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Variable Frequency Transformer – A New Alternative For Asynchronous Power Transfer

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***Abstract* - A new power transmission technology has been developed. The variable frequency transformer (VFT) is a controllable, bi-directional transmission device that can transfer power between asynchronous networks. Functionally, the VFT is similar to a back-to-back HVDC converter.**

The core technology of the VFT is a rotary transformer with three-phase windings on both rotor and stator. A motor and drive system are used to adjust the rotational position of the rotor relative to the stator, thereby controlling the magnitude and direction of the power flowing through the VFT.

The world's first VFT was recently installed in Hydro-Quebec's Langlois substation, where it will be used to exchange up to 100 MW of power between the asynchronous power grids of Quebec (Canada) and New York (USA).

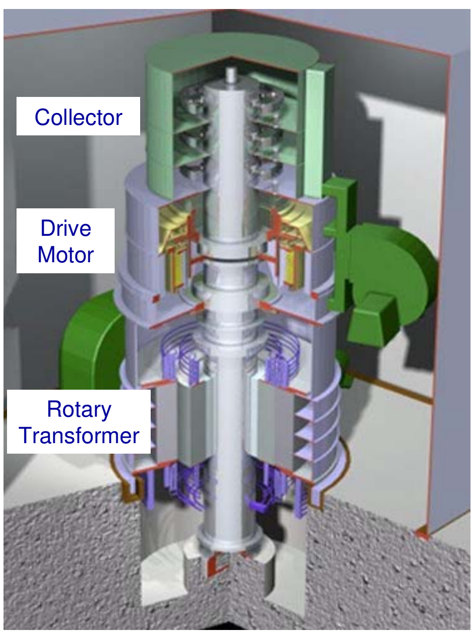
This paper describes the VFT technology and provides an overview of the VFT equipment installed at Langlois substation. Results of commissioning tests are also included.

***Index Terms* - Interconnections, Asynchronous, Electric Power Transmission, Controlled Power Flow**

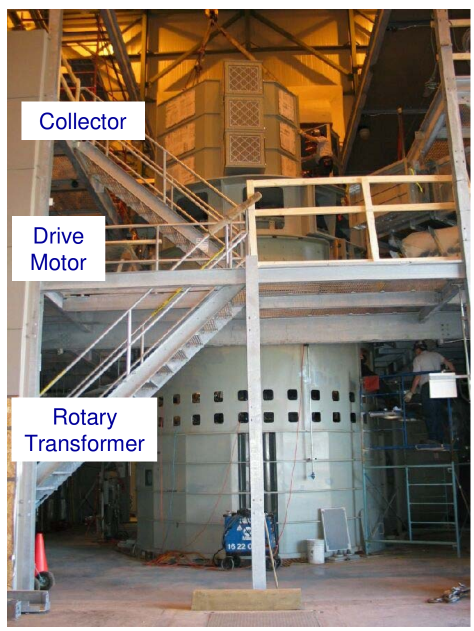
I. General VFT Concept and Core Components

The variable frequency transformer (VFT) is essentially a continuously variable phase shifting transformer that can operate at an adjustable phase angle. The core technology of the VFT is a rotary transformer with three-phase windings on both rotor and stator (see Figure 1). The collector system conducts current between the three-phase rotor winding and its stationary buswork. One power grid is connected to the rotor side of the VFT and another power grid is connected to the stator side of the VFT.

Power flow is proportional to the angle of the rotary transformer, as with any other ac power circuit. The impedance of the rotary transformer and ac grid determine the magnitude of phase shift required for a given power transfer.



Cut-away Drawing of VFT



Photograph of Langlois 100 MW VFT

Figure 1. Core components of the VFT

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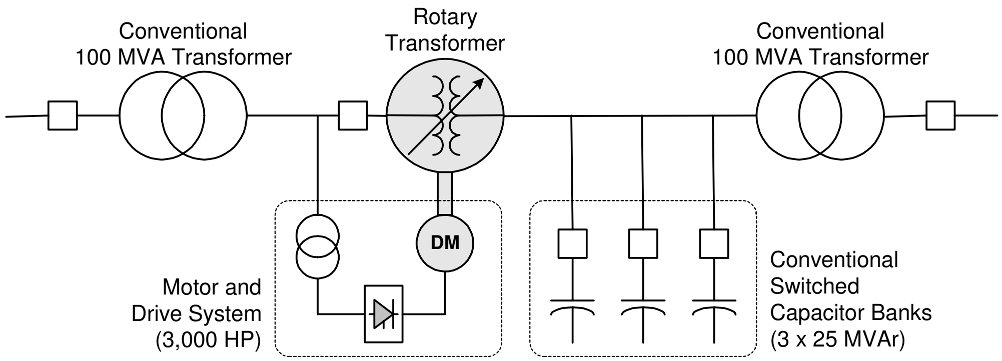

Figure 2. One-line diagram of Langlois VFT.

Power transfer through the rotary transformer is a function of the torque applied to the rotor. If torque is applied in one direction, power flows from the stator winding to the rotor winding. If torque is applied in the opposite direction, power flows from the rotor winding to the stator winding. Power flow is proportional to the magnitude and direction of the torque applied. If no torque is applied, no power flows through the rotary transformer. Regardless of power flow, the rotor inherently orients itself to follow the phase angle difference imposed by the two asynchronous systems, and will rotate continuously if the grids are at different frequencies.

Torque is applied to the rotor by a drive motor, which is controlled by the variable speed drive system. When a VFT is used to interconnect two power grids of the same frequency, its normal operating speed is zero. Therefore, the motor and drive system is designed to continuously produce torque while at zero speed (standstill). If the power grid on one side experiences a disturbance that causes a frequency excursion, however, the VFT will rotate at a speed proportional to the difference in frequency between the two power grids. During this operation the load flow is maintained. The VFT is designed to continuously regulate power flow with drifting frequencies on both grids.

A closed loop power regulator maintains power transfer equal to an operator setpoint. The regulator compares measured power with the setpoint, and adjusts motor torque as a function of power error. The power regulator is fast enough to respond to network disturbances and maintain stable power transfer.

Reactive power flow through the VFT follows conventional ac-circuit rules. It is determined by the series impedance of the rotary transformer and the difference in magnitude of voltages on the two sides.

Unlike power-electronic alternatives, the VFT produces no harmonics and cannot cause undesirable interactions with neighboring generators or other equipment on the grid.

II. Langlois 100 MW VFT Station

Hydro-Quebec's Langlois substation is located southwest of Montreal, Quebec, at the electrical interface between the Quebec and USA power grids. A 100 MW VFT was installed at Langlois to enable power transfer between the two asynchronous power grids.

Figure 2 shows a simplified one-line diagram of the Langlois VFT, which is comprised of the following:

- One 105 MVA, 17 kV rotary transformer
- One 3000 HP dc motor and variable speed drive system
- Three 25 MVAr switched shunt capacitor banks
- Two 120/17 kV conventional generator step-up transformers

Figure 3 shows a typical physical layout for a 200 MW VFT station, with two 100 MW VFT units. The Langlois VFT station will ultimately be similar to this. At present, the first 100 MW stage has been completed at Langlois. The existing building is designed to be expandable. The yard has space for transformers, capacitor banks, and switchgear associated with the second VFT unit.

Figure 3. Physical layout of a 200 MW VFT station with two units.

III. VFT Operation and Control Features

From an operational perspective, a VFT is very similar to a back-to-back HVDC converter station. The VFT has automated sequences for energization, starting, and stopping. When starting, the VFT automatically nulls the phase angle

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