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V/f CONTROL OF NON-ISOLATED HIGH GAIN CONVERTER FED THREE PHASE INDUCTION MOTOR

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ABSTRACT

In this paper, it deals with v by f control of a three-phase induction motor which is fed from a high gain dc to dc converter. The high gain converter introduced has the advantage of utilizing two different duty ratios. With the incorporation of two different duty ratios, each having smaller values it is possible to obtain high gain. By utilizing a single duty ratio with higher values as in most of the conventional converters reliability of operation is affected. A low dc input is sufficient to drive a large load since the converter provides high gain. Closed-loop control of the converter by PI tuning is given to obtain a constant output voltage. The output of the high gain converter is fed to a three-phase SPWM inverter and with v by f controlled switching of the inverter, speed control of a three-phase induction motor is achieved**.**

Keywords: *High Gain Converter, SPWM Inverter, Open-loop v/f Control, Three Phase Induction Motor, Closed Loop Control*.

1. INTRODUCTION

Three-phase induction motors find many applications in industrial as well as in commercial areas. Small and rugged construction, less cost and less maintenance, no additional need of a starting motor, and not necessary to be synchronized are the key features of a three-phase induction motor which allows it to be used in commercial, industrial, residential applications. The proposed system uses a high gain dc to dc converter[1] to feed the three-phase induction motor[8]. An inverter stage is required in between the high gain converter and induction motor. The overall efficiency and performance of the system depend on the power conversion stages. So the selection of a proper dc to dc converter is important. The practical voltage gain of a conventional boost converter is decreased due to using a single duty ratio with extreme value and the resulting switching stress and diode reverse recovery problem restrict the practical voltage gain. Conventional boost converters are not suitable for high voltage gain in the power sector due to high switching loss.

Different types of boost converter topologies have been discussed in [2-7].In isolated converter topologies, the major drawbacks are reduced efficiency, higher converter weight, volume, and added circuit complexity to limit the effect of leakage inductance and core saturation makes it unsuitable for many applications. To solve the problems associated with isolated converter non-isolated converter topologies were introduced. In these converters, no need for isolation transformers, and size, weight, cost reduced with the absence of a transformer. The main non-isolated boost converter topologies include quadratic boost[5], voltage lift[3], switched capacitor[6], coupled inductor[4,5].

In switched inductor technique due to less energy in the size and cost of the magnetic elements of the inductors are reduced, reduced current stress in switching elements. But the circuit is complex and voltage stress on the switches is high. A voltage lift circuit [3]addition in this converter improves the circuit characteristics but the addition of this circuit limits output voltage and output power of the converter using coupled inductors[7]. It is possible to reduce input current ripple and makes the system stable. But the system operates with low efficiency and the gain ratio is only 3-4 times. If the turns ratio of coupled inductor is increased to obtain the desired voltage gain, then the addition of an input filter is required to reduce the current ripple.[1]

The problems associated with these converter topologies can be solved to a great extent by the non-isolated converter topology proposed. In this converter, it is utilizing two different duty ratios with smaller values to obtain high gain with reduced switching stress. The converter output is fed into a three-phase SPWM inverter and the inverter switches are operated by v by f control technique. The inverter's controlled output is fed to a three-phase induction motor to control its speed.v by f control is done in an open-loop where the flux is kept constant.

2. BLOCK DIAGRAM

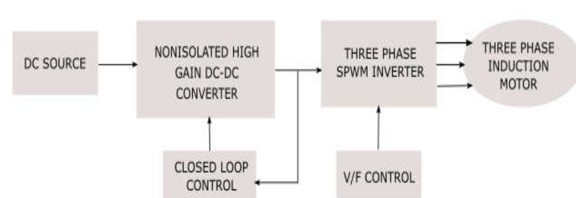

Figure 1 . Block diagram of the proposed system.

The block diagram of the v by f control of three-phase induction motor is as shown in figure 1. It consists of a dc source as the power source. A non-isolated high gain dc dc

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converter is for the conversion of low dc input to a high dc input at the inverter input terminal. Closed-loop control is provided to the high gain converter with high gain converter output taken as reference. The next section is the inverter section. Here an SPWM inverter is used. The pulses to the inverter switches are provided by comparing a triangular wave with a reference sinusoidal reference wave.

The inverter is provided with v by f control and open-loop v by f control is used here. v by f control technique is used to keep the voltage to frequency ratio a constant or to keep the flux constant. So here the v by f control is used to control the speed of the three-phase induction motor by taking the three-phase induction motor speed as a reference.

3. CIRCUIT DIAGRAM DESCRIPTION

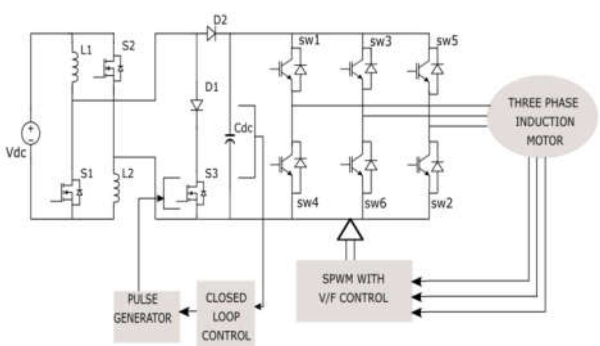

Figure 2. Circuit diagram of high gain converter fed induction motor.

The circuit diagram consists of a dc source, high gain converter, SPWM inverter, a three-phase induction motor. The inverter switches are controlled with v by f control and the high gain converter switches are controlled with closed-loop current control. The switches 1 and 2 of the high gain converter are fed from the same pulse generator with the same duty ratio. The third switch is triggered by the gate pule provided by the closed-loop control section. For the high gain converter, there are three modes of operation.

- **Mode1.**
- **Mode2.**
- **Mode3.**

A. Mode1

In mode 1 switches S_1 and S_2 are on and switch S_3 is off. D_1 and D_2 are reverse biased. The energy of the source is stored in both inductors. Here the inductors are in parallel with the source. The capacitor supplies the load. So the voltage across both inductors are the same.

B. Mode2

In mode 2 switches S_1 and S_2 are off and switch S_3 is kept on. The energy of the source flows through L_1, D_1 and L_2. The capacitor supplies the load. The inductors are in series connection. The source voltage is thus the sum of inductor voltages.D_1 forward biased and D_2 reverse biased.

C. Mode3

In mode3 all the switches are turned off. Here the load is supplied by source and the two inductors. Diode $D_1$is reverse biased and D_2 is in forward biased condition. The capacitor charges in this mode. The inductors are in series as in the previous mode. So the current in both inductors is the same and the sum of inductor voltage is equal to the difference between input and output voltages.

The gain equation for the high gain converter [1] is

$$\frac{V_o}{V_i} = \frac{1+D_1}{1-D_1-D_2} \qquad (1)$$

The selection of inductor and capacitor values for the converter is based on the following equations,

$$L_{1citical} = L_{2citical} = \frac{V_i D_1}{\Delta i_L f_s} \qquad (2)$$

$$C = \frac{P_o}{V_o \Delta V_c f_s} \qquad (3)$$

The voltage stress on the switches of the converter[1] is given as,

$$V_{DS1} = V_{DS2} = \frac{V_o + V_i}{2} \qquad (4)$$

$$V_{DS3} = V_o \qquad (5)$$

The output of this controlled high gain converter is fed to a three-phase SPWM inverter. The pulses to the inverter switches are also controlled by v by f control technique. For the functioning of v by f control reference speed of three-phase induction motor is taken.The gain equation of the converter is given in equation.1. From equation 2 and 3 inductor and capacitor values can be obtained.

4. OPEN-LOOP V/F CONTROL

The v by f control block and the controlled switching for the inverter is given by the fig.3

In this open-loop v by f control block speed of induction motor is taken as a reference. The speed reference is converted into a magnitude angle and time period by proper addition of gain block. This is given to function blocks where it is converted to sinusoidal functions with proper delay.

These functions are compared to the repeating sequence. So three signals are obtained and these are given to a NOT block to obtain signals for the other three switches. Thus the switching pulses for SPWM inverter are obtained. Due to this controlled switching speed control of a three-phase induction motor is made possible.

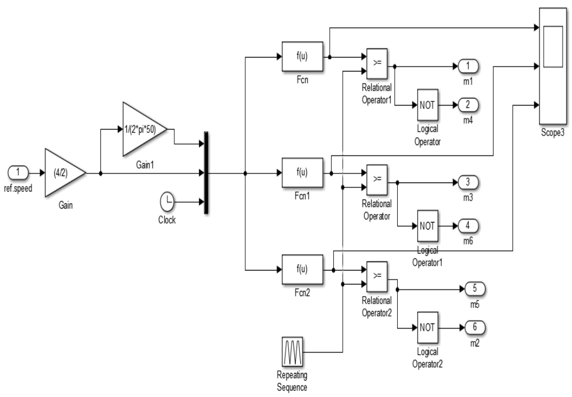

Figure 3. v by f control block

5. SIMULATION RESULTS

The entire system can be viewed in two sections. Section 1 consists of closed-loop control of high gain dc to dc converter and the next section deals with the v by f control of three-phase induction motor fed from the high gain converter.

1. High Gain Converter

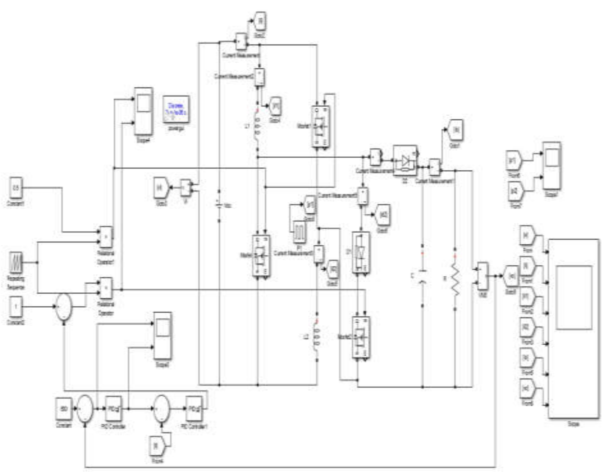

Figure 4. simulink model for high gain converter

In the simulation of the high gain converter, the pulses for the first two switches are given by a pulse generator with the same duty ratio and switch S3 is controlled by a pulse generated from the closed-loop feedback control block. The closed-loop control block consists of a sum block that compares the actual and desired output voltage. The output of the sum block is fed to a PID controller which by manual tuning will compensate for the error voltage. The output is a current signal and it is compared with the inductor current is given to another PID controller. The output of this PID controller is the pulse of the third switch. The pulse for the first two switches is given as constant and the third pulse from the PID controller is check for its phase relation by using two relational operators as shown in fig.4. The closed-loop controlled high gain converter is also shown in fig.4.

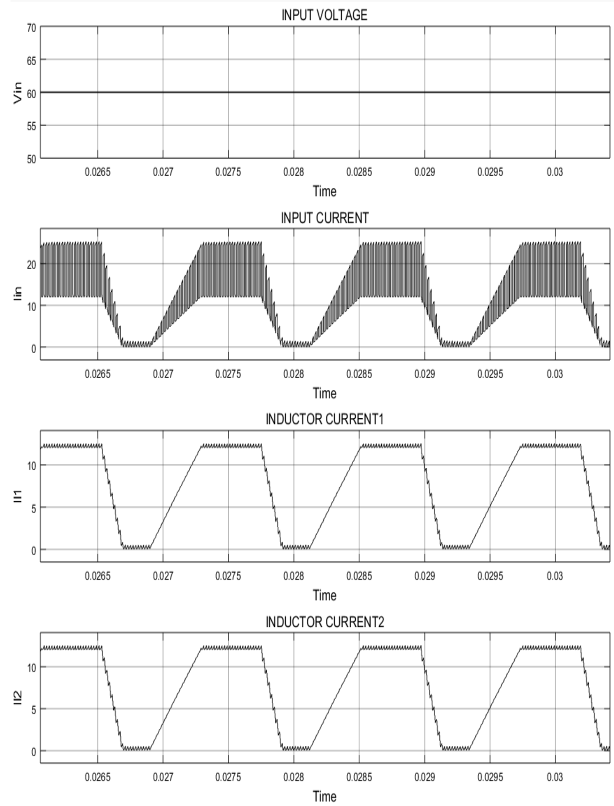

Figure 5. simulink result for high gain converter.

Fig.5. shows input voltage,input current,inductor voltage for two inductors L1 and L2 respectively.Fig.6. shows the output voltage and output current waveforms of the converter.For the simulation the parameters are chosen as 60V input voltage, 600V, output voltage, and D_1=50% , D_2=35%, f=50KHz .

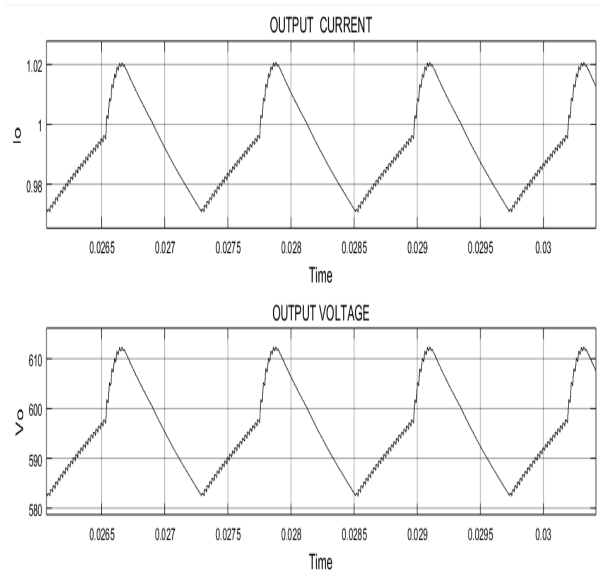

Figure 6. output voltage and output current of high gain converter in simulink

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2. V by F Control Of Three-Phase Induction Motor

V by F control of three-phase induction motor is shown in fig.7.In this circuit, the subsystem can be understood from fig.3 in the section 4. The reference speed is taken as a constant value since it is open-loop v by f control. Speed is given in rps. At the motor output, it is converted into rpm by providing a gain block. Here the simulation results are shown for two reference speed input in rps.Fig.8. and Fig.9. shows the speed in rpm and torque in N.m. for 100 rps and 150 rps respectively. These reference speed is converted into three delayed sinusoidal pulses and after giving to a NOT block in the simulink remaining three signals are obtained. These six pulses are used to drive the SPWM inverter. Hence with the incorporation of the v by f control block inverter switches can be triggered to control the speed of the induction motor.

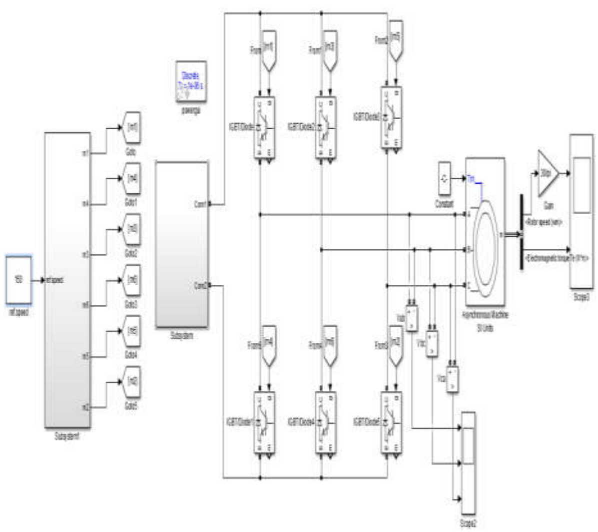

Figure 7. simulink model for high gain converter fed three-phase induction motor

In the v by f control, a reference speed in rad/s is converted into required v by f switching pulses for the inverter as explained in section IV. The induction machine is 5.4hp, 400V, 50HZ, 1430rpm rated. Due to the v/f controlled switching of the SPWM inverter, the speed of the induction motor is obtained as constant. The input for the inverter is fed from the high gain converter which is shown as a subsystem. The high gain converter is rated to feed the required input for the SPWM inverter. The reference speed is converted into required pulses by multiplying with required gain values. The simulink model for the high gain converter fed three-phase induction motor is shown in figure.7 and the obtained output waveform for the induction motor fed from the high gain converter is shown in fig8. Fig8.shows the output for 100rps and fig.9. shows output for 150 rps reference. In the waveform, the rated speed and electromagnetic torque are given in the figure.

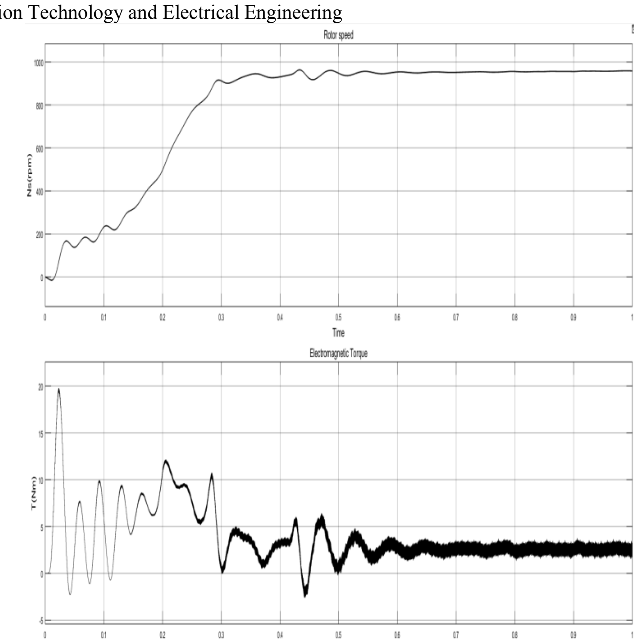

Figure 8.simulink result for high gain converter fed three-phase induction motor for 100rps.

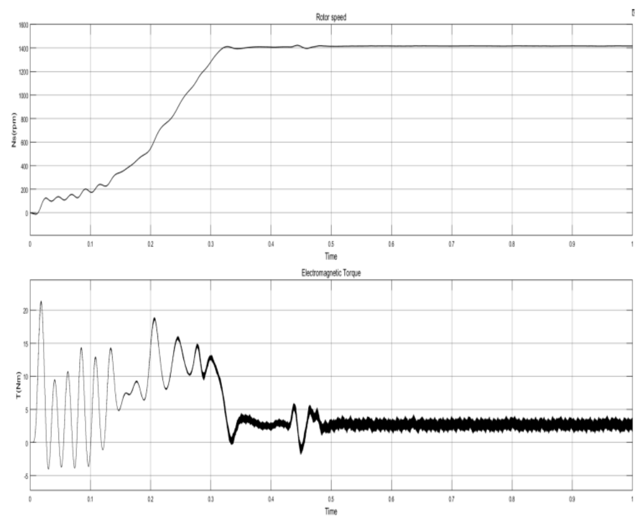

Figure 9.simulink result for high gain converter fed three-phase induction motor for 100rps.

6. CONCLUSION

In this paper, a non-isolated high gain dc to dc converter is proposed. It can be used for driving a three-phase induction motor at a required constant speed. Here the converter switches are controlled by closed-loop current control and v by f control is used by the inverter switches for speed controlling of induction motor. The high gain converter operates with two different duty ratio to eliminate the effects of using a single duty ratio with high value. So high voltage gain is thus possible and the voltage stress on the switches is significantly reduced. Since it is a non-isolated type converter transformer core saturation problem and other transformer related problems are solved. It uses an SPWM inverter with

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switching provided by v by f control technique. The system simulation is performed in Matlab simulink and the expected results are obtained. The main advantage of the system by using a low dc source at the input and a high-speed induction motor can be controlled by proper gain conversion ability of the high gain converter.

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