Voltage Control of A 3-Ø Self – Excited Induction Generators Using TSC (Thyristor Switched Capacitance)

Abhishek Kumar[*] and Abhishek Chaubey [**]

[*]Systems Engineer (Embedded and Industrial Automation) , Infosys Limited,
Mysore, Karnataka, a.kmr2008@gmail.com

[**]Assistant System Engineer, Tata Consultancy Services Limited,
Chennai, Tamil Nadu, abhishekvit05@gmail.com

ABSTRACT

With burgeoning demand and dwindling fossil fuels resources, it is important for the world to look towards alternative renewable energy re-sources like wind which may provide a solution to the problem of increasing energy crisis. Wind energy is tapped by using wind generators. Self - Excited Asynchronous Generator (SEASG), generally Induction generator has emerged as a possible solution for this purpose. A SEASG doesn't have its own magnetizing circuit so it requires reactive power to set up and sustain magnetization and hence generate power. In grid connected Induction Generators this requirement is met by the grid, which unnecessarily burdens the grid and in some cases the amount of reactive power consumed might even exceed the amount of active power generated. To alleviate these effects, the reactive power required for each Induction generator can be compensated locally by using any VAr source. We made an attempt to develop the voltage regulator using **TRIAC** as a power switch. Firing scheme for the **TRIAC** was developed in such a way that the external capacitor was injected to the existing power system when the current across the capacitor was minimum to ensure the minimum surge losses.

Keywords: SEASG, TRIAC, Thyristor Switched Capacitance, Firing circuit, Wind energy.

1 INTRODUCTION

Among the various available **VAR Schemes** our work is based on the **TSC (**Thyristor Switched Capacitor**)** scheme using **TRIAC** since it minimizes the number of power components required. We made an attempt to develop the voltage regulator using **TRIAC** as a power switch. The problem associated with the capacitor connection to the existing power system is that, under what conditions the capacitor can be connected? The literature review concludes that the capacitor should either be pre charged or the capacitor current should be minimum when it is connected to the network. We consider the latter case, in such a way that the firing scheme for the **TRIAC** was developed and tested. This project describes the voltage regulation of a 3-Ø SEASG with constant power operation in an isolated distributed power system. It consists of an asynchronous generator, load, **TRIAC** based voltage regulator, excitation capacitors connected at the terminals of the SEASG to build up the rated terminal voltage and the external capacitor $(\mathbf{C_{EX}})$ to maintain a constant voltage with the changing user loads.

1.1 Objective

The objectives of the project are threefold:

- To find the minimum capacitance required for a self-excited induction generator.
- To find the external capacitance required to regulate the terminal voltage for varying loads.
- Development of firing circuit for TSC in voltage regulation of SEIG.

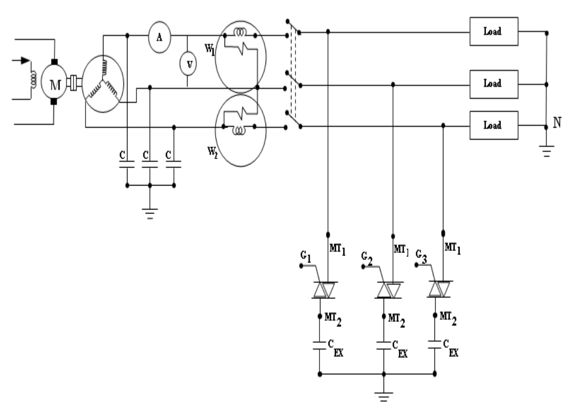

Figure 1: Schematic arrangement of proposed stand alone power generation scheme using triac as the control device

1.2 Synchronous impedence test to determine C_{min} for the induction generator

To determine the magnetizing reactance at different air gap voltages Vg, the machine is driven at synchronous speed by the DC motor; and the input voltages and currents are measured. The speed has to be maintained constant at the synchronous speed of the machine. From the graph obtained between the terminal voltage and current a load line is drawn such that it intersects the curve at the rated terminal voltage. The slope of the graph is equal to $\mathbf{X_m}$ (Magnetizing reactance in ohms) which is equated to $\mathbf{X_c}$ (Capacitive reactance of the System in ohms) to obtain the minimum capacitance value. This is the minimum value of capacitance required to run the induction motor as a generator. Since with the application of load the load voltage decreases therefore in practical applications for running an induction motor as an induction generator the capacitance value is taken slightly higher than $\mathbf{C_{min}}$.

2 EXPERIMENTAL WORK

The major part of our project work comprises of the design of triggering circuit for TSC scheme. Our design consists of mainly synchronous linear ramp generation, comparator part, monostable pulse generation and finally amplifier part to steer the pulse got and get it to desired level so that we can fire the TRIAC easily.

2.1 List of Major Components Used in Our Circuit.

1. Transistor
2. IC – 741
3. IC – 74121
4. Pulse Transformer
5. TRIAC
6. Capacitors

3 EXPLANATION OF TRIGGERING CIRCUIT

The synchronous linear ramp is generated at third transistor and is fed to the second pin of Ic-741. This ramp input is compared with the positive reference voltage fed at the third pin of 741. Thus the Op-Amp here is used as a comparator and its output is a rectangular wave which is obtained at pin 6. The reference voltage is set in such a way that the rectangular wave generated is of 50% duty cycle. Now the rectangular wave is fixed to a level of 5v by the help of zener diode and this is fed to Ic-74121. Ic74121 is a monostable generator. It is designed in such a way that the monostable output is obtained at negative edge of the rectangular wave. The pulse obtained is not capable of triggering the TRIAC so it is amplified by SL100 transistors and the final amplified pulse is obtained at the secondary of the pulse transformer. The negative portion of this amplified pulse is clipped using a diode. The positive triggering pulse thus obtained is given to the gate of the TRIAC which turns it ON and the capacitor is injected at the desired moment.The amplified triggering pulse is adjusted with the peak value of the input signal to ensure that capacitor is injected at the peak value of input voltage, so that the current is minimum. At this point the switching surges in capacitor will also be minimum

$$V_c = \frac{1}{C}\int i\,dt$$

Thus when V_c = max. , I_c = min.

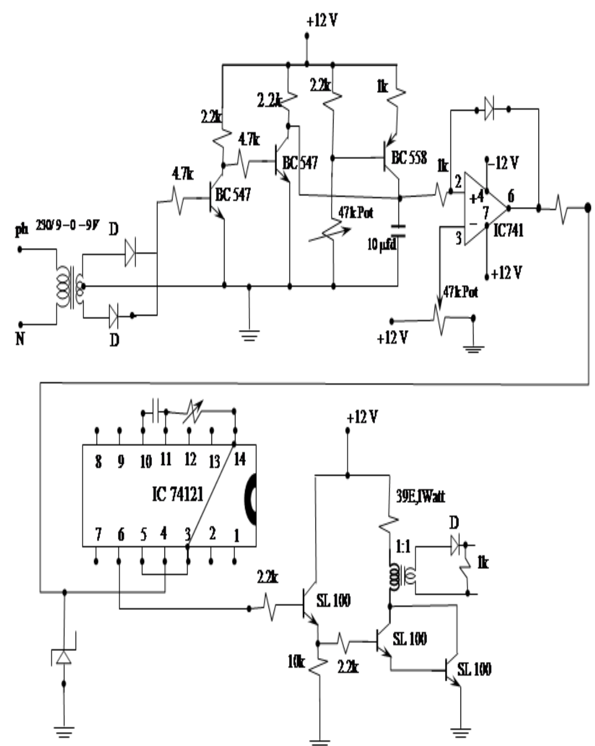

Figure 2: Schematic diagram of the triggering circuit.

3.1 Firing Circuit

For the above firing circuit we needed a **power circuit** which could provide a constant DC output of +12v, -12v and +5v.The +5v obtained from the power circuit through 7805 is fed to the pin 3, 5 and 14 of IC74121 in the form of high input. These inputs make it capable of generating monostable pulse at the negative edge of the rectangular wave fed at pin 3.The +12v and -12v are obtained through 7812 and 7912 ICs respectively and they are fed to IC741

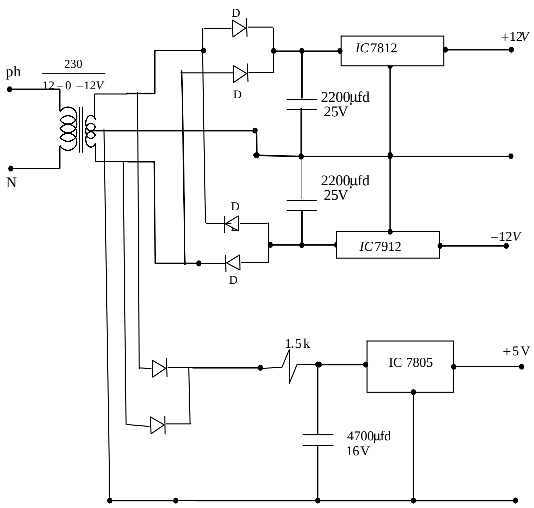

Figure 3: Schematic diagram of the power circuit.

4 EXPERIMENTAL RESULTS AND DISCUSSIONS

The results of the various experiments conducted are discussed below along with their respective graphs.

4.1 The output waveforms of the triggering Circuit are as follows

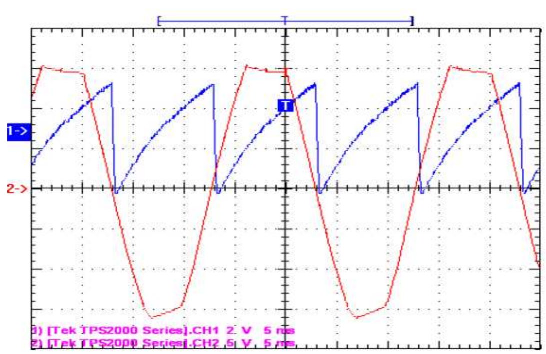

Figure 4: Input waveform vs synchronous linear ramp wave

The above output shows the input waveform and the generation of synchronous linear ramp wave. The input is not proper sine wave due to the harmonics present in the input and the type transformer used. Rating of the centre tapped transformer used is 230v / 9v-0-9v for triggering circuit and 230v / 12v-0-12v for power circuit. Amplitude of input signal is 30v (it is measured at the output of 12v-0-12v) and the amplitude of ramp signal is 5v.The ramp generated is linear because as the frequency of input signal is changed the frequency of ramp also changes simultaneously.

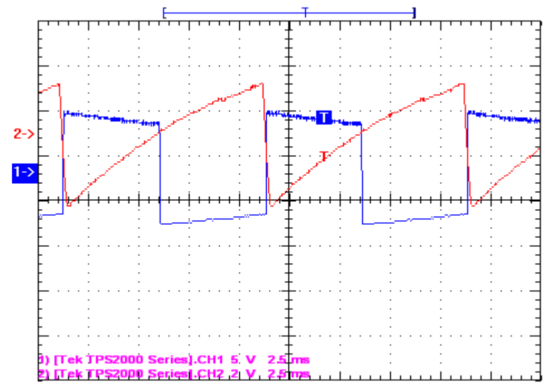

Figure 5: Synchronous linear ramp wave vs rectangular wave

The above output shows the rectangular wave generated at the output of IC-741. The amplitude of ramp signal is 5v and the amplitude of rectangular wave signal is 10v.The duty cycle of rectangular wave is set as 50% by adjusting the reference signal supplied to IC741. With this adjustment we will get the negative edge of the rectangular pulse at the peak value of the input voltage. IC74121 is designed in such a way so as to give the monostable output at the negative edge of the rectangular wave.

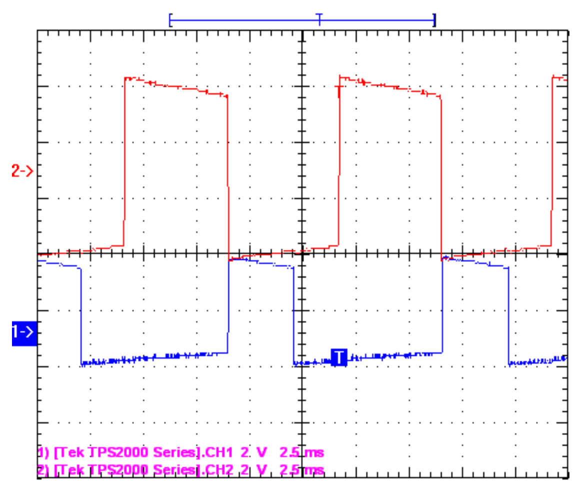

Figure 6: Rectangular wave vs monostable pulse

The above graph shows the rectangular wave output at zener diode and the negative edge generation of monostable pulse at the pin6 of IC74121. The amplitude of rectangular wave is 5v and the amplitude of monostable signal is 4v.The amplitude of this monostable signal is not sufficient to trigger the triac therefore this signal is amplified using SL100 transistors.

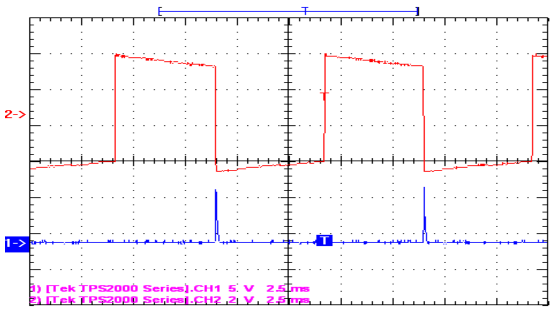

Figure 7: Rectangular wave vs amplified monostable pulse

This graph shows the required amplified pulse generated at the negative edge of rectangular wave at the secondary of the pulse transformer. The pulse is adjusted with the peak value of the input signal so that the voltage across the capacitor is maximum and as a result of which the capacitor current is minimum. At this instant the capacitor can be injected with minimum surge losses.The amplitude of the required amplified pulse is 7v which is sufficient to trigger the TRIAC.

4.2 Load Curve Obtained For Various Values of Capacitors Injection

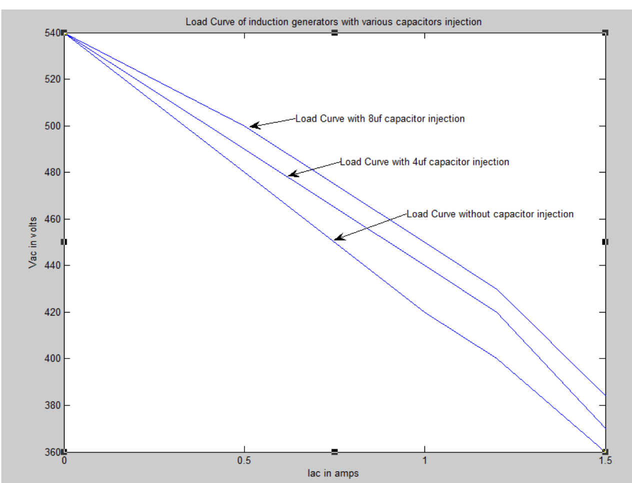

Figure 8: V_{ac} in volts vs I_{ac} in amps

The above graph shows that there is a rapid decrease in the terminal voltage of an Induction generator with the application of load. It further conveys that by increasing the value of external capacitor, the rate of decrease in the terminal voltage of an Induction generator can be controlled.

5 CONCLUSION

From our experimentation and observation we conclude that when an induction generator first starts to turn it must be magnetized by momentarily running it as a motor so that a voltage builds up. Since an induction generator lacks a separate field circuit, it cannot produce any reactive power. In fact, it consumes reactive power and there is a rapid decrease in the terminal voltage with the application of load. Therefore, an external source of reactive power must be connected to it all times to maintain its stator magnetic field and also to control its terminal voltage. We applied a capacitor bank to supply the reactive power to the generator and concluded that the applied capacitance value for the excitation of the induction generator must be greater than the calculated value of minimum capacitance because as the load increases the voltage decreases proportionally and thus the minimum theoretical value of the capacitor may not be sufficient to excite the induction generator. We found that when a monostable pulse generated at the negative edge of the rectangular wave using IC-74121 was amplified, it was able to trigger the TRIAC and when this pulse was aligned with the peak value of the input signal the capacitor was successfully injected using TSC scheme, which regulated the terminal voltage of the induction generator.

REFERENCES

[1] ALI M. ELTAMALY "New Formula to Determine the Minimum Capacitance Required for Self-Excited Induction Generator", IEEE transactions, pp 106-110, 2002 .

[2] Ching-Huei Lee Li Wang, "A NOVEL ANALYSIS OF PARALLEL OPERATED SELF-EXCITED INDUCTION GENEPMTORS", IEEE Transactions on Energy Conversion, Vol. 13, No. 2, pp 117-123, June 1998.

[3] Shashank Wekhande Vivek Agarwal "A VARIABLE SPEED CONSTANT VOLTAGE CONTROLLER FOR MINIMUM CONTROL REQUIREMENTS SELF-EXCITED INDUCTION GENERATOR", IEEE International Conference on Power Electronics and Drive Systems, PEDS'99, pp 98-103 July 1999, Hong Kong.

[4] T. Tudorache, L. Melcescu, and S.V. Paturca "Finite Element Analysis of Self-Excited Induction Generator for Isolated Small Power Wind Turbines".

[5] MICHAEL B. BRENNEN AND ALBERTO ABBONDANTI "STATIC EXCITERS FOR INDUCTION GENENRATORS", IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. IA-13, NO. 5, PP 422-427 SEPTEMBER/OCTOBER 1977.