

Installation, testing and commissioning of variable frequency drive in 50 ton draw bench pipe manufacturing unit

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Abstract— In this paper we are going to see the procedure to install, test and commission the variable frequency drive in 50 ton draw bench tube manufacturing machine in a field and take a survey on its performance characteristics. Tube Draw Bench machine (cold) is used mainly for drawing different sizes of stainless steel round pipe, square pipe, and rectangular pipe. A Draw bench is a machine used to do cold work on a metal, such as changing the shape of the metal without applying heat and applying only pressure.

Variable frequency drives are extensively used for controlling electrical energy utilization at optimum cost and provide smooth motor acceleration, reliable, reduce power supply problems in the facility and have flexibility of control. Further, the use of VFD brings the total system cost down because of the elimination of various system components which are required for valve control. VFD has attractive returns on investment in most of the applications. In high power installations, harmonic distortion can be reduced by supplying multi-pulse rectifier-bridge VFDs from transformers with multiple phase –shifted windings.

Index Terms— VFD, converter, inverter, draw bench

I. INTRODUCTION

A Variable Frequency Drive (VFD) is a motor controller which adjusts the frequency and voltage supplied to the drive according to the need of the application. Popular speed control devices used in industrial, commercial and residential applications. In present scenario VFD is used for effective and energy efficient method in controlling pumps, fans, compressors. In high power installations, harmonic distortion can be reduced by supplying multi-pulse rectifier-bridge VFDs from transformers with multiple phase –shifted windings.

II. VARIABLE FREQUENCY DRIVE

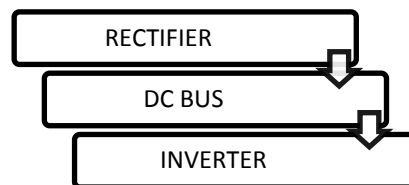


Fig1: Block diagram process of VFD

Rectifier /converter

One of the three primary sections of a VFD's main power circuit, and first in terms of power flow. Incoming ac line voltage is rectified to dc voltage in the converter section. It consists of diodes, silicon-controlled rectifiers (SCRs), or insulated gate bipolar transistors (IGBTs) connected in a full-wave bridge configuration.

Dc bus

The second primary section of a VFD's main power circuit, chiefly comprised of capacitors that store power rectified by the converter.

Inverter

The third and final primary section of a VFD's main power circuit. The inverter section is comprised of IGBTs that create sinusoidal output current using pulsed dc bus voltage, or pulse width modulation (PWM). VFDs themselves are sometimes called inverters, as the presence of an inverter section is the primary difference between VFDs and dc drives.

III. DRAW BENCH

A **Draw bench** is a machine used to do cold work on a metal, such as changing the shape of the metal without applying heat and applying only pressure. Drawing is a metal working process which uses tensile forces to stretch metal. As the metal is drawn (pulled), it stretches thinner, into a desired shape and thickness. Drawing is usually done at room temperature, thus classified a

cold working process, however it may be performed at elevated temperatures to hot work large wires, rods or hollow sections in order to reduce forces. The pointed/reduced end of the bar or coil, which is smaller than the die opening, is passed through the die where it enters a gripping device of the drawing machine. The drawing machine pulls or draws the remaining unreduced section of the bar or coil through the die. The die reduces the cross section of the original bar or coil, shapes the profile of the product and increases the length of the original product.

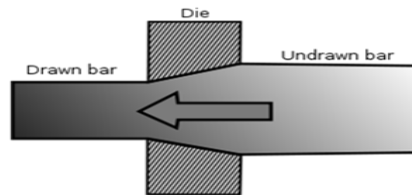


Fig2: Drawing process

A. Advantages of drive

The Variable frequency drive enables step less control and better accuracy. It provides cost saving possibilities. Within an hour we can have multiple startup. When VFD's are used initial power surge and mechanical shock is eliminated. By reducing magnetic losses and improving the power factor overall efficiency is improved by VFD's.

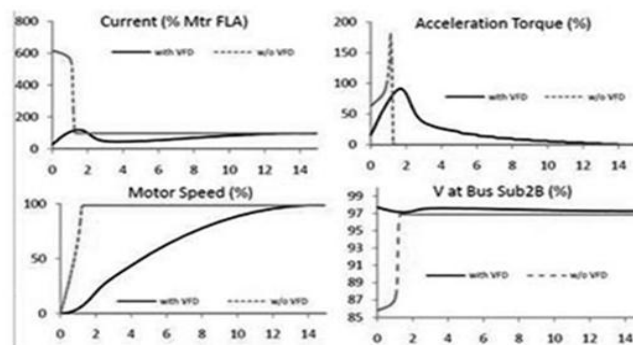


Fig3: Motor acceleration responses with and without VFD

B. Installation

Placing of insulating mat- An insulating mat is laid installation.

Positioning the panel- Panel is positioned after considering the factors like front and rear clearance.

Tightening of the basement- After positioning the panel the base is tightened and if VFD is used in vibration prone area welding is done.

as a safety measure

Laying of 3-phase supply- Incoming cable is laid from the mains to the drive.

Connecting to output cable- This means drawing of the cable from the drive to the application(50 ton draw bench).

Cable scheduling-This provides details about internal wiring given by the supplier. External cable setting- This provides the necessary external cable connection from the drive to the draw bench machine. A cable is provided between control desk and VFD panel. For protection purpose proper earthing cables are provided.

C. Testing

Three types of testing is carried out and they are:

MOTOR TESTING

VFD TESTING

CONTROL DESK TESTING

1) Motor testing

a) Insulation resistance testing

Check the megger value for knowing if earthing is good and value is read as zero

The formula for insulation resistance value is:

$$IR = 1 + [\text{rated voltage}/1000]$$

If the value of IR is greater than 1.415 MΩ then the motor is healthy for the case of resting condition. Else if the value of IR is greater than 100MΩ in case of running condition then the motor is healthy. If these are violated then we must check the winding for damage.



Fig 4: Motor testing

b) Winding resistance checking

Connect the terminals of the motor to the ohm meter. Then read all the resistance values between R, Y and B phases. If the value of resistances for R, Y and B are more or less equal to each other with tolerance of $\pm 5\%$ then the motor is healthy.

Motor specifications

| S.No | Factors | Ratings |
|------|-----------------------|---------------------|
| 01 | Motor | 3ph induction motor |
| 02 | Type | 3LA0283-4YA70 |
| 03 | Insulation class | Class F |
| 04 | Standard | IS325 |
| 05 | Frame | 280M |
| 06 | Duty | S1 |
| 07 | Protection Standard | IP55 |
| 08 | No.NB/ | 31646 |
| 09 | Power | 90KW |
| 10 | Load current | 156A |
| 11 | Voltage | 415V(DELTA) |
| 12 | Speed | 1480 rpm |
| 13 | Efficiency | 94.5 |
| 14 | Frequency | 50Hz |
| 15 | Rotor type | KL16 |
| 16 | Drive end bearing | 631703 |
| 17 | Non drive end bearing | 631703 |

Table1: Motor specifications

VFD testing

Earthing- Two types of earthing namely internal earthing and external earthing. It is verified if it is as per the diagram. Panel internal earthing is taken care the same way. The wires are checked whether they are properly earthed. After this two wires are taken from the panel and connected to earth pit.

Incoming supply voltage- Incoming supply is given from the LT panel. Based on the voltage rating the cables are terminated and voltage will be measured.

Drive wiring checkup- This means checking the tightness of the wire.

Checking of Indication lamps, voltmeter and ammeter readings- In this test indication lamps, voltmeter and ammeter are checked. For example if R phase is turned on that particular lamp must glow. If it glows then it means the lamps are working properly. Then we need to check whether the voltmeter reading is correct. For this we must check the voltage by using a multimeter and compare it with the voltmeter reading.

Testing of drive setting parameters- These parameters are discussed in detail in the commissioning procedure.

Drive ON/OFF load- First the drive is turned on without load and at the other end it is checked whether the supply is available. Then the drive is turned off and checked whether the supply is not available. Now again the drive is turned on and the same test is carried out.

Drive remote- In the drive is tested whether it can be turned on from the control desk of the application i.e. from the draw bench.

Loading and monitoring the values- In this test the application is loaded for different load values and the corresponding values are monitored.

Drive Specifications

| S.No | Factors | Ratings |
|------|-------------------|--------------|
| 01 | Drive type | VFD |
| 02 | Maker of drive | Siemens |
| 03 | Model | G120 |
| 04 | Input voltage | 360-480 V AC |
| 05 | Input frequency | 47-63 Hz |
| 06 | Output Frequency | 0-240 Hz |
| 07 | Power | 200KW |
| 08 | Temperature | 0-50 deg |
| 09 | Acceleration time | 0-600 sec |
| 10 | Deceleration time | 0-600 sec |
| 11 | Efficiency | 97.5 |

Table2: Drive specifications

IV. COMMISSIONING

Purpose of commissioning

The main purpose of commissioning is to check whether AC converter and motor have been correctly installed and whether the wiring and safety standards are met as per IEC 60364, then to check whether the power and motor cables are correctly sized, installed and terminated. Then control cables are also checked whether they have been installed according to the control system design. At the next stage all power cables shields are monitored whether they have been correctly earthed at both ends, to the protective earth terminal at the converter, at the motor and at the distribution board or MCC. In case of control cables shields have been correctly earthed at one end only, preferably at the process control system end only. For the first time before energization there will not be any faults on the cables.

Basic parameter setting

Some of the basic parameters that are checked namely,
 Correct base voltage- Standard voltage is 3-phase, 415 V
 Correct base frequency- Standard frequency is 50 Hz

After setting the basic parameters the connections to the cooling fan is checked. We have enormous number of choices of parameters but we don't need to set all those parameters there a few parameters which are the basic parameters and they need to be set correctly.

Other parameter setting

Acceleration/deceleration time- Acceleration time is the time required by output frequency from 0 Hz to the maximum frequency, and deceleration time is from maximum frequency dropped to 0 Hz. We set this parameter to restrict the rise of frequency during the starting of motor to prevent over-current and limit the frequency to prevent over-voltage during deceleration period.

Torque boosting- It is also known as the torque compensation. Sufficient torque boost must be selected to ensure that VFD exceeds breakaway torque of the load during starting. Torque compensation is to compensate the torque decrease in low speed for the stator winding resistance of the AC motor, by increase the low-frequency range of V/F.

Electronic thermal overload protection-This function is set to protect the electric motor from overheating. We can calculate the AC motor temperature rise by VFD's internal CPU based on the operation of current and frequency and enable overheating protection.

$$\text{Electronic thermal protection setting value (\%)} = \frac{\text{electric motor rated current (A)}}{\text{ac driver rated output current (A)}} \times 100\%$$

Frequency limitation-The minimum and maximum value of frequency is to be set. If it is not set properly then the devices will be damaged. Frequency limitation is to prevent the failure of inappropriate operation or external frequency setting signal source from outputting frequency too high or too low, it's a protective function to prevent damage the devices.

Frequency bias- It is the frequency deviation setting. We can adjust the output frequency value to a minimum value when frequency is set by an external analog signal. When the frequency setting signal is 0% deviation value is from 0 to f_{max} .

Frequency setting signal gain-This feature is only effective when the frequency set by external analog signal. It is used to compensate the inconsistencies between the external setting signal voltage and the variable frequency drive internal voltage (+10v); at the same time it's convenient for voltage selection of the analog signal, in setting, when the analog input signal is maximum (10v, 5v or 20mA), obtained the output frequency percentage of V/F graphics and treat it as a parameter to set it; Take an example, external setting signal is 0 - 5v, VFD output frequency is 0 - 50Hz, then signal gain value is set to 200%.

Torque limit-This parameter has two torque limitation- drive torque and brake torque limitation. Drive torque limitation controls the motor slip and it monitors such that it is within the maximum limit. If brake torque limit is less then braking force will be more

Acc/dec mode selection – This parameter has three curves namely-

Linear curve, non-linear curve and S curve. Mostly linear and non linear curves are used. For constant torque loads S curve is used.

Torque vector control- Vector control is based on the theory: asynchronous motors and DC motors have the same torque mechanism. Vector control mode is decomposing the stator current into magnetic current and torque current and controlled separately, meanwhile, output the stator current to the motor after their synthesis. Therefore, we can obtain the same control performance with DC motor in principle. The motor can output maximum torque in variety operating conditions when adopts torque vector control function, especially the ac motor in the low-speed operating status.

Energy saving control-Fans and pumps are all belong to decrease torque load, means the load torque decreases proportional to the square of rotation speed in the speed decline, the VFD is designed with energy-saving control function dedicated V/F mode, this mode can improve the efficiency of the electric motor and the VFD drive, the output voltage can be decreased automatically according to the load current, to achieve energy saving purposes. You can enable or disable it according to the specific circumstances.

V. SIMULATION

A Simulink model

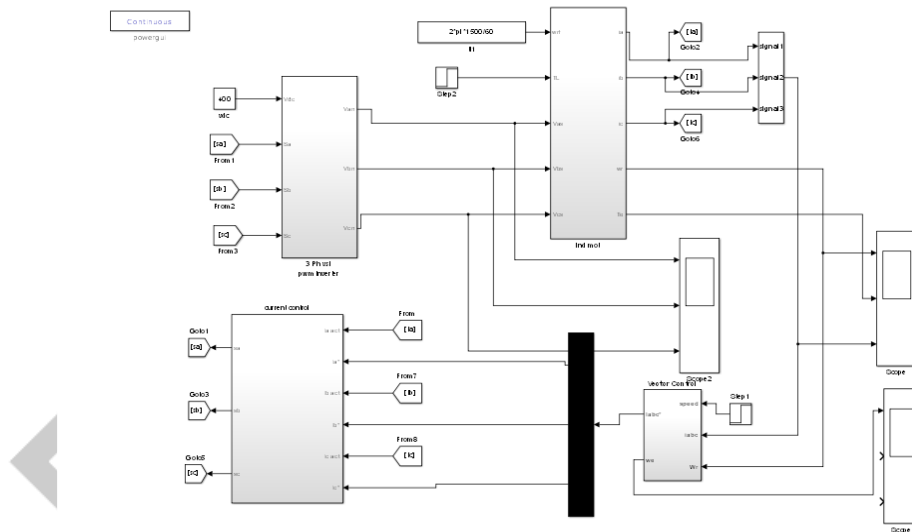


Fig 5: Simulation block

B. Simulation results

Direct Quadrature (d-q) transformation is a mathematical transformation used to simplify the analysis of three phase circuit. In the case of balanced three phase circuits, application of d-q transformation reduces the three AC quantities to 2 quantities. Simplified calculations can then be carried out on these imaginary quantities before performing the inverse transformation to recover the actual three phase ac results. Stator d-q axis flux behavior is given below in the fig6. Detailed analysis of the individual waveform is given below

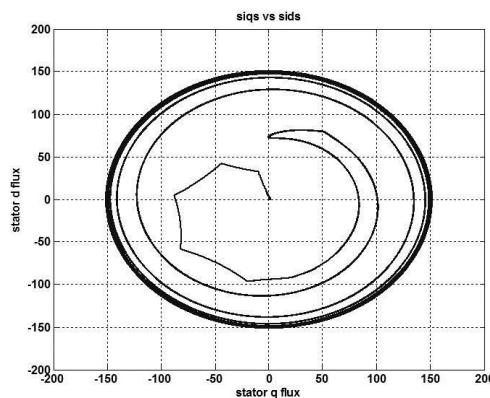


Fig 6: Stator d-q axis fluxes

Variation Rotor speed, stator current and torque of IM

For the duration between 0 sec to 0.1 sec IM speed accelerates to attain the reference speed of 500 rpm. At this condition the motor torque leads the load torque and stator current oscillates between -40 amps to +40 amps. After reaching the reference speed motor torque falls to 0 Nm, meanwhile stator current reaches steady state. At 0.3 sec when motor is loaded and speed is maintained constant, load torque and motor torque increases along with an increment in stator current. The motor accelerates as the load increases. As frequency increases during this condition waveform looks congregated. At 1 sec to decelerate the IM faster its made to run with negative torque. All these are shown in the fig7 below.

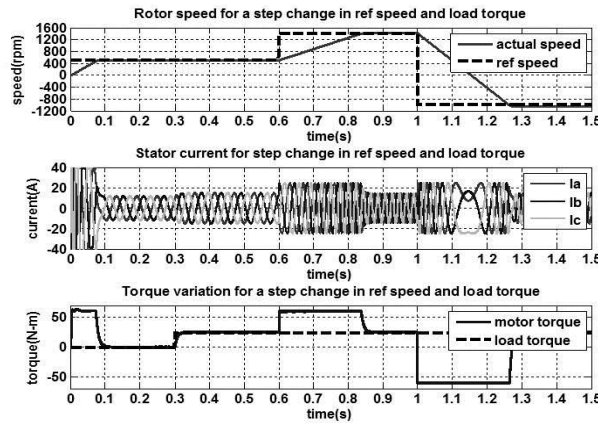


Fig7: Rotor speed, stator current and torque of IM

Variation of Id and Iq current for a change in speed and torque

An induction motor can be modeled most simply (and controlled most simply) using two quadrature currents rather than the familiar three phase currents actually applied to the motor. These two currents called direct (I_d) and quadrature (I_q) are responsible for producing flux and torque respectively in the motor. By definition, the I_q current is in phase with the stator flux, and I_d is at right angles. I_d is direct current and the magnitude has a fixed value. I_q is quadrature current and the magnitude follows the torque value. T_e is Torque and the magnitude follows the torque of the load as shown below in the fig8.

This fig8 indicates the change in I_d and I_q for change in speed and torque of motor. As the motor accelerates to reach rated speed, also when motor torque is leading the load torque, I_q is larger in magnitude. When motor is at rated speed, load torque and motor torques are at equal level I_q is at zero. Slowly when loading is done load torque rises simultaneously increasing the I_q . Throughout loading and unloading, I_d is maintained constant (10A) When we apply negative torque for motor to decelerate I_q also falls low.

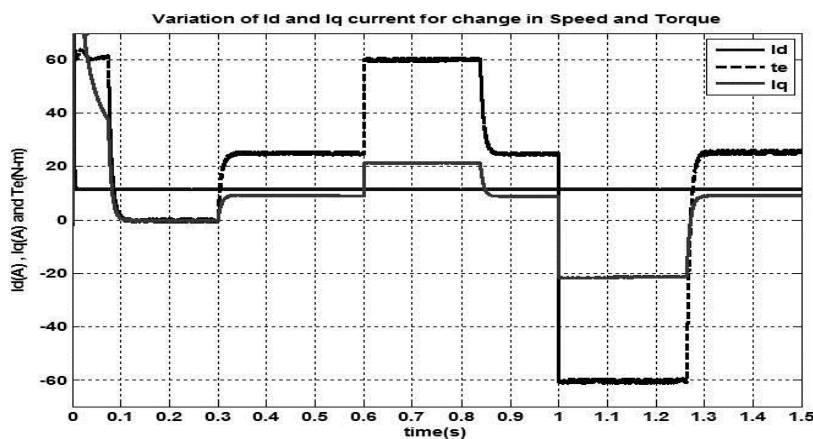


Fig8: Variation of Id and Iq current for a change in speed and torque

Inverter output voltages

The inverter output voltage between the two phases of the three phase supply wave form is given below in this fig9. The Voltage between phases V_{RY} , V_{YB} and V_{BY} shown. It is observed that all the three voltages magnitudes are equal and wave form is having shift of 120deg with the other waveforms.

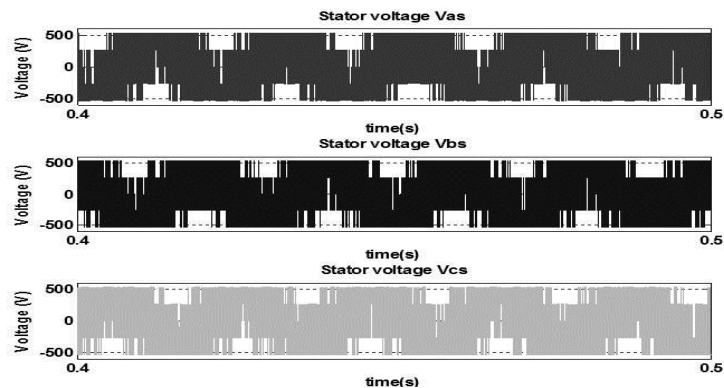


Fig9: Inverter Output Voltages

Induction Motor input currents

The input current of the three phase motor is given below in fig10. The phases R,Y and B are shown. It is observed that all the three phase magnitude are equal and wave form is having shift of 120deg with the other waveforms.

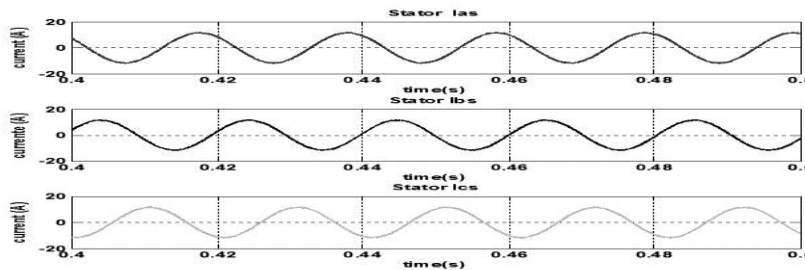


Fig10: IM Input Current

VI. CONCLUSION

Installation of VFD is done to provide speed control of industrial applications with energy saving. It certainly leads to the best performance and high efficiency of the induction motor. In recent years the shortage of electricity is a major threat in few regions. In such case, the unwanted energy should be saved. As a result, the implementation of VFD helps in saving a large amount of energy by reducing the sudden jerks happening at the starting of the motor. A modern industrial power system may include variable frequency drive (VFD) loads at several locations. The complete system 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, which is filtered by the use of an inductor in series and capacitor in parallel and then through squirrel cage induction motor. We witnessed the drives performance by simulating it and applying varying load parameters resembling our application (draw bench) using matlab.

REFERENCES

- [1] A Text book on "Fundamental of Electrical Drives" by Gopal.K.Dubey
- [2] A text book on "High performance control of AC drives" published by wiley and sons limited.
- [3] Analysis of Electric Machinery and Drive Systems, Second Edition by Paul C. Krause, Oleg Wasynczuk, and Scott D. Sudhoff, Purdue University, published by IEEE Press, ISBN 0-471-14326-X, 2002
- [4] Bimal K Bose "Modern power electronics and AC drives" Prentice Hall ISBN 0-13-016743-6.
- [5] BurakOzpineci, Leon M. Tolbert, "Simulink Implementation of Induction Machine Model", Oak Ridge National Laboratory and Department of Electrical and Computer Engineering, The University of Tennessee
- [6] International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064, "Research to study variable frequency drives and its energy savings
- [7] Saffet Ayasun, Member, IEEE, and Chika O. Nwankpa, Member, IEEE, "Induction Motor Tests Using MATLAB/Simulink and Their Integration Into Undergraduate Electric Machinery Courses
- [8] Simulation of PWM inverter for VFD using MATLAB, International Journal of Engineering Research and Development e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com Volume 10, Issue 4 (April 2014), PP.94-103