1. **Introduction**

Al-Khafji Joint Operations (KJO) in the Kingdom of Saudi Arabia operates a gas processing facility to treat the associated gas from the offshore Oil production for gas lift and power generation. Shortly after the plant was revamped in 2014, IPCOS was asked to conduct an audit and optimize the base control layer to improve production uptime and processing stability.

Following an initial audit IPCOS decided to tune the PID layer within the DCS. This was a highly interactive process so a multivariable tuning approach was taken for tuning these PID loops. The PID tuning services for KJO included a review and analysis of all PID loops of the gas plant. Poorly tuned PID loops were identified, prioritized and tuned using IPCOS’ INCA AptiTune software.

The Schematic below shows an overview of the KJO Gas processing facility for which PID tuning activities were performed.

2. **Methodology for PID tuning**

In order to get optimal results, it is important to take a systematic approach when tuning PID loops. IPCOS has developed proven methodology for PID tuning. As part of these best practices, the typical steps followed are:

- Collection & analysis of historical data for all PID loops with the use of INCA Discovery software.
- Prioritize the list of poorly tuned loops.
- Make steps in final control element, collect data and tune with the use of INCA AptiTune software.
- Simulate the tuning in INCA AptiTune and update the PID tuning parameters in the DCS.
- Verify the tuning by making a few steps in the setpoint and observe behavior for 2 to 3 days.

The PID tuning methodology is visualized in Figure 2, where the Blue line represents the setpoint and the red line represents the process value of the PID loop.
In order to review the historical performance of the PID loops, data from 2 months was extracted and analysed using INCA Discovery, a data analysis tool developed by IPCOS.

Based on this analysis, the PID loops were categorized as follows:

- **No action required**: The PID loops do not have to be tuned as their tuning is acceptable.
- **Not in operation**: The PID loops cannot be verified as the loop is not in operation.
- **To be tuned**: Loops which are poorly tuned and require retuning.
- **Instrumentation**: PID loops cannot be verified, because of instrumentation issues.

A prioritization of the loops was made, based on discussions with the KJO operations personnel and information from data analysis. The high priority issues which were faced by the operations personnel were related to the fluctuations of the flows, levels and temperatures of the Low Temperature Separator (LTS), Deethanizer and Condensate stabilizer (for more details see process overview in Figure 1).

### 3. Results

The overall tuning improvements on the LTS and deethanizer are shown in Figure 3, Figure 4 and Figure 5. Those units where marked as high priority. In Figure 6 and Figure 7 two examples are shown of other lower priority loops for which tuning was improved.
Improved tuning on the LTS

It was found during the data analysis that the gas coolers and gas dryers caused temperature and level fluctuations in the LTS. The effect of stabilizing the temperature of the gas cooler can be clearly observed in Figure 3. This has a stabilizing effect on the level in the LTS as well as the flow out of the LTS going to the deethanizer and condensate stabilizer.

![Figure 3: Improved tuning LTS](image)

Original and updated PID parameters of the temperature of the gas cooler:

<table>
<thead>
<tr>
<th>Tag</th>
<th>Original tuning</th>
<th>Updated tuning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K</td>
<td>T1</td>
</tr>
<tr>
<td>2303TIC0320A</td>
<td>0.43</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 1: PID parameters of the temperature of the gas cooler

As already indicated in Figure 3 the temperature stabilization of the gas cooler has a big impact on stabilizing the level in the LTS. In Figure 4 a more detailed result is presented, which shows major improvement in stabilizing the level of the LTS.
Although the PID tuning has improved the setpoint tracking of the LTS level, there is still a small deviation observed in the level of the LTS. During the data analysis it was found that this deviation is caused by the gas dryers switching from “normal” mode to “regeneration” mode. The controller has been tuned to reduce those deviations as far as possible, however cannot be made too aggressive as otherwise instability of the control loop can be observed. Therefore small deviations from the setpoint are still observed. Thus by tuning the PID loop and stabilising the loop this interaction was to be discovered and understood.

Figure 4: Improved tuning of the level of the LTS
Improved tuning on the Deethanizer

During the data analysis and interviews with the operators it was observed that the deethanizer flow, level and temperature fluctuations were caused by:

1) Flow coming from the LTS.
2) Poor Tuning of Level controller.
3) Poor Tuning of the deethanizer hot-oil reboiler.

The effect of the improved tuning can be clearly observed in Figure 5. The temperature, flow and level of the deethanizer are not oscillating since the tuning was updated; they are now following their setpoint correctly.

As explained in this case study the LTS was stabilized by updating the PID parameters of the temperature of the gas cooler. Due to the interaction between the different units of the gas plant, the stabilization of the LTS also has a stabilizing effect on the deethanizer. The different setpoints of the deethanizer level, flow and temperature are better tracked. This can be observed in Figure 5.

### Table 2: PID parameters of the deethanizer

<table>
<thead>
<tr>
<th>Tag</th>
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<th>Updated tuning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K</td>
<td>T1</td>
</tr>
<tr>
<td>2303FIC0402A</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>2303LIC0422A</td>
<td>0.03</td>
<td>2.5</td>
</tr>
<tr>
<td>2303FIC0407A</td>
<td>0.35</td>
<td>0.25</td>
</tr>
<tr>
<td>2303TIC0432A</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

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Examples of improved tuning of other parts of the KJO Gas Process Facility:
The control of the hot oil outlet temperature was made more robust. The temperature setpoint is now being tracked more accurately. The improvement of the tuning of this loop can be observed in the screenshot below:

![Graph showing improved tuning of hot oil outlet temperature](image)

Figure 6: Improved tuning of the hot oil outlet temperature

Original and updated PID parameters of the hot oil outlet temperature:

<table>
<thead>
<tr>
<th>Tag</th>
<th>Original tuning</th>
<th>Updated tuning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K</td>
<td>T1</td>
</tr>
<tr>
<td>1701TIC0817B2</td>
<td>0.65</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 3: PID parameters of the hot oil outlet temperature
The instrument resolution of the Fuel Gas Pressure is improved. A filter on PV signal was introduced to remove high frequency noise on the PV signal. The improvement can be observed in the screenshot below:

![Screenshot of improved instrument resolution](image.png)

**Figure 7: Improved instrument resolution of the fuel gas pressure**

Original and updated PID parameters of the fuel gas pressure:

<table>
<thead>
<tr>
<th>Tag</th>
<th>Original tuning</th>
<th>Updated tuning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1701PIC0835C</td>
<td>0.6 0.7 0</td>
<td>0.6 0.7 0</td>
</tr>
</tbody>
</table>

**Table 4: PID parameters of the temperature of the fuel gas pressure**

4. Conclusion

In total 178 loops of the KJO gas processing facility were reviewed, to determine which PID loops required instrumentation improvements and which PID loops required re-tuning.

a. From those 178 loops a total of 26 control loops were re-tuned during the site visit which has had a major improvement to the overall stabilization of the KJO gas processing facility.

b. From those 178 loops a total of 11 loops required instrumentation improvements, which was highlighted to the KJO operations personnel. With the suggested instrumentation improvements, operations can run even more efficient and stable.

The improved tuning of the high priority loops of the LTS, Deethanizer and the condensate stabilizer has had a major improvement to the overall stabilization of the KJO gas processing facility. This was a problem before the PID tuning exercise for KJO and required significant manual actions by the KJO operations personnel.
Accomplishments of the updated tuning of the LTS:
1) The critical LTS level is now controlled robustly and is now following its setpoint more accurate. With a reduction of setpoint deviation from +/- 18% to +/- 5%. This avoids the high-high level alarm being tripped to avoid shutdowns. Previously manual intervention was required constantly to control to avoid this situation.
2) The LTS inlet temperature is controlled closer to its set point. As the LTS inlet temperature has a large interaction with the LTS level, stabilizing the LTS inlet temperature also has a stabilizing effect on the critical LTS level.
3) The LTS outlet flow is controlled more tightly, stabilizing the flow to the downstream units: deethanizer, condensate stabilizer, export facilities.

Accomplishments of the updated tuning of the deethanizer:
1) The deethanizer flow and level are not oscillating anymore and are following their setpoint correctly. The improved tuning reduced the amount of manual actions by the KJO operations personnel.
2) The deethanizer temperature is now following its setpoint correctly. As the deethanizer temperature has a large interaction with the deethanizer level, stabilizing the deethanizer temperature also has a stabilizing effect on the deethanizer level.
3) The deethanizer outlet flow is controlled more tightly, stabilizing the flow to the downstream units: condensate stabilizer and export facilities.

Accomplishments of the updated tuning of the condensate stabilizer:
1) By controlling the critical LTS level and the deethanizer level the level of the condensate stabilizer has also become more stable and robust.
2) Flow controller of the condensate stabilizer is controlled more tightly, stabilizing the flow to the export facilities.

The improved tuning of the lower priority loops of the KJO gas processing facility improved stability in several different units, which also has a benefit to the overall stabilization of the KJO gas processing facility.