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A Self Governing Wind Potency Transmutation System using Voltage and Frequency Controller

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Abstract- **The control of voltage and frequency of Self governing wind potency transmutation system based on isolated asynchronous generator. The proposed voltage and frequency controller in here of three single phase insulated gate bipolar junction transistor based voltage source converter VSC along with battery energy storage system at its dc link. The complete electro mechanical system and its controller is modeled and simulated in the MATLAB using the simulink.**

Key words: - Self governing wind potency transmutation system, voltage and frequency controller, battery energy storage system

I. INTRODUCTION

In remote areas of India where it is impossible or too expensive to access main power lines, one solution is to obtain electric power from a small stand-alone wind power plant. In such a situation, the turbine is driven by a steady flow of wind. It is preferable to use a self-excited induction generator, due to its low cost and ruggedness. When the induction machine is driven by a prime mover, the residual magnetism in the rotor produces a small voltage in the stator windings. If a bank of capacitors is connected to the stator winding, the small voltage causes a capacitive current to flow. This resulting current provides a positive feedback that causes a further increase in the voltage. This process is called self-excitation which is eventually limited due to the magnetic saturation of the machine [1].The voltage and frequency of such an induction generator in stand-alone operation are very sensitive to load changes. Methods to control the voltage and frequency of a self-excited induction generator have been proposed in [2.3]. These methods employ a controller consisting of a phase controlled bridge and a DC-chopper to achieve the regulation. To overcome these disadvantages this thesis proposes a power controller which includes a Voltage Source Inverter for regulation of the voltage and frequency of the stand-alone self-excited induction generator. The proposed controller uses IGBTs along with fast integrated electronic protection. This approach makes the system more reliable.

II.SYSTEM MODEL OF STANDALONE INDUCTION GENERATOR

Figure 3.1.1 shows the wind turbine, induction generator, and load. The dynamic and steady state models and behavior of these components are discussed in the literature in detail [2, 3]. For all equations, per unit system is used in this thesis. All equations, and variables presented are in per unit unless otherwise specified.

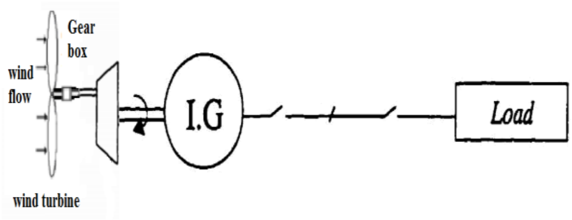

Figure 1: The wind turbine, Induction generator, and load.

It is assumed that the wind turbine delivers a certain constant power to the induction generator according to a given wind turbine and air pressure.

The differential equations are expressed in the synchronous frame where the generator voltage (Vs) is chosen as the reference such that the imaginary component of the generator voltage is zero and this voltage is aligned to the real axis.

1. Reactive Power of induction generator

In order to calculate the reactive power required to excite the induction generator, it is necessary to develop steady-state equations to determine the required reactive power under full load and no load. Reference [2] has already developed a computational method that determines the reactive power required for the excitation of the induction generator at full load. Following the same procedure and considering Figure 3.2.1 where the capacitor (C_{vsi}) represents the equivalent steady state capacitance of the VSI-based controller one can derive the equivalent circuit of Figure 3.2.2 which can be used to calculate the required reactive power at no load.

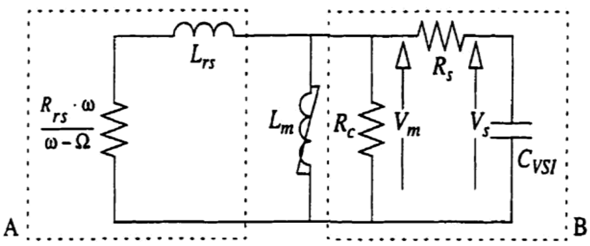

Figure 2. The per-phase steady-state mode1 at no load.

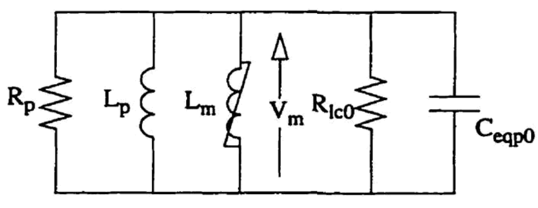

Figure 3.The parallel equivalent circuit at no load

The reactive power is calculated for a desired operating point with known generator voltage (Vs.) and frequency (ω).

III.VOLTAGE SOURCE INVERTER BASED CONTROLLER

The primary objective of the VSI-based controller is to introduce a semiconductor controlled device which is capable of emulating the characteristics of the excitation capacitors and injecting adequate reactive power into the induction generator and the load. The secondary objective is the regulation of the real power. The proposed controller employees a DC side resistor such that the unwanted real power will be consumed in this resistor. As a consequence, the induction generator will always observe a constant real power demand. This VSI-based controller can replace the earlier reported impedance controller and eliminates the need for excitation capacitor. Due to the nature of the VSI-based controller, a wider control range that can contain various control operations of the overall system is achievable. The controller is capable of delivering or receiving real and reactive power. This control should be performed in such a way that the real and reactive power components can be controlled independently. Moreover, the VSI-based controller should be able to respond rapidly to the control commands, and drive the operating point of the system to the desired one. Sinusoidal Pulse Width Modulation (SPWM) is use to control the switching of the VSI controller. The PWM pattern is generated by comparing the modulating waveforms with a carrier signal. Three sinusoidal modulating signals that are 120 degrees apart are compared to a triangular carrier signal in order to generate three-phase sinusoidal output waveforms. In this method the modulation index is defined as the ratio of the peak amplitude of the modulating sine wave (Vs) to the peak amplitude of the triangular carrier wave (V_{tri}) where this ratio is less than or equal to 1 ($m \leq 1$).

IV.CONTROL STRATEGY OF STUDY SYSTEM

The regulation of the voltage and frequency of the stand-alone induction generator is very sensitive to the load and prime mover variations. These disturbances can be categorized into slow and fast types [2].

The slow disturbances represent small or slow changes in the system model, changes in operating parameters, and small variations in the head of water. The fast disturbances stem from rapid changes in the load. If it is assumed that the wind turbine is driven by a constant speed where the change in air flow is slow, then the major disturbance is due to sudden changes of real power and/or power factor of the load. These are the fast disturbances that can be best controlled by immediately compensating the load current changes by adjusting the controller current as proposed in [2]. This compensation scheme is illustrated in Figure 4, where the relation among controller (I_{ct}), generator (I_g), and load (I_l), currents for an arbitrary resistive-inductive load is shown.

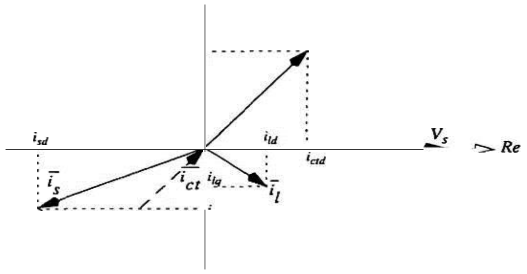

Figure 4. The relation among controller, generator, and load currents for an arbitrary resistive and inductive load.

V. RESULTS

During these tests only a feed-forward controller was employed to regulate the voltage and frequency of the self-excited generator. The steady-state errors present in the results can be eliminated by employing a feedback controller. Many tests were carried out some typical results have been selected to demonstrate the performance of the VSI-based controller. Simulations of proposed system have been stated in the following section. This test represents a large change in the load with unity power factor. During this test the system is configured such that the maximum real power generated is delivered to a load resistance of 50K. This load is suddenly disconnected from the generator system. As a result the real power generated is directed to be consumed in Rd, by the controller such that the frequency remains unchanged. It uses a Discrete PWM generator for generating 6 pulses for IGBT. For a 3-arm bridge, six pulses are generated. Pulses 1, 3 and 5 are respectively for the upper switches of the first second and third arm. Pulses 2, 4 and 6 are for the lower switches. A resistive-inductive load is used for this test such that a more realistic scenario can be examined.

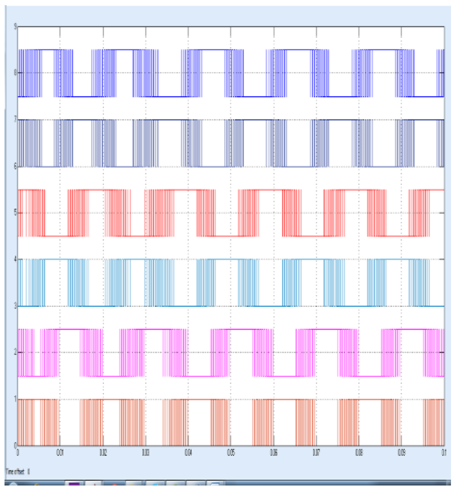

Fig.5. Six input clock pulses

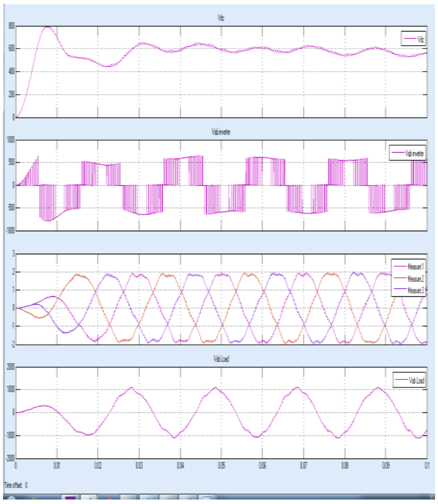

Fig.6. Vdc., Inverter voltage & load voltage

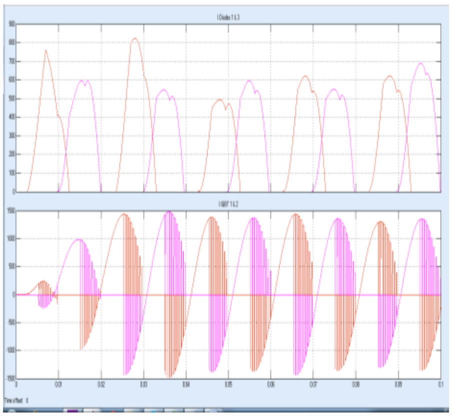

Fig7. Diode & IGBT outputs

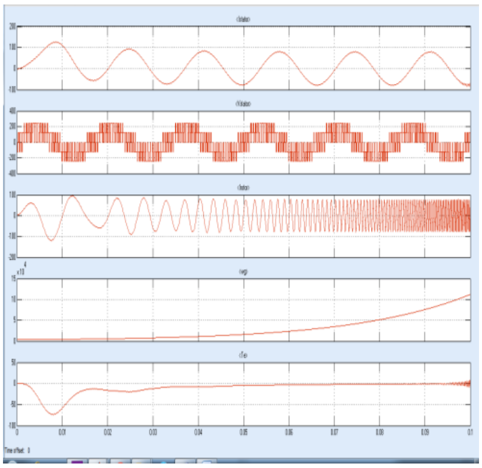

Fig.8.Induction generator outputs with speed & torque

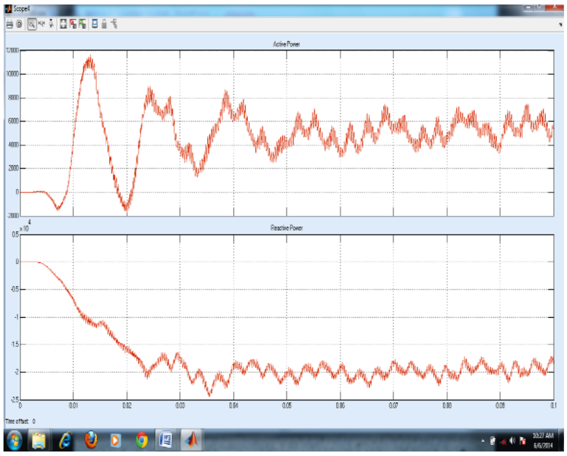

Fig.9. Active & Reactive power of Induction generator

VI. CONCLUSION

1. Introduction of a VSI-based controller for regulation of voltage and frequency of self-excited induction generator.
2. Total elimination of the large AC capacitor bank required for excitation of the induction generator employed by the earlier methods. The VSI controller will provide not only the reactive power required for the excitation of the induction generator at full load, but also will compensate for any inductive-resistive load. Nevertheless, a small filter capacitor is connected to the generator output terminals so as to eliminate the higher frequency harmonies.
3. Development of the control range and the rating of the VSI-based controller which provides rating rules for the design engineer.
4. The controller also deals with the startup process. The VSI-based controller can initiate the excitation process if the DC side capacitor on the VSI has been pre-charged.
5. The experimental results confirm the predicted performance of the VSI-based controller. The experimental results also demonstrate the direct switch-on capability of an induction motor load for the proposed system. To the best of this author's knowledge such a feature has not been reported for the existing methods.

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