ADJUSTABLE SPEED CONTROL OF INDUCTIONMOTOR USING VARIABLE FREQUENCY DRIVES

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ABSTRACT

OUR VARYING INDUSTRIAL NEEDS DEMAND MORE PRECISE CONTROL OF THE OUTPUTS OF OUR BASIC ELECTRICAL PRIME MOVERS I.E. THE MOTORS. BASICALLY DC MOTORS ARE EASY TO CONTROL COMPARED TO THEIR AC COUNTER PARTS, BUT THEY HAVE THEIR OWN LIMITATIONS WITH INCREASE IN CAPACITY. CONVERSELY AC MOTORS IN PARTICULAR SQUIRREL CAGE INDUCTION MOTORS ARE VERY ECONOMICAL BUT THEIR SPEED CONTROL IS COMPARATIVELY DIFFICULT BECAUSE IT REQUIRES ALTERATION OF SUPPLY FREQUENCIES. DUE TO TECHNOLOGICAL ADVANCEMENTS SOME DRIVES WHICH CAN CONTROL AC MOTORS ARE AVAILABLE WHICH ARE ECONOMICAL, EASY TO USE AND WHICH CAN PROVIDE WIDE RANGE OF SPEED CONTROL BOTH BELOW AND ABOVE BASE SPEEDS. THESE DRIVES FUNDAMENTALLY ALTER THE VOLTAGE AND FREQUENCY BEING FED TO MOTOR ACCORDING TO THE REQUIREMENTS USING A TECHNIQUE CALLED PULSE WIDTH MODULATION. THESE ARE INCREASINGLY BECOMING POPULAR DUE THEIR REASONABLE COST AND OTHER USER FRIENDLY FEATURES. SINCE THEY USE EMBEDDED SYSTEMS THEY CAN BE INTERFACED TO THE COMPUTERS AND CAN BE PROGRAMMED FOR AUTOMATIC CONTROL REDUCING MANUAL INTERVENTION. VARIABLE VOLTAGE VARIABLE FREQUENCY DRIVE (VVVFD) IS A SYSTEM FOR CONTROLLING THE ROTATIONAL SPEED OF AN ALTERNATING CURRENT (AC) ELECTRIC MOTOR BY CONTROLLING THE FREQUENCY OF THE ELECTRICAL

POWER SUPPLIED TO THE MOTOR. A VARIABLE FREQUENCY DRIVE IS A SPECIFIC TYPE OF ADJUSTABLE-SPEED DRIVE. VARIABLE-FREQUENCY DRIVES ARE ALSO KNOWN AS ADJUSTABLE-FREQUENCY DRIVES (AFD), VARIABLE-SPEED DRIVES (VSD), AC DRIVES OR INVERTER DRIVES.

***Keywords* –** Variable frequency, inverter, frequency control circuit, induction motor, variable speed drive.

I. INTRODUCTION

Induction motors are widely used in many commercial, industrial and utility applications. This is because the motor have low manufacturing cost, wide speed range, high efficiency and robustness. But they require much more complex methods of control, more expensive and higher rated power converters than DC and permanent magnet machines. Previously, the variable speed drives had various limitations such as poor efficiencies, larger space, low speed and etc. the power electronics transformed the variable speed drive into a smaller size, high efficiency and high reliability. The development of speed control system using frequency control has been designed by combinations of PWM control circuit, driver circuit and H-bridge inverter which makes the system simple, robust and compact open loop PWM controller circuit to control single phase induction motor and single phase induction motor can be driven to variable speed and frequency. But it is desirable to replace the single phase induction motor drives by three phase induction motor drives in farming and low power industrial applications. Induction motors have performed the main part of many speed control systems and found usage in several industrial applications. The advances in microprocessor and power electronics gives permission to implement modern techniques for induction machines such as field oriented control. Slip frequency control. Then a modern speed Ac machine system is equipped with adjustable frequency drive for speed control of electric machine. The speed of machine is controlled by converting fixed voltage and frequency to adjustable values on machine side. The three phase inverter circuit changes the DC input voltage to three phase variable frequency variable voltage output. The three phase Ac is rectified into DC and then filtered to minimize the ripple current. This controlled dc is converted into controlled pulses by means of voltage to frequency converter. These controlled pulses are fed to Inverter Bridge for producing variable voltage variable frequency output. This output is fed to induction motor for controlling its speed this paper gives idea about to implement variable speed drive for maintaining the constant speed of three phase induction motor system requires constant speed.

II. What is a Variable Frequency Drive (VFD)?

A VFD is a type of motor controller that drives that drives an electric motor by varying the frequency & voltage supplied to the electric motor. Other names for a VFD are variable speed drive, adjustable speed drive, AC drive, Microdrive,& inverter. Frequency (or hertz) is directly related to the motor's speed (RPMs).In other words, the faster the frequency, the faster the RPMs go. If an application does not require an electric motor to run at full speed, the VFD can be used to ramp down the frequency & voltage to meet the requirements of the electric motor's load. As the application's motor speed requirements change, the VFD can simply turn up or down the motor speed to meet the speed requirement. Commonly used in a myriad of applications, a VFD can be found operating ventilation systems, pumps, conveyors & machine toll drives. A variable frequency drive, also known as a VFD or AFD (adjustable frequency drive) .

III. METHODOLOGY

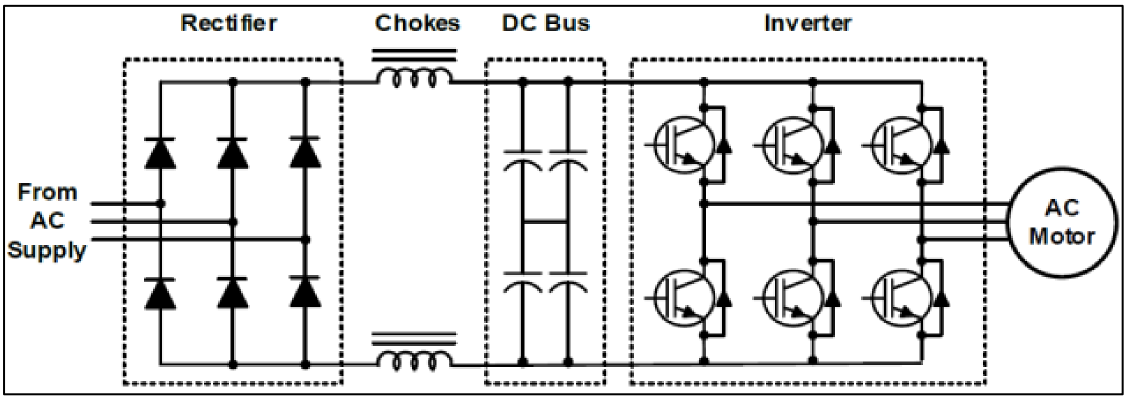


Fig 1. Variable Frequency Drive Main Circuit Diagram

VFD is a power electronics based device which converts a basic fixed frequency, fixed voltage sine wave power (line power) to a variable frequency, variable output voltage used to control speed of induction motors (s). It regulates the speed of a three phase induction motor by controlling the frequency & voltage of the power supplied to the motor.

Speed (rpm) = frequency (hertz) x 120 / no. of poles

Example: 2-pole motor at different frequencies

3600 rpm = 60 hertz x 120 / 2 = 3600 rpm 3000 rpm = 50 hertz x 120 / 2 = 3000 rpm 2400 rpm = 40 hertz x 120 / 2 = 2400 rpm

Since the number of pole is constant the speed ***Ns*** can be varied by continuous changing frequency.

Any **Variable Frequency Drive** or **VFD** incorporates following three stages for controlling a three phase induction motor.

Rectifier Stage

A full wave power diode based solid state rectifier converts three phase 50 Hz power from a standard 220, 440 or higher utility supply to either fixed or adjustable DC voltage. The system may include transformer for high voltage system.

Inverter Stage

Power electronics switches such as IGBT, GTO or SCR switch the DC current from rectifier on & off to produce a current or voltage waveform at the required new frequency. Presently most of the voltage source inverter (VSI) use pulse width modulation (PMW) because the current & voltage waveform at output in this scheme is approximately a sine wave. Power electronics switches such as IGBT, GTO etc. switch DC voltage at high speed, producing a series of short width pulses of constant amplitude. Outer voltage is varied by varying the gain of the inverter. Output frequency is adjusted by changing the number of pulses per half cycle or by varying the period for each time cycle. The resulting current in an induction motor simulates a sine wave of the desired output frequency. The high speed switching action of a PWM inverter results in less waveform distortion hence decrease harmonic losses.

Control System

Its function is to control output voltage i.e. voltage vector of inverter being fed to motor & maintain a constant ratio of voltage to frequency (V/Hz) . It consists of an electronic circuit which receives feedback information from the driven motor & adjusts the output voltage or frequency to the desired values. Control system may be based on SPWM (Sine Wave PWM), SVPWM (Space Vector Modulated PWM).

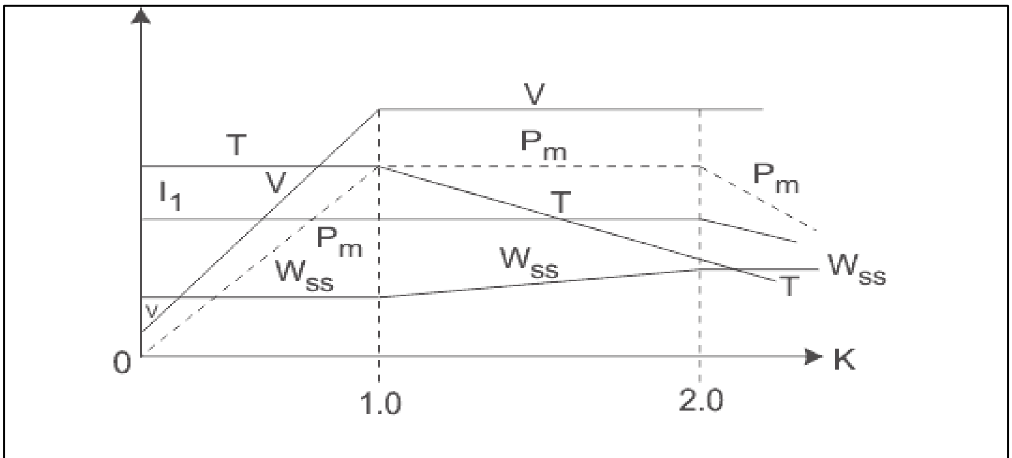
IV. Induction Motor Characteristics under VFD

In an induction motor voltage induced in stator, E is proportional to the product of the slip frequency & the air gap flux. The thermal voltage can be considered proportional to the product of the slip frequency & flux, if stator drop is neglected. Any reduction in the supply frequency gap flux which will cause magnetic saturation of motor. Also the torque capability of motor is decreased. Hence while controlling a motor with the help of Variable Frequency Drive we always keep the V/f ratio constant.

Now define variable ‘K’ as, **K = f/frated**

For operation below K<1 i.e. below rated frequency we have constant flux operation. For this we maintain constant magnetization current Im for all operating points.

For K>1 i.e. above rated frequency we maintain terminal voltage Vrated constant. In this field is weakened in the inverse ratio of per unit frequency ‘K’.For values of K=1 we have constant torque operation & above that we have constant power application.



V(Terminal Voltage), T(Torque), P_m(Power), I_1(Stator Current) and W_{ss} vs. K plot

Fig 2.IM Characteristics under VFD

V.VFD Fundamental

When the frequency applied to an induction motor is reduced, the applied voltage must also be reduced to limit the current drawn by the motor at reduced frequencies. (The inductive reactance of an AC magnetic circuit is directly proportional to the frequency according to the formula XL = 2πfL. Where : π = 3.14, f = frequency in hertz, & L = inductive reactance in Henrys.)

Variable speed AC drives will maintain a constant volts/hertz relationship from 0 – 60 hertz. For a 460 motor this ratio is 7.5 volts/Hz. To calculate this ratio divide the motor voltage by 60Hz. At low frequency the voltage will be low, as the frequency increases the voltage will increase. (note: this ratio may be varied somewhat to alter the motor performance characteristics such a providing a low end boost to improve starting torque.)

Depending on the type of AC Drive, the microprocessor control adjusts the output age waveform, by one of several methods, to simultaneously change the voltage & frequency to maintain the constant volts/hertz ratio throughout the 0 – 60 Hz range. On most AC variable speed drives the voltage is held constant above the 60 hertz frequency.

VI. Pulse Width Modulation (PWM)

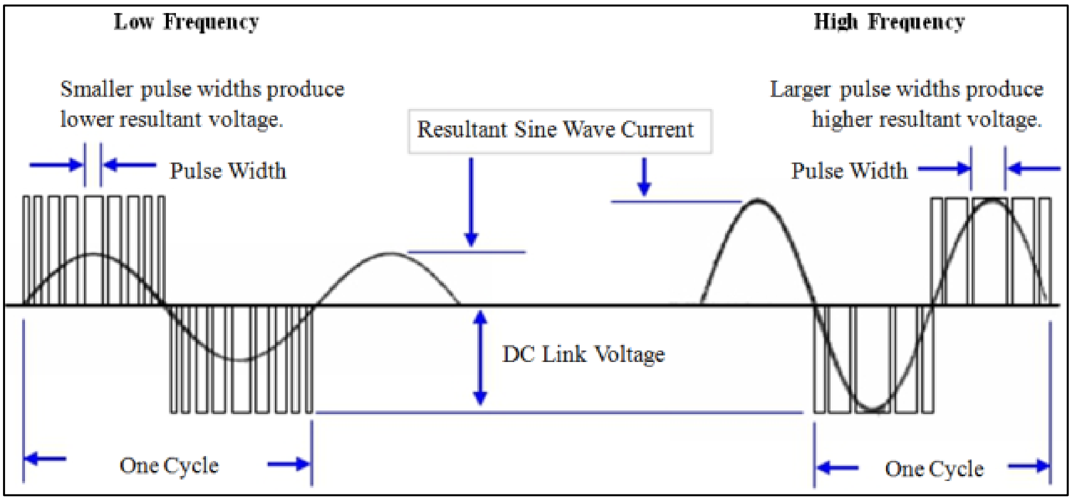


Fig 3. PMW Sine Wave Synthesis

- VFD drive DC link voltage is constant.
- Pulse amplitude is constant over entire frequency range & equal to the DC link voltage.
- Lower resultant voltage is created by more & narrower pulses.
- Higher resultant voltage is created by fewer & wider pulses.
- AC output is created by reversing the polarity of the voltage pulses.
- Even though the voltage consists of a series of square-wave pulse, the motor current will very closely approximate a sine wave. The inductance of the motor acts to filter the pulses into a smooth AC current waveform.

- Voltage & frequency ratio remains constant form 0 – 60 Hz. For a 460 motor ratio is 7.6 volts/Hz. To calculate this ratio divide the motor voltage by 60Hz. At low frequencies the voltage will be low, as the frequency increases the voltage will increase.
- For frequencies above 60Hz the voltage remains constant. Some AC drives switch from a PWM waveform to a six step waveform for 60Hz & above.

VII. The installation of VFD for textile machine has the following advantages

• Reduction in breakdowns and smooth start

• Reduction in breakages and motor burning

• Improved life of the motor and increased production

• Reduction in production cost and maintenance cost due to frequent failures of belts, bearings, yarn breakages

• Improved power factor (0.98 across speed range)

• Maximize power distribution system

• Reduced Inrush current

• Minimize peak demand charges

• Eliminates mechanical shock and stress on power train (couplings, belts, drives, shafts, gear boxes, etc.)

• Reduce Utility operating costs

• May qualify for utility rebates due increase in power factor

• Controlled acceleration and deceleration

• Eliminates Motor Voltage Imbalance

VIII. Experimental Part

List of Components

1. LMW 75 Kw Induction Motor
2. DANFOSS FC302 P55K VLT Automation Drive
3. 4 mm square Cable (Nos.3)
4. Power Source (415VAC)
5. MCB(Miniature Circuit Breaker)
6. Digital Tachometer

Component Specification

LMW Ring Frame Head Stock Induction Motor

Type	Kw	Volts (AC)	Amps	Frequency (Hz)	Phase Connection	Speed (Rpm)	P.F.	Frame	Duty
INX	75	415	135	87	3	2580	0.91	LE225S	S1

Danfoss VLT Automation Drive

F/C	FC-302P55KTSE21H2BGCDXX8032XAXBXCXXXXXDX
P/N	134F5352
KW	75KW(400V)/100HP(460V) (In NO)
IN	3x300-500V 50/60Hz 133-188A(In NO)
OUT	3x0-Vin0-1000Hz 147/118A(In NO)
Type	1 / IP21
Temp	50°C/ 122 F
O/N	134F5352
S/N	034015G382
SW VER.	6.27

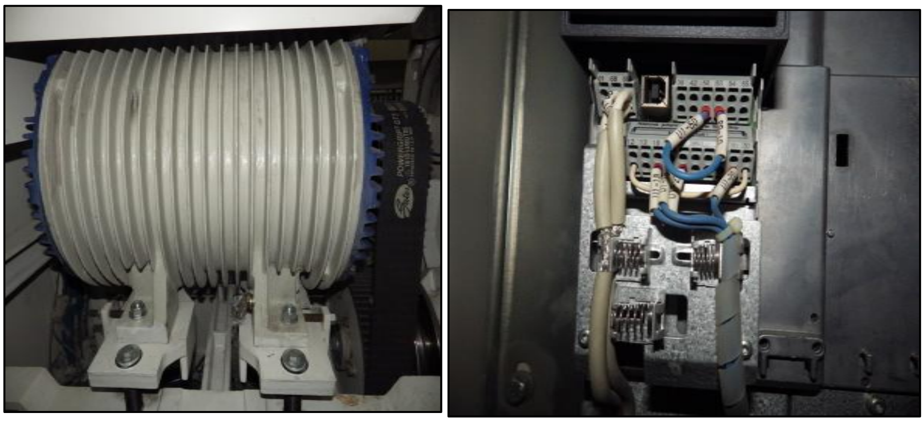


Fig.4 Photos of VFD & Motor

IX. Circuit Diagram

This diagram(Fig.5) shows a typical installation of VLT Automation Drive FC302

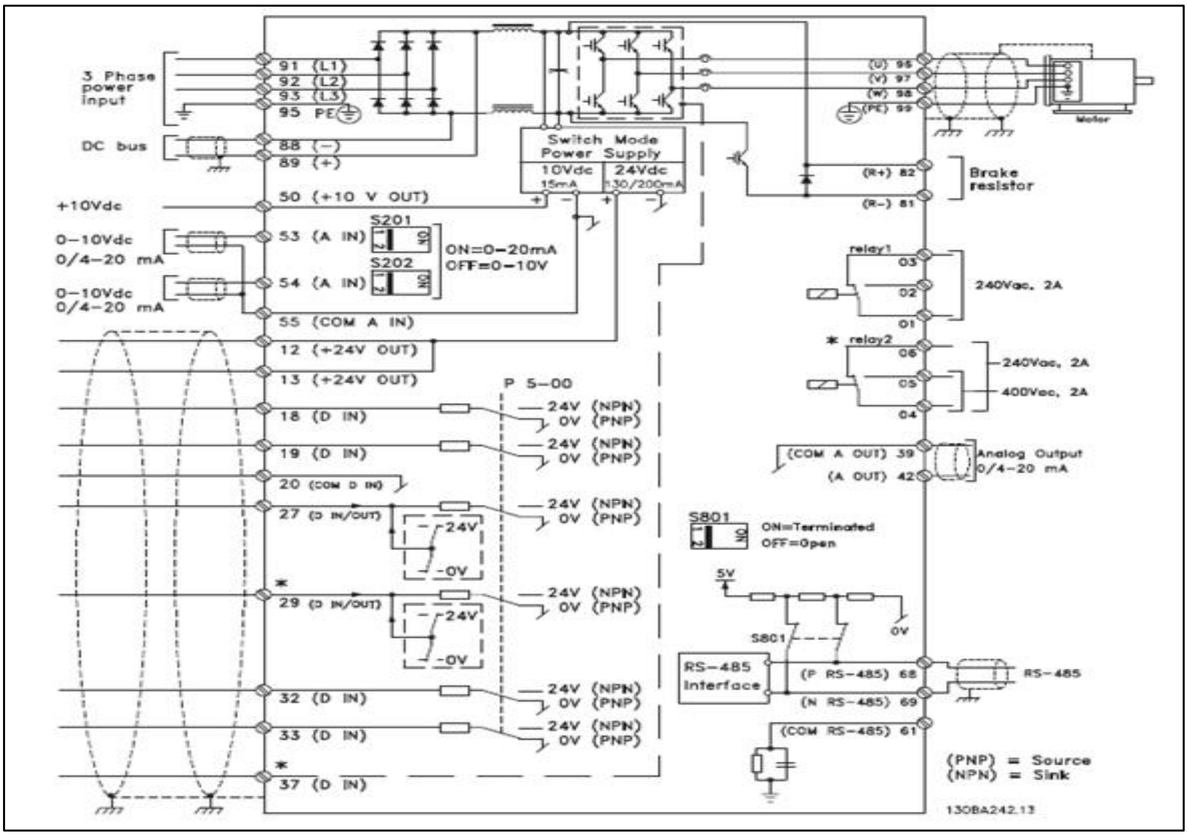


Fig5.A typical installation of VLT Automation Drive FC302

The pulse width modulated (PWM) inverter for variable speed drive of induction motor circuit drives induction motors up to about 134 horse power, 430 volts, variable frequencies.

The frequency may be adjusted from 0 Hz to 87Hz. So, the motor speed can be varied from 0 rpm to 2580rpm. The complete system of this thesis consists of an AC voltage input that is put through a diode bridge rectifier to produce a DC output which across a shunt capacitor, this will, in turn, feed the PWM inverter. The PWM inverter is controlled to produce a desired sinusoidal voltage at a particular frequency to the squirrel cage induction motor.

X. Experimental Data

Motor speed (rpm) is dependent upon frequency varying the frequency output of the VFD controls motor speed:
Speed (rpm)=frequency(Hz)x120/no.of poles

Input supply frequency(Hz)	Motor Speed(rpm)
0	0
25	750
40	1200
60	1800
75	2250
80	2400
85	2550

XI. The Purpose

- ✓ Energy savings on most pump and fan applications
- ✓ Better process control and regulation
- ✓ Speeding up or slowing down a machine or process
- ✓ Inherent power-factor correction
- ✓ Emergency bypass capability
- ✓ Protection from overload currents
- ✓ Safe Acceleration
- ✓ Save energy and improve efficiency
- ✓ Process controllability

- ✓ Reduced mechanical wear and shock
- ✓ Improved power factor
- ✓ Coordination of motion on various shafts
  & easy interfacing with automation system

XII. Control Arrangements for a VFD

There are many control arrangements are present to control all these arrangement. Some of them are as follow

1. Local or Hand Control
2. Remote or Auto Control
3. Multi-motor
4. Closed Loop
5. Cascade Control – Fixed Stages
6. Cascade Control – Variable Stages
7. BuildAutomationSystem(BAS)Enabled

XII. Conclusion

VFDs have the lowest starting current of any starter type.It also reduce thermal and mechanical stresses on motors and belts.VFD installation is as simple as connecting the power supply to the VFD.

It provides the most energy efficient means of capacity control.VFDs provide high power factor, eliminating the need for external power factor correction capacitors.and also provide lower KVA, helping alleviate voltage sags and power outages.

The use of a Variable Frequency Drive for a textile application usually offers an energy efficient & environmentally friendly solution. VFD very useful for the textile plant where high power rating motors are used & used at a variable speed. The device used in this having very fast operating speed. These devices are in compact size. Higher operating speed gives high starting torque. Using this drive we can save the power by controlling the speed of the motor. The frequency range of the constructed circuit is 10Hz to 85Hz at constant voltage for charging the speed of induction motor theoretically between 300rpm to 2550rpm, 3 phase induction motor is used.

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