The ERS Taimeralm: a 2.5MW turbine with an annual production of approximately 11.5GWh

POWER FROM PIPELINES

Thomas Rother explores energy recovery in crude oil pipelines

In some oil pipelines pressure reduction systems are installed to guarantee a smooth and safe operation (mainly in pipelines with high elevation differences). Such systems convert pressure or kinetic energy into heat. The question is whether it is also possible to transform the kinetic energy into electricity? The answer is yes.

ILF recently had the chance to investigate a potential pipeline system for the installation of a turbine for energy recovery in a crude oil pipeline. The system needed to overcome a hill. To avoid slackline regions, which makes it easier for leak detection and pigging, a back pressure control valve (PCV) was installed. Depending on the pipeline system flow rates the PCV converted energy in the range of 1.5MW to 8MW.

PIPELINE SYSTEMS AND ENERGY RECOVERY CONFIGURATIONS

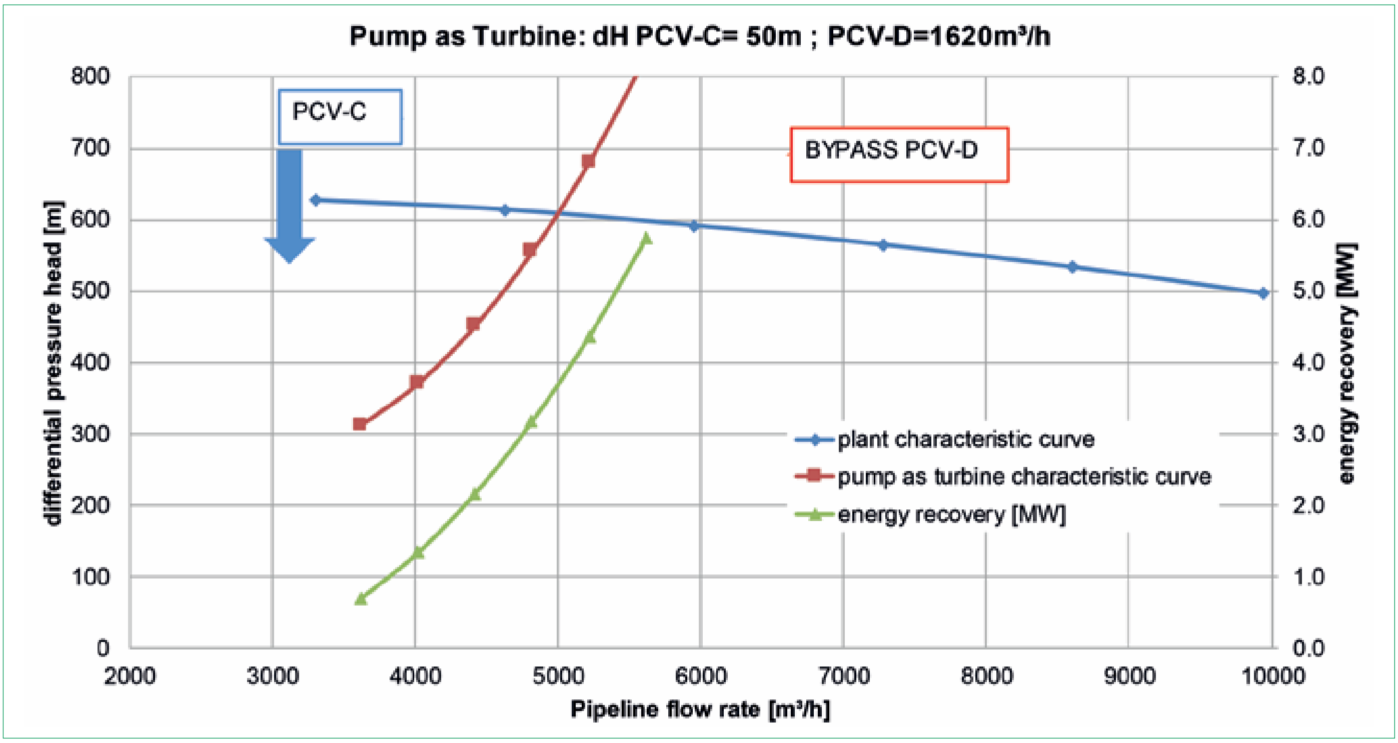
Starting with two pipeline sections, the potential energy that could be recovered was discussed. One main aspect was that the energy recovery system must not influence the goal of the pipeline system: oil transport. Another aspect was that pipelines are normally operated at different throughputs with changing pressure conditions. The resulting system curves needed to be considered when selecting the recovery system, which could be a reverse-operating pump or turbine. In addition, the task of the recovery system influenced the sizing of the energy recovery system. Energy can be produced either for consumers in a demand-driven island-mode or for a grid with a maximum possible energy recovery mode.

In general, systems can be used where pressure reduction or back PCVs are installed. At each pressure reduction valve pressure will be converted into heat, vibration and noise. In the above example a 48in pipeline is considered. A hill (with about 700m height) is located 30km upstream of the storage tank terminal.

Within the project it was decided that only one unit, either one pump as turbine (PaT) or one turbine, should be used. Together with the required power recovery range of between 1.5 and 3.5MW, at all given process conditions (flow/pressure) the task was to find proper solutions for both systems. For a pump there is one characteristic curve. To recover a specific amount of energy the pump must be operated at the corresponding intersection point between the system curve and pump characteristic.

Fig. 1 shows the system curve (blue) together with the pump characteristic curve (red line). The green line shows the recovered energy that can be obtained (for a certain crude density of 834kg/m^3). The energy values of the green line are calculated by the pump head, pump flow and efficiency. Pump characteristic curve and energy recovery curve cover always the same flow range.

Fig. 1. Pump as turbine - operating point



The recovered amount of energy is given at the intersection point between the system curve and the pump characteristic. In this case the recovered energy would be about 3.6MW. The pipeline flow is about 5,000m^3/h, the flow through the bypass PCV, PCV-D is 1,620m^3/h and an additional pressure loss of 50m must be generated at PCV-C.

For turbines, the given ratio between flow and pressure head leads to a design with operating points on the left side of the turbine characteristic. The required energy can be recovered in the range between 1.5MW and 3.5MW. However, the turbine is oversized regarding the initial approach. The potential energy recovery of the turbine is up to about 8MW.

Using that turbine it was possible to recover the requested energy with all different pipeline operations. The request to recover energy up to 3.5MW even at smaller flow rates requires turbine operation with high differential head. This enables the turbine to recover energy up to 8MW, too. To handle the higher amount of energy, the electrical system needs to be adapted accordingly.

OPERATIONAL CHALLENGES

The installation of the system must be done in a way that the main goal of pipeline operation is possible all the time. Therefore, the energy recovery system needs to be installed in parallel to the existing line. In addition the existing task of the control valves must be kept. That is to control the backpressure – to avoid slackline operation.

The energy recovery systems can only be used if the pipeline is operation. Furthermore, the energy recovery system must be easily started and stopped.

In case of a pipeline emergency shutdown (ESD), the turbine generator will be stopped immediately; energy can't be recovered any more. In this case the grid load must be considered. The evaluation of the grid stability is one of the main tasks. If the recovery system is designed for island mode, a kind of priority list can be installed to stop electrical consumers in preferred order. In island mode it is also important to ensure the energy balance between energy recovery and consumers. What happens if the island consumers need less energy than the minimum recoverable energy? In that case the installation of a load bank can help.

COMMERCIAL ISSUES

What is the benefit of an energy recovery system? It can be estimated using the following rule of thumb. Pressure loss (in bar) of the PCV divided by 10 and multiplied with the flow rate [m^3/s] results in the potential energy (in MW). Assuming that 70% of the potential energy could be recovered this leads to:

P [MW] = dP [bar] / 10 * Q [m^3/s] * 0.7"

The energy recovery is only an add-on. It is not required for the normal operation and main task of the pipeline. One important question needs to be clarified: is it possible to feed the grid all the time? Together with the pipeline availability this results in the benefit of such systems. Assuming 10 €/MW, the earning per year (in total 70% of the year energy recovery operation: 6,132 h) can be calculated:

Earning [€] = P [MW] * operating hours [h] * 10 [€]
Example 1 = 3.5 [MW] * 6132 [h] * 10 [€] ~ 214.000€
Example 2 = 2.1 [MW] * 6132 [h] * 10 [€] ~ 129.000€

Installing energy recovery systems in oil pipelines is not something that's done as standard. There is no general, ready-to-use solution. Each system must be designed individually and the required machines must be carefully selected. Therefore, there must be close contact with the manufacturers. In contrast to many conventional tasks, such projects also have to take into account the efforts of the manufacturers, as otherwise it may be difficult to obtain the necessary information in time. ●

Thomas Rother is with ILF.
www.ilf.com