VIBRATION ANALYSIS OF PUMP WI TH VFD TECHNOLOGY

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VIBRATION ANALYSIS OF PUMP WI TH VFD TECHNOLOGY
(Industrial Application)

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Abstract - A Variable Frequency Drive (VFD) regulates the speed of a 3-phase AC electric motor by controlling the frequency and voltage of the power it delivers to the motor. Today, these devices (also known as Adjustable Speed Drives or Variable Speed Drives) are becoming prevalent in a wide range of applications throughout industry, from motion control applications to Cooling Towers, from water treatment facilities to machining areas, and many others. Considering the Economical and Environmental factors, it is advisable to modify the existing system rather than replacing it with new one. This project exercises this concept of vibration control in order to obtain smooth running by soft water pump and cooling tower pump.

Keywords - *Controlling the frequency and voltage, Economical and Environmental factors, Savings in power consumption, Variable frequency drive, Vibration Control.*

I. INTRODUCTION

Pumping systems account for nearly 20% of the world's energy used by electric motors and 25% to 50% of the total electrical energy usage in certain industrial facilities. Significant opportunities exist to reduce pumping system energy consumption through smart design, retrofitting, and operating practices. In particular, the many pumping applications with variable-duty requirements offer great potential for savings. The savings often go well beyond energy, and may include improved performance, improved reliability, and reduced life cycle costs. Most existing systems requiring flow control make use of bypass lines, throttling valves, or pump speed adjustments. The most efficient of these is pump speed control. When a pump's speed is reduced, less energy is imparted to the fluid and less energy needs to be throttled or bypassed. Speed can be controlled in a number of ways, with the most popular type of variable speed drive (VSD) being the variable frequency drive (VFD).

Reducing energy use makes perfect business sense; it saves money, enhances corporate reputation and helps everyone in the fight against climate change. This technology guide discusses variable speed drives (VSDs) and lists energy saving opportunities for businesses. It demonstrates how installing VSDs in appropriate applications could save energy, cut costs and increase profit margins.

II. VFD OPERATION

2.1 What Is a Variable Frequency Drive?

Adding a variable frequency drive (VFD) to a motor-driven system can offer potential energy savings in a system in which the loads vary with time. VFDs belong to a group of equipment called adjustable speed drives or variable speed drives. (Variable speed drives can be electrical or mechanical, whereas VFDs are electrical.) The operating speed of a motor connected to a VFD is varied by changing the frequency of the motor supply voltage. This allows continuous process speed control.

Motor-driven systems are often designed to handle peak loads that have a safety factor. This often leads to energy inefficiency in systems that operate for extended periods at reduced load. The ability to adjust motor speed enables closer matching of motor output to load and often results in energy savings.

2.2 How Does a VFD Work?

Induction motors, the workhorses of industry, rotate at a fixed speed that is determined by the frequency of the supply voltage. Alternating current applied to the stator windings produces a magnetic field that rotates at synchronous speed. This speed may be calculated by dividing line frequency by the number of magnetic pole pairs in the motor winding. A four-pole motor, for example, has two pole pairs, and therefore the magnetic field will rotate 60 Hz / 2 = 30 revolutions per second, or 1800 rpm. The rotor of an induction motor will attempt to follow this rotating magnetic field, and, under load, the rotor speed "slips" slightly behind the rotating field. This small slip speed generates an induced current, and the resulting magnetic field in the rotor produces torque.

Since an induction motor rotates near synchronous speed, the most effective and energy-efficient way to change the motor speed is to change the frequency of the applied voltage. VFDs convert the fixed-frequency supply voltage to a continuously

variable frequency, thereby allowing adjustable motor speed.

A VFD converts 60 Hz power, for example, to a new frequency in two stages: the rectifier stage and the inverter stage. The conversion process incorporates three functions:

- **Rectifier stage:** A full-wave, solid-state rectifier converts three-phase 60 Hz power from a standard 208, 460, 575 or higher utility supply to either fixed or adjustable DC voltage. The system may include transformers if higher supply voltages are used.
- **Inverter stage:** Electronic switches - power transistors or thyristors - switch the rectified DC on and off, and produce a current or voltage waveform at the desired new frequency. The amount of distortion depends on the design of the inverter and filter.
- **Control system:** An electronic circuit receives feedback information from the driven motor and adjusts the output voltage or frequency to the selected values. Usually the output voltage is regulated to produce a constant ratio of voltage to frequency (V/Hz). Controllers may incorporate many complex control functions.

Converting DC to variable frequency AC is accomplished using an inverter. Most currently available inverters use pulse width modulation (PWM) because the output current waveform closely approximates a sine wave. Power semiconductors switch DC voltage at high speed, producing a series of short-duration pulses of constant amplitude. Output voltage is varied by changing the width and polarity of the switched pulses. Output frequency is adjusted by changing the switching cycle time. The resulting current in an inductive motor simulates a sine wave of the desired output frequency (see Figure 1). The high-speed switching of a PWM inverter results in less waveform distortion and, therefore, lowers harmonic losses.

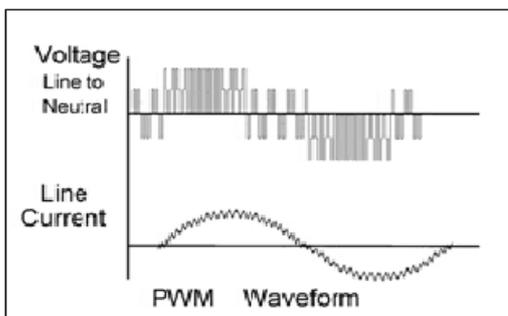The availability of low-cost, high-speed switching power transistors has made PWM the dominant inverter type.

Fig. 1 : Inverter's Pulse Width Modulation Output

The rectifier in a VFD is used to convert incoming ac power into direct current (dc) power.

One rectifier will allow power to pass through only when the voltage is positive. A second rectifier will allow power to pass through only when the voltage is negative. Two rectifiers are required for each phase of power. Since most large power supplies are three phase, there will be a minimum of 6 rectifiers used (see Figure). Appropriately, the term "6pulse" is used to describe a drive with 6 rectifiers. A VFD may have multiple rectifier sections, with 6 rectifiers per section, enabling a VFD to be "02 pulse," "18 pulses or 24 pulses." The benefit of *multiples* VFDs will be described later in the harmonics section. Rectifiers may utilize diodes, silicon controlled rectifiers (SCR), or transistors to rectify power. Diodes are the simplest device and allow power to flow any time voltage is of the proper polarity. Silicon controlled rectifiers include a gate circuit that enables a microprocessor to control when the power may begin to flow, making this type of rectifier useful for solid-state starters as well. Transistors include a gate circuit that enables a microprocessor to open or close at any time, making the transistor the most useful device of the three. A VFD using transistors in the rectifier section is said to have an "active front end."[2]

After the power flows through the rectifiers it is stored on a dc bus. The dc bus contains capacitors to accept power from the rectifier, store it, and later deliver that power through the inverter section. The dc bus may also contain inductors, dc links, chokes, or similar items that add inductance, thereby smoothing the incoming power supply to the dc bus. The final section of the VFD is referred to as an "inverter." The inverter contains transistors that deliver power to the motor. The "Insulated Gate Bipolar Transistor" (IGBT) is a common choice in modern VFDs. The IGBT can switch on and off several thousand times per second and precisely control the power delivered to the motor. The IGBT uses a method named "pulse width modulation" (PWM) to simulate a current sine wave at the desired frequency to the motor. [2], [4]

III. EXISTING SYSTEM

3.1 Water Treatment Plant at FIAPL

    3.1.1 Application: Transfer of soft water from soft water storage tank to entire plant.

    3.1.2 Previous System: Star Delta starter for motor operation.

    3.1.3 Pump Specifications: Soft Water Pump [1]

Capacity	55 m^3/hr
Make	Kirloskar
Model	CPHM-50/20
Quantity	4 nos.

3.2 Compressor House at FIAPL

3.2.1 **Application**: Transfer of water from cooling tower to compressors and dryers for cooling.

3.2.2 **Previous System**: Star Delta starter for motor operation.

3.2.3 **Pump Specifications**: Cooling tower (CT) pump[1]

IV. OBJECTIVE

Vibration Testing in soft water and cooling tower pump in Pump house by incorporating VFD

V. FOCUS

Reduction in Vibration in pumps as compare to previous system

VI. ADVANTAGE

The Efficiency of the system will increase as the system will reduce frequency of pumps when there are fewer requirements thereby reducing energy consumption, Vibrations and Constant power factor.

VII. SCHEME DESCRIPTION

i. Use of one VFD for 4 numbers of Pumps one at a time.

ii. Switching over from one pump to second pump on real time basis.

iii. Pressure transmitter feedback from common pipe line to VFD for close loop pressure control to improve energy efficiency.

iv. Provide BY PASS VFD in One fails to have system redundancy.

v. One Drive is used for to drive one single Pump in close loop with pressure transmitter mounted on common pipe line. The VFD will throttle the Pump as per the pressure SET Point selected by user.

vi. Each Pump motor is fed by VFD through Contactor and over load Relay (OLR). The OLR is used for Individual Pump Motor Protection. This contact also can be taken to PLC. In case of tripping of any Pump, user can program to switch different Pump to have halted less process.

vii. To have equal run hours of each pump the pumps are switched by small PLC which has capacity of Real time clock and Pump Altering feature. The Running time of each pump can be programmed by user.

viii. In case of Failure of One VFD, second VFD will take over and functioning of system will continue. This can be done automatically by mean of same PLC or manually by selector switch.

ix. All messages, errors, can be displayed on a built in display of PLC. In addition separate Display can be given or through Mod bus connectivity this system can be hooked to any other main BMS system.[1]
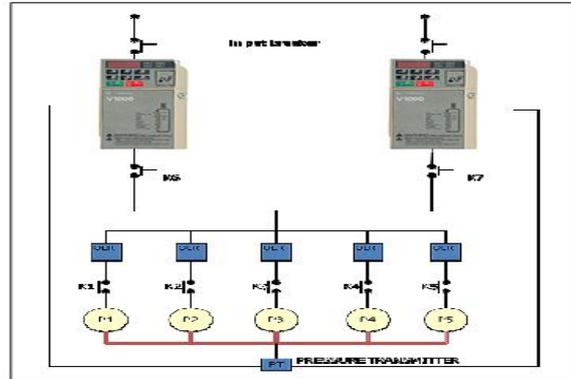

Fig. 2 : Block Diagram of VFD Network

VIII. FEEDBACK CONTOL

VFD controls the speed of motor by changing the frequency. Speed frequency depends upon output of the system. Here we set a pressure in the range of 3.5 to 5.5 for output, and pressure transmitter is connected at output line. When pressure fall below set point, pressure transmitter senses and speeds the motor to achieve the set pressure and vice-versa. In Figure 4, PV denotes the actual pressure value from transmitter and SV denotes the set pressure value. [1]

Fig. 3 : Pressure transmitter

Fig. 4 : Panel Display

IX. FIRST FIELD TEST OF VFD:

9.1 Readings from Vibrometer for Soft water Pump in Pump House BEFORE VFD Installation[1]

DRIVE (MOTOR)			
Point	Horizontal	Vertical	Axial
Drive End	3.3	2.8	1.4
Non Drive End	1.4	1.8	2.5

DRIVEN (PUMP/FAN PLUMBER BLOCK)			
Point	Horizontal	Vertical	Axial
Drive End	2.3	2.8	4.4
Non Drive End	1.2	1.4	1.8

9.2 Readings from Vibrometer for Soft Water Pump in Pump House AFTER VFD Installation[1]

DRIVE (MOTOR)			
Point	Horizontal	Vertical	Axial
Drive End	1.2	2.5	1.4
Non Drive End	1.4	1.4	2.8

DRIVEN (PUMP/FAN PLUMBER BLOCK)			
Point	Horizontal	Vertical	Axial
Drive End	2.0	1.8	3.2
Non Drive End	0.7	0.9	1.8

➢ From above test it is observed that Vibrations of the equipment is less when it is operated on VFD

X. SECOND FIELD TEST OF VFD:

10.1 Readings from Vibrometer for Cooling Tower Pump in Pump House BEFORE VFD Installation[1]

DRIVE (MOTOR)			
Point	Horizontal	Vertical	Axial
Drive End	6.7	3.3	2.0
Non Drive End	8.2	8.2	10.3

DRIVEN (PUMP/FAN PLUMBER BLOCK)			
Point	Horizontal	Vertical	Axial
Drive End	3.7	1.8	3.6
Non Drive End	2.6	0.8	3.0

10.2 Readings from Vibrometer for Cooling tower Pump in Pump House AFTER VFD Installation[1]

DRIVE (MOTOR)			
Point	Horizontal	Vertical	Axial
Drive End	5.2	2.8	0.7
Non Drive End	6.6	6.9	10.0

DRIVEN (PUMP/FAN PLUMBER BLOCK)			
Point	Horizontal	Vertical	Axial
Drive End	2.4	1.8	2.2
Non Drive End	1.9	0.9	1.8

➢ From above test it is observed that Vibrations of the equipment is less when it is operated on VFD

XI. BENEFITS OF VFD

Single-speed drives start motors abruptly, subjecting the motor to high torque and current surges up to 10 times the full-load current. In contrast, variable-frequency drives offer a "soft start" capability, gradually ramping up a motor to operating speed. This lessens mechanical and electrical stress on the motor system and can reduce maintenance and repair costs and extend motor life.

Variable-frequency drives allow more precise control of processes such as water distribution. Pressure in water distribution systems can be maintained to closer tolerances. Water treatment plants can consistently maintain desired pressure over a wide range of flow and temperature conditions by using automated controls to link temperature sensors to variable-frequency drives on the output.

Wide range of speed, torque and power output giving a greater degree of control. For example, the electronically controlled VFD has the ability to set various parameters such as: Allowing differing acceleration rates for different speed changes and having the ability to increase/decrease the torque output at different speeds

XII. RESULT

1. VFDs have the lowest starting current of any starter type. Hence Soft Starting can be achieved.
2. Mechanical & Electrical stresses during starts of the motor reduced to negligible. Hence the life of the equipment increased.
3. System power consumption reduced.
4. Any reduction in speed achieved by using a VSD has major benefits in reducing pump wear, particularly in bearings and seals.

XIII. CONCLUSION

1. Pressure transmitter feedback from common pipe line to VFD improves functional efficiency.
2. Payback period for soft water pump is only up to 15months and for cooling tower pump it is up to 19 months
3. VFD installation is as simple as connecting the power supply to the VFD.
4. VFDs provide high power factor, eliminating the need for external power factor correction capacitors.

5. Presence of a supervisor or monitoring of the level got avoided. Hence the human error gets reduced.

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