The use of variable speed drives in the water industry

Jamie Pearce ABB Pty Australia +61(0)408256161 jamie.pearce@au.abb.com

Abstract

Saving energy techniques are very much a part of every day life. Water and waste water applications are no exception.
The use of variable speed drives is becoming more and more accepted and used throughout the water and waste water industry and is becoming a very effective and efficient way of maximizing the pump efficiency, providing energy savings as well as complete motor and system related protection.

This paper describes the energy saving concept behind the use of variable speed drives in water and waste water pumping applications and considerations that should be taken when designing and incorporating variable speed drives into your water and waste water application.

Pump efficiency example

Total efficiency of the system depends on many factors. In general, the bigger the variable speed drive (VSD), motor or pump, the better the efficiency. When running the system at low speeds, the total efficiency also decreases. In the normal operating area of the pump, which is 35 to 50HZ, the total efficiency of the system does not vary too much. Efficiency is about 83%.(Europump and Hydraulic institute 2004) In general, the pump efficiency varies between 50 to 85%, depending on the speed of the pump and the system.

Affinity laws

Affinity laws in table 1 show the proportion of speed (n) flow (Q) head (H) and power (P). Speed and flow are proportional. The power needed is proportional to the cube of the speed or flow. When operating the pump at the nominal point, the efficiency of the system is normally at its highest. Based on the affinity laws it is possible to optimize the energy efficiency if the speed of the pump is reduced, for example, by 10% from 50HZ to 45HZ. At the same time, the flow is 10% smaller, so the time needed to achieve the same flow is 11% longer. The power needed is only 73% of the original. With this change 19% less energy is needed (1-(0, 73x1, 11)). Total efficiency of the system stays within the same range, but the energy needed is reduced.

Table 1: Affinity laws

Flow $\frac{Q_1}{Q_2} = \frac{n_1}{n_2}$	**Head** $\frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2$	**Power** $\frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^3$

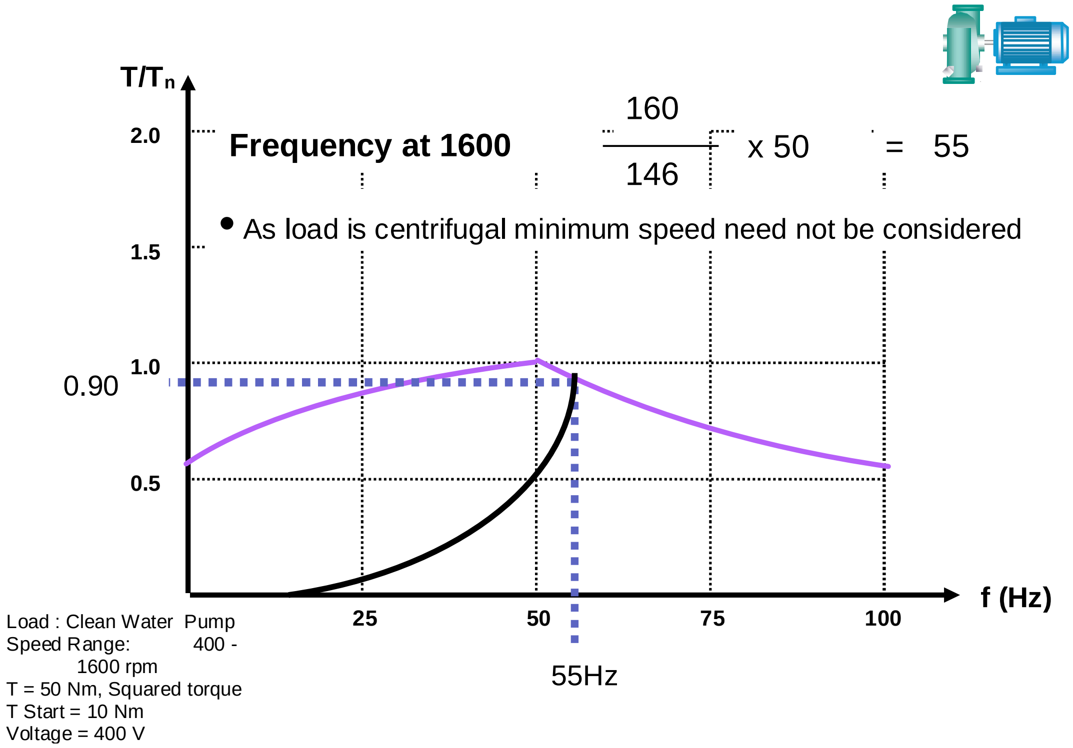
Using this efficiency speed (45Hz in this case) creates a 19% energy saving with a 10% smaller capacity. To keep efficiency speed as the primary control method and use nominal speed only when full capacity is needed, it is possible to achieve double digit energy savings in the long run.

Considerations for sizing your Variable speed drive application

The motor is selected according to the basic information about the process. Speed range, torque curves, ventilation method and motor load-ability give guidelines for motor selection. Often it is worth comparing different motors because selected affects the size of the frequency converter.
When selecting a suitable frequency converter there are several things to be considered. Frequency converter manufactures normally have certain selection tables where typical motor powers for each converter size are given.
The dimensioning current can also be calculated when the torque characteristics is known. The corresponding current values can be calculated from the torque profile and compared to converter current limits. The motors nominal current gives some kind of indication. It isn't however always the best possible dimensioning criteria because motors might for example be de-rated (ambient temperature, hazardous area etc.)
The available supply voltage must be checked before selecting the frequency converter. Supply voltage variations affect the available motor shaft power. If the supply voltage is lower than the filed weakening point shifts to a lower frequency and the available maximum torque of the motor is reduced in the field weakening range.
The maximum available torque is often limited by frequency converter. This has to be considered already in the motor selection phase. The frequency converter may limit the motor torque earlier than stated in the motor manufactures data sheet.
The maximum available torque is also affected by transformers, reactors, cables etc. in the system because they cause a voltage drop and thus the maximum available torque may drop. The systems power losses need to be compensated also by the frequency converter rating.

Pump and Fan application example.
Check the speed range and calculate power with highest speed.
Check the starting torque needed
Choose the pole number of the motor. The most economic operating frequency is often in the field weakening range.
Choose motor power so that power is available at maximum speed. Remember the thermal load-ability.
Choose the frequency converter. Use pump and fan rating. If the pump and fan rating is not available choose the frequency converter according to the motor current profile. One very important thing to keep in mind is that increasing the Frequency above 50Hz does not give you any increased efficiency. This can be seen in the following table by noting that as the frequency increases past 50Hz the efficiency reduces.

Motor Selection



Electro Magnetic compatibility

EMC stands for Electromagnetic Compatibility (EMC). It is the ability of electrical/electronic to operate without problems within an electromagnetic environment. Likewise, the equipment must not disturb of interfere with any other product or system within its locality. As variable speed drives are described as a source of interference, it is natural that all parts which are in electrical or airborne connection within the power drive system(PDS) are part of the EMC compliance. The concept that a system is as weak as its weakest point is valid here.

Immunity, electrical equipment should be immune to high frequency and low frequency phenomena. High frequency phenomena include electro static discharge (ESD), fast transient burst, radiating electromagnetic field, conducting radio frequency disturbance and electrical surge. Typical low frequency phenomena are mains voltage harmonics, notches and imbalance.

Emission, the source of high frequency emission from frequency converters is fast switching of power components such as insulated gate bipolar transistors (IGBT) and control electronics. This high frequency emission can propagate by conduction and radiation.

Power Drive system, the parts of a variable speed drive controlling driven equipment as a part of an installation are described in EMC product standard EN61800-3. Another worthwhile resource is www.aca.gov.au which is Equipment standards, compliance and labeling index. C – tick.

Levels in Australian EMC Scheme

Level 1 applies to products whose interfering emissions would have a low impact on devices using the radio frequency spectrum. This level covers products that only contain:
Manually operated switches or simple relays
Brushless squirrel cage induction motors; or
Resistive elements.

Level 2 applies to products whose interfering emissions have a higher risk of serious impact on devices using radio frequency spectrum. Examples of these products are:
A microprocessor or other clocked digital device
A commutator or slip ring motor
Arc welding equipment; or
Switch mode power supplies, lighting dimmers and motor speed controllers.

Level 3 applies to products whose interfering emissions have a higher risk of serious impact on devices using radio frequency spectrum. This level covers products in the scientific and medical group 2(CISPR11) and telecommunication terminal equipment under information technology (CISPR22) categories.

Requirement in an Australian scheme,

Level 1 Voluntary C-tick marking
Level 2 Supplier must ensure product complies with an applicable standard and hold compliance records
A completed declaration of conformity
A product description
A test report or technical construction file (TCE)
Level 3 supplier must ensure product complies with an applicable standard
A completed declaration of conformity
A product description
A test report or technical construction file (TCE)

Installation environments

The PDSs can be connected to either industrial or public power distribution networks. The environment class depends on the way the PDS is connected to the power supply. The environment classes are the first and second environment.

First Environment

The First Environment includes domestic premises. It also includes establishments directly connected without intermediate transformer to a low- voltage power supply network which supplies buildings used for domestic purposes.

Second Environment
Second Environment includes all establishments other than those directly connected to a low-voltage power supply network which supplies buildings used for domestic purposes.

Solutions for EMC compatibility.
There are some basic principles which have to be followed when designing and using drive systems incorporating AC drive products. These same principles were used when these products were initially designed and constructed, where such issues as printed circuit board layout, mechanical design, wire routing, cable entries and other special points were all considered in great detail. Drive products are normally immune to a majority of disturbances; otherwise they would be affected by their own disturbances. So in this context only emissions need to be handled.

Conducted emission
Conducted disturbances can propagate to other equipment via all conductive parts including cabling, earthing and the metal frame. Conductive emissions can be reduced in the following way,
By RFI filtering for HF disturbances.
Using sparking suppressors in relays, contactors, valves to attenuate switching sparks
Using ferrite rings in power connection points.

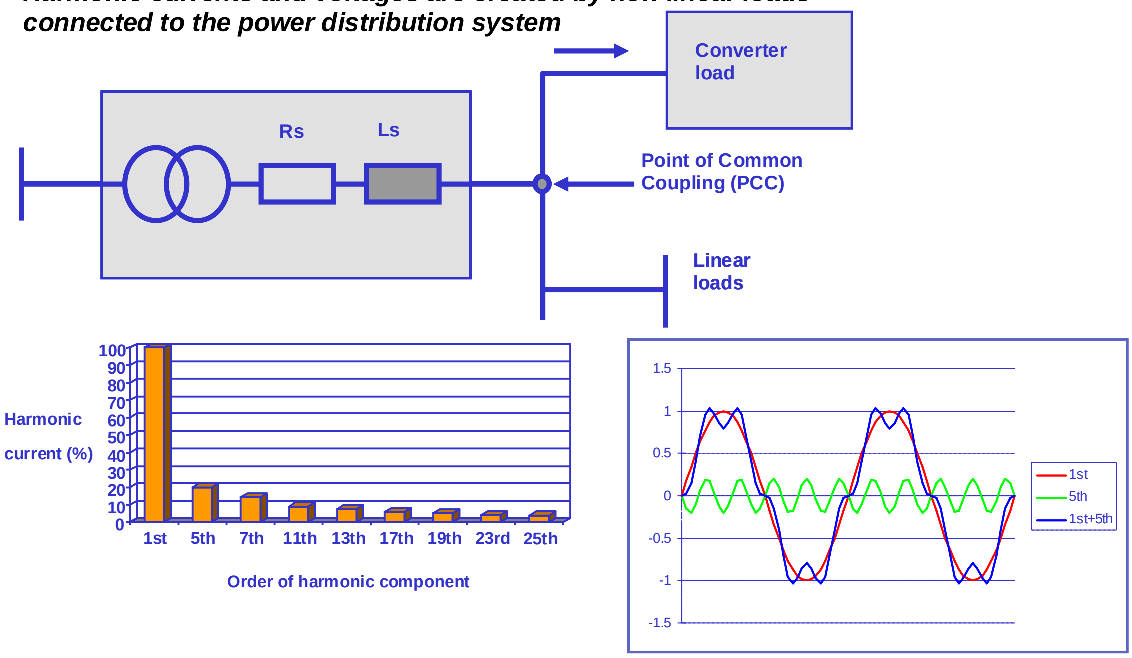
Radiated Emission
To be able to avoid disturbance through air, all parts of the PDS should form a Faraday Cage against radiated emissions. The PDS includes cabinets, auxiliary boxes, cables, motors etc.
Please consult your variable speed drive manufacturer to discuss the following topics before designing your system,
VSD enclosure
Cabling and wiring
Installation, High frequency earthing
RFI filtering

Harmonic distortion

Harmonic currents and voltages are created by non linear loads connected on the power distribution system. Harmonic distortion is a form of pollution in the electric plant that can cause problems if the sum of the harmonic currents increases above certain limits. Some examples of non linear loads include, motor starters, variable speed drives, computers, electronic lighting welding supplies and uninterrupted power supplies. The effects of harmonics can be overheating of transformers, cables, motors, generators and capacitors connected to the same power supply with the devices generating the harmonics. Electronic displays and lighting may flicker, circuit breakers can trip, computers may fail and metering can give false readings.

Basics of the harmonics phenomena

Harmonic currents and voltages are created by non-linear loads connected to the power distribution system



Other things to harmonic consideration are, the content of harmonic current can be affected by the construction of the variable speed drive, i.e. the level of inbuilt harmonic filtering. AC vs DC choke. The type of rectifier or IGBT rectifier, 6 pulse, 12 pulse or 24 pulse.

The harmonic voltage depends on the harmonic current of the drives and other loads connected to the line. However the harmonic voltage also depends on the line impedances' caused by cables, transformers and filters.

There are now significant methods that variable speed drive manufactures have used to reduce the amount of total harmonic voltage distortion (THVD) and careful consultation with your supplier will help you understand the any harmonic mitigation necessary and help you provide a workable and efficient solution.

Summary

The use of variable speed drives within any water and waste water application can provide the design team, end user / operator a very cost effective solution and energy efficient solution that will provide many benefits. These alone are not restricted to the electrical and power components but extend to the mechanical system where other such factors are critical including but not restricted to, life cycle costs, maintenance requirements user interface and ease of operation. In this paper I have discussed some of the broad topics that you will have to consider when incorporating a variable speed drive into your systems however the message is, consult you VSD manufacturer during the design and commissioning stage and ensure you understand all the issues so you can make an informed and correct decision that will provide you with a very workable and energy efficient system.

References: AC Drives Technical Guide Book ABB Oy Drives PO Box 184 FIN-00381 Helsinki Finland
Variable speed pumping. A guide to successful applications. Europump and Hydraulic institute. UK: Elsevier Advanced Technology 2004