Start-up of Parallel Turbo Expander-Compressor Units Operating In Hydrocarbon Processing Plants

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Doug Bird bp Energy Canada
Reza Agahi Atlas Copco Gas and Process
Behrooz Ershaghi Mafi-Trench Co.
Capacity of hydrocarbon processing plants have increased since turbo expander-compressor technology was utilized in early 1960’s.
• Upper limit of installed experience for turbo expander-compressors power is at 15,000 KW
• Due to large capacity many plants have parallel turbo expander-compressor trains
Operational Challenge:

• Simultaneous Start-up

Similar to a single train start-up
Case Study Reference:

For this case study a bp gas plant with two parallel turbo expander-compressor trains with the following gas dynamics performance was considered:

<table>
<thead>
<tr>
<th></th>
<th>Turbo Expander</th>
<th>Compressor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mw</td>
<td>19.38</td>
<td>18.23</td>
</tr>
<tr>
<td>$P_1$ (Psia)</td>
<td>1,080</td>
<td>290</td>
</tr>
<tr>
<td>$T_1$ ($^\circ$F)</td>
<td>-6</td>
<td>107</td>
</tr>
<tr>
<td>$P_2$ (Psia)</td>
<td>350</td>
<td>430</td>
</tr>
<tr>
<td>$T_2$ ($^\circ$F)</td>
<td>-96</td>
<td>172</td>
</tr>
<tr>
<td>Flow (lb./hr)</td>
<td>706,000</td>
<td>615,000</td>
</tr>
<tr>
<td>HP</td>
<td>7,876</td>
<td>7,725</td>
</tr>
<tr>
<td>Liquid Fraction</td>
<td>14.70%</td>
<td></td>
</tr>
</tbody>
</table>
Case Study Reference:

An efficiency curve for parallel EC could be developed to guide operation for one or two trains in service for the maximum efficiency.
Operational Challenge:

Start-up of one unit when the parallel unit is in full load operation:

• Compressor cannot compress directly into discharge header and hence Requires recirculation.
Operational Challenge:

The following conditions are to be monitored during start up of an EC while recycle valve open:

- Compressor discharge process gas temperature
- Axial Loads
- Radial Loads

Development of the above conditions depends on pressure ratio of the compressor. Two scenarios will be examined:

- Low Pressure Ratio \( \leq 1.2 \)
- High Pressure Ratio \( > 1.2 \)
**Operational Challenge:**

**Low Pressure Ratio Compressor**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Turbo Expander</th>
<th>Compressor</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_w$</td>
<td>19.29</td>
<td>18.88</td>
</tr>
<tr>
<td>$P_1$ (Psia)</td>
<td>1,080</td>
<td>550</td>
</tr>
<tr>
<td>$T_1$ ($^\circ$F)</td>
<td>- 6</td>
<td>110</td>
</tr>
<tr>
<td>$P_2$ (Psia)</td>
<td>600</td>
<td>670</td>
</tr>
<tr>
<td>$T_2$ ($^\circ$F)</td>
<td>- 80</td>
<td>144</td>
</tr>
<tr>
<td>Flow (lb./hr)</td>
<td>700,000</td>
<td>650,000</td>
</tr>
<tr>
<td>HP</td>
<td>4008</td>
<td>3978</td>
</tr>
<tr>
<td>Liquid Fraction</td>
<td>7.5%</td>
<td></td>
</tr>
</tbody>
</table>
Operational Challenge:

Low Pressure Ratio Compressor P2/P1 <1.20

Figure 5 Turbo Expander – Compressor Thrust Loads at Start Up
Operational Challenge:

How Pressure Ratio Compressor $P_2/P_1 > 1.20$

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<tr>
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Operational Challenge:

High Pressure Ratio Compressor \( P2/P1 > 1.20 \)
Comparison of compressor discharge gas temperature for low and high pressure ratio cases.
Therefore the main operational problem associated with start up parallel turbo expander-compressor units is process gas temperature at the compressor discharge for high pressure ratio compressors.

The following remedies may be applied depending on circumstances. All these shall continue until the compressor discharge pressure approaches to compressor discharge header pressure:

- Diluting closed loop warm recycle gas with cold gas
- Venting compressor discharge to a lower pressure sink
- Venting /flaring compressor discharge flow
Diluting Closed Loop Warm Recycle Gas with Cold Gas

Adding cooling gas from expander inlet to the recycle gas to maintain the discharge temperature below the Alarm Level.
Venting Compressor Discharge to a Lower Pressure Sink

Venting the recycle gas to expander discharge piping
Venting /Flaring Compressor Discharge Flow

More common in Older plants
Pros and Cons of the remedies:

• Diluting closed loop warm recycle gas with cold gas:
  1. Loss of refrigeration
  2. Loss of condensate recovery
  3. Requires cold gas piping, valves, space, etc.
  1. No loss of process gas
  2. No environmental consequences

• Venting compressor discharge to a lower pressure sink
  1. Loss of refrigeration
  2. Loss of condensate recovery
  3. Requires gas piping, valves, space, etc.
  1. No loss of process gas
  2. No environmental consequences
Pros and Cons of the remedies:

• Venting /flaring compressor discharge flow
  1. Loss of process gas
  2. Environmental consequences

  1. No piping loop
  2. Suitable for older plant with no expansion provisions

• Because of loss of process gas and environmental consequences requires special attention
Three start up alternatives will be evaluated:

**Alternate -1** Maintain flow of the operating unit at 100%

**Alternate-2** Increase flow of the operating unit to 130%

**Alternate-3** Decrease flow of the operating unit 70%
Turboexpander Performance parameters during start up

- Speed/design speed
- Compressor pressure ratio
- Power - KW per unit
- EXP - wt% liquid

Graphs showing the relationship between mass flow and speed, pressure ratio, power, and liquid content over the range of % mass flow from 0 to 150.
Cumulative Economical Consequences

- Poly. (100% Flow)
- Poly. (70% Flow)
- Poly. (130% Flow)
Conclusions:

- Capacity of cryogenic gas plants have increased over the last forty years.
- There are many cryogenic natural gas processing plants with parallel turbo expander-compressor units.
- Start up of one train EC while the other is in operation is an operational challenge.
- Compressor gas recycling is mandatory during start up.
- Several operational parameter of EC are to be monitored. Compressor discharge gas temperature is the critical parameter to be controlled.
- Two scenarios were considered, low pressure ratio (<=1.2) and high pressure ratio (>1.2) compressor.
- The former scenario does not impose any operational challenge during start up.
- The latter scenario demands special attention and procedures:
  1. The most convenient method is to vent the recycle flow into the expander discharge stream.
  2. The compressor recycle gas may be cooled down by diluting it with cold gas from the expander discharge.
  3. If neither of the above is possible, the only remedy is to vent/flare gas.
     - The most economical approach is to increase flow of the operating EC to 130% and then start up the parallel EC.