).

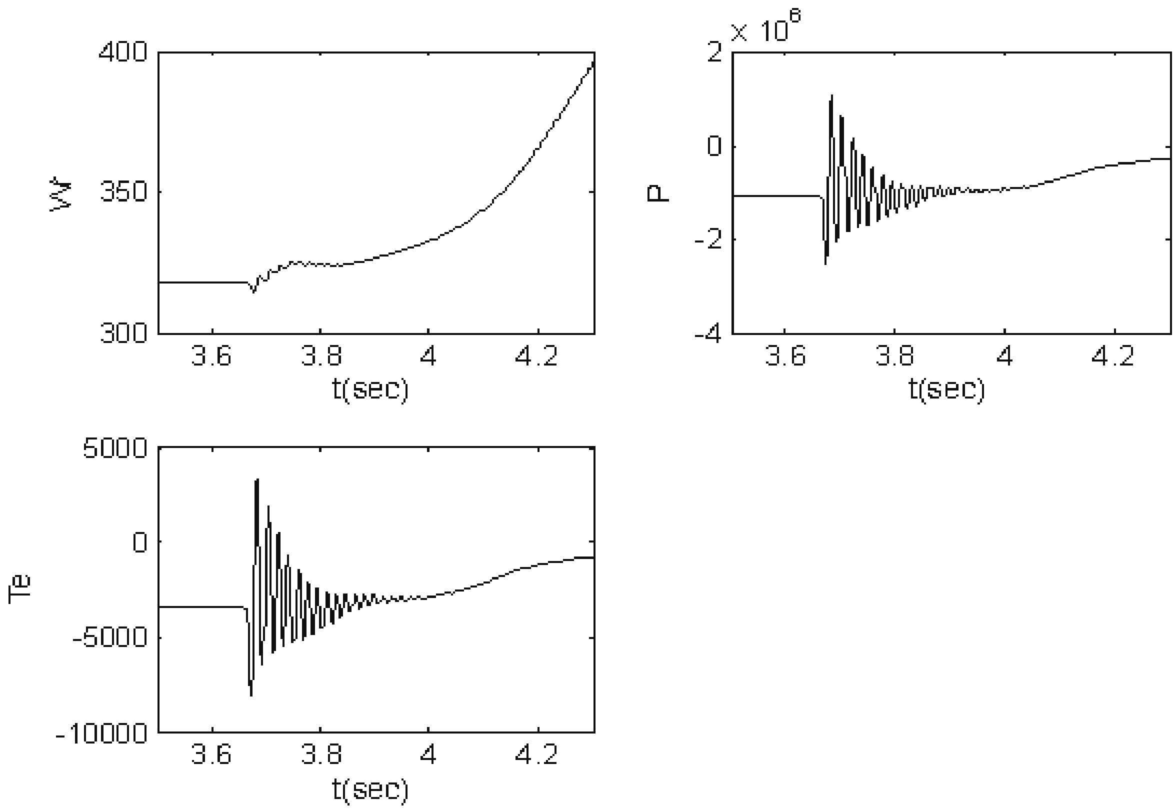

Figure-7. Curves of torque, active power and speed (two phase fault).

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4. CONCLUSIONS

In this paper, we present transient current, active power, etc. analysis formulas of induction generator used in wind power system before and after balanced and unbalanced fault conditions. The simulation result obtained induction generator behavior in any network fault. These simulations can be used to study the dynamic behavior of the induction generator under balanced and unbalanced fault in short circuit or open circuit

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APPENDIX

Machine parameters

Table 1. System parameters.

Rated Power	674kVA
Rated Line-to-Line Voltage	690V
Rated Frequency	50Hz
Number of Poles P	4poles
Stator Resistance r_s	0.0118p.u.
Stator Leakage Inductance L_{ls}	0.217p.u.
Rotor Resistance r'_r	0.0156p.u.
Rotor Leakage Inductance L'_{lr}	0.186p.u.
Excitation Inductance L_m	7.28p.u.
Line Resistance R_l	0.0585p.u.
Line Inductance L_l	0.585p.u.
Inertia constant J	18.03kg m^2
Inertia constant J_1	∞ kg m^2