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Design and Fabrication of IGBT based Converter for Excitation System of Synchronous Generator

Prof. P. N. Kapil, Prof. S. N. Jani

Electrical Engineering, Institute of Technology, Nirma University, Ahmedabad, India.

Abstract

Synchronous generator requires field winding for production of EMF in the armature winding. So generally DC field winding is used in case of excitation system of synchronous generator. Recently thyristor based converters were used for excitation system of synchronous generator but the system has some disadvantages. So to overcome that IGBT based converter is used which can fulfil that requirement.

I. INTRODUCTION

Main task is to design and fabricate IGBT based converter for automatic excitation system of synchronous generator, which can keep the terminal voltage constant with fluctuation in load. In this project IGBT based controlled converter is designed and simulated on MATLAB software and actual analysis of the same is carried out on hardware and both results are compared.

II. EXCITATION SYSTEM

A Principle of Synchronous Generator:

The alternator is working on the principle of Fleming's Right Hand Rule. As the rule says, "When a motional conductor is placed in a magnetic field (Direction of motion is perpendicular to the magnetic field),then an induced EMF is produced, which circulates a current in the close loop of the motional conductor." The system use to generate that alternating or direct field is known as excitation field and that winding to produce that field is known as excitation winding.

B Basic functions of excitation system:

- Basic function of excitation system is to provide field current to Synchronous Generator's field winding.
- Excitation system performs control and protective functions essential to the satisfactory performance of power system.
- In control function, It mainly control the voltage generated by synchronous generator and reactive power flow in the power system.

C Block diagram of Excitation system of Synchronous Generator:

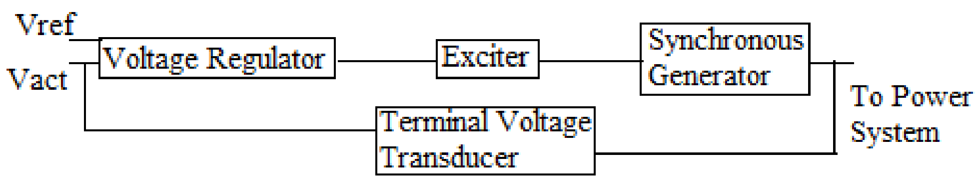

Fig 1: Block diagram of excitation system

In the above figure main block diagram of any basic excitation system is drawn. Here in case of generator excitation system first the terminal voltage of the generator is compared with the reference value of the generator where it supposes to operate. This is done by voltage transducer which will convert the terminal voltage in to appropriate foam and then it is to be compared with the reference value this comparison is done by the Op-Amp circuit from which error signal is to be generated and that main signal is send to the Voltage regulator block of the system. Here appropriate switching is done on the converter and according to that signal is given to the exciter of the generator and again by that field winding voltage will be at the terminal of generator can be obtained.

Here, the voltage regulator part can be separately explain with considering different aspect of like keeping terminal voltage constant or reactive power flow or power supply stability.

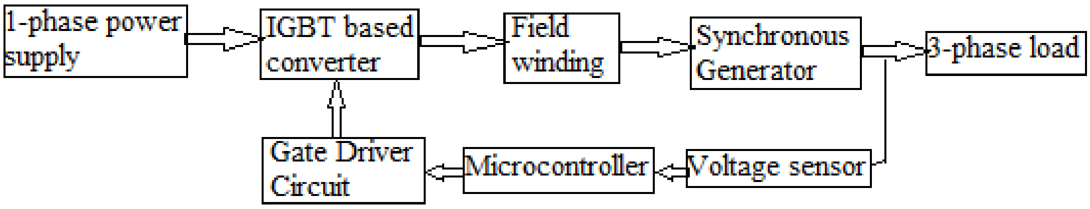

Fig 2. Block Diagram of project

III. PWM GENERATION PATTERN FOR CONVERTER:

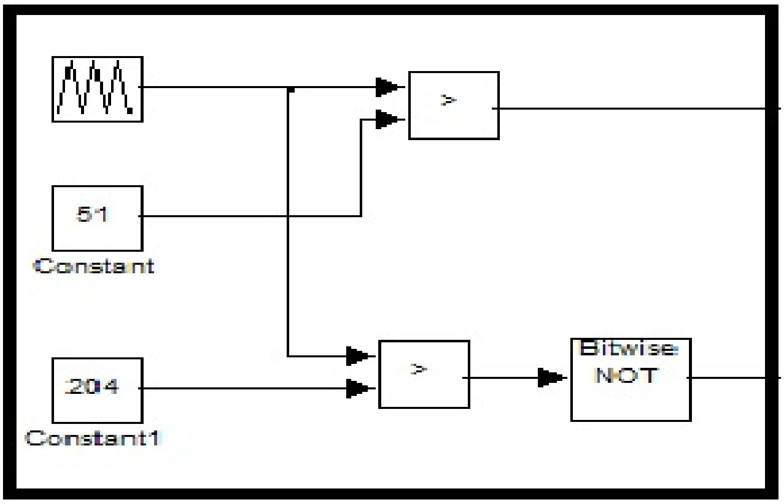

Fig 3: PWM generator circuit for converter

As shown in fig: 3 Triangular wave of 1000Hz frequency is generated using internal timer of Atmega328 microcontroller. This wave is compared with two dc value of resistor. As shown by one of them is taken as inverting by not gate IC7404, so that both are 180 degree phase shifted. Thus bipolar generated signals are given to appropriate IGBT.

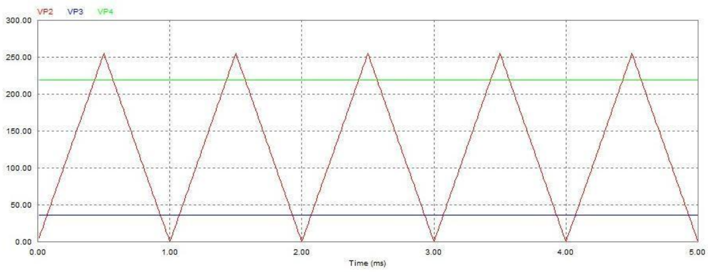

Fig 4: Comparison of triangle and DC level

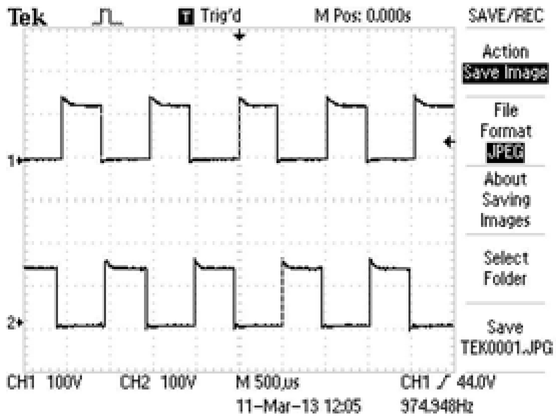

Fig 5: Actual results of triangle and DC compression, X axis-voltage and Y axis-time

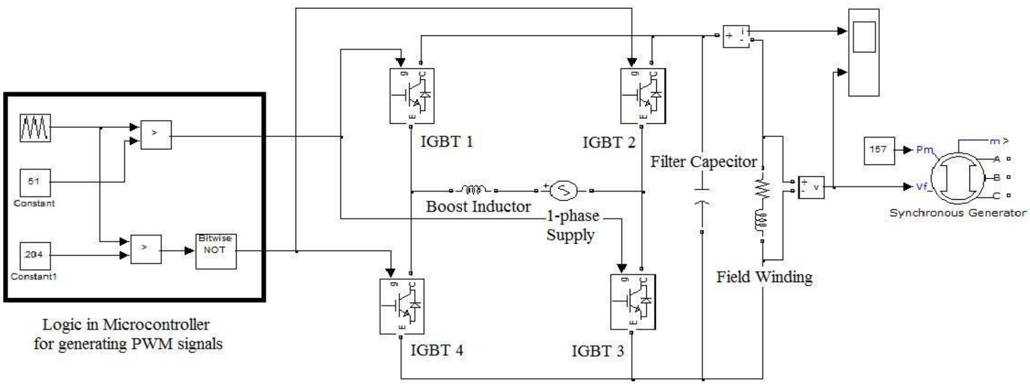

Fig 6: Simulation of Bridge

IV. FABRICATION AND OPERATION OF FULLY CONTROLLED RECTIFIER

A Fabrication of H-Bridge-

As show in fig.6, AC source is given as input to H-bridge through Inductor. Field winding of alternator will act as a load. Here for operation of circuit, output voltage should be higher than peak value of AC input voltage then only IGBT can be controlled. To get output voltage higher, we have used inductor of 30 mh. At output side we use 2200 µf,500V capacitor. Output Of rectifier is controlled by varying pulse width of gate given as input to switches. Terminal voltage across alternator is measured by voltage Sensor. This Voltage Sensor will give attenuated d.c voltage output in the range of 0 to 5 volt. Voltage Sensor's output is given as input to Atmega 328(arduino) controller. Gate Pulse width of IGBT is controlled by controller in such way that voltage across synchronous generator will remain constant. If voltage measured by sensor is less than the reference voltage, Rectifier will generate higher d.c voltage across field winding of generator, hence (current through field winding will increase which increase flux inside the generator) voltage across generator will increase and try to remain constant.

Same if voltage across it is higher than the reference than vice-versa changes will be there in excitation system.

At starting higher magnitude spikes is generated which may damage switches. So to protect switches from it, snubber circuit is used. As Shown in fig. 0.1 mf capacitors and 10k resistors are used to reduce dv/dt across switches.

B Operation of circuit:

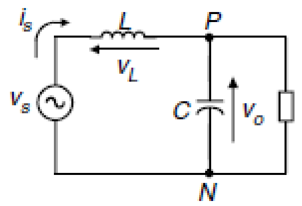

Fig.7 Equivalent circuit with I1 and I3 ON

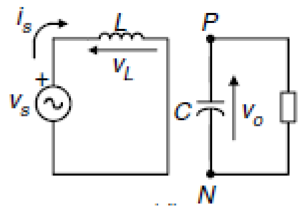

Fig.8 Equivalent circuit with I2 and I4 ON

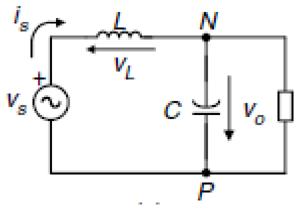

Fig.9 Equivalent circuit with I1 and I2 ON or I3 and I4 ON

As shown in fig.6, Using bipolar PWM switching strategy. This converter may have two conduction states. (fig.7) IGBT 1 and 3 are in ON state and 2 and 4 are in the OFF state and vice versa in (fig.8) state.

But in this topology, the output voltage Vo must be higher than the peak value of the ac source voltage to ensure a proper control of the input current.

Fig.7 shows the equivalent circuit with IGBT I1 and I3 on. In this case, the inductor voltage is given by

$$v_L = L\frac{di_s}{dt} = v_s(t) - V_0 < 0$$

In this case (as voltage across inductor negative) current flowing through inductor is reduced.

Fig.8 shows the equivalent circuit with IGBT I2 and I4 on. Here, the inductor voltage has the following expression

$$v_L = L\frac{di_s}{dt} = v_s(t) + V_0 > 0$$

whichmeans an increase in the instantaneous value of the input current.

Finally, Fig.9 shows the equivalent circuit with IGBT I1 and I2 or I3 and I4 are in the on-state. In this case, the input voltage source is short-circuited through inductor L, which yields

$$v_L = L\frac{di_s}{dt} = v_s(t) + V_0 > 0$$

which implies that the current value will depend on thesign of input voltage.

Table I: Practical results as taken on 3.2 KW, 415 V, 4.4A, 1500 rpm cylindrical Alternator

Load (A)	Terminal Voltage (V)	DC Field Voltage (V)	Field Current (A)
No load	220	74	0.44
0.24	218	76	0.47
0.75	218	78	0.46
1.51	216	82	0.49
2.55	218	94	0.58
3.85	217	108	0.65

C Output Results:

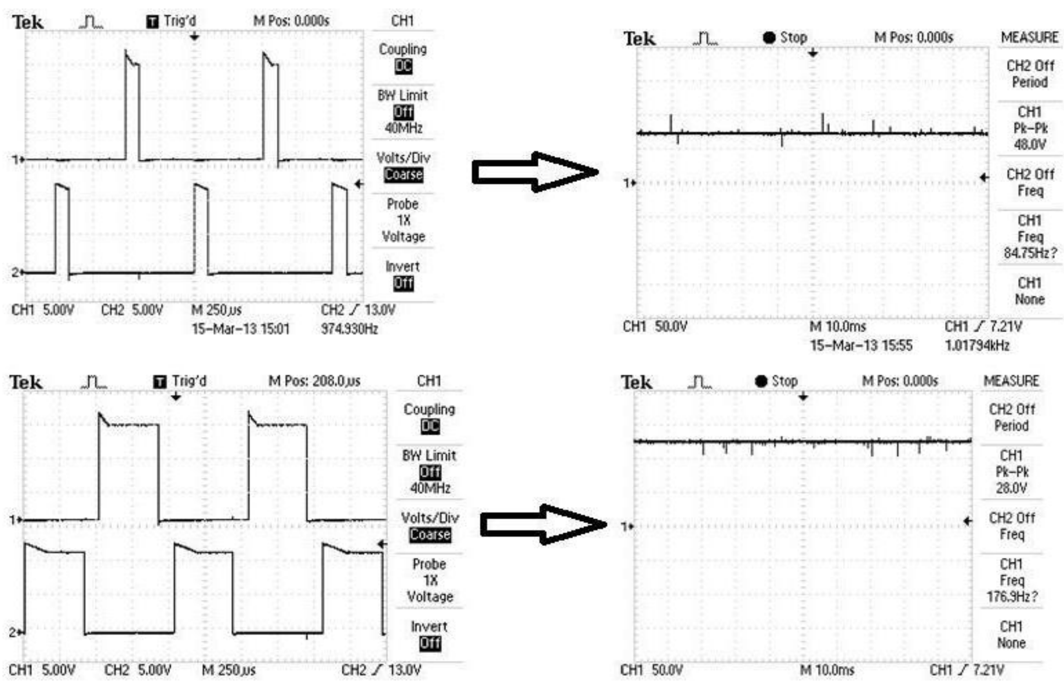

Fig.10 Waveform of Controlled D.C voltage, X axis-voltage and Y axis-time

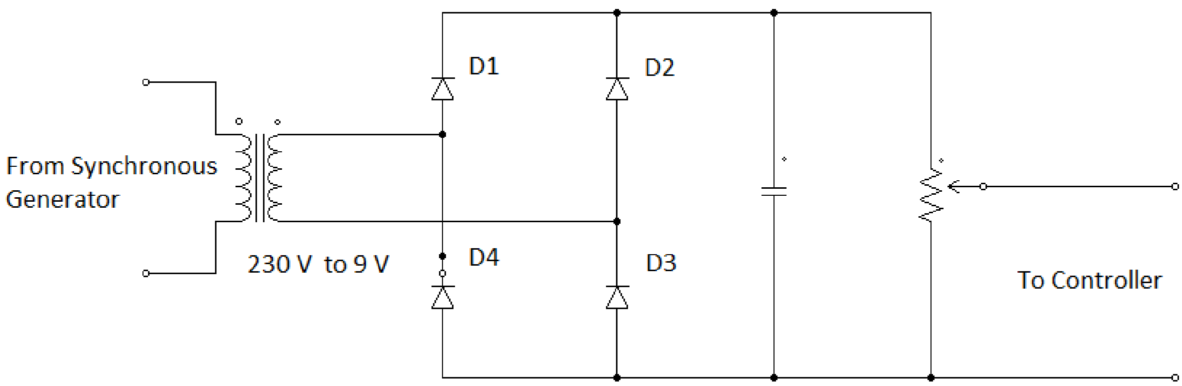

Fig 11: Simulation of voltage sensor

V. VOLTAGE SENSING UNIT

Main function of voltage sensing unit is to measure phase voltage of alternator. To measure this voltage, instrumentation transformer of 230 V / 9 V is connected between phase and neutral of generator. This output of generator is given to diode bridge rectifier and the bridge rectifier output is filtered by a 1000 F capacitor, which is given to 1 KΩ pot. This pot will give attenuated d.c voltage in the range of 0 to 5 V d.c of voltage across generator. Attenuated D.C voltage is given to microcontroller.

A.PI controller

A PI Controller (proportional-integral controller) is a special case of the PID controller in which the derivative(D) of the error is not used.

The controller output is given by

$$K_p\Delta + K_I \int \Delta dt$$

VI. CONCLUSION

The aim throughout this project was to develop a motor drive which incorporated the facility of IGBT based Automatic Voltage Regulator in it. For achieving same IGBT based bridge rectifier was developed which worked at varying duty cycle, as per the condition required, thus making it adaptive.

Along the entire period of the project, the motor drive was developed in parts, viz the programming logic in microcontroller ATMEGA328p, the gate driver circuit using TLP250, the power circuit involving IGBT 15N120ANTD and voltage sensor. After the fabrication of the sub circuit and their interlinking, the system was brought under testing for generator of 3.2 kW, 415V.

The results obtained for the test have been as desired and following points have been derived:

We have compared the output results of simulation and actual, we are getting approximately same results.

Conventional diode and Thyristor based rectifier can be replace by IGBT based controlled rectifier as now they are available for higher voltage and current rating.

Percentage THD can be further reduce, power factor can be further increased by proper switching pattern of IGBT.

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