POWER QUALITY AND RELIABILITY ISSUES OF INDUCTION GENERATOR FOR WIND POWER PLANTS

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ABSTRACT

Induction generators connected to the local grid may lead to severe power quality problems such as flicker, voltage dip etc. Further, unbalancing of the supply system may distort the supply voltage at the point of common coupling (PCC). The power quality and reliability issues of an induction generator for embedded generation have been analyzed in this paper. The behavior of the grid with connection/disconnection of the induction generator, variable wind speed operation, unbalancing, and harmonic injection have been simulated using MATLAB. The voltage dip transients, harmonics, voltage flicker, voltage unbalance of the supply system have been described to ascertain the impact of induction generator on reliability and power quality of the supply.

Keywords: *Power quality, system reliability, induction generator, voltage drip, harmonics, wind power plant.*

1. INTRODUCTION

Renewable sources such as wind energy, hydro, tidal, solar etc. are intermittent in nature. While feeding the customer loads reliability and quality of the supply are the important factors. There is increasing interest in the connection of generation to distribution networks particularly for the exploitation of the new renewable energy sources, eg wind and small hydro. The renewable energy resource dictates the location of this generating plant which is often in remote rural areas where there is only modest capacity in the distribution circuits and limited customer loads, It is common for both fixed speed wind turbines and some small hydro-plant to use asynchronous, induction generators [1]. This is partly because of the robust nature and economy at certain sizes of induction machines but also because of the very significant damping which they introduce into the mechanical drive train. This embedded generation plant is not able to contribute reactive power and, in fact, plays no direct role in maintaining the distribution network voltage. As it is connected to high impedance circuits there is also the possibility of voltage instability.

A further important factor is that the primary interest of the operators of the embedded generation plant is the export of kWh at minimum cost. Therefore, when any scheme is considered there is a strong desire to reduce the capital cost, and hence the capacity, of the connection and any reinforcement of the distribution network. Although local power factor correction may be applied to reduce the reactive power drawn by the generators this is only in response to rather simple charging mechanisms for reactive power which may not produce the most desirable effect for the voltage of the distribution network [2]. Recently interest in the renewable sources of energy embedded in the local network has increased because of reduction in gaseous emission, energy efficiency or rational use of energy, deregulation or competitive policy, and diversification of energy resources. Modern distribution systems were designed to accept bulk power at the bulk supply transformers and to distribute it to customers. Thus the flow of both real power and reactive power was always from the higher to the lower voltage levels. However, with significant penetration of embedded generation the power flows may become reversed and the distribution network is no longer passive supplying loads but an active system with power flows and voltages determined by the generation as well as the loads [3] and [11].

Different power quality aspects usually considered important are transient voltage variations and harmonics. Embedded generation plants can cause transient voltage variations on the network of relatively large current changes during connection and disconnection of the generator. The magnitude of the current transients can to a large extent be limited by careful design of the embedded generation plant, although for single generators connected to weak systems the transient voltage variations caused may be the limitation on their use rather than steady-state voltage rise. However disconnection of the generators when operating at full load may lead to significant, if infrequent, voltage drops. Also some forms of prime mover (e.g. fixed speed wind turbines) may cause cyclic variations in the generator output current, which can lead to so-called flicker, a nuisance if not adequately controlled, unacceptable voltage distortion. Directly connected generators can also lower the harmonic impedance of the distribution network and so reduce the network harmonic voltage at the expense of increased harmonic currents in the generating plants and possible problem due to harmonic resonance. This is of particular importance if power factor correction capacitor bank is connected to compensate the induction generator [4]-[5].

Embedded generation is being connected increasingly to distribution networks. For many new renewable energy schemes this will involve the connection of induction generators to weak rural networks. It has been shown by studies and subsequent operating experience that relatively high ratios of wind farm capacity to network short circuit level can be accommodated successfully if conditions are favorable. However, voltage stability of the system is likely to be an important limiting factor to the continued increase of the ratio of generation capacity to network short circuit level [17]-[20]. Embedded system comprising of a mini hydro having synchronous machine operating as a grid feeding a constant power and a wind turbine with induction generator has been simulated using MATLAB. Various system abnormal conditions like connection/ disconnection (islanding) of the induction generator, variable wind speed operation, unbalancing, and harmonics injection have been simulated to analyze the power quality issues [7]-[9].

2. SYSTEM DESCRIPTION

The local grid consists of 480 V, 300 kVA synchronous machine, a wind turbine driving a 480 V, 275 kVA induction generator, a 50 kW customer load and a variable secondary load (0 to 446.25 kW). At low wind speeds both the induction generator and the diesel-driven synchronous generator are required to feed the load [10]. When the wind power exceeds the load demand, it is possible to shut down the diesel-generator. In this all-wind mode, the synchronous machine is used as a synchronous condenser and its excitation system controls the grid voltage at its nominal value [12]-[16]. A secondary load bank is used to regulate the system frequency by absorbing the wind power exceeding consumer demand. The nominal power of each set follows a binary progression so that the load can be varied from 0 to 446.25 kW by steps of 1.75kW. For the simulation mini hydro is operated at 0.5 PU power.

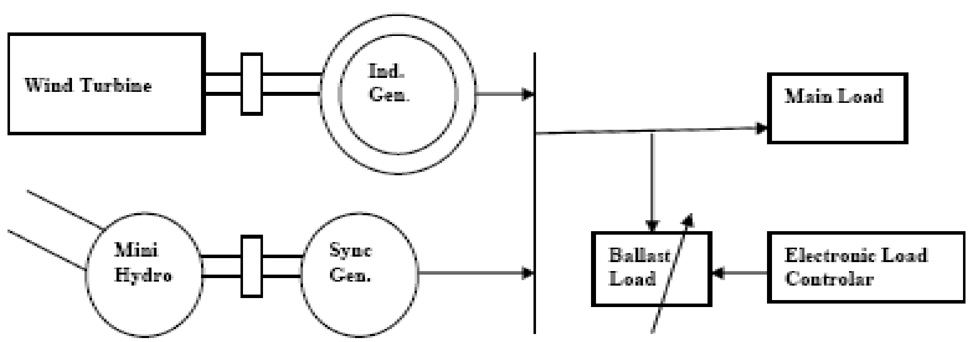

Figure 1. System configuration of the embedded generation

3. MATLAB SIMULATION OF THE LOCAL GRID

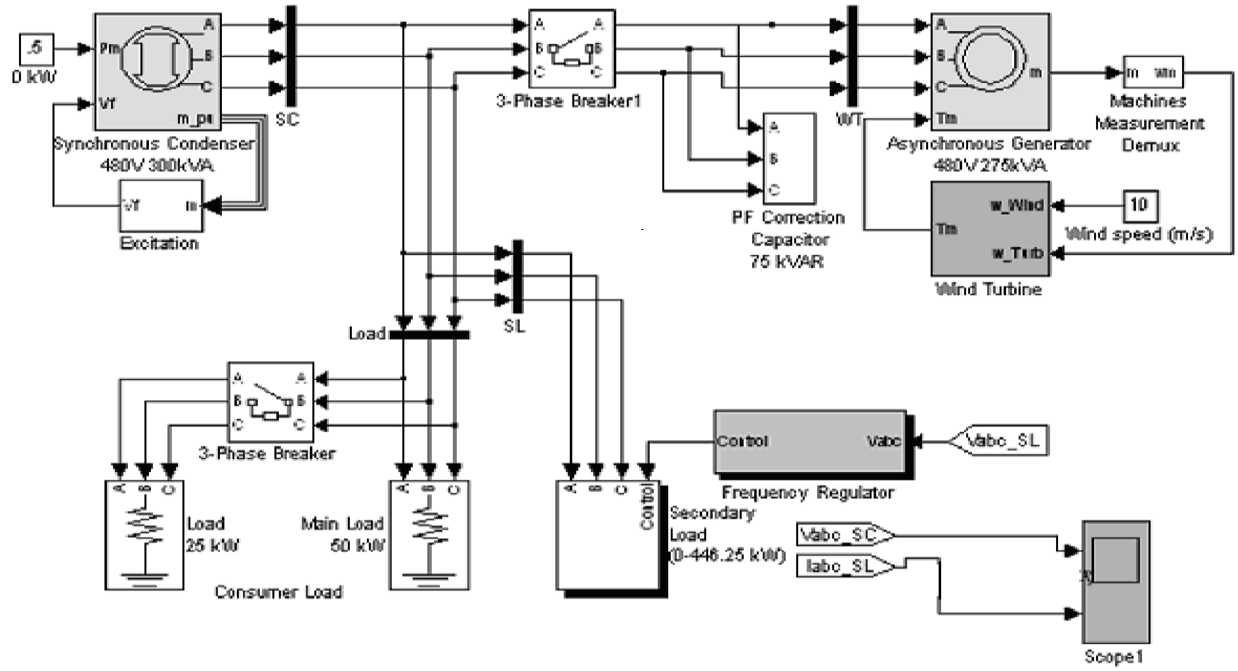

Figure 2. MATLAB simulation of the local grid

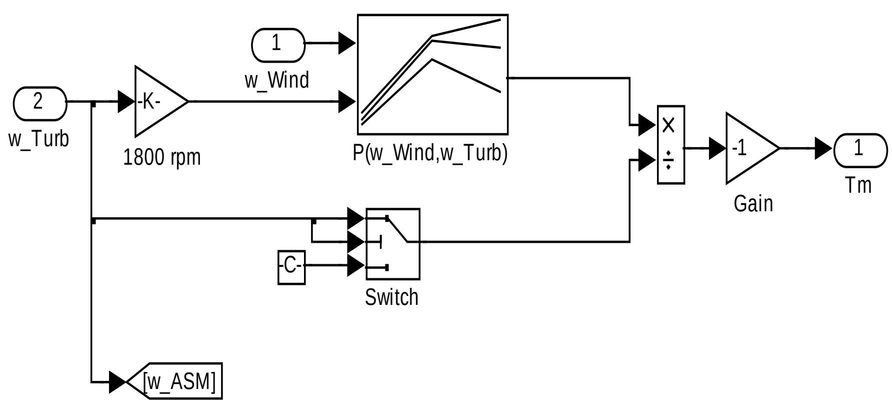

Figure 3. Wind turbine

The wind turbine block uses a 2-D Look up Table to compute the turbine torque output (T_m) as a function of the wind speed (w_Wind) and turbine speed (w_Turb). When we open this model, the P(w_Wind, w_Turb) characteristics are automatically loaded in workspace (psbwindgen_char array).

3.1 Secondary Load Block

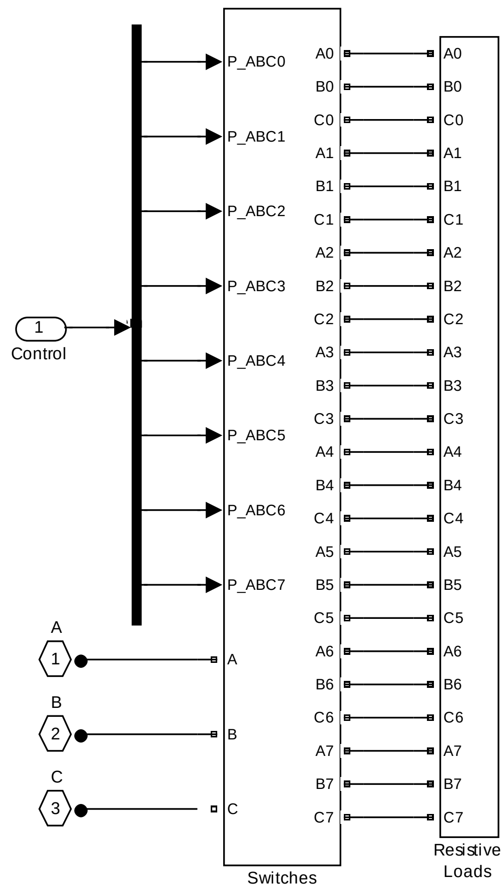

Figure 4. Secondary load block

The Secondary Load block consists of eight sets of three-phase resistors connected in series with GTO thyristor switches. The nominal power of each set follows a binary progression so that the load can be varied from 0 to 446.25 kW by steps of 1.75kW. GTOs are simulated by ideal switches.

3.2 Discrete Frequency Regulator

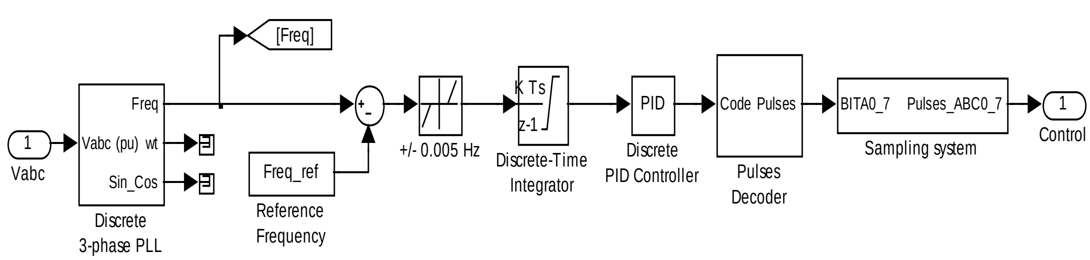

Figure 5. Discrete frequency regulator

The frequency is controlled by Discrete Frequency Regulator block. This controller uses a standard three-phase Phased Locked Loop (PLL) system to measure the system frequency. The measured frequency is compared to the system frequency (60 Hz) to obtain the frequency error. This error is integrated to obtain the phase error. The phase error is then used by a Proportional – Differential (PD) controller to produce an output signal representing the required secondary load power. This signal is converted to an 8-bit digital signal controlling switching of the eight three-phase secondary loads. In order to minimize voltage disturbances, switching is performed at zero crossing of voltage.

4. SIMULATION RESULTS AND DISCUSSION

The above said system was simulated in MATLAB to study the power quality issues related to embedded generation. The SIMULINK model of the system is shown in *Figure*. The voltage dip transients, harmonics, voltage flicker, voltage unbalance of the supply system are analyzed to ascertain the impact of induction generator on power quality of the supply.

A. Connection of Induction Generator to the local grid

Figure 6 shows the voltage dip at the connection of induction generator. The synchronous generator initially builds up and runs at steady state condition supplying 50 kW main loads. After 1.0 seconds, wind driven induction generator is connected to the local grid. The wind speed is kept constant at 10 m/s. At this speed induction generator gives 200 kW to the system load. However the reactive power demand of the induction generator has to be supplied by the local grid. Induction generator connection to the grid causes voltage dip in the supply system as shown in Fig. 3 since the generator draws roughly six times the rated currents and at poor power factor. This dip may affect the surrounding customer load and may cause sensitive loads to malfunction. The synchronous voltage controller responds immediately and reduces the voltage dip transients. The reactive power supplied by the synchronous generator suddenly shoots up and once the induction generator transients are over the reactive power demand is reduced. As the system main load is only 50 kW, the surplus power generated by both the generators is dissipated in the dummy load.

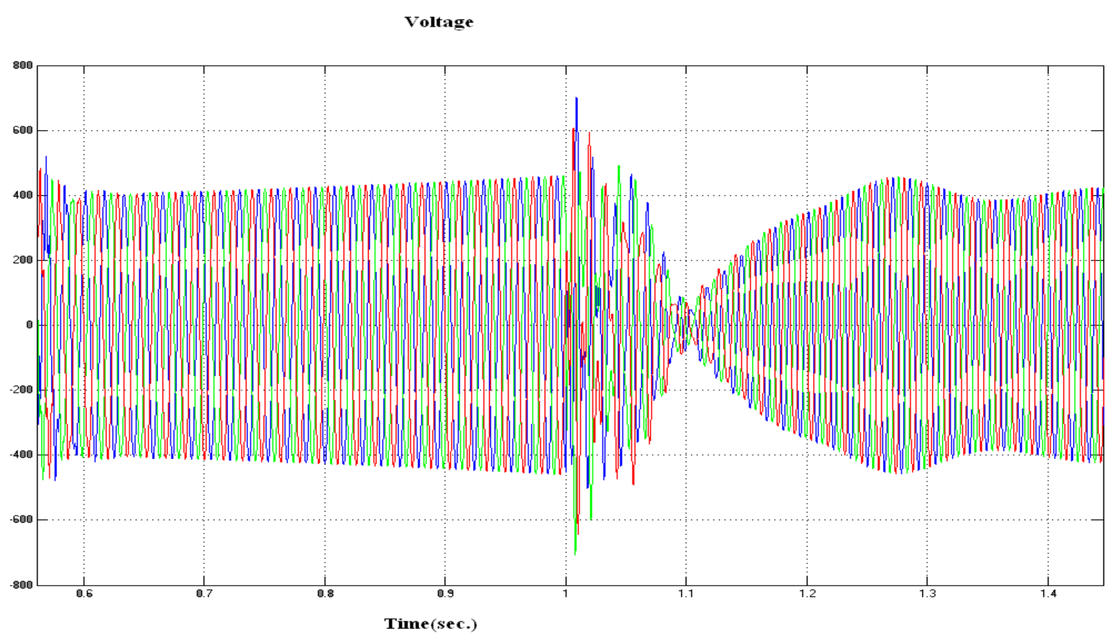

Figure 6. Voltage dips at the connection and disconnection of wind energy system

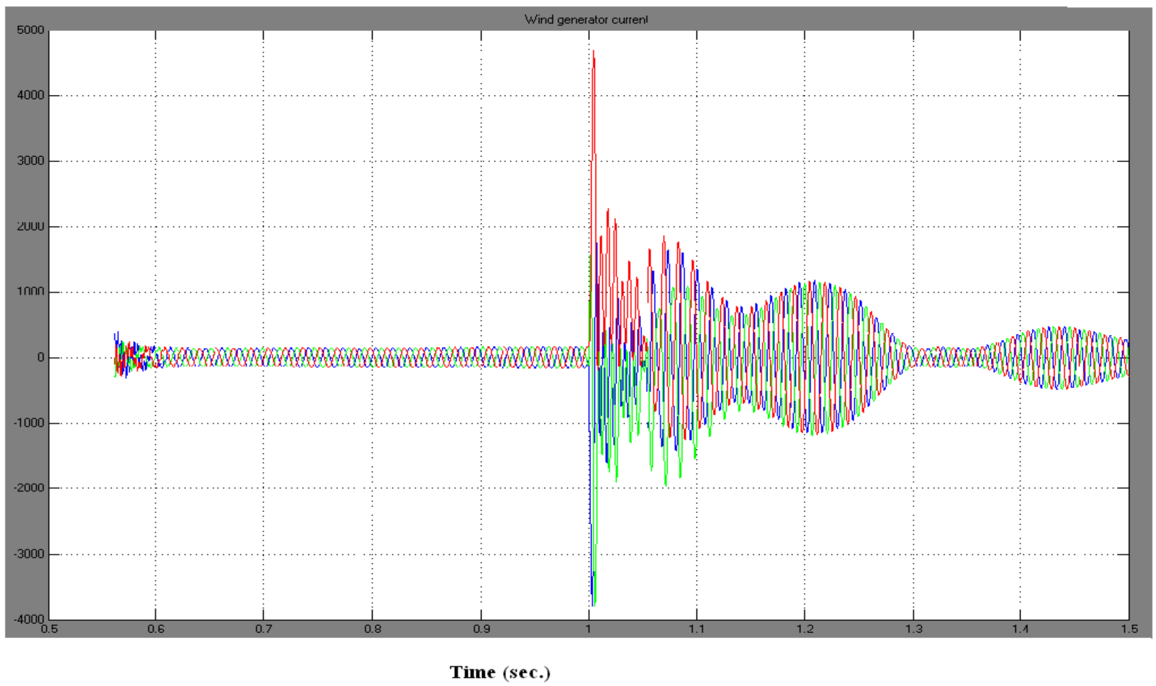

Figure 7. Wind generation current

B. Islanding of the Induction Generator

Figure 8 shows the parallel operation of induction generator with the local grid may result is islanding operation of induction generator due to operation of circuit breaker. In a time of 2.0 seconds the islanding is done. The system then recovers to normal condition.

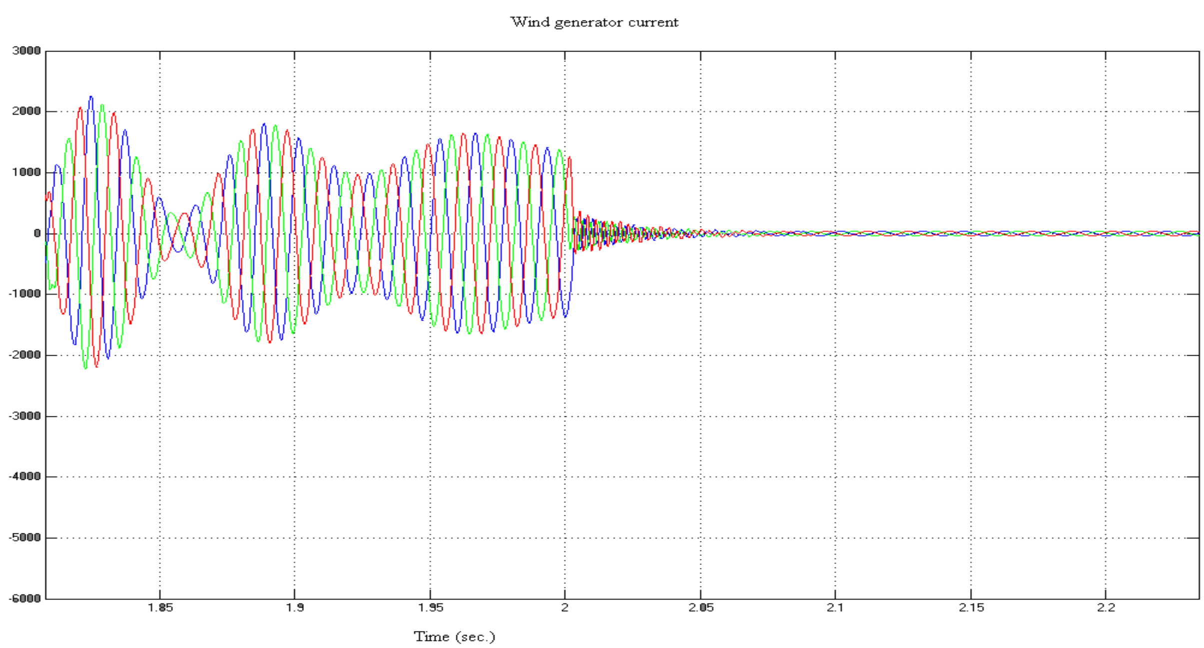

Figure 8. Wind generator current

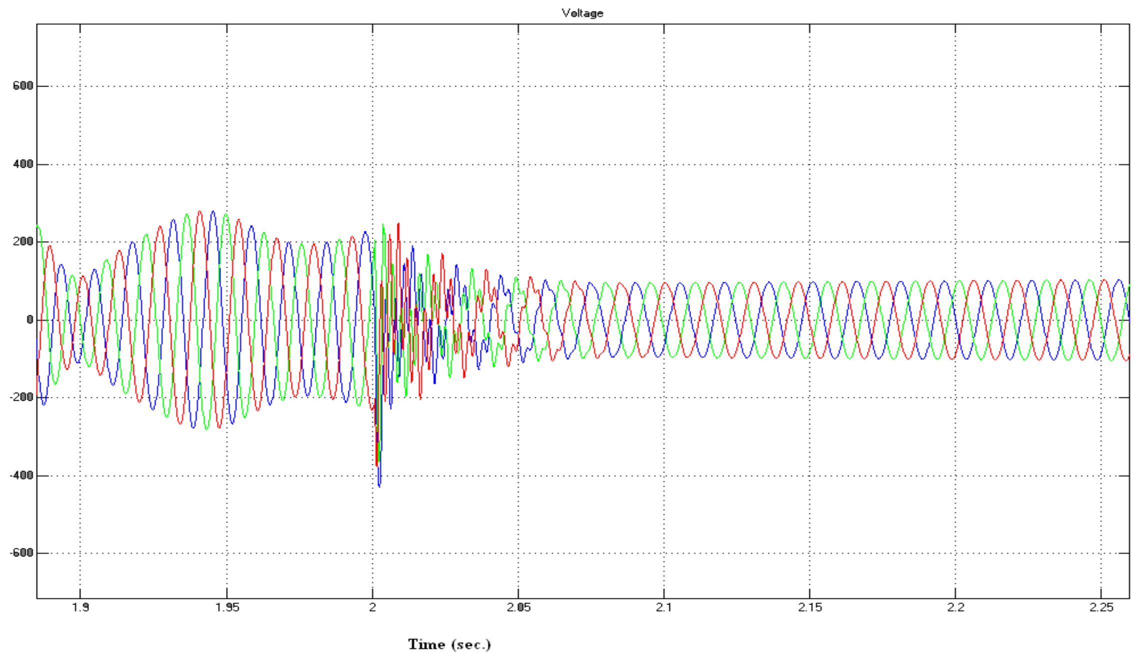

Figure 9. Voltage dip at the connection and disconnection of wind energy system

C. Unbalancing of wind generator

Figure 10 shows the voltage unbalancing at PCC due to unbalancing of wind generator. The single phasing of wind generator results in voltage unbalancing.

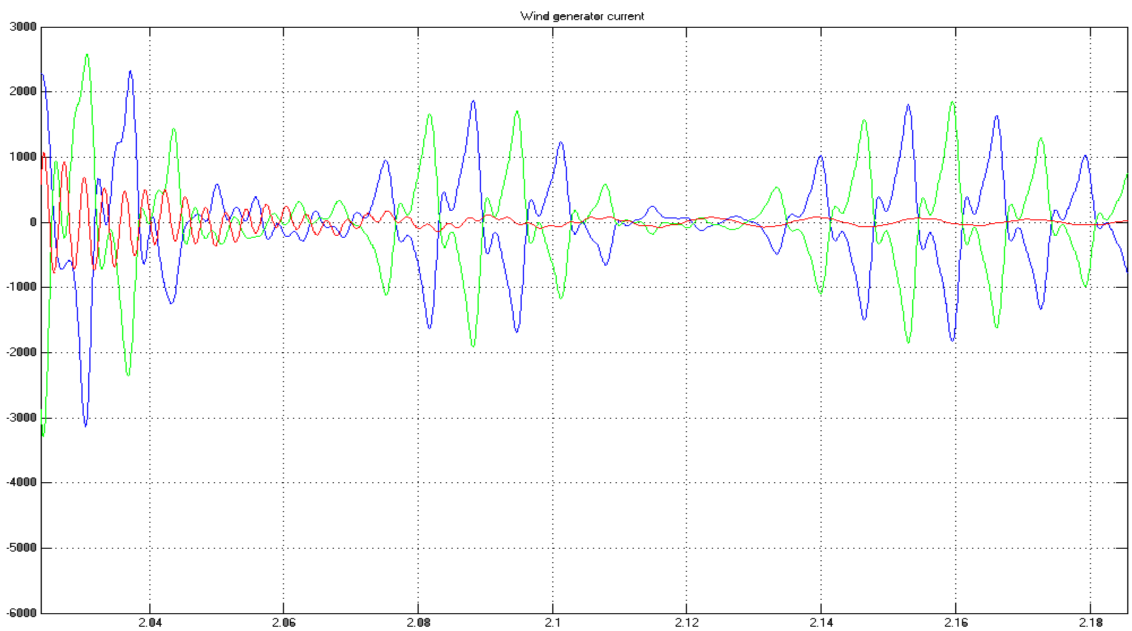

Figure 10. Wind generation current

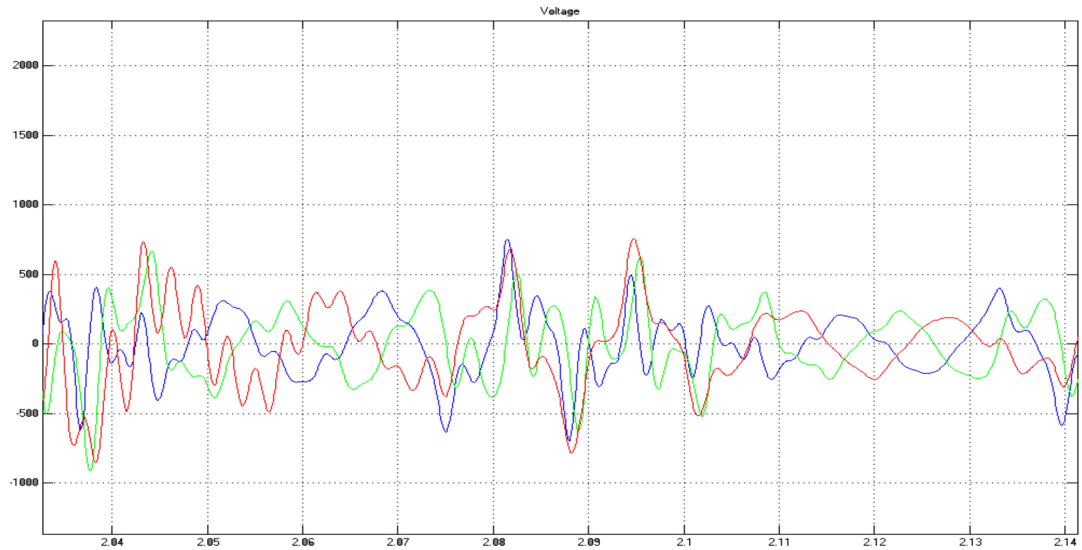

Figure 11. Voltage unbalancing due to unbalanced supply

D. Harmonics effects

As shown in the Figure 12 the wind generator having induction machine does not lead to harmonic distortion at PCC. Further the capacitor bank improves the current profile along with the provisioning of reactive power.

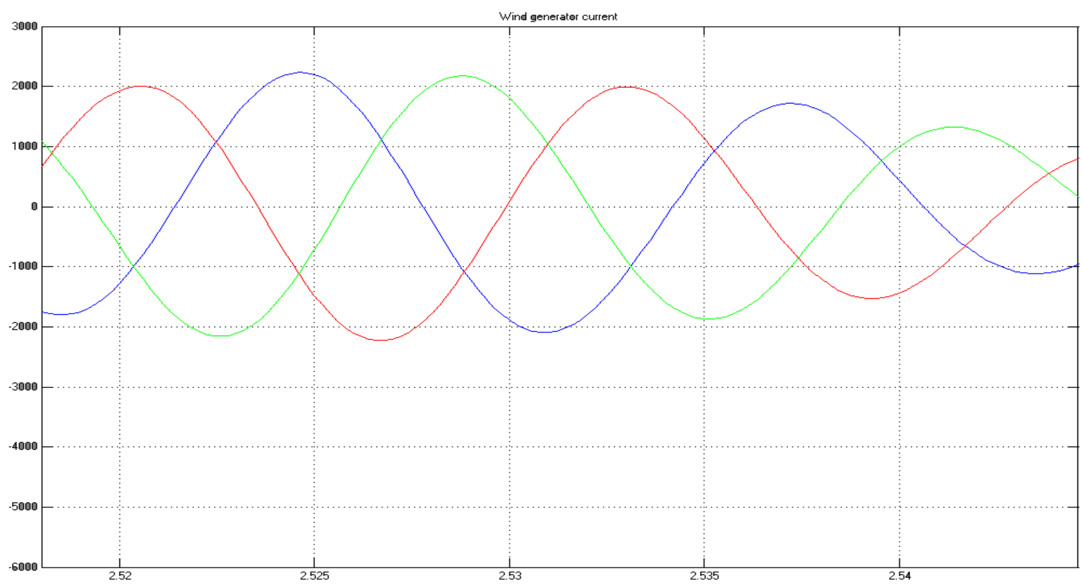

Figure 12. Wind generation current

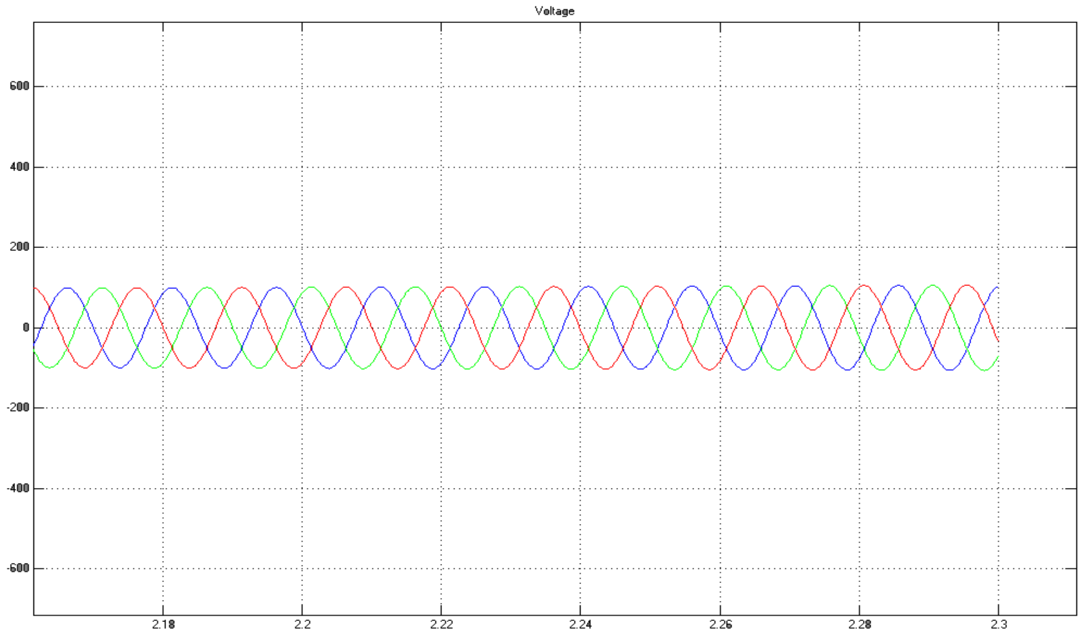

Figure 13. Voltage at PCC and wind generator current

5. CONCLUSION

Renewable sources such as wind energy, hydro, tidal, solar etc. are intermittent in nature. While feeding the customer loads reliability and quality of the supply are the important factors. The above said system has been simulated in MATLAB to study the power quality issues related to embedded generation. The SIMULINK model of the system is shown in the Figure. The voltage dip transients, harmonics, voltage flicker, voltage unbalance of the supply system are analyzed to ascertain the impact of induction generator on power quality of the supply.

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