AVOIDING CASCADING TRIPS ON INTERDEPENDENT TURBOMACHINERY

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The two main refrigeration compressor strings at Tangguh LNG are highly dependent on each other during operation

- A cascading trip can happen within seconds

This case study focuses on how to keep either string online when the other trips

- Avoid surging the compressor
- Avoid excessive recycle that can overload the drivers
Propane circuit cools the MR circuit and Feed Gas
- 4 stage compressor with sidestreams
- Driven by Frame 7 GT with ST helper

MR circuit cools Natural Gas in MCHE to produce LNG
- 3 stage compressor with MR HP stage on PR drive train
- Driven by Frame 7 GT with ST helper
When the MR circuit trips

- Loss of MR flow to the propane chillers will lead to the PR flow (vapor production) decreasing in a relative short time and eventually resulting in no vapor production
- Sudden loss of flow through the MR HP compressor due to MR MP discharge check valve closing

When the PR circuit trips

- A trip of MR HP ASV results in sudden loss of flow through the MR LP/MP stages due to closure of MP discharge check valve
The original control system design was based on lessons learned from a similar LNG plant installation.

Feed Forward Control (FFC) by unloading the online compressor when the other compressor trips:

- Temporarily initiate the antisurge controllers’ Stop sequence to ramp open the ASVs.
- Duration based on the Stop ramp rate and desired ASV target opening position.
- Additional IGV or speed control adjustments were not necessary.
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<th>Mixed Refrigerant Compressor</th>
<th>Propane Compressor</th>
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<td>LP Stage</td>
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<td>Propane Unit Trip</td>
<td>Ramp 15%/s for 3sec</td>
<td>Trip, valve steps open to 100%</td>
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<td>Ramp 8%/s for 5s</td>
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<td>Mixed Refrig Unit trip</td>
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MR HP ASV was recorded at 100% open after FFC

Cause: Controller’s open loop line crossed causing it to step open output to 100% and switch to Shutdown

PR string tripped on underspeed 11 seconds after FFC

Cause: PR HP ASV was manually opened at 55% at the time of FFC signal resulting in the ASV going to 100% open and GT high power limit being reached

MR string trips 7 seconds after FFC signal

Cause: MP stage surge trip
Ramp rates in the MR ASC need to be increased

ASV target positions need to be adjusted

Ramp ASV to a fixed target position and not a fixed amount

ASC needs to remain active during FFC
Standard features of ASC Stop mode

- Maximum Stop ramp rate is 16.7%/s
- When the operating point crosses the controller’s open loop line, the controller immediately steps open the ASV and goes into Shutdown state
- The antisurge controller’s Surge Counter/Trip functions are not active during Stop/Shutdown state
Propose ASC Software Modification

- Separate Unload signal
- Configurable ramp rate to 99.9%/s (LVL6)
- Configurable ramp target (LVL7)
- Configurable hold timer (LVL8)
- Allow ASC to override Unload sequence
- Output goes to 100% if open loop line crossed put remain in Run state
Run dynamic simulation
- Verify increased ramp rates and ASV target openings for MR compressor
- Simulate both design and off design conditions
- Verify GT power stays within acceptable limits

Site acceptance test
- Verify new controller software functionality
- Verify logic used to activate the Unload signal
## NEW CONFIGURATION SETTINGS

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<td>HP Stage</td>
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<td><strong>Propane Unit Trip</strong></td>
<td>Ramp 50%/s to 50% open for 60s</td>
<td>Trip, valve steps open to 100%</td>
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<td>Ramp 60%/s to 60% open for 60s</td>
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<td>Ramp 50%/s to 70% open for 60s</td>
<td>Ramp 5%/s to 50% open for 60s</td>
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<td>Ramp 5%/s to 40% open for 60s</td>
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TREND RESULTS FROM FIELD

MR LP trip

MR MP trip

MR HP FFC

70% Open
TREND RESULTS FROM FIELD

- PR LLP FFC
  - 50% Open
  - MR Trip

- PR LP FFC
  - 70% Open
  - MR Trip

- PR MP FFC
  - 50% Open
  - MR Trip

- PR HP FFC
  - 40% Open
  - MR Trip
CONCLUSION

- No reports of cascading trips since modification

- Additional benefits of software modification
  - Changes allow for a clearer understanding of the control system response after an event
  - More flexibility in configuration changes
    - Ramp rates and target levels can be changed independently
  - Settings can be easily changed on line