

# Simulation of Volt/Hertz (V/F) Control For Converter Fed Induction Motor Drive

<sup>1</sup>Aditya Nandan, <sup>2</sup>Shubham Chowdhary, <sup>3</sup>Amit Kr. Singh

<sup>1,2,3</sup>Department of Electrical and Electronics Engineering, Sikkim Manipal Institute of Technology, Sikkim

**Abstract:** The electric drives system used in industrial applications are increasingly required to meet the higher performance and reliability requirement. Today about 90% of all industrial motor applications use 3 phase induction motor because they are simple in design, easy to maintain, and are less costly than other designs. The speed control of an induction motor is a necessity because it ensures smooth operation and provides torque control.

This paper provides the Matlab simulation of speed control of a 3 phase induction motor by Volts/ Hertz (V/f) method. Here constant V/f ratio is maintained in order to get torque constant over the full operating range. This method will most probably provide the precise output after the application of load to the induction motor. MATLAB Simulink software is being used for making simulations and the results will be obtained by fabricating the experimental setup.

**Key Words:** constant V/f, rectifier, Cuk Converter, Inverter, Induction Motor

## INTRODUCTION:

There are number of advancements took place in scalar v/f control technique which is one of the method of speed control of squirrel cage induction motor (IM). Many papers suggests the improvement in the system can be done by boosting the lagging voltage[1], stator resistor compensation, slip frequency compensation, oscillation suppression compensation can also be done for this purpose[2].But limitations were observed as there were constraints on which only it gives required result and also, the motor performance deteriorates at low frequencies [3]. Again, it is difficult to determine the boost voltage [1]. The system is relatively complicated and many control parameters should be designed sophisticatedly to keep system stable. The slip frequency compensation is complicated [2]. In industry, many applications involves the use of D.C. drives where wide range and smooth speed control is required. But presence of commutator leads to continuous maintenance which makes it unsuitable for high speed applications. For these reasons preference is then given to adjustable speed IM drives because IM is cost efficient, robust in construction and more economical to operate and maintain. But the IM is essentially a constant speed, as its stable operation is restricted within a narrow range of speed. Also, another major disadvantage of IM is its low operating power factor [4].

The chief methods of speed control are: -

1. Variable-Frequency Operation

2. Constant Volts/Hertz Operation
3. Variation of Number of Poles
4. Variation of Motor Resistance
5. Variation of Motor Reactance

This paper deals with Matlab simulation of Volts/Hertz control for converter fed IM drive. Since, the V/F speed control of IM requires constant V/F ratio, hardware implementation of the same is a complex process. Frequency and voltage needs to vary simultaneously and thus by maintaining a constant V/F ratio, the maximum torque of the motor becomes constant for all values below the base speed of IM. This paper also consists of MATLAB simulations of the various components required to achieve the V/F speed control of an IM.

## STUDY OF CONSTANT VOLTZ/HERTZ METHOD:

Among all the methods, the easiest and most efficient method is constant v/f which is also called as scalar v/f control. The V/f control method is, in principle a control method for maintaining the air-gap flux constant by controlling voltage V of stator and stator frequency f so to keep ratio V/f constant. 3 phase IM having the synchronous speed  $N_s$  is given by

$$N_s = \frac{120 \times f}{p} \quad (1)$$

Where,

$N_s$  = the synchronous speed (RPM)

p = the number of poles on the stator

f = the supply frequency (Hertz)

When the supply is given to the three phase squirrel cage the motor, the alternating voltage is induced which is responsible for the production of magnetic field in rotor. To match the speed, with respect to the stator, the rotor starts moving in the exact same direction as that of the stator flux and tries to catch up the speed with the rotating flux. But the rotor never succeeds in "catching" to the stator field. So, the rotor runs slower than the stator field speed. This speed is called the Base Speed ( $N_b$ ). The difference of  $N_s$  and  $N_b$  is called the slip. The slip varies directly in the proportion to load. An increase in load will cause the rotor to reduce its speed or increase slip. A reduction in applied load will cause the rotor to speed up or decrease slip. [5]

$$\%Slip = \frac{N_s - N_b}{N_s} \times 100\% \quad (2)$$

Where,

$N_s$  = the synchronous speed (RPM)

$N_b$  = the base speed (RPM)

The motor torque developed is directly proportional to the stator magnetic field. But, the stator voltage is directly proportional to the product of angular velocity and stator flux. This makes the stator flux proportional to the ratio of voltage applied and supply frequency. By varying the frequency, the motor speed can be varied. Therefore, varying the voltage and frequency by the same ratio, flux and thus, the torque can be kept constant throughout the speed range[6][7].

This can be relate as follows:

$$\begin{aligned} \text{Stator Voltage}(V) & \propto [\text{Stator Flux}(K) \\ & \times \text{Angular Frequency}(T)] \end{aligned}$$

$$V \propto K \times 2Bf \quad (3)$$

$$K \propto \frac{V}{f}$$

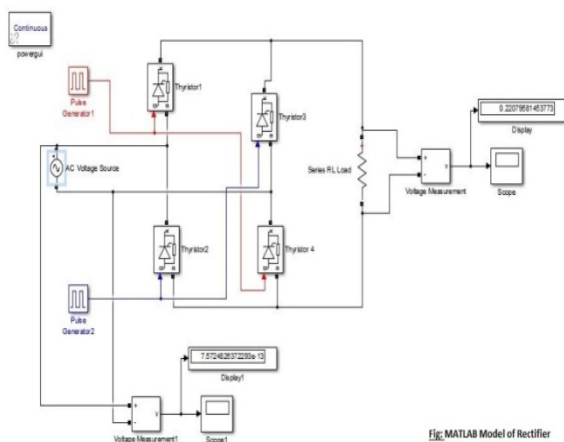
Where, K is constant.

## METHODOLOGY:

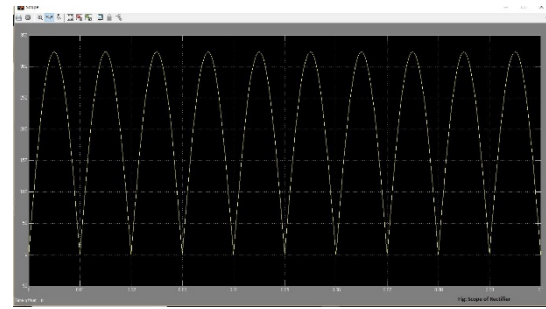
### 1. Design of Rectifier:

A rectifier is an electrical device composed of one or more switches that converts alternating current (AC) to direct current (DC).

The initial power supplied to our experimental setup will be alternating in nature. This will be fed to the rectifier which comprises of thyristors (SCR) as switches. With the help of this device readily available AC current can be used for the experiment.



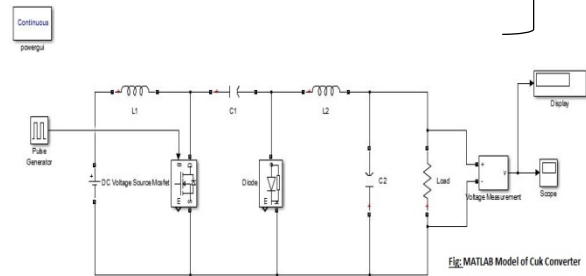
The simulation result of the above depicted MATLAB model is given below:



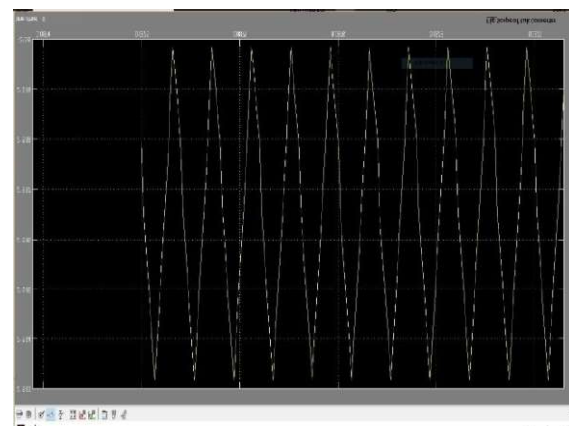
### 2. Design of Cuk Converter:

The Cuk converter is a type of DC/DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is essentially a boost converter followed by a buck converter with a capacitor to couple the energy.

The Cuk Converter gives us control over the buck as well as boost conversion part by simply changing the duty cycle. The rectified input with DC nature will be now fed into the converter and the voltage will be incremented or decremented with help of duty cycle.



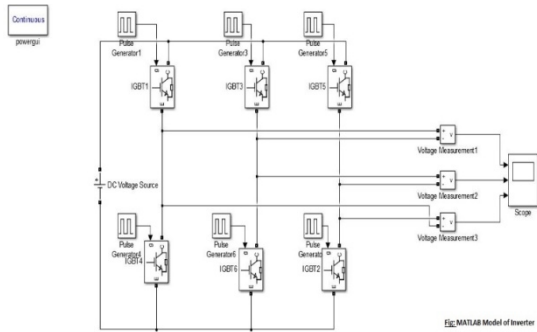
The simulation result of the above depicted MATLAB model is given below:



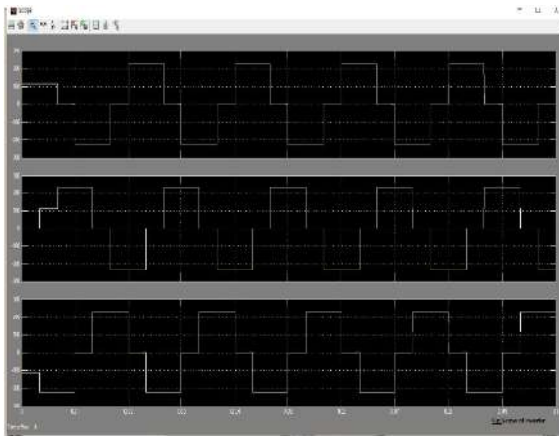
### 3. Design of Inverter:

An inverter is an electrical device which converts DC voltage, almost always batteries, into standard household AC voltage so that it is able to be used by common appliances. In short an inverter converts direct current into alternating current.

The inverter will be fed by the increased or decreased dc voltage provided to it by the Cuk Converter. The inverter will convert the DC input into an AC output which will be used to run the IM.



The simulation result of the above depicted MATLAB model is given below:



#### 4. Combinations

The above devices will be combined to get a voltage/frequency control for our experiment. The combination of rectifier and cuk converter will be made and tuned to get the desired result. Then this combination will be further connected to inverter and tuned again if necessary. When completed the final simulation will be made and IM will be added, further tuning will be done if required. This will provide us with the specific values of the various hardware components which can be used for fabrication of the setup.

#### Conclusion:

This paper presents a review on speed control topologies of an IM using V/f control. In order to use an alternating supply, a rectifier is first simulated in Matlab/Simulink platform. Here, voltage and frequency are varied simultaneously, keeping the ratio constant. For variation in voltage and frequency, cuk converter and inverter

have been simulated respectively, in Matlab/Simulink platform. Further, the simulation results of proposed method are shown. Future endeavors include the combinations of these simulations.

#### REFERENCES:

- [1] Chimezie O. Adiuku, Abdul Rahiman Beig, Saikrishna Kanukollu, "Sensor-less Closed Loop V/f Control of Medium Voltage High Power IM with Synchronized Space-Vector PWM", Proceedings of the 8th IEEEGCC Conference and Exhibition GEEEC, pp. 1-6, 14 February, 2015
- [2] Bin Chen Wenxi Yao Zhengyu Lu, Kevin Lee, "A Novel Stator-Flux Oriented V/f Control Method in Sensorless IM Drives for Accuracy Improvement and Oscillation Suppression", International Conference on Energy Conversion Congress and Exposition (ECCE), pp. 5092 - 5099, 14-18 Sept. 2014.
- [3] Mineo Tsuji, Xiaodan Zhao, He Zhang, Shinichi Hamasaki, "A New Simplified V/f Control of IM for Precise Speed Operation", International Conference on Electrical Machines and Systems (ICEMS), pp. 1-6, 2023 Aug. 2011.
- [4] B. K. Bose, Ed, Adjustable Speed AC Drive Systems, New York, IEEE Press, 1981
- [5] Puja Talukder, Prashant Kumar Soori and Benetta Arango, "Speed Control Of Induction Motor Drive Using Universal-Controller", IEEE International power engineering and optimization conference (PEOCO2012), Melaka, Malaysia, pp. 509 - 514, 6-7 June 2012
- [6] T. Kotaoka, Y. Sato and A. Bendiabdellah "A Novel volts/Hertz control method for an IM to improve the torque-characteristics in the low speed range", 1993, Tokyo Institute of Technology, Japan USTO Algeria, pp. 485-488.
- [7] P. Pillay, senior member, IEEE, and V. Levin, "Mathematical Models for Induction Machine", 1995, New Orleans, LA 70148, pp. 606-616. [6] B. K. Bose, Ed, Adjustable Speed AC Drive Systems, New York, IEEE Press, 1981.

