TRANSIENT STABILITY ANALYSIS AND ITS INTENSIFICATION-IN MICROGRID

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Abstract—Technology evaluation, environmental concerns are often vast and messy in electrical power system. Hence, the study of transient stability plays a vital role for secured and planning operation in the power system. Today's challenge is the implementation of renewable energy into existing power system. Thus, microgrid an effective means of integrating distributed energy source. However, low inertia power electronics interface make microgrids sensitive to disturbance. It is therefore essential to investigate the transient stability characteristic of microgrid in detail. This paper presents the transient stability analysis of microgrid under different loading conditions and system voltage and critical clearing time is observed. The test system is simulated and stability analysis is carried out using MATLAB/Simulink Library.

Index Terms—Transient stability, Microgrid, Distribution generation (DG), WECS

INTRODUCTION

Electricity demand is continuously increasing. With the traditional technologies, fossil fuel like coal and natural gas is burnt to convert, to produce electrical energy in large scale power plants, polluting environment. This situation needs an urgent solution for the near future. There are many alternative promising solutions for the above problem, and one such solution is the concept of microgrid. It has become more important for modern power systems in terms of a possible means of achieving clean energy generation with updated and proven generation technologies. Microgrid is a technological innovation and business model response to fundamental technical flaws, economic constraints, environmental costs, and brittleness in the electrical grid. Microgrid is a sustainable technology for achieving energy security and more energy independence through energy efficiency, on-site generation and energy management.

The concept of microgrid scheme is based on distributed generation (DG) and the use of power electronics devices [1].The micro grid can work in grid connected mode as well as in islanded mode with the help of power electronic converter. The state-space modeling for such inverters based micro-grid [2] is available. The typical issues like transient stability, over voltage, under voltage, oscillations, offset voltage which are present in central grid are also observed in microgrid. Microgrid could be an answer to our energy crisis. Most of the microsources are interfaced through power electronic converters. Thus, microgrid has the characteristic of low inertia and extensive use of power electronic converters. Low inertia reduces the spinning kinetic energy of a system and the possibility of transient instability when the microgrid oscillates between the grid connected and islanded mode. The power electronics of the microsources generally has fast response but they may be susceptible to transient overloads. An extensive literature survey reveals that the concerted efforts have been on by researchers in the field of renewable energy and allied areas. Quite a good number of papers have been discussed about the concept design, implementation and operation of standalone grids and microgrids.

Thus, the transient stability of microgrid should be investigated. In this paper an attempt is made to study the power system issues under the transient condition in microgrid.

MICROGRID

The main objective behind the development of microgrid concept is to integrate as much as renewable energy sources, e.g. PV, wind turbine, fuel cell etc, which if directly integrated in the bulk grid system, would have increased the chances of system instability. The microgrid system acts like a plug and play power unit that can easily isolate itself during any grid disturbance or outage and continue supplying its loads in an islanded state. Also, microgrids provide a platform for effective utilization of sustainable energy sources and test their potential to replace the conventional power system. The microgrid controllers play a vital role in maintaining the microgrid in its islanded state.

A microgrid that is an integral part of a bulk grid system can only have the following modes of operation:

(*A*) *Grid connected mode*: The microgrid is connected to the utility grid via a switch at the point of common coupling (PCC). At this stage, the DGs of the microgrid share its local loads with the grid supply. In this mode the grid determines the voltage amplitude and frequency of the entire microgrid. This mode encourages the possibility of a bidirectional power flow, where excess generation by the DGs is returned to the utility grid system.

(*B*) *Transition mode*: The microgrid, on sensing a grid outage can disconnect itself from the grid by opening the switch at the PCC. This sudden absence of a power supply can trigger cascaded tripping inside the microgrid unless any proper control action is taken. Therefore, advanced controllers are designed to handle the transition from the grid connected to islanded mode. Similarly, controller action should also ensure a synchronized transition from islanded to grid connected mode.

(*C*) *Islanded mode*: In this mode the microgrid behaves as an autonomous power system, supplying its own load demands (both local and common), with the help of proper control actions. In absence of the utility grid, the DGs now determine the frequency and the voltage of the microgrid. Controllers play a key role in sharing loads among DGs, handling DG trips and non-linearity of loads. Success in this mode can make microgrid an effective solution to the centralized problem of the conventional grid system.

TRANSIENT STABILITY CONDITIONS

The transient stability of power systems is a nonlinear problem, the system stage is changing where if the transition is considered from one equilibrium to the other then due the large disturbances occur. So improving the transient stability is the main requirement. The transient stability studies are important both in operational planning as well as real-time operation.

Generator behaviour under transient conditions:

Transient stability is influenced by the non linear characteristic of an Electric power system. The equations describing phenomena cannot be linearized, thus assumptions are made in transient stability.For the purpose of studying electromechanical phenomena the generator can be represented by a driven rotating mass (equivalent to all turbines, shafts and generator rotors) which is broken by an electromagnetic field [3].

In steady state operation the mechanical power delivered to the rotating mass equals the electric power produced by the rotor electromagnetic field. In this equilibrium point the mechanical turbine torque τ_m is equal to the electric torque τ_e+ mechanical damping synchronous speed troque τ_d (rotational losses) and no relative rotor motion appears.

As soon as mechanical and electric torque are no more in equilibrium the rotating masses are accelerated or decelerated following Newton's law

$$J\frac{d\omega_r}{dt} + D\Delta\omega_r = \tau_m - \tau_d - \tau_e \qquad (1)$$

where

$$\omega_r = \omega_0 + \Delta\omega_r \qquad (2)$$

J represents the total moment of inertia of rotating masses (kg-m^2), ω_r is the rotor angular velocity (rad/s), $\omega_0$is synchronous speed (rad/s), $\Delta\omega_r$ is the rotor angular speed deviation (rad/s), D is damping torque coefficient(Nms) and τ_m , τ_e , τ_d (Nm)are the torques as explained in above paragraph.The mechanical damping torque τ_d is small and can be neglected for all practical purposes [4].The main source of damping in equation (1) ($D\Delta\omega_r$) is a generator damping winding. In synchronous operation there is no damping thus $\Delta\omega_r$ equals 0.In transient conditions which are interesting for phenomena related to transient stability the generator air gap flux penetrates the damper winding and induces voltage (emf) whenever $\omega_r \neq \omega_0$

As a consequence of this voltage , current flows in the damper winding which further causes a torque opposite to the change of rotor's relative angle(according to Lenz's law).This torque can be small speed deviations be assumed to be proportional to $\Delta\omega_r$ and can be referred to as asynchronous torque.For convenience and clarity of explaination, considerations let this damping be neglected.

Considering the assumptions, equation (2) and the factω_0 is a constant, equation (1) can be written as

$$J\frac{d\omega_r}{dt} = \tau_m - \tau_e \qquad (3)$$

Let δ_r, be defined as a rotor angle with respect to the synchronous rotating reference axis. Then:

$$\Delta\omega_r = \frac{d\delta_r}{dt} \qquad (4)$$

And according to equation 3

$$J\frac{d^2\delta_r}{dt^2} = \tau_m - \tau_e \qquad (5)$$

Multiplying equation 5 by the synchronous velocity ω_0 and taking into considerations that power is the product between torque and angular velocity equation (5) can be rewritten as follows

$$J\omega_0\frac{d^2\delta_r}{dt^2} = \frac{\omega_0}{\omega_r}P_m - \frac{\omega_0}{\omega_r}P_e \qquad (6)$$

Where P_m is shaft power provide to the generator and P_e is the electrical air gap power .In all practical cases it can be assumed that the rotor speed of a synchronous machine is so close to the synchronous speed that

$$\frac{\omega_0}{\omega_r} \approx 1 \qquad (7)$$

Considering also that the product equals the angular momentum finally the basic equation is obtained that describes rotor dynamics-is called switch equation.

$$M_r\frac{d^2\delta_r}{dt^2} = P_m - P_e \qquad (8)$$

Often rotor angular momentum M_τ is expressed either with,

i) Normalized inertia constant H(s), defined as a stored kinetic energy of rotating masses in mega joules at synchronous speed, normalized with the machine rating S_N

$$H = \frac{1 J\omega_0^2}{2 S_N} \Rightarrow M_r = \frac{2HS_N}{\omega_0} \qquad (9)$$

ii) Mechanical time constant T_a(s), defined as the time in which a generator rotating mass would reach the synchronous speed if the nominal mechanical torque (S_N/ω_0) was suddenly applied to the turbine shaft of the generator at rest.

$$T_a = 2H \Rightarrow M_r = \frac{T_a S_N}{\omega_0} \qquad (10)$$

The changes in mechanical power P_m are dependent upon the turbine power (frequency) controller. The time constants of mechanical power control are high compared to the rotor initial-swing time interval, therefore during the transients, characteristic for transient stability, P_m can in our theoretical considerations be assumed constant(pre-disturbance steady-state value).

Methods of improving transient stability:

By using UPFC

This method mainly gives the answer to the following question: How to unified power flow controller (UPFC) parameters and how it should be controlled in order to achieve the maximal desired effect for solving first swing stability problem. These types of problems mainly appear for bulky power systems with long transmission lines. There are various methods of reference identification of the series part, in order to improve the transient stability of the system based on: optimal parameters, state variables and also injection models were studied [5]. Finally, a method based on state variables and using the local measurement was proposed.

By using multiple models and switching

Most common problem in adaptive control is the poor transient response which is observed when adaptation is initiated. Here a stable strategy is developed for improving the transient response by using multiple models of the plant for controlling and switching between them. These models are identical except for initial estimates of the unknown plant parameters and control is applied to determine at every instant by the model which best approximates the plant. Result which we get after simulation indicates the improvement in performance that can be achieved.

Transient Stability Simulation by the Waveform Relaxation Methods

In this a new methodology for power system dynamic response calculations is presented. This technique is known as the waveform relaxation which is extensively being used in transient analysis [6] of VLSI circuits and it can take the advantage of new architectures in computer systems such as parallel processors and gives the computational results.

Renewable Energy Integration:

Effect of renewable energy integration on transient stability must be assessed on a case-by-case basis and depends more on distribution of asynchronous generator and controller types [7]. Depending on grid characteristic, it is necessary to limit penetration of renewable energy sources.

SCHEMATIC DESCRIPTION AND WORKING

The wind farm consists of 1.0 MW wind turbines connected to a 25 kV distribution system exporting power to a 120 kV grid through a 30 km 25 kV feeder. A 50 kW load is also connected on the 575 V bus of the wind farm. The wind turbine and the induction generator (WTIG) are as shown in Figure (1).

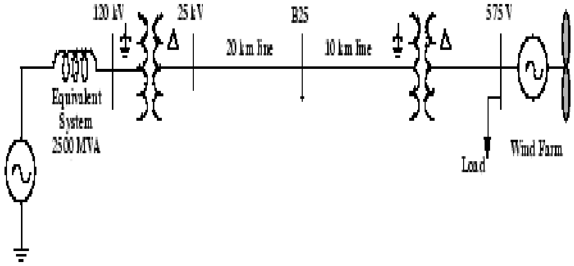


Figure 1. Single line diagram of Microgrid

The stator winding is connected directly to the grid and the rotor is driven by the wind turbine. The power captured by the wind turbine is converted into electrical power by the induction generator and is transmitted to the grid by the stator winding. The pitch angle is controlled in order to limit the generator output power to its nominal value for high wind speeds. In order to generate power the induction generator speed must be slightly above the synchronous speed. The reactive power absorbed by the induction generator is provided by the grid.

Both the wind turbine and the motor load have a protection system monitoring voltage, current and machine speed. The stator winding is connected directly to the 60 Hz grid while the rotor is fed at variable frequency through the converter.

Thus, the technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. The optimum turbine speed producing maximum mechanical energy for a given wind speed is proportional to the wind speed.

Rotor speed varies approximately between 1p.u at no load and 1.005 p.u at full load. Wind speed varies from 8-14m/s, pitch angle varies from -2^0 to 12^0, maximum rate change of pitch angle is 5^0.

MATLAB AND SIMULINK MODEL

Figure (2). shows the Simulink model of Microgrid in which micro source is connected in parallel with the resistive/reactive load at PCC .The proposed system is modeled using phasor simulation in Simpower system Library with ode 23tb solver.

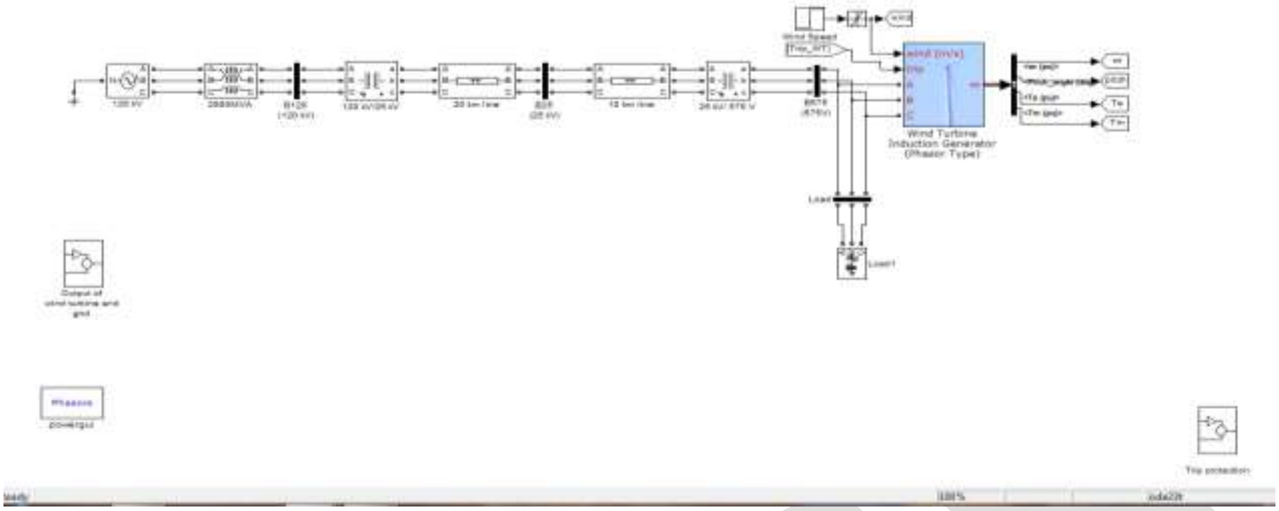


Figure 2. Simulink model of the proposed system

RESULTS AND DISCUSSIONS

Performance of Microgrid under different operating condition.

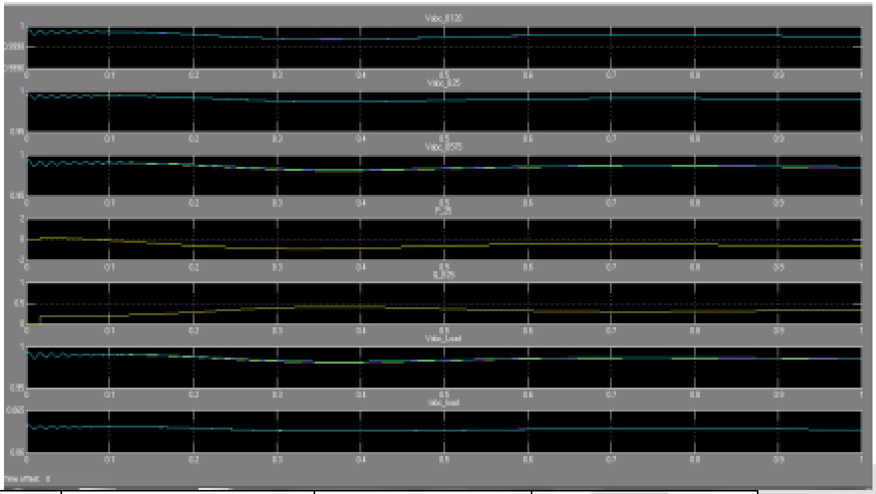
Case1: Under Normal load condition

The performance of the system with WECS as microsources under normal load condition with RL load is as shown in simulation results below.

	Vabc_ B120	Vabc_ B25	Vabc_ B575	Vabc_ Load	Iabc_ Load	V1_575
	p.u	p.u	p.u	p.u	p.u	p.u
Magnitude	0.9999	0.9996	0.99	0.99	0.063	1
Time(s)	0.1	0.1	0.1	0.1	0.1	0.05

Table 1.

Thus, the table 1. briefly explains about the transient operation taken to reach the steady state with magnitude of voltage at grid side, voltage at PCC (point of coupling),voltage and current at consumer side, mean voltage of the wind turbine w.r.t to time in seconds.

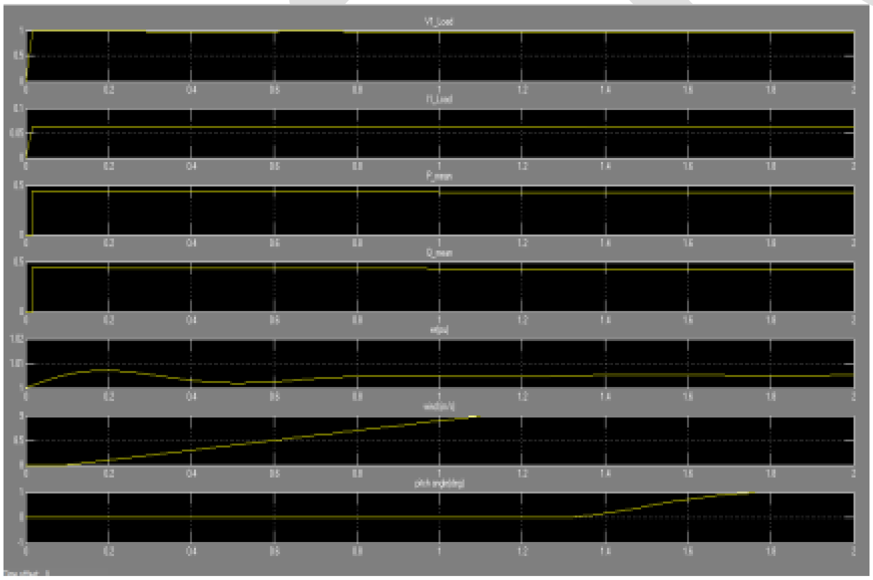


V1_Load	I1_Load	Pmean	Qmean
p.u	p.u	p.u	p.u
1	0.6	0.44	0.44
0.05	0.05	0.05	0.05

Table 2.

Mean voltage, mean current, mean active power and mean reactive power of the wind turbine as shown in table 2.

The simulation results of wind speed (m/s), rotor speed and pitch angle are also shown.



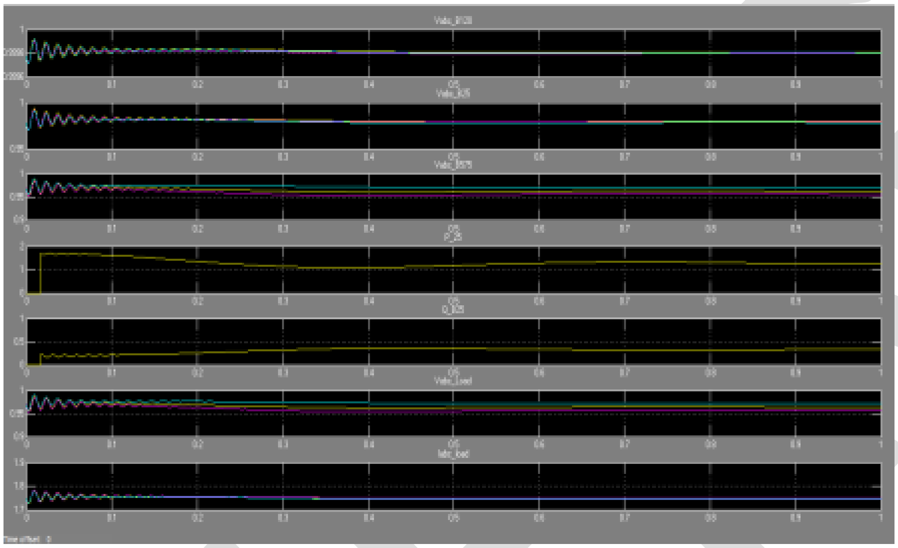
Case2: Under Over load condition

The performance of the system with WECS as micro sources under overload condition with RL load (2MW, 50kvar) is as shown in simulation results.

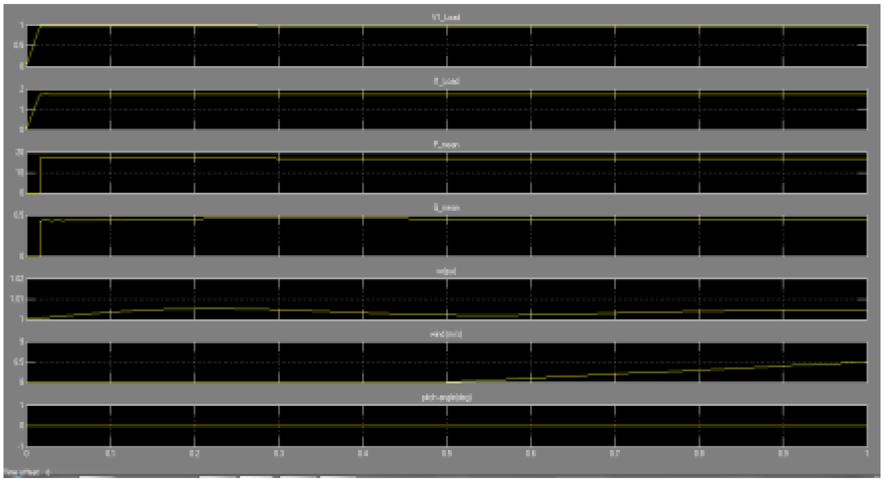
	Vabc_ B120	Vabc_ B25	Vabc_ B575	Vabc_ Load	Iabc_ Load	V1_575
	p.u	p.u	p.u	p.u	p.u	p.u
Magnitude	0.9998	0.997	0.98	0.975	1.75	0.99
Time(s)	0.2	0.2	0.2	0.2	0.2	0.055

Table 3.

The above table 3. shows the transient operation taken to reach the steady state with magnitude of voltage at grid side, voltage at PCC (point of coupling), voltage and current at consumer side, mean voltage of the wind turbine w.r.t to time in seconds.



V1_Load	I1_Load	Pmean	Qmean
p.u	p.u	p.u	p.u
1	1.8	1.7	0.45
0.055	0.055	0.2	0.2



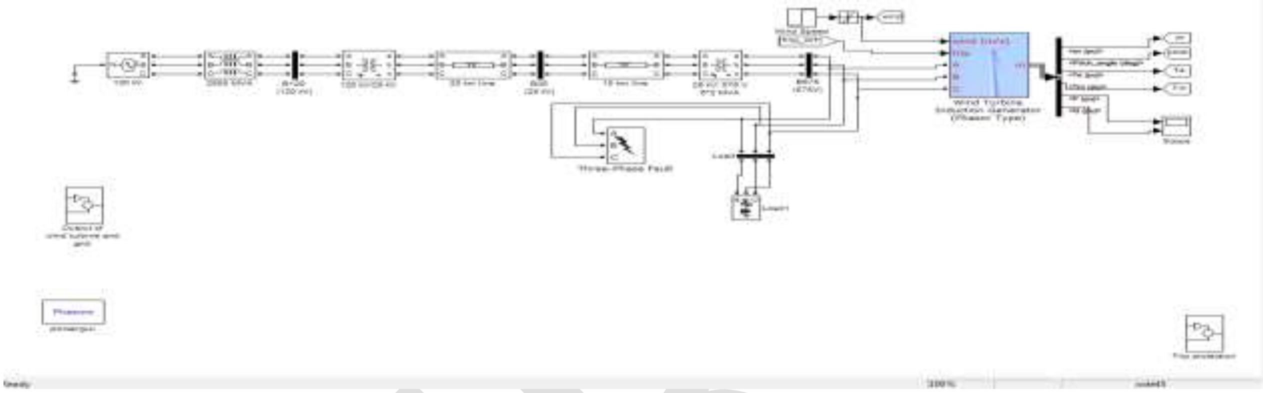


Figure 3. Simulink model of the proposed microgrid system with faulty section

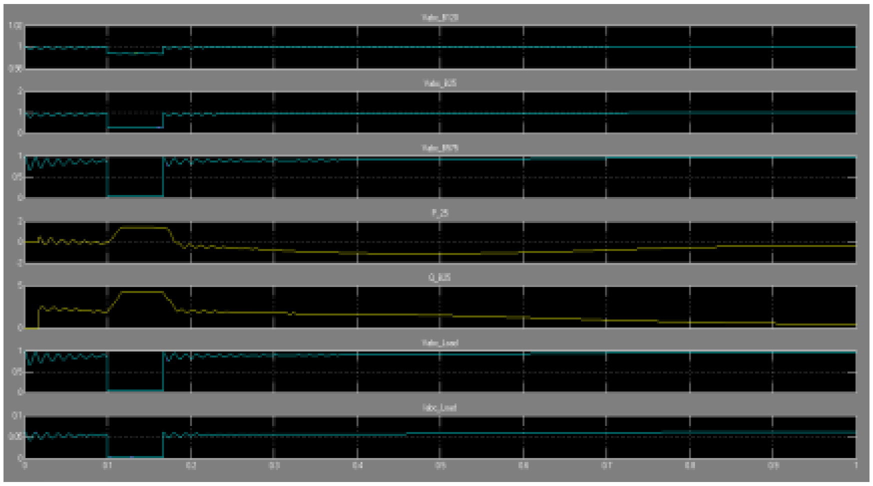
Case 3_1: Fault Condition (LLLG Fault at bus 575,60Hz RL,50kw,50kvar)

The performance of the system during fault condition at initial period at t=0.5 to 0.8 seconds, the time taken by the system to reach to steady state value is given in table 4. shown below

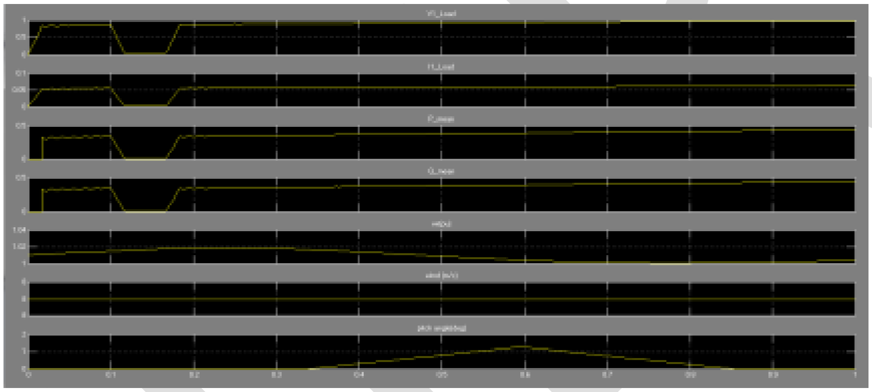
	Vabc_ B120	Vabc_ B25	Vabc_ B575	Vabc_ Load	Iabc_ Load	V1_575
	p.u	p.u	p.u	p.u	p.u	p.u
Magnitude	0.9996	0.92	0.89	0.91	0.06	0.91
Time(s)	0.3	0.3	0.3	0.3	0.3	0.065

Table 4.

The above table 4.state with magnitude of voltage at grid side, voltage at PCC (point of coupling), voltage and current at consumer side, mean voltage of the wind turbine w.r.t to time in seconds



V1_Load	I1_Load	Pmean	Qmean
p.u	p.u	p.u	p.u
0.9	0.056	0.34	0.34
0.06	0.06	0.25	0.25



CONCLUSION

This paper has addressed the enhancement and relevant study of transient stability analysis for microgrid. A Simulink model is developed with DG unit to design the microgrid. Using this model, transient stability analysis is carried out under different operating conditions. Thus, it was observed that under different loading condition the critical clearing time is increased as the load increases at consumer point. Thus, transient stability analysis becomes a major role for optimal design of microgrid.

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