Use of Expansion Turbines in Natural Gas Pressure Reduction Stations

Jaroslav Poživil [1]

Využití expanzních turbín při redukci tlaku zemního plynu

Through the use of expansion turbines in natural gas pressure reduction stations it is possible to produce clean, "green" electricity. Such energy recovery unit utilize the potential energy of natural gas being delivered under high pressure. Expansion turbines are not only efficient and profitable but meet the environmental criteria – no emissions of sulfur dioxide, nitrogen oxides or carbon dioxide.

Key words*: Expansion Turbines, Natural Gas Pressure*

Introduction

Natural gas is transported for longer distances through transit pipeline at high pressures (5 - 7 MPa). In a place of consumption or at passing into a lower pressure pipeline the pressure of the gas must be reduced. In transmitting stations the pressure must be reduced from 5-7 MPa to 1.5-4.0 MPa (usually to 2.5 MPa) into high pressure intrastate pipeline, then to approximately 0.3 MPa into medium pressure intrastate pipeline.

Standardly, gas pressure reduction is accomplished in throttle-valves, where the isenthalpic expansion takes place without producing any energy. Most gases cool during the expansion (Joule-Thompson effect). The temperature drop in natural gas is approx. 4.5-6°C per 1 MPa, depending on gas composition and state. The gas must be preheated before the expansion to ensure that no liquid or solid phase condenses at the output temperature.

When an expansion turbine driving a generator is used in place of the throttle valve, the energy in the gas can be used to produce electricity. The work the gas performs is gained from its internal energy (enthalpy) and the gas cools rapidly in the turbine. The temperature drop in the expansion turbine is approx. 15-20°C per 1 MPa of pressure drop in transmitting stations from transit pipeline depending on gas composition and state, and on turbine's isentropic efficiency. When using an expansion turbine, gas outlet temperature must remain above hydrate zone and dew point. This means the gas must be pre-heated before it enters the turbine to temperatures higher than when using throttle valves, usually to 55-85°C. Reliability of the pressure regulating and reduction stations must be assured, and therefore the expansion turbines are installed parallel to existing conventional pressure reducing valves.

Expansion turbines are relatively small and compact, and are usually coupled with a generator in one power pack. The power output can be between hundreds of kW to several MW. Radial expansion turbines are, based on natural gas pressure drop, either one- or two- pressure stage constructions. Regulation valve is used to control the flow-rate of the gas; the turbines used are high-speed with variable wheel speed (for smaller turbines with power output of hundreds of kW this is as much as 40 000 rpm), and therefore the produced alternate current must be converted to 50^{o}Hz in frequency converter. An alternate configuration is often encountered where a turbine with fixed shaft speed is used, connected to a gearbox that reduces it to 3 000 rpm to produce alternate current directly at 50 Hz. The waste heat produced in the system (generator, gearbox, frequency converter) is used to preheat the gas.

Mathematical Model of Expansion Turbine

In our work we are using general flowsheet simulator HYSYS.Process 2.2 [1], [2] that is intended particularly for steady state continuous chemical processes simulation. It is provided with simple and user friendly graphics interface. Gas processing is believed to be an area where simulations could be used very advantageously because hydrocarbons and other organic compounds do not cause such troubles at calculations as strong polar and strong dissociated compounds.

HYSYS differs from many of the alternative simulators in two main respects. First, it has facility for interactively interpreting commands, as they are entered one at a time, whereas most of the other flowsheet simulators require that a RUN button be pressed after new entries are completed. Whenever a stream variable is altered, the adjacent process unit is resimulated. Second, it has the unique feature that information propagates in

[1] *Jaroslav Poživil*, Prague Institute of Chemical Technology, Dept. of Informatics and Control Engineering, Technická 1905, 166 28 Praha 6, Czech Republic, tel. +420/224 354 259, fax +420/224 311 082, pozivilj@vscht.cz

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both forward and reverse direction. This bidirectionality often makes iterative calculations and the use of ADJUST operation unnecessary. The HYSYS simulator is a notable exception in that any combination of specifications is permitted for each simulation model. These two features make the program fast responding and relatively ease to use.

Model of expansion turbine has been created in HYSYS (Fig. 1). For computation of state variables we have used Peng-Robinson's variant of Redlich-Kwong equation. Bidirectional information flow in HYSYS enables that after entering of temperature of output stream temperature of input gas and necessary heat flow so as the output temperature achieves just 3°C that secures no liquid or solid phase condensation.

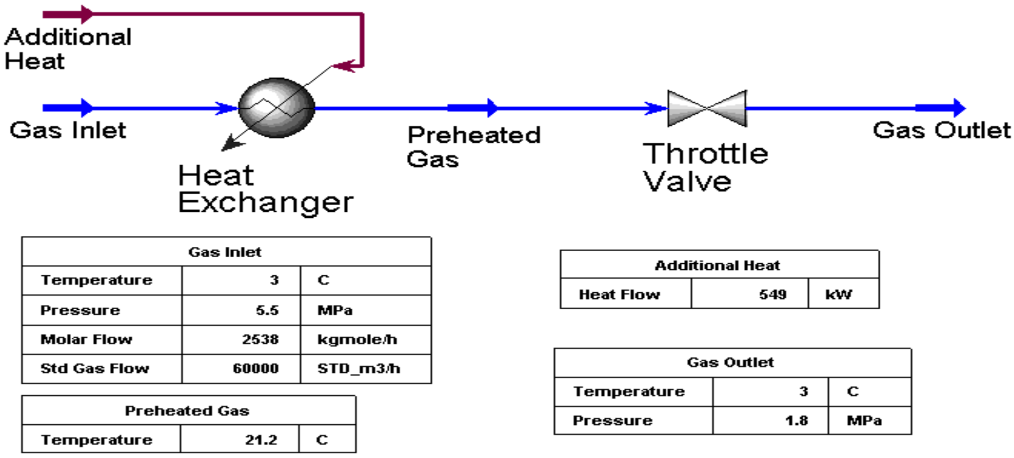

Fig. 1 Process flowsheet diagram of expansion turbine

Simulation of expansion turbine requires following input data:

- natural gas flow rate and its composition
- gas pressures at the inlet of reduction station and at the outlet of reduction station (pressure drop)
- desired value of the expander's discharge temperature
- isentropic efficiency of expander, electricity generator efficiency and frequency converter efficiency or gearbox efficiency (accordance with the way of transmission of high rotation speed to 50 Hz)

The main simulation results are electric power output and requirements for preheating of natural gas (necessary heat flow). The calculated value of temperature at the input of turboexpander is necessary for choice of the heating medium.

Simulation Results and Discussion

As input data for our calculations we used parameters of natural gas in gas transmitting station Velké Němčice [3]. Standard (average) values with which we compare our further results are: gas flow rate of 60 000 Nm^3/h, the inlet and outlet temperatures are both assumed to be 3°C, the pressure in transit pipeline is assumed to be 5.5 MPa, reduced to 1.8 MPa. Composition of gas was taken of analysis of Russian natural gas (96 vol.% CH_4, 0.6 vol.% C_2H_6, 0.2 vol.% C_3H_8, 3.1 vol.% N_2 a 0.1 vol.% CO_2. Further input data are: turbine‘s isentropic efficiency 80 %, electricity generator efficiency 95 % and frequency converter efficiency 97 %. Heat losses were estimated on the basis of our measurements [4] whereas we identified 80 % waste heat recovering.

First we have computed the results for standard (average) values. Results of the computation are shown in column 1 of Table 1. Further we have examined influence of pressure drop in bounds that commonly occur at gas transmitting station Velké Němčice. Columns 2 and 3 of Table 1 illustrate influence of input pressure and columns 4 and 5 the influence of output pressure. It should be evident that pressure drop is an important parameter that greatly influences both power output and requirements on preheating. Columns 6 and 7 of Table 1 show the influence of outlet temperature; this temperature is often kept at +3°C even if dew point is even -10 or -15°C. The most important characteristic of expansion turbine is isentropic efficiency. It is defined as a ratio of the real turbine output in which losses of mechanical energy through friction happens to the theoretical ideal turbine output. Isentropic efficiency depends on turboexpander design, e.g. efficiency of radial inflow turbines is higher than efficiency of axial turbines. It defines the highest power output we can obtain from a gas in a given state. With our model we calculated influence of turbine's isentropic efficiency on power output, heat consumption and temperature at expander inlet. The results are represented in Fig. 2.

Tab. 1 Results of simulation of a typical expansion turbine installation

Input Data								
gas properties at inlet:								
column number		1	2	3	4	5	6	7
flow rate	Nm^3/h	60000	60000	60000	60000	60000	60000	60000
temperature	°C	3	3	3	3	3	3	3
pressure	MPa	5,5	6,3	4,5	5,5	5,5	5,5	5,5
gas properties at outlet:								
temperature	°C	3	3	3	3	3	-7	13
pressure	MPa	1,8	1,8	1,8	1,4	2,3	1,8	1,8
Results								
temperature at turbine inlet	°C	71,3	80,2	58,3	86,1	56,7	60,2	82,3
heat energy requirements	kW	1939	2242	1525	2356	1530	1617	2261
power generation	kW	1367	1547	1107	1719	1036	1309	1424
thermal efficiency	%	70,5	69,0	72,6	73,0	67,7	81,0	63,0
thermal efficiency after subtraction of the heat for elimination of J.-T. effect	%	98,3	98,3	98,4	98,3	98,4	98,4	98,4

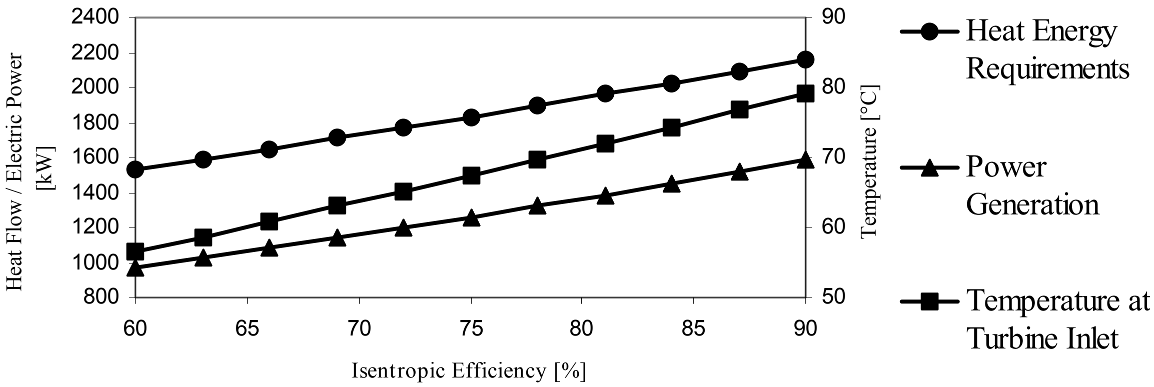

Fig. 2 Dependence of power output on expansion turbine's isentropic efficiency

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