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PWM-based Controller of Output Voltage for Wind-Driven Individual Self-Excited Induction Generator

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Abstract

Background/Objectives: The objective of this research owes to propose a fixed voltage controller for wind energy based individual Self-Excited Induction Generator (SEIG). The ideology is that simple as to exploit the use of a voltage source inverter, employing with the fundamental principle of PWM technique that in corporate an individual battery source for the smooth operation. **Methods/Statistical Analysis**: The incidence of depressed voltage regulation because of the unexpected alteration in the speed and the load is one of the main demerits of the SEIG. In order to overcome this complicated situation, a modification of phase shift in the sinusoidal PWM is introduced, which standardizes the voltage of SEIG, when it is subjected to unexpected alteration in the load. **Findings:** It is likely to attain a fixed value of voltage when the load is altered from empty load to the complete load. The simulation of the presented scheme has been carried out by MATLAB/SIMULINK modeling. The consistency of the proposed model is determined by the outcomes of the prototype testing. **Application/Improvements:** By varying the modulating index of the voltage source inverter, the stabilization of output voltage for SEIG has been achieved. One of its major advantages is that by simply checking the dc link voltage, the characteristics of the current state can be predictable.

Keywords: Alteration in Load, Induction Generator, PWM, Self-Excited, Voltage Controller, Voltage Source Inverter

1. Introduction

Of late, the growth in wind-energy sector has been remarkable and exponential, which is always knitted with a myriad of non-conventional power schemes, as the energy obtained from them being the most important in practical and economical considerations as well. Wind energy uses the flow of air over the turbine to mechanical power producers for producing the electrical power. Wind energy is a substitute for combusting fossil fuels, as it is always abundant, recyclable and broadly dispersed. Further, it yields no greenhouse gasses that are not at all released throughout the process unlike thermal power stations and utilizes less land space as well in contrast to its rivals, in terms of electrical power generation. The gross effects on the surroundings are extremely less challenging than those of conventional energy resources.

The choice of the machine depends on abundant features which are listed as kind of uses, care, rate etc. Presently, AC machines are very widespread contrasted with other machineries. But, the need of excitation power remains as one of the most potential drawbacks out of it, which is usually offered via umpteen techniques, extending from the use of capacitors to the application of voltage source inverter etc. The additional restriction of SEIG in

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the individual system stands as its inherent inability in governing the system frequency and the load voltage in accordance to the velocity of the wind and the variation in the loads respectively. In order to mitigate it, there happens to be lots and lots of approaches being considered. The excitation of the capacitor is appropriate only when the load is fixed at the induction generator terminal and is operated at a fixed speed. Conversely any variations in the burden and speed of the rotor may possibly end in a loss of excitation. Usually, to offset this issue, a sequence of banks of capacitors corresponding to the variation of speed of the wind and that of the loads may either be committed or de-committed at the generator terminals by way of either contactors or through power electronic devices.

A different way of providing excitation includes the possibilities of providing through saturable reactor incorporated across each of the three phases of the induction generator. The current in the stator gets saturated over the progressive use of inductor using stepped air gap that results in meeting the load, despite being large and costlier. It is usually in practice that over these systems of power electronics, with a view of increasing routine of the system, the variety of control strategies likes vector control and sliding mode control are recommendable. However the usage of vector control procedure progresses the routine of the structure, the total arrangement turn into difficult. To mention a few of the issues being faced in individual systems are the consistency and easiness in control assembly and their prolonged presence may impact the objectives.

In this work, the incorporation of power converters makes the excitation schemes possible that supply the required reactive power in energizing the generators and their outcomes have been exploited from the procedures laid down for building up its requisite voltage. Since the vibrant activities of self-excited induction generator are only little known, the control strategy may be bit difficult, which poses a paradigm shift in the objective lines of this work that in turn forces to devise an efficient and a modest control approach without much burdens on such prevailing outlines. The projected controller has been found out to be the best and robust in managing the loads of reactive power, but not in need of mechanical speed detectors, ac voltage or current detectors, thereby decreasing the total price and prototype-complication and all of these factors guarantee for consistency in operation.

Disregard to the alteration in loads, a constant voltage is maintained to be available at the terminals of the generator through varying the frequency of the inverter and its modulation index is instrumental in controlling the magnitude of terminal voltage at the induction generator.

Unlike the variety of systems stated in the existing literatures, the proposed methodology does not involve a dump load. In order to demonstrate the competence of the system, Matlab/Simulink has been exploited to show the results of simulation, besides their viability and feasibility that are also being confirmed through the investigational outcomes by means of a laboratory model.

2. Principle of Operation of the Circuit

The schematic block diagram of the intended modelhas been illustratedin figure 1 as given below;

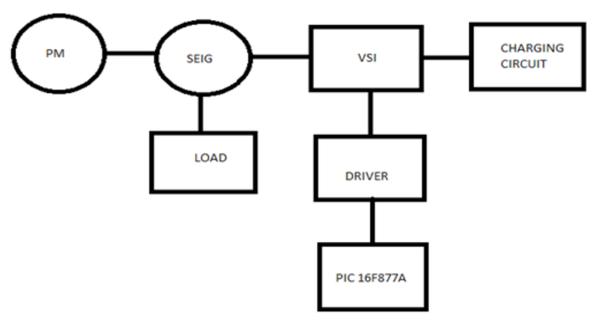

Figure 1. Overall block diagram of proposed system.

To start the circuit, a 12V battery is employed on the input side of the inverter. The quadrature power needed by the self-excited induction generator and the load are delivered by the VSI. Hence, the rating of the VSI is selected based upon the excitation power of induction generator and the necessities of quadrature power to the load.

It has been so ensured that the controller sets the frequency of the stator lesser than that of the rotor, thereby the power formed by the induction generator can be used to charge the capacitor associated crosswise the dc link to a set value at the time of starting up, wherein this case, the reference voltage is maintained at 250 V. The inaccuracy concerning the reference and original voltage of the capacitor is handled by the partial integral controller in the simulation.

If the actual voltage of the capacitor is greater than the set value, then the frequency of the stator is improved by means of the controller. It then leads to decreasing the power and torque delivered by induction generator. Contrarily, when potential difference available across the capacitor is found to be less, the reference value of stator frequency may go low.

It is noteworthy that the sine and cosine waveforms are produced by the harmonic oscillator, whose input is controllable by the PI controller. In order to acquire the voltages at three phase's viz. V_a, V_b and V_c, the modulation index (m_a) has been exploited using their graphs. The pulses that are needed to switch the IGBT based voltage source inverter are produced from the comparison of wave forms of sine wave and triangular carrier signal wave of 1 kHz.

At all type of changes in yield power of induction generator is openly specified with the change in the output voltage of SEIG. If the capacitor voltage falls below the set value, then it indicates that the real power taken by the load is greater than that of the generated power by the induction generator. The voltage source inverter poses disparity in the delivery of power and hence it leads to a drop in the dc link voltage, because of which, the load varies, giving room for the decrease in shaft speed, resulting in the fall of power fed to the SEIG. Furthermore, the rise in voltage of the capacitor shows that the real power essential for the load is decreased because of the withdrawal of load. Under such scenarios, the real power from the induction generator seems to be more than that of it is required for meeting out the loads.

3. Modified Sinusoidal PWM Technique

While considering sinusoidal PWM waveform, the width of the pulse does not vary considerably with the change in the modulation index. The reason is due to the features of the sinusoidal waveform. Moreover a 60 degree phase shift is presented in this method. Hence this sinusoidal PWM technique is modified, so that the carrier signal is applied at the time of the first and last 600 intervals for each half cycle[1-12].The fundamental component is improved and its harmonic characteristics are enhanced. The key benefits of this method include a better change in fundamental component, better harmonic characteristics, less quantity of switching devices and reduced switching losses. Another significant merit of this method is that using this scheme, the voltage control can be attained without using any extra components, besides excluding the lower order harmonics.

4. Simulation Results

The established prototypes of sub divisions of the system are combined and the simulation for final end system has been performed using the MATLAB/SIMULINK platform. The evaluation of the machine and the machine parameters of the equivalent circuits used in this system are given below in the considerations of SEIG. With a view to effectively throw light upon the feasibility of the proposed approach, a PIC16F877A-based prototype model is devised and established, whose fruitful outcomes through the process of simulation have been shown in the Figure 2 that presents the output voltage of the induction generator and Figure 3 shows the obtained output current of the established model.

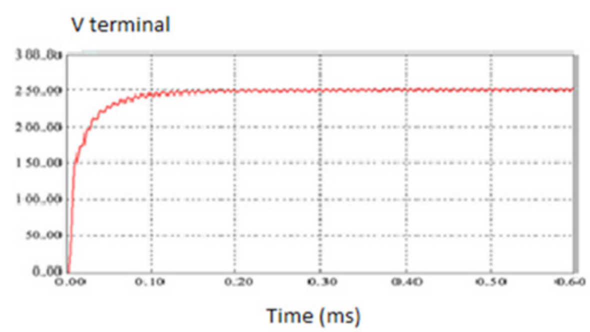

Figure 2. Output terminal voltage waveform.

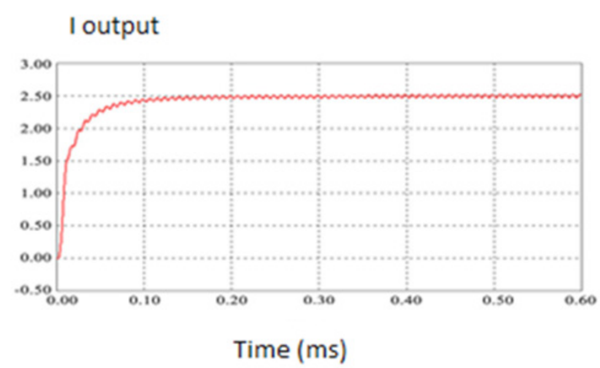

Figure 3. Output current waveform.

It is worthwhile that various parameters of SEIG including the frequency, terminal voltage and the capacitor voltage tend to get decreased, when there happens to be a sudden loading upon the SEIG. However, its output voltage can be brought back to the pre-defined values by varying the frequency of inverter, which is quite noticeable as well while its loads are suddenly withdrawn, on the other hand. During the latter phenomenon, the output voltage and the frequency of the stator end to rise, wherein the terminal voltage and voltage of the capacitor will increase owing to the misalliance in the active power generation of the induction generator. In this methodology, a closed loop controller has been employed that alters the frequency of the inverter, so as to keep the output voltage at the desirable value, even though there occurs changes that are due to small variations in the load in terms of the frequency of the stator and capacitor voltage.

5. Conclusion

From the objectives to the working model to its simulation results, it can be summarily concluded that an embedded based topology has successfully been proposed, implemented and verified for a fixed and continuous controller of voltage towards an individual stand alone wind energy system supported by an SEIG, whose controller has been designed to be robust and capable of upholding a predefined voltage at the terminals of the SEIG despite small variations in the load. The control system so designed has rapid and vibrant reaction, yet consistent, wherein the necessity of the manual speed detector does not arise and hence decreasing the price and the prototype complication. The procedure for the controller is realized on PIC16F877A microcontroller using assembly level language. MATLAB/SIMULINK modeling is carried out to study the feasibility and the reliability of the processes that are ascertained by their trial results accomplished through the prototype model.

6. Practical Considerations of SEIG

Type of phase –Three Phase
Type of Connection Assembly– Delta type
Nominal voltage - 230 volt
Nominal Current - 2.5 ampere
Revolutions per minute - 1470 RPM
R_S - 8.5ohm
R_R- 8.36ohm
L_S- 0.545 Henry
L_R - 0.567Henry
Nominal power - 1.7 kilo Watt
Poles - 4
J - 0.654 ($kg.m^2$)

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