

Energy Efficient Hydraulics

Variable Frequency Drives as Pump Prime Movers

It is obvious what we want to achieve with variable speed pumps: saving energy and reducing noise and possibly increasing the power density of hydraulics. To explain only how to put the electro-hydraulic package together gives not enough insight. The total hydraulic system functionality needs to be looked upon in the light of its competing technologies.

In industrial applications hydraulic pumps are electrically driven since ever. The conversion to variable speed is more an upgrade of an existing solution than a major modification. In mobile systems hydraulic pumps are diesel driven today. Electricity to move the pump needs to be additionally generated either by a diesel driven generator or a fuel cell and then stored in batteries. Both leads typically to a complete vehicle redesign and therefore it is a longer way in mobile to get to frequency controlled pump speeds. Technically there is no major difference beside the conversion from the DC battery supply to the AC for the motor

Nevertheless it is worth to look at the paradigm shift which the introduction of variable frequency drives has at electrically generated rotary and linear motion. Hydraulics is seen here only as one gear box mechanism amongst others. The so called “Electro Hydraulic Actuator” may be an interesting solution in some special applications but not a viable general solution in multiple motion applications. There is additional cost for converting electric power into hydraulic pressure and flow. This conversion can commercially not be carried per motion. The conversion should be done in a central power unit and the cost spread over multiple motions.

The electric drive should not be seen only as competition but as partner bringing technological progress and making hydraulics more competitive. Electric drives have made great progress in eliminating gear boxes and converting huge forces into linear motion. There are many examples of full electric presses which were in the past a domain of hydraulics.

There are different electric motor principles on the market from the induction motor over the permanent magnet motor to the reluctance motor which all need to be well understood by the hydraulic engineer putting the electro-hydraulic pump package together.

In hydraulic linear motion the asymmetry of a single rod cylinder can be compensated with modern integrated regenerative valves. This needs consideration in minimizing the flow demand from the pump before laying out the electric drive and hydraulic pump package

The beauty of a 3 phase electric grid is its design to generate the rotating field of an electric motor. It only needs the determination of the number of poles in the motor to set the speed. If we insert a frequency inverter and make the speed variable to the lower and to the higher side we only need to choose the motor with the most suitable RPM range to drive our hydraulic pump. Typically the 4 pole induction motor is the preferred choice or a permanent magnet motor with an equivalent RPM range. Special consideration needs the motor cooling because a hydraulic pump runs down to very low speed and up to high speed. The design of the motor cooling varies from heat dissipation through the housing surface, to a cooling fan rotating with the motor RPM, to a separate cooling fan, to fluid cooling of the housing. The most common for induction motors is the fan running with motor speed. This solution is particular sensible to full torque at low speed and the motor size needs careful dimensioning.

There are different hydraulic pump principles on the market from gear over vane to piston pump. Their speed range under full pressure varies a lot with their frame size. Generally a smaller pump goes to higher max speed and creates less noise. The min speed depends more on the pumping principle than on the frame size. A hydraulic pump is lubricated by the hydraulic fluid. All pumps need to rotate for lubrication and cannot stand still under pressure. The marriage of the hydraulic pump and the electric motor starts with the selection of the pump under consideration of the desired speed for achieving the flow. The torque to turn the pump and thus the motor size depends only on the chosen pump displacement and the pressure. The required drive power is the torque multiplied with RPM. Higher RPM results in higher power density of the motor and of the pump as well.

Variable Frequency Drives as Pump Prime Movers were introduced into the market with the internal gear pump. Small displacement pumps with low inertia can run with flow and pressure control from the motor. High precision gears are complicated to make and due to a single pumping chamber strong bearings are needed to keep the gear position in tight tolerances. The over decades well known vane pump offers here - with its two balanced pumping chambers and interchangeable cartridge w/o bearings - new opportunities. The cartridge can be integrated in a motor with extended shaft and allow an extremely compact package. Vane pumps are also available as double or triple pumps in a common housing and work as simple switchable pump combination in order to choose the smallest possible motor for the application. A variable piston pump needs either to stroke in reverse flow direction to decompress or alternatively a pressure compensated pump is used with a small relief. The relief is piloted by the pump controller. A combination of a fix vane with its low losses at low pressure and a variable piston pump with its high efficiency at high pressure is very often the most energy saving solution.

Putting the electro-hydraulic package consisting of drive, motor and pump together means all inefficiencies get added up and the target is to minimize. Good results cannot be achieved in a try and error approach. An intelligent software tool is needed which has stored all individual component efficiencies in relation to their parameters. At first the flow and pressure demand vs time is entered into the so called DriveCreator tool. A pump or pump combination is selected. The pump choice determines the required torque and hence the motor is selected. The motor temperature is calculated at the given machine cycle in continuous operating mode. The chosen motor requires a current and hence a suitable drive is selected. Different solutions can be compared with regard to their consumed energy. A solution with inverter can be compared against running the motor straight from the grid. How much energy is saved in a specific application depends entirely on the machine cycle.

For the startup of the drive a set up tool is helpful to reduce the amount of programming work. The motor data can be entered from the nameplate and a preconfigured operating mode e.g. accumulator charging, p/Q control or other can be chosen.