# Transient and Islanding Performance of Grid-Connected Induction Generator Feeding Induction Motor and Resistive Loads

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***Abstract*—This paper presents transient and islanding time-domain simulation of grid-connected induction generator feeding induction motor and resistive loads. The behavior of the system following a three-phase short-circuit in the grid network is investigated. Also the behavior of the system when it is suddenly disconnected from the grid is investigated under various loading conditions. Reactive power requirements of the induction generator and motor are supplied by the grid in addition to a local capacitor bank. Transient performance of the system due to a balanced three-phase short-circuit in the grid network is investigated. It is found that there is a critical clearing time for the system to maintain stability. Islanding (disconnection from the grid) performance of the system is also investigated. It is found that islanding may cause overvoltage and stability problems, depending on the active and reactive power deficit caused by disconnection from the grid.**

***Keywords- wind energy systems; induction generator; grid-connected ; induction motor; transients;islanding; grid separation.***

## I. INTRODUCTION

In recent years, due to increased public concerns regarding clean environment and fast depletion of fossil fuel, increased research emphasis has been placed on wind energy systems as clean and renewable energy systems. In almost all wind energy systems, the generator used is the three phase self-excited induction generator. Reference [1] is overview and exhaustive survey of literature on self excitation of three phase induction generators. Transient analysis of wind driven induction generators, as stand-alone or grid-connected are investigated by many authors [2-9]. The advantage of grid-connected operation is to supply the reactive power requirement of the induction generator from the grid and deliver any surplus real power from the induction generator to the grid. Due to large amounts of reactive power drawn by induction generators specially at low wind speeds, and the dynamic nature of wind turbines, utilities are facing severe problems such as poor power factor and transients caused by sudden disconnection from the grid [10-13]. This paper studies transient and islanding performance of a grid-connected induction generator feeding induction motor and resistive loads. A majority of electrical loads such as flour mills, water pumping, etc. are induction motors. Therefore, the transient behavior of such systems is of interest from the view point of assessing their stability and protection. The reactive power necessary to establish the air-gap flux of both machines must be provided by the grid or local capacitor banks. The time-domain transient analysis program PSCAD [14] is used to model and simulate system transients and islanding performance. The system is assumed to be running in steady state when a three phase short circuit occurs in the grid network forcing grid voltage to be zero. Wind turbine torque is assumed to remain constant over the period of study (10 seconds). During short circuit, power output from the induction generator is reduced and hence its speed increases. If the short circuit is not cleared the induction generator becomes unstable and speed continues to increase. If the short-circuit is rapidly cleared before the induction generator becomes unstable, the speed starts oscillating and goes back to its original value. This is similar to oscillations of synchronous generators following system short circuit clearing. To study the behavior of the induction generator and motor following disconnection from the grid, the system is assumed to be running at steady state when the circuit breaker connecting it to the grid is suddenly opened. In order for the system to maintain stability and operate separately at normal voltage and frequency, the local real and reactive loads must meet certain requirements as explained in the discussion of results.

## II. SYSTM LAYOUT

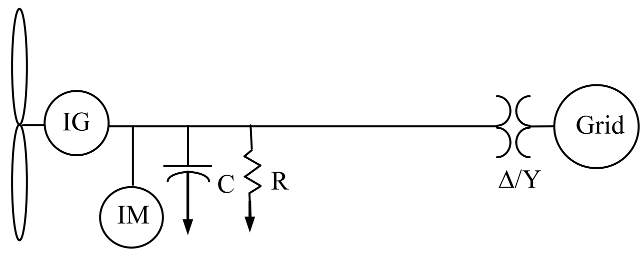


Figure 1. System One-Line Diagram

The system one-line diagram is shown in Fig. 1. The induction generator and motor are rated at 5000 hp and 2500 hp respectively, 13.8 kV. The resistive load is rated 700 kW, 13.8 kV and the capacitor is rated 2500 kVar, 13.8-kV.

## III. SYSTEM MODELING

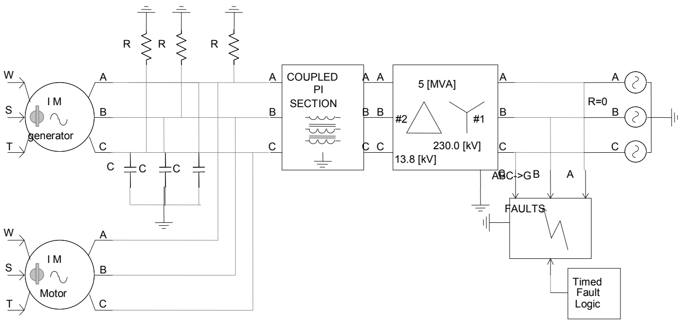


Figure 2. Partial PSCAD Simulation Diagram.

System components are modeled using the built-in models in PSCAD. The induction machine model is used for both generator and motor, while the capacitor and load are modeled using passive lumped parameters. The built-in transformer model is used to model the Δ/Y transformer and the feeder is represented by a mutually coupled bi-sections. Fig. 2 shows partial PSCAD simulation diagram.

## IV. SIMULATION RESULTS

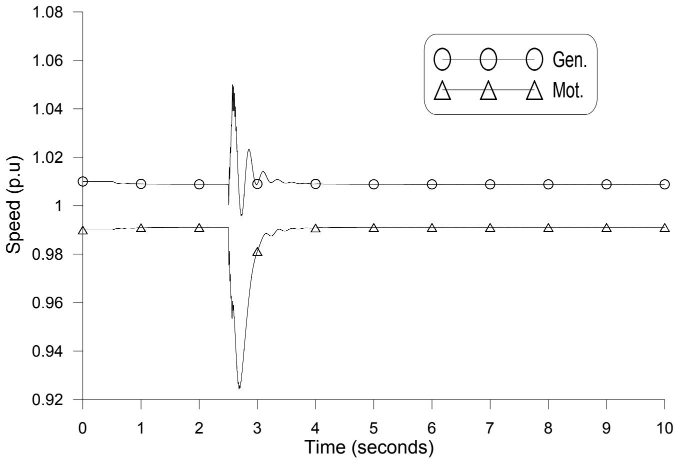


Figure 3. Speed for 3-$\phi$ fault, clearing time 0.06 Sec.

In Fig. 3 the system is stable since the short-circuit is cleared after 0.06 seconds. Generator and motor speed go back to their original values 1.01 pu and 0.99 pu respectively.

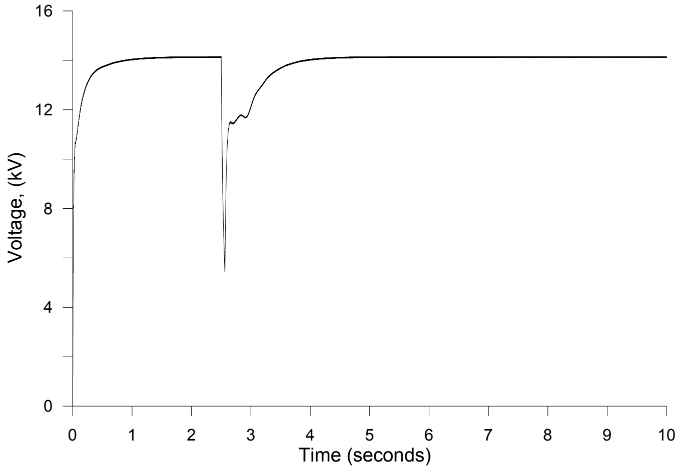


Figure 4. Voltage for 3-$\phi$ fault, clearing time 0.06 Sec.

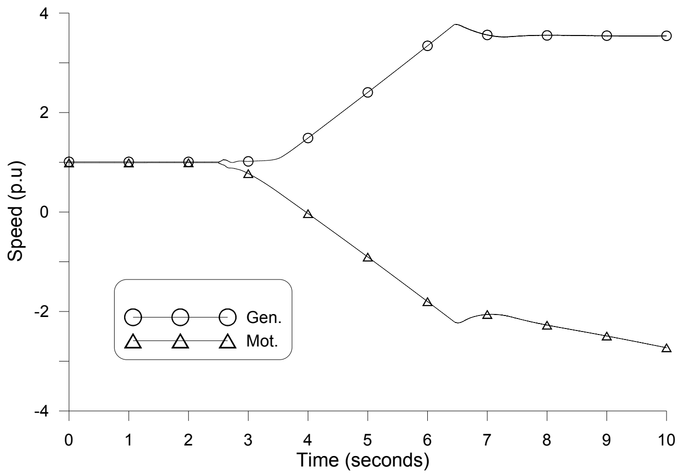


Figure 5. Speed for 3-$\phi$ fault, clearing time 0.07 Sec.

In this case, since short circuit clearing is delayed until 0.07 seconds, the system is unstable and speed and voltage increase considerably as shown in Figs 5 and 6.

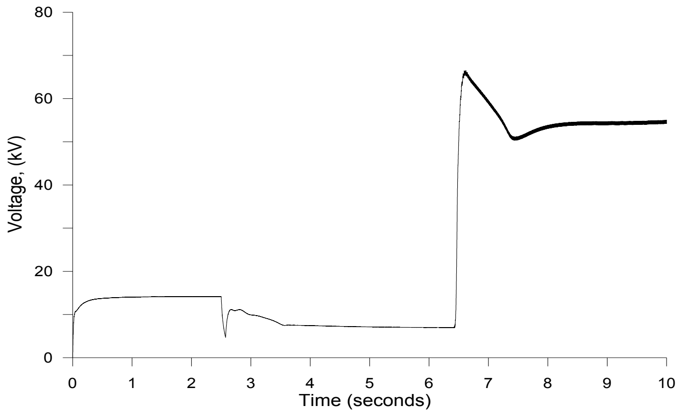


Figure 6. Voltage for 3-$\phi$ fault, clearing time 0.07 Sec.

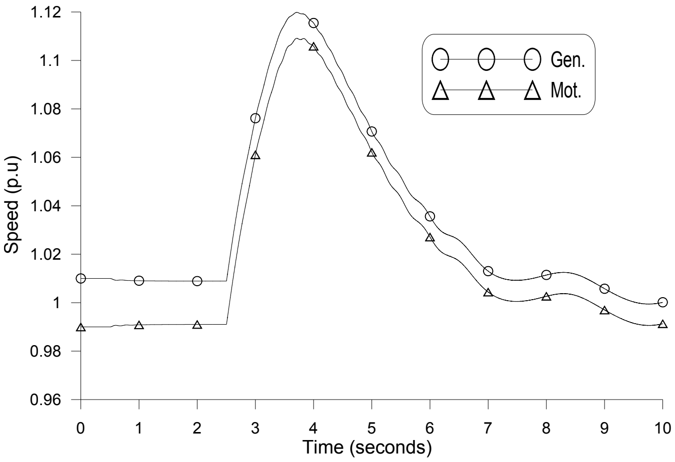


Figure 7. Speed during islanding, with 700-kW resistive, and 2500-kVar capacitive loads.

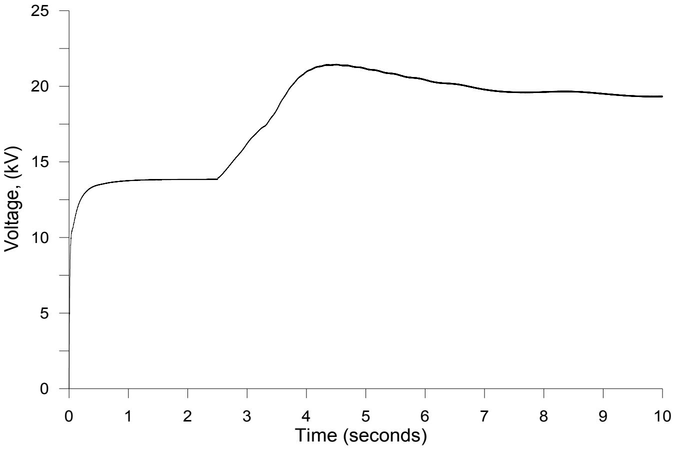


Figure 8. Voltage during islanding, with 700-kW resistive, and 2500-kVar capacitive loads.

Fig. 8 shows increase in voltage due to self-excitaion at higher speed.

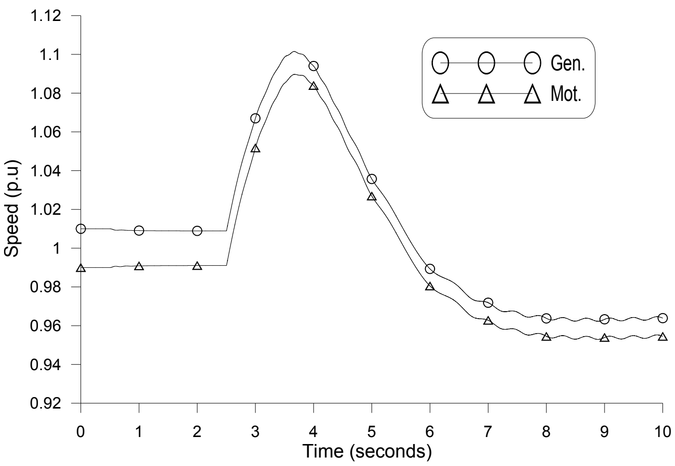


Figure 9. Speed during islanding, with 800-kW resistive, and 2500-kVar capacitive loads.

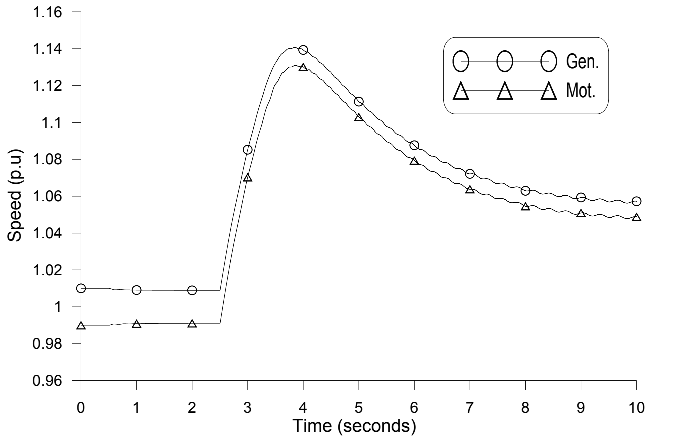


Figure 10. Speed during islanding, with 600-kW resistive, and 2500-kVar capacitive loads.

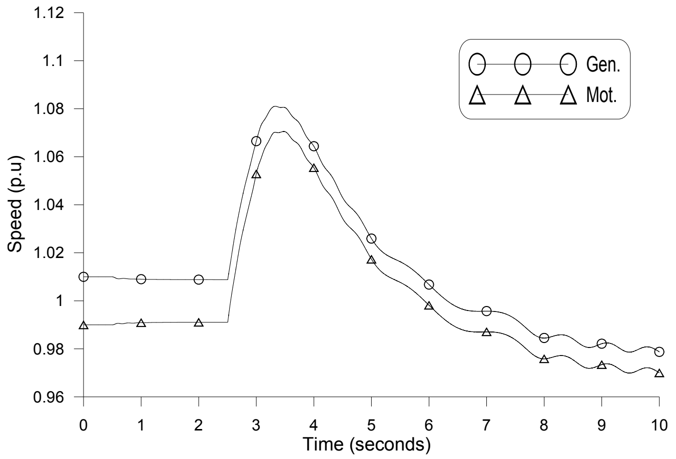


Figure 11. Speed during islanding, with 700-kW resistive, and 3000-kVar capacitive loads.

Fig. 11 shows the effect increased local real and rective power on stability and speed of the system after separation from the grid.

## V. CONCLUSIONS

In this paper transient and islanding performance of grid-connected induction generator feeding induction motor and resistive loads is studied. The system is assumed to be running at steady state when a three phase balanced short circuit occurs at the grid bus or when the breaker connecting the system to the grid is suddenly opened. It is found that the short circuit must be cleared within a critical (maximum) clearing time for the system to return to its pre-fault conditions. Separation from grid causes increase in speed due to interruption of real power flow to the grid, unless the local resistive load is sufficient enough to absorb this surplus real power. Also if the local capacitive load is not sufficient to compensate for the loss of reactive power supplied by the grid, the generator may self-excite at a higher terminal voltage due to increased speed.

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