Benefits of VSDs for chiller systems

**Summary**

Ontario Hydro Technologies (OHT), in cooperation with the Canadian Electricity Association (CEA) and Siemens Relcon, have installed a 200 hp variable-speed drive (VSD) package to a centrifugal chiller. This variable-speed chiller demonstrated annual energy savings of 41% over a conventional chiller system. The system has operated problem-free since start-up with total harmonic distortion at less than 2.5%. The modified chiller has successfully met all the air-conditioning requirements of the building. Annual savings total around CAD 60,000, resulting in a simple payback period of approximately 7 years.

**Highlights**

- 41% energy savings
- Reduced operation costs and preventive maintenance
- Eliminates complex system controls (vanes)
- Precise control of HVAC system

Centrifugal chiller (175 tons) with VSD drive.
Aim of the Project

The project was undertaken to demonstrate the benefits of variable-speed drives (VSD) in HVAC centrifugal chiller systems and to develop a base of accurate and detailed information for building owners and consultants. While variable-speed drives offer many advantages, they are seldom used in an HVAC centrifugal chiller system. One reason for this is a general unfamiliarity with these systems. This project was initiated to help building owners and HVAC consultants understand the benefits of VSDs, and involved retrofitting a 200 hp variable-speed drive to a 615 kW (175 tons) centrifugal chiller. Monitoring of the modified chiller occurred over one cooling season.

The Principle

Variable-speed drives work by converting AC signals to DC using rectifiers and then inverting these DC signals back to AC. There are several types of VSD drives: frequency drives (maintaining a constant volts-per-hertz ratio), flux vector drives, and servo drives. The variable-speed drive installed at the OHT site is a variable frequency type drive (VFD). The various types of VFDs available include current source, variable voltage and pulse-width modulated (PWM) drives; the OHT site uses a PWM device. These devices are claimed to be the most reliable, affordable, and smallest type of VFD, with a constant volts-per-hertz ratio.

The PWM drive at the site uses Inter Gate Bi-Polar Transistor (IGBT) technology and is 98% efficient. The manufacturer puts the power factor at near unity (0.98).

VSDs can reduce the output capacity of a chiller and still maintain the full-load efficiency. Chillers are normally selected to meet the “worst case” cooling load, usually the hottest day of the year. Consequently, the chillers run at part load for most of the cooling season, though part load operation is usually less efficient and wastes energy. Savings are possible by “overspeeding” the VSD chiller in a multiple chiller system, although this was not required at OHT. Overspeeding can increase chiller capacity so that a second chiller does not need to come online.

The Situation

OHT, in conjunction with Relcon Drives Division of Siemens Electric Limited (Siemens Relcon), has installed and monitored two VSDs on a chiller at the Mechanical Testing and Development building, situated within the Ontario Hydro Kipling Complex. The building was constructed in 1984 and has 7,000 m² of usable floor space. During the cooling season, which lasts from May to October, air conditioning is provided by two York 615 kW (175 ton) R-11 freon centrifugal chillers. Only one chiller operates at any one time, with the other on standby.

In the new situation, the main chiller drive is a 150 kW (200 hp) VSD unit requiring a 575 VAC, three-phase,
60 hertz AC power supply. The unit has the following physical dimensions: 0.91 m x 0.58 m x 2.28 m (see cover photograph). The second VSD is an 11 kW (15 hp) unit for the cooling tower fan (see Figure 1). The drives have a front-mounted operator keypad with a display for accessing information and controlling the VSD.

Power quality effects were studied and do not appear to be a concern. Total harmonic distortion is less than 2.5% and the power factor ranges from 0.75 to 0.87. No VSD operating problems were encountered during the test period and the unit met the air conditioning requirements of the building. Energy and power consumption were monitored along with temperature, pressure and flow rate information. Recorded energy savings are approximately 120,000 kWh, or 41% for this particular site, while demand savings range from 41.4 kW, at an outdoor ambient air temperature of 14°C, to 17.4 kW at 24°C.

Table 1 illustrates energy savings after installation of the VSD system.

The VSD installation did face some barriers. The critical issues are related to availability and compatibility. In a retrofit VSD chiller application, the drive, control package and chiller must operate together. In the OHT case, York did not make a 575 VAC drive for this retrofit application. The chiller and drive manufacturers need to collaborate to convince the owner of the system’s merits. Another important factor is that the chiller warranty may be voided if a company other than the chiller manufacturer supplies and installs the VSD. Finally, a very important aspect of VSD installation is the training of maintenance staff. The VSD and its control package contain state-of-the-art technology, so training sessions should be part of the installation and commissioning process.

The Company

OHT (formerly the Research Division of Ontario Hydro) is a subsidiary of Ontario Hydro and supports its other business units in the operation of the electric power system. Ontario Hydro Technologies has a wide range of experience in all aspects of the electric power system, from electrical, metallurgical and chemical to environmental. It has a staff of around 550 professional, technical and support employees. Ontario Hydro is a member of the Canadian Electricity Association (CEA).

Economics

The cost of the VSDs, installation and commissioning was approximately CAD 60,000 including CAD 37,000 for the drives, CAD 8,000 for the controls, and CAD 15,000 for installation and commissioning. The total annual energy savings of the retrofitted system were approximately 119,000 kWh, i.e. the chiller VSD saved 115,000 kWh (43%) and the cooling tower VSD saved 4,000 kWh (19%). Based on an energy cost of CAD 0.07/kWh, the VSD saves CAD 8,300 per year. This translates into a simple payback period of 7.2 years. However, there are other savings associated with the VSDs, such as reduced preventive maintenance and improved reliability. Also, when chiller manufacturers eventually offer VSDs as standard equipment, the total package price will be far less than retrofitting a VSD on a conventional chiller.

Table 1: Energy savings after installation of the VSD system.

<table>
<thead>
<tr>
<th>Energy Consumption (kWh)</th>
<th>Main chiller</th>
<th>Cooling tower</th>
</tr>
</thead>
<tbody>
<tr>
<td>without VSD</td>
<td>268,572</td>
<td>19,968</td>
</tr>
<tr>
<td>with VSD</td>
<td>153,416</td>
<td>16,227</td>
</tr>
<tr>
<td>Energy Savings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>in kWh</td>
<td>115,156</td>
<td>3,742</td>
</tr>
<tr>
<td>in percentage (%)</td>
<td>43%</td>
<td>19%</td>
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</tbody>
</table>
### IEA

The IEA was established in 1974 within the framework of the OECD to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the 24 IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology, and research and development (R&D).

This is achieved, in part, through a programme of energy technology and R&D collaboration currently within the framework of 40 Implementing Agreements, containing a total of over 70 separate collaboration projects.

### The Scheme

CADDET functions as the IEA Centre for Analysis and Dissemination of Demonstrated Energy Technologies. Currently, the Energy Efficiency programme is active in 12 member countries and the European Commission.

This project can now be repeated in CADDET Energy Efficiency member countries. Parties interested in adopting this process can contact their National Team or CADDET Energy Efficiency.

Demonstrations are a vital link between R&D or pilot studies and the end-use market. Projects are published as a CADDET Energy Efficiency ‘Demo’ or ‘Result’ respectively, for ongoing and finalised projects.

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