International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 6, No. 4, December 2015, pp. 723~729
ISSN: 2088-8694

Voltage and Frequency Control of Variable Speed Induction Generator using One Cycle Control Technique

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Article Info

Article history:

Received Apr 24, 2015
Revised Aug 11, 2015
Accepted Sep 10, 2015

Keyword:

Electronic load controller
Frequency control
Induction Generator
One cycle control
Voltage control

ABSTRACT

Induction generators are widely used to extract the energy from renewable sources, particularly as a wind power generator either grid connected or isolated operation. The problem associated with stand-alone mode operation is voltage and frequency control. An electronic load controller is used for frequency / voltage control. It uses PI controller to generate the gating signal for the DC chopper. This method has the fault of bad dynamic response and thedistortion of output voltage at zero-crossing. To overcome the defect of PI controller when steady state error is equal to zero, a one cycle control technique suggested and implemented. Simulation of wind driven self-excited induction generator (SEIG) performance is studied and results are discussed.

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1. INTRODUCTION

To meet the shortfall in power demand, power generation from wind contributes major role among other renewable energy sources such as solar, tide etc., and, advancement of power electronics technology also support to generate more power from wind. The future trend of wind energy conversion systems (WECS) is to increase the power capacity of wind turbines and generators to reduce the cost of generated electricity[1]-[5]. The power electronic technologies used in wind turbine application have changed dramatically during last 30 years [6]-[7].

In remote area electric power supply, standalone operation of SEIGs has a vital role. In order to optimize the cost of the system induction motor is used as generator. It has significant advantages such as easy maintenance and control, no need of separately exciting source instead of that, capacitor connected across the stator winding is sufficient to excite the machine, and, rugged in rotor construction is more suitable for wind turbine rotations. The voltage generation and generated frequency depends on the wind velocities. The problem associated with this scheme is to control the frequency and voltage.

Bhim Singh et al [8] suggested a load control technique to solve the above problem. Transient analysis of SEIG considered on their further research [9]. However, the method suggested by them incorporated PI controller to generate the gate pulse for the chopper switch which is controlling power flow through the dump load/ additional load.

One-cycle control is a typical practical nonlinear controltechnology; it has rapid dynamic response and trackperformance [10]. It is designed to control the duty-ratioof the switch in real time. The aim of this work to eliminate the problem associated with PI controller as and when the steady state error is zero by implementing one cycle control (OCC). The OCC is presented in subsequent section in detail.

This paper organized as section 2 describes the system configuration, Frequency control, one cycle control and its operation. Simulated results and conclusion presented in section 3 and 4 respectively.

2. SYSTEM CONFIGURATION

The proposed system is shown in Figure 1. It comprises with SEIG, Electronic load controller, one cycle controller, consumer load and wind turbine emulator.

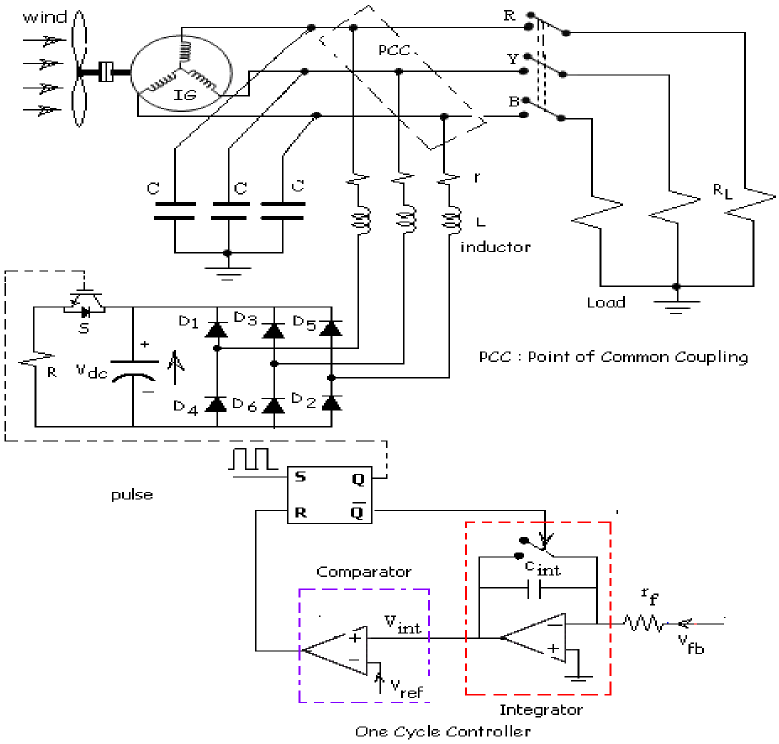

Figure 1. Schematic diagram of SEIG with Electronic Load controller and one cycle controller

The torque generated by the wind turbine emulator with wind velocity of 6 m/sec is applied to the induction motor. Since the torque is in negative and adequate capacitor connected across the stator winding, as soon as the rotor speed exceed the synchronous speed (Ns = 120f/P) voltage induced across the stator winding and also builds up, to the rated value is called self-excitation process. So called self-excited induction generator.

The SEIG supply the power to a three-phase wye connected consumer load and an additional (dump load) is shown in Figure 1. Dump load is controlled by the proposed one cycle controller. The function of the controller is to maintain the power generated by SEIG is constant at all condition.

2.1. Frequency Control

The Electronic load controller can be used to connect or disconnect the dump load whenever the consumer load fluctuates. It consists of a diode rectifier and a step down chopper circuit connected in series with a dump load. The duty cycle of the IGBT switch is controlled depending on the variations in consumer load which eventually decide the amount of power to be dumped.

The AC voltage from the SEIG terminal is rectified by means of an uncontrolled bridge rectifier and a capacitor is connected across the diode bridge rectifier to filter out the ripples. The effective input resistance seen by the source at point of common coupling (PCC) is,

$$R_i = \frac{V_s}{I_o} = \frac{V_s}{\frac{\alpha V_s}{R}} = \frac{R}{\alpha} \tag{1}$$

From eqn. (1), the duty cycle can be varied from 0 to1 by varying T or f and the input resistance (R_i) as a function of duty cycle α.

2.2. One Cycle Control Tecnique

One cycle control can be used to control a switched variable and a switch controlled by this method fully rejects the input signal and reproduces the control reference at the output [10]. The basic assumption here is that the switching frequency is much higher than the maximum frequency of the input and reference signals.

One cycle controller uses the constant frequency pulse to turn on and turn off the transistor and active the integrator. It is new non linear control technique implemented to control the duty ratio of switch in real time, in each cycle the average value chopping waveform of switch output is exactly same as control reference voltage. This sample signal is taken from the chopped voltage not from the output voltage. One-cycle control method reject input voltage perturbation in only one switching cycle and follow the control reference very quickly.

Let u(t) be an input to a switch operating at variable on and off times (Ton and Toff),total cycle time Ts, duty ratio d(t) and producing the average of the switched output i.e., effective signal, is

$$w(t) = \frac{1}{T_s}\int_0^{T_{ON}} u(t)\,dt \approx u(t)\,d(t) \tag{2}$$

The duty ratio has to be generated as a control input to the switch based on areference signal vref (t). The integration of the switched variable is made exactly equal to the integration of the control reference by regulating the duty-ratio of the switch in each cycle, i.e.,

$$\int_0^{T_{ON}} u(t)\,dt = \int_0^{T_s} V_{ref}(t)\,dt \tag{3}$$

If the switching period is constant in each cycle, then the average value of the switched variable is precisely equal to control reference. Thus, the average of the switched variable at the switch output is controlled instantaneously within one cycle of time duration, i.e.,

$$y(t) = \frac{1}{T_s}\int_0^{T_{ON}} x(t)\,dt = \frac{1}{T_s}\int_0^{T_s} V_{ref}(t)\,dt = V_{ref}(t) \tag{4}$$

The nonlinear technique used to control switches based on this concept is known as the “One-Cycle Control technique” (OCC). With thistechnique, the effective output signal of the switch is

$$w(t) = V_{ref}\;u(t) \tag{5}$$

In OCC technique, the non-linear switch leads into a linear path by rejecting the input signal of the switch and linearly passing the control reference W_{ref}.The integrator and the re-setter are the key components of the OCC technique. As the switch is turned on with the fixed frequency clock pulse, the integration gets starts. The integration value is,

$$V_{\text{int}} = k\int_0^{t} x(t)\,dt \tag{6}$$

Where k is a constant the integration value and the control reference $V_{ref}(t)$ are compared instantaneously. Thus, the controller made the switch to turned off when the integration value V_{int} reaches the control reference $V_{ref}(t)$ and the controller automatically resets the integrator value to zero. The duty ratio (d) of the present cycle is calculated by using the following equation:

$$k \int_{0}^{dT_s} u(t)\, dt = V_{ref}(t) \qquad (7)$$

Since the switch period, T = constant and K = l/kTs is also constant. Thus, the average value of the switched variable in each cycle at the switch output y (t) is admitted to be

$$w(t) = \frac{1}{T_s} \int_{0}^{dT_s} u(t)\, dt = \frac{1}{kT_s} V_{ref}(t) \qquad (8)$$

This control strategy can be implemented with a simple integrator with reset. Areset pulse is generated by a clock of required switching frequency. At the start of everycycle the switch is turned on by the reset pulse. The input is integrated and when theintegrated output just exceeds the reference signal vref, the switch is turned off. Theintegrator resets after time Ts and the switch goes on again.

3. MATLAB/SIMULK BASED SIMULATION RESULTS

Simulink connection of wind driven SEIG employed in standalone power supply for a remote places and its control is shown in Figure 2.

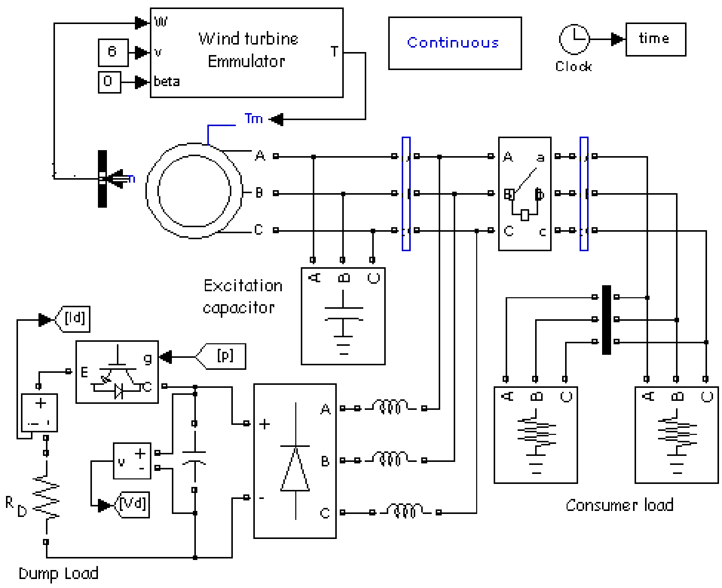

Figure 2. Simulation circuit of proposed system

One cycle control technique is implemented using the built-in libraries of power system toolbox of Matlab/Simulink softwareis shown in Figure3.In order to solve the equation ode23tb is considered for the simulation time of 6 seconds.

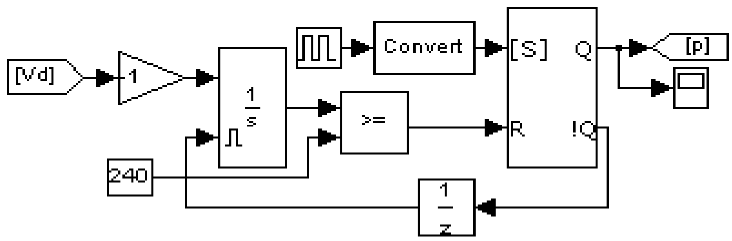

Figure 3. Implementation of one cycle control in Matlab/Simulink

The consumer load of 323W and 200W is connected at 2.5 and 4 seconds respectively. Voltage and frequency is controlled by controlling the active power consumed by the consumer and dump loads.

3.1. Voltage Control

The source voltage and current waveform is shown in Figure 4(a), the load voltage and current waveform is shown in Figure 4(b).

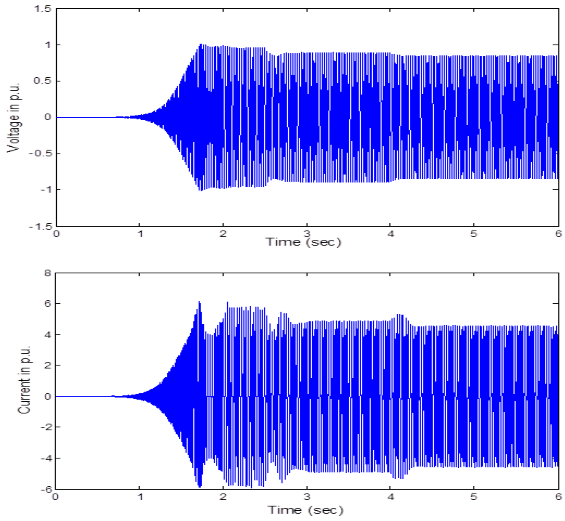

Figure 4(a). Source voltage and current waveforms

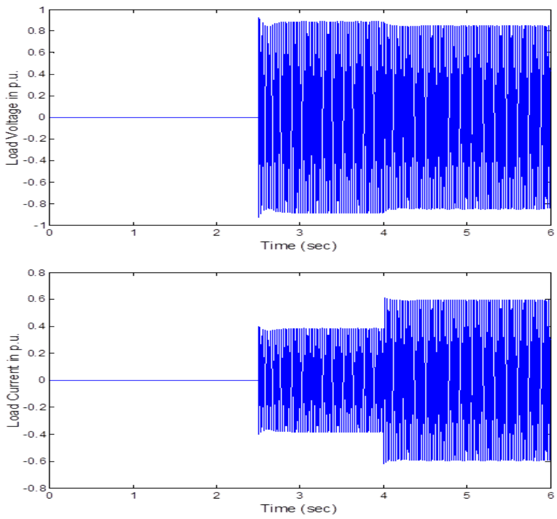

Figure 4(b). Load voltage and current waveforms

Figure 5 illustrate the active power generation of SEIG and feeding to the loads, from 2.5 to 4 and 4 to 6 seconds the consumer load is connected to the SEIG terminals and the variations is shown in Figure 5(b).

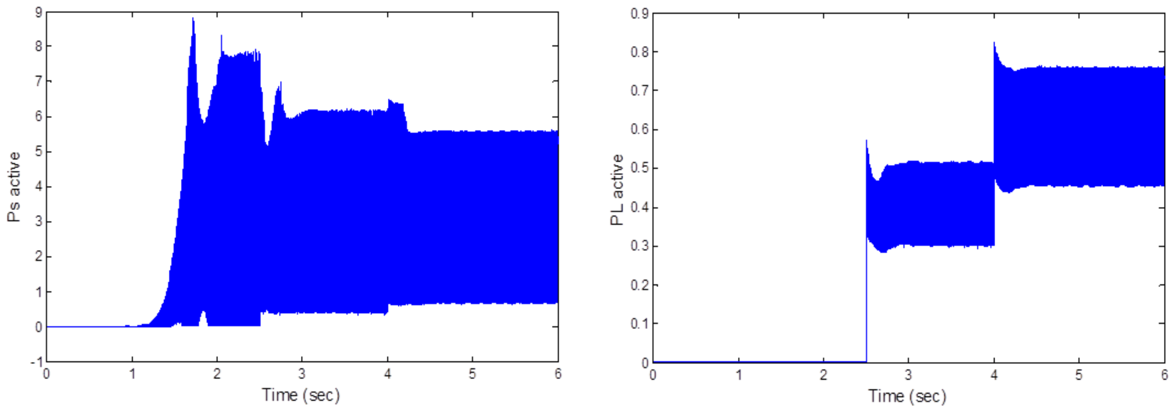

Figure 5. variations of active power in (a) source, and (b) consumer load.

Figure 6 illustrate the variations of dc voltage and power consumed by the dump load.

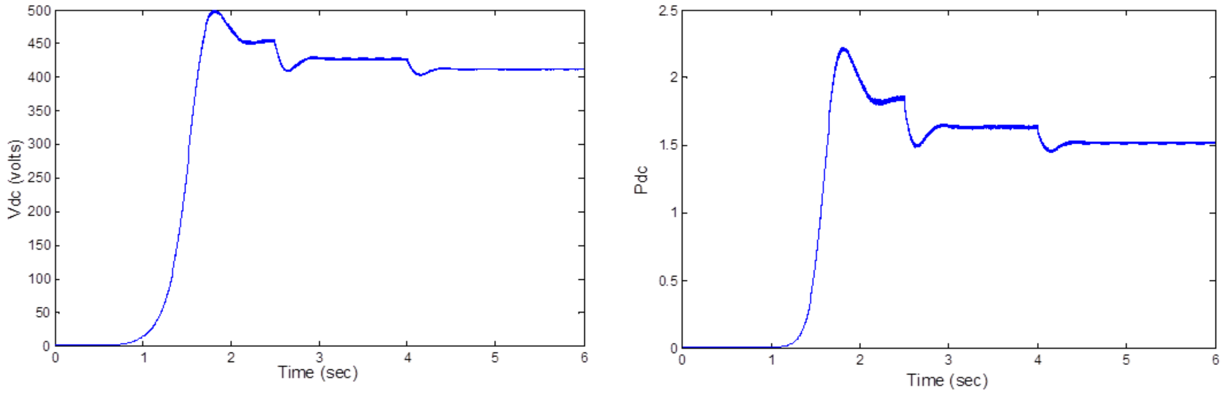

Figure 6.Variations of dc voltage and power across the dump load

3.2. Frequency Control

Figure 7 illustrates the frequency variations; it lies within in the prescribed limit.

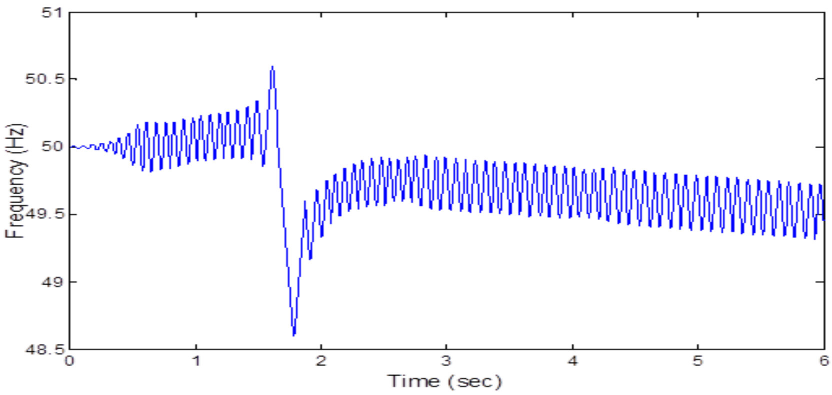

Figure 7. Frequency variations

4. CONCLUSION

A simple voltage and frequency control of SEIG using one cycle control is simulated and results are discussed. The result shows the terminal voltage is almost nearly constant irrespective of wind velocity. It is observed that there is voltage reduction in SEIG terminal before point of common coupling (PCC) slightly because of inductance connected before the dumb load controller needs a reactive power controller.

ACKNOWLEDGMENT

The authors acknowledge the management and the research committee members, for their valuable successions to complete this work successfully.

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