Knowledge Based Assessment of the Condition of Gas Turbines

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TIGER is a registered trademark of Turbine Services Limited
Gas turbines are the critical drivers of the plant. 
Do not want to stop. 
Need maximum operating efficiency. 
Need to know what to maintain and when. 
Impossible to manually assess the turbine condition.
The Desire

- Understand the condition of the turbine.
- Detect problems at the earliest possible stage.
- Understand what happens when problems arise.
The Approach

- Continuous monitoring **AND DIAGNOSIS** at 1/second.
- Comprehensive automated fault detection.
- Multiple levels of diagnostics.
- Easy to read summary of events.
- Extensive data archives and displays.
What is Condition Monitoring?

**Key Aspects**
- Frequently checking the machine
- Detecting problems at the earliest stage
- Assessing the condition of the machine
- Create ‘picture’ of the machine's condition

**Tiger’s Approach**
- Receives 600+ data points every second
- Thousands of fault detection checks
- Knowledge based analysis and diagnosis
- Easy to read fault manager display
TIGER Overview Display

Tiger - Knowledge Based Gas Turbine Condition Monitoring

Turbine 07
- Operating
  - Gas Overview
  - Gas Compressor
  - Gas Fuel Pattern
  - Gas Lubrication
- Performance
  - Gas Generator
- Controller
  - Gas Analog 1
  - Gas Analog 2
  - Gas Analog 3
  - Gas Digital 1
  - Gas Digital 2

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Valves Pos (%): SRV, GCV, P2, CFD, IGV, HP, EEM
Pressure (Bar): 24, 15.1, 10.3, 2.0, 0.2
Angle (°): 90, 55, 110, 32, 32
Max VIB (mm/see): 200
Exhaust Temp (DegC): 850
Frequency/Reactor (MW): 53
Generator: TTHM 340.9 DegC
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Diesel Speed: 0.0%
Discharge Temp: 340.8 DegC
Discharge Press: 10.5 Bar
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STATUS
- Ready
- Gen In Proc
- Comm Dqq

FLAME
- 2RFU_2
- 2RFU_3
- 2RFU_8

SPEED RELAYS
- WR
- WH
- WSO

FUEL CONTROL
- Acceleration
- Speed Droop
- Speed Limit
- Temperature

MESSAGE DISPLAY
- Base Load

06:37:02 05/09/2004 Bearing vibration transducer 11 and 12 major divergence - indicates transducer fault
06:40:49 05/09/2004 Exhaust temperature spread 1 is too high
### Fault Manager Summary

<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
<th>Status</th>
<th>Value</th>
<th>Unit</th>
<th>High Value</th>
<th>Current Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:35:56</td>
<td>Vibration sensor 2 (BS2) too high. Limit 8.00 mm/s Highest Value: 9.53 Current Value: 9.02</td>
<td>Limit Exceeded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08:35:56</td>
<td>Lube oil thermocouple turbine header (LTTH1) too high. Limit 52.10 degC Highest Value: 60.66 Current Value: 57.60</td>
<td>Limit Exceeded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08:35:56</td>
<td>Turbine temperature-wheelspace 2nd stage outer (TTWS2AO2) too high. Limit 465.00 degC Highest Value: 490.92 Current Value: 485.15</td>
<td>Limit Exceeded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08:35:56</td>
<td>WNLX - Steam Injection on</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08:35:56</td>
<td>Turbine temperature-wheelspace 2nd stage outer (TTWS2AO1) too high. Limit 465.00 degC Highest Value: 504.57 Current Value: 498.28</td>
<td>Limit Exceeded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08:35:56</td>
<td>TCFA flame UV counter 4 (FD_INTENS_4) too low. Limit 100.00CNT15 Lowest Value: 0.00 Current Value: 0.00</td>
<td>Limit Below</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08:35:56</td>
<td>Vibration sensor 1 (BS1) too high. Limit 8.00 mm/s Highest Value: 9.61 Current Value: 9.02</td>
<td>Limit Exceeded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08:35:56</td>
<td>Air pressure - inlet duct (APFC_S) too low. Limit -110.00 mmH2O Lowest Value: -238.33 Current Value: -276.23</td>
<td>Limit Below</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08:35:56</td>
<td>Standby ventilation fan running (L4PF_1AG_ALM) not in expected state (actual 1 expected 0)</td>
<td>Not in Expected State</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>08:35:56</td>
<td>Frame detector trouble (L25F_AlM) not in expected state (actual 1 expected 0)</td>
<td>Not in Expected State</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:45:48</td>
<td>Combustion trouble (L33SPA) not in expected state (actual 1 expected 0)</td>
<td>Not in Expected State</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:09:37</td>
<td>Exhaust thermocouple trouble (L30SPA) not in expected state (actual 1 expected 0)</td>
<td>Not in Expected State</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06:40:55</td>
<td>Combustion monitor actual spread 1 (TTXSP1) too high. Limit 50.00 degC Highest Value: 64.51 Current Value: 639.08</td>
<td>Limit Exceeded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06:40:55</td>
<td>Exhaust temperature thermocouple 14 (TXXD_14) too low. Limit 980.00 degC Lowest Value: -84.19 Current Value: -84.19</td>
<td>Limit Below</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06:40:55</td>
<td>Exhaust temperature spread 1 is too high</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06:41:02</td>
<td>High exhaust temperature spread detected - probably due to exhaust thermocouple fault</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>07:01:35</td>
<td>Exhaust thermocouple 14 fault. Limit -17.90 Lowest Value: -84.19 Current Value: -84.19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:51:57</td>
<td>Turbine is running in high load range using gas fuel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:51:57</td>
<td>Exhaust thermocouple 14 - very low deviation from median temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:51:57</td>
<td>Turbine is running in high load range</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:54:55</td>
<td>Steam injection flow delta P transmitter (SDSJ2) too low. Limit 1070.00 mmH2O Lowest Value: 785.43 Current Value: 855.60</td>
<td>Limit Below</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Diagnostic Explanation

- 10:34:56 24/11/2002 Exhaust temperature - rapid increase
  Determined by
  10:34:56 24/11/2002 Exhaust temperature significant increase
  Accounts for
  10:34:58 24/11/2002 Exhaust thermocouple 17 and 18 diverged for 1 seconds by more than 90.00
  10:34:59 24/11/2002 Exhaust thermocouple 14 and 15 diverged for 1 seconds by more than 90.00
  10:34:57 24/11/2002 Turbine significant speed increase detected
  10:35:03 24/11/2002 Turbine significant speed increase detected
  10:35:05 24/11/2002 Exhaust temperature is increasing rapidly, and is too high - overtemperature trip possible
  Determined by
  10:35:04 24/11/2002 Exhaust temperature significant increase
  10:35:05 24/11/2002 Exhaust temperature high alarm detected
  Accounts for
  10:34:56 24/11/2002 Exhaust temperature significant increase
- 10:35:05 24/11/2002 Gas fuel P 2 pressure problem - too high
- 10:35:05 24/11/2002 Gas fuel intevalve pressure significant increase
- 10:35:06 24/11/2002 Gas turbine firing ended
- 10:35:06 24/11/2002 For raising L20FL1X (L4_X TP) change from 0 to 1
- 10:35:06 24/11/2002 Gas turbine trip
- 10:35:06 24/11/2002 Turbine trip due to exhaust over temperature
- 10:35:06 24/11/2002 Post ignition trip
- 10:35:07 24/11/2002 Gas fuel control problem due to loss of hydraulic trip oil pressure
- 10:35:08 24/11/2002 TCD loss of master protective (L4Y) change from 0 to 1
- 10:35:11 24/11/2002 Faulty flame detector 2
- 10:35:11 24/11/2002 Wheelspace thermocouple stage 1 aft cuter 1 and 2 diverged for 1 seconds by more than 25.00
Real Time and Replay Graph

Tiger: Knowledge Based Gas Turbine Condition Monitoring

<table>
<thead>
<tr>
<th>Tag Name</th>
<th>Min</th>
<th>Value</th>
<th>Max</th>
<th>Description</th>
<th>Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>B81</td>
<td>0.360</td>
<td>3.721</td>
<td>4.223</td>
<td>[mm/s] Vibration transducer # 1 (turb)</td>
<td>Demo</td>
</tr>
<tr>
<td>B82</td>
<td>0.670</td>
<td>4.037</td>
<td>4.483</td>
<td>[mm/s] Vibration transducer # 2 (turb)</td>
<td>Demo</td>
</tr>
<tr>
<td>B83</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>[mm/s] Vibration transducer # 3 (turb)</td>
<td>Demo</td>
</tr>
<tr>
<td>B84</td>
<td>1.327</td>
<td>2.915</td>
<td>24.160</td>
<td>[mm/s] Vibration transducer # 4 (turb)</td>
<td>Demo</td>
</tr>
</tbody>
</table>
Performance Monitoring

ISO Corrected Performance

Heat
- Dry Corrected Heat Rate
- Heat Rate After Crank Wash

Power
- Dry Corrected Power
- Power After Crank Wash
Diagnostic Query: Issues over time

- [67] Gas fuel - control valve problem
- [24] Gas fuel hydraulic trip pressure low
- [5] Gas fuel low pressure alarm detected
  - 16:01:01 26/04/2002 Gas fuel - speed ratio valve leaking
  - 16:01:28 26/04/2002 Gas fuel - speed ratio valve leaking
  - 16:01:56 26/04/2002 Gas fuel - speed ratio valve leaking
- [2] Gas fuel control problem due to loss of hydraulic trip oil pressure
  - 16:17:41 11/03/2002 Gas fuel control problem due to loss of hydraulic trip oil pressure
  - 15:23:46 26/04/2002 Gas fuel control problem due to loss of hydraulic trip oil pressure
- [1] Gas fuel control problem due to loss of hydraulic pressure
  - 06:58:33 04/03/2002 Gas fuel control problem due to loss of hydraulic pressure
    - Determined by
      - 06:58:33 04/03/2002 Hydraulic supply pressure low (L63HQ1L) change from 0 to 1
      - 06:58:33 04/03/2002 Gas fuel control valve position significant decrease
      - Accounts for
        - 06:58:33 04/03/2002 Hydraulic pressure problem detected - too low
- [1] Gas fuel stop valve sticking - indicated by trip oil problems
  - 14:53:10 22/03/2002 Gas fuel stop valve sticking - indicated by trip oil problems
Multiple Turbine Diagnostics

Currently abnormal diagnostics for turbine Alarm Server with tag: all msg: all severities: critical

- **GT03 - Diagnostics for turbine Turbine 03**
  - 17:27:22 18/08/2004 GT03 - Gt electric protection shutdown (L40X) not in expected state (actual 1 expected 0)
- **GT04 - Diagnostics for turbine Turbine 04**
  - 17:27:24 18/08/2004 GT04 - Emergency trip pushbutton - alarm (L5E2) not in expected state (actual 1 expected 0)
- **GT07 - Diagnostics for turbine Turbine 07**
  - 06:40:56 05/09/2004 GT07 - Exhaust temperature spread 1 is too high
  - 06:41:02 05/09/2004 GT07 - Exhaust thermocouple fault - indicated by alarm and very low thermocouple temperature
  - 06:41:02 05/09/2004 GT07 - High exhaust temperature spread detected - probably due to exhaust thermocouple fault
  - 11:51:57 05/09/2004 GT07 - Exhaust thermocouple 14 - very low deviation from median temperature
- **GT23 - Diagnostics for turbine Turbine 23**
  - 16:12:32 25/09/2004 GT23 - Exhaust thermocouple 11 - very low deviation from median temperature
  - 16:12:40 25/09/2004 GT23 - High exhaust temperature spread detected - probably due to exhaust thermocouple fault
  - 04:36:34 26/09/2004 GT23 - Exhaust temperature spread 1 is too high
- **GT24 - Diagnostics for turbine Turbine 24**
  - 06:42:58 26/09/2004 GT24 - Exhaust thermocouple fault - indicated by alarm and very low thermocouple temperature
  - 17:33:42 19/08/2004 GT24 - Gas fuel purge valves slow or failed to open
  - 17:33:42 19/08/2004 GT24 - TCEA state of bypass relay 2 (L4PTR4_FB) not in expected state (actual 1 expected 0)
TIGER Alarm Server for Multiple Sites
TIGER: Other Key Features

- TIGER includes a performance monitoring package to track efficiency changes.
- TIGER has monitored over 200 fired years of gas turbine operation and has been used to investigate over 1500 faults.
- TIGER uses the existing sensors and does not require additional instrumentation.
- TIGER monitors a wide range of turbine sub-systems.
- TIGER includes extensive data display, trending and archive facilities.
- TIGER can be used remotely to monitor or troubleshoot gas turbines via a modem or network link.
TIGER $150,000 Benefits Club

- **CHP Plant 1** - Hydraulic pressure problems
- **CHP Plant 2** - Steam injection, major refurbishment
- **Offshore Turbine** - Liquid fuel unstable at low load
- **Smelter** - Two atomising air compressor failures
- **Chemical Plant** - 2nd stage nozzles
- **IPP** - Major oscillation problem
- **District H & P** - Stuck valves, bad flame scanners
- **CHP Plant 3** - Delayed a Shutdown until convenient

**Warranty claim made:** Actioned 39/64 on Turbine 1  
Actioned 29/50 on Turbine 2
TIGER Benefits

For routine monitoring:

- Know **EVERYTHING** that happens
- Download diagnostics, not data
- Verify faults quickly, identify faults that will prevent a restart
- New window into the turbine operation
Consistent Benefits

Rapid and continuous payback by:

- Minimize downtime
- Maximize service intervals
- Optimize cleaning cycles
- Advance anticipation of faults
- History tracking and replay
TIGER: Summary of Benefits

- Know **EVERYTHING** that happens to the turbine.
- Detect the first symptoms of a developing problem.
- Capture transient/short events.
- Rapidly troubleshoot major incidents.
- Understand the condition of the gas turbine.
- Enables condition based maintenance.