Reducing pressure—increasing efficiency

In several industrial processes, a fluid under high pressure must be throttled to suit subsequent process steps. Typically, conventional pressure-reducing valves are used to dissipate, and consequently waste, this hydraulic energy. Hydraulic power recovery turbines (HPRT’s) can convert the excess pressure into mechanical shaft energy and increase the overall process efficiency. Sulzer Pumps has years of experience in using reverse running pumps as turbines as an economical solution to recover energy.

Generally, pumps are a means of fluid transport that convert mechanical energy into hydraulic energy; i.e., pumps increase fluid pressure. When process conditions call for pressure to be dissipated, a pump running backwards may be used to capture that otherwise wasted energy. The reverse running mode converts hydraulic energy into mechanical energy and can be used to drive a generator or to assist the driver of other rotating machines. By using an HPRT, as much as 85% of the energy otherwise wasted in a throttling valve can be captured. When modified standard pumps are used as HPRTs, investment costs are low as compared with those for conventional turbines. Energy recovery may merit consideration even if the pressure reduction is relatively small.

Almost any centrifugal pump can operate as a turbine. The direction of fluid flow is reversed compared with that in a pump. The pump discharge flange becomes the inlet of the HPRT, and the pump suction flange becomes the outlet, or exhaust. For larger HPRTs, the interior of the pump casing is modified to provide uniform flow to the runner.

Energy recovery
Conventional hydraulic turbines can be of axial, mixed, or radial flow type, and single or multistage. Differential head, flow, and speed govern which type is applied for a particular application. These three parameters determine the specific speed of a hydraulic machine. Specific speed is a characteristic number for each pump or turbine, and it increases with higher flow and lower head. High specific speed (axial flow) runners are used for lower head and higher flow, as in run-of-river hydropower plants.

Single-stage or multistage radial-flow or mixed-flow turbines are used for higher heads. For very low flow with high head, an impulse, or Pelton turbine may be an appropriate choice. The power output of a hydraulic power recovery device is a function of flow and head. Reaction type turbines are used for power ratings between 500kW and about 700MW in hydropower plants.

In some industrial installations, such as reverse osmosis plants, petroleum refineries, fertilizer plants, and gas treating facilities, some processes may need to operate at high pressure. For example, amine contactors are widely used to scrub CO₂ and H₂S from natural gas. The contactor operates at pipeline pressure. Then pressure is reduced to flush out various components of the process stream. Usually throttling devices (valves, orifices etc.) are used to reduce the pressure. Single-stage HPRTs can be used to recover that energy. In refining hydrotreaters, multistage HPRTs may be needed due to the large pressure drop required.

Know-how for correct layout
When planning the use of a pump as turbine, it is essential to know the differences in machine performance when reversing flow direction and sense of rotation. For equal rotational speed and runner diameter, the following general differences are noted:

- The efficiency at the best operating point of the turbine corresponds...
approximately to that of the pump, or it can be slightly higher depending on the size of the machine.

- The efficiency curve under overload conditions drops more slowly in the turbine than in the pump mode since the losses are associated with a high power.
- The best efficiency point of the turbine is located at higher flow rate and higher head. That means the capacity is higher in the turbine mode than when pumping.
- In most instances, the shaft power at the best operating point of the turbine is somewhat higher than that at the corresponding point of the pump.
- Susceptibility to cavitation is lower in the turbine than in the pumping mode, since the low pressure zone is at the runner outlet in turbine mode.

Sulzer has provided hundreds of HPRTs in various configurations and has established methods to calculate HPRT performance from pump performance. However, if exact data are necessary, it is essential to test the HPRT. Turbine testing requires a lot of equipment and thus costs measurably more than pump testing.

A booster pump with sufficient power must be used to provide the inlet flow and high inlet pressure. The output power of the HPRT must be measured with a calibrated generator, torque meter, or dynamometer. Measurements of power, flow, and pressure are used to calculate turbine efficiency. To avoid cavitation at the HPRT outlet, backpressure at the outlet must be controlled.

**Considering the complete system**

Determination of the runaway speed is essential for the operation of the reverse running pump. Runaway is the operation at maximum speed and no load. This is an exceptional case that occurs when the generator loses its grid connection due to a power outage or lightning strike. Runaway could occur in fractions of a second and has to be considered in the layout of a hydraulic system. Runaway speed of a radial machine

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1. Large water turbines can have a power rating of 700 MW or more. At much smaller ratings, conventional pumps running as turbines are an economical solution for pressure reduction in industrial processes.
In many cases, a single-stage HPRT is used to capture the process stream energy and drive a multistage pump. 

Typical HPRT test setup in a closed loop.

Hydropower turbines have flow control devices, such as wicket gates, which help to avoid high pressure surge during transient conditions. In process HPRT applications, the turbine bypass is always slightly open and is quickly adjusted to maintain inlet vessel level control when the turbine inlet valve trips.

Operating with two-phase flow
Care must be taken when starting up an HPRT. When an HPRT is driving a generator, it is normally spun-up to near synchronous speed, the generator is switched to the power grid, which provides a load. Without load, the HPRT may quickly overspeed.

Process control is important when applying HPRTs. If the pressure in the exhaust vessel is lowered by 20%, head across the turbine increases, and it will generate 20% more power than at the rated flow and head. For that reason, it is often prudent to oversize the HPRTs, shunt torque capacity to take into account various system upsets in pressure control.

Processes have to be started before the HPRT can be brought on stream. Often, there will be a full-size pump with motor driver to get the process started and a parallel HPRT clutch motor pump that is used during normal operation.

For processes with entrained gas or vapor (natural gas treating, fertilizer plants, hydrotreaters, etc.), a small volume percent of gas at the high-pressure side will turn into a measurable volume at the low-pressure side. This gas volume at the outlet may influence the size of the HPRT. The high gas volume in the exhaust may not be an issue if the shaft is robust, the runner is made of cavitation-resistant materials, and the wear parts are hardened to reduce contact damage. However, gas bubbles in the seal chamber will surely do damage to the mechanical seals. Dual seals within Plan 53 or 54 are therefore recommended for process HPRTs to assure that the mechanical seals operate in a controlled, liquid state.

Application in hydrocarbon processing
A large Brazilian oil company is using pumps as turbines instead of throttle valves and is thus recovering energy.

In one case, liquid charged with gas must be expanded in a scrubbing tower. Sulzer worked with oil company engineers to understand the multiphase flow. That knowledge was then used to design the HPRT’s runner and rotor. The experience of Sulzer Pumps in designing such HPRTs helped to find a solution for these challenging conditions.

Between the inlet and outlet of a turbine, the pressure drops in very short time. Gas dissolved in the fluid at high pressure diffuses out of the liquid causing gas bubbles to form, resulting in two-phase flow. The required pressure reduction is from 74.8bar (1080psi) to 14.8bar (210psi). A five-stage HPRT with one dummy stage was chosen, so that a further stage may be fitted for smaller flow rates in the future. The continuous power of 258kW recovered from the expansion assists the 870-kW motor driving the pressure increasing pump. A pump running as a turbine is difficult...
to regulate. Depending upon the pressure drop and application, an HPRT flow rate may be established amounting to 80%–90% of the effective throughput. The remaining 10%–20% of the flow is expanded via a bypass valve and is used to control the vessel level supplying the HPRT.

During plant startup, the turbine cannot perform work and may actually consume energy. If the motor must be used for startup, an overrunning clutch prevents the motor from having to put additional energy into the turbine during this phase. Once the hydraulic energy at the inlet to the HPRT is sufficient, the turbine runs up to the motor speed. The overrunning clutch now ensures that the HPRT cannot run faster and supplies its hydraulic energy to the drive train.

### Short payback times

In many industrial processes, hydraulic power recovery turbines (HPRTs) can provide substantial savings with a short payback period. It is not uncommon to find that over 1.5 MW can be recovered. Careful attention to process conditions and HPRT controls assures reliable, useful operation for years of service.

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