# **Remote Monitoring and Diagnostics for Power Generation Gas Turbines**



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#### **Abstract**

Remote monitoring and diagnostics for power generation gas turbines requires collecting, analysing and distributing information about the turbine. The information may be in raw form or may have been analysed by monitoring and diagnostic software before it reaches staff.

Staff need certain skill levels dependent on what support there is from diagnostic software analysis. The experience of monitoring power generation turbines remotely over many years allows us to detail required software capabilities, staffing structures and reporting mechanisms along with reasons why we choose these.

Some problems are identified early leading to scheduled outages whilst other problems lead to turbine trips that need to be investigated after the event. Communication with the site is very important as some fault conditions cannot be determined by the sensor input available.

Various problems will accrue over time and mechanisms need to be in place to track these. Knowing the outstanding problems allows for efficient scheduling for repairs during either planned or unplanned outages. Awareness of the operating condition of the turbine and reacting to this as necessary is important for increasing availability and reliability.



### **Contents**

Abstract
1. Introduction
2. Skill Sets Needed
3. Infrastructure for Handling Turbine Data
3.1 Collecting Data On-Site
3.2 Storing Data
3.3 Distributing Data
4. Diagnostics
5. Monitoring Activities 11
5.1 Frequency Based Checking 11
5.2 Event based checking 12
5.3 Reporting back to site
6. Examples
7. Conclusion 14
Appendix 1. Example - Frame 5 Status Summary 15
Appendix 2. Example – Frame 5 Tiger Incident Report 19
Appendix 3. Example – Frame 6 Daily Automated Report Sample Pages



#### **1. Introduction**

Remote monitoring and diagnostics for power generation gas turbines requires:

- collecting data from the gas turbine
- information technology infrastructure to make this data available remotely
- a means of processing this data to identify incidents and faults
- reporting mechanisms back to site

The processing of the data to identify incidents and faults can be done manually or computer software can be used to assist in the process. Where skilled manpower resources are in short supply we would like to have as much assistance from computer software as possible for this identification.

The filtering of large quantities of data for significant events by the monitoring and diagnostics software produces a spectrum of diagnostics from the detection that something is abnormal through to the complete diagnosis of a fault.

Identifying the details of the faults that require repair is a mixture of using the diagnostics provided by the monitoring and diagnostics system, using data exploration tools to get more information and in some cases examining the turbine itself. Various support tools are needed to ensure proper exploration of conclusions such as graphing and diagnostic message management. The ease of use of these tools is one of the key aspects to providing a successful monitoring and diagnostic system.

Organisations have a hierarchy of expertise and specialism within them. Depending on the core role of the organization, they may resort to third party help in resolving problems. Information flow within and out with the organisation is key to applying manpower resources effectively.

Various problems will accrue over time and mechanisms need to be in place to track these. Knowing the outstanding problems allows for efficient scheduling for repairs during either planned or unplanned outages. Awareness of the operating condition of the turbine and reacting to this as necessary is important for increasing availability and reliability.

#### 2. Skill Sets Needed

Engineering staff resource is scarce. Monitoring and diagnostic contracts are usually part of some larger long term service agreement (LTSA) framework. Often the details of what goes on are hidden, and sometimes the data is too. You do need some turbine knowledge to use a monitoring and diagnostic system effectively.

We have found that it is easier to train staff with some turbine knowledge to use monitoring and diagnostic software than it is to train computer literate people about turbines. Using monitoring and diagnostic software is a relatively easy task since it involves exploring data using provided structures. Very little is created so it is essentially simpler than mastering the full complexities of a database system or programming language.



Using a monitoring and diagnostic system is a good way for trainee engineers to learn more about turbines as it reinforces theoretical understanding and allows them to investigate real problems with assistance from more experienced staff as required. We think the best balance is that monitoring turbines on a daily basis should form only part of the workload for any given member of staff. Ideally that person has other work involvements with the site being monitored. Compare this to a dedicated monitoring and diagnostic centre where this is the sole function of the staff.

Getting the information remotely to the monitoring and diagnostic staff and then, if necessary, remotely again to experienced personnel makes for efficient use of staff resources.

#### 3. Infrastructure for Handling Turbine Data

#### 3.1 Collecting Data On-Site

Data comes from the turbine control system, plant control system and any specialised hardware that is connected such as vibration monitoring or emission monitoring systems. The data collected from a turbine will depend on the age of the controller and the options installed.

For example, with GE heavy duty gas turbine controllers we cannot get data from Speedtronic Mk I and Mk II as they are analog. The cost of adding instrumentation to these controllers to collect data for remote monitoring rapidly takes us toward the price of a new control system. The cost of maintenance of these older controllers is such that many are being replaced with new digital control systems, either from the OEM or from third parties.

Speedtronic MkIV controllers often have the ability to send data to a DCS system via "datadump" or in the case of the later models, via modbus over a serial link. In both these cases it is possible to tap into these signals and send a copy to the monitoring and diagnostic software. Alternatively, the monitoring and diagnostic software can get information from the printer output by setting the controller to print information continuously and capturing and storing this electronically.

Speedtronic MkV controller data output will depend on the type of HMI attached and the software running on that HMI. The most basic is the <I> HMI which is capable of producing a serial modbus feed whose points can be configured by site. At the other end of the spectrum the Cimplicity HMI provides an OPC server that makes data available.

Modern control systems generally provide an OPC interface and there are third party software products that provide OPC interfaces to older digital controllers.

The data sampling frequency will depend on the type of faults to be detected and the amount of storage available. Typically a once-per-second sampling provides the appropriate compromise for an overview of many tags over many years. The diagnostic information may relate to an immediate incident or refer to a longer time frame.



#### 3.2 Storing Data

The data collected needs to be stored and analysed. The storage of the data can be accomplished on-site and/or remotely. The technology used to store the data will influence this choice. Ideally we would like to have no degradation of data resolution over time and be able to move chunks of data around via email, FTP sites and USB keys. Usually this means that the data is stored as files rather than in a database.

#### Remote Storage

Some monitoring and diagnostic systems transmit all the data remotely for storage to a central server. The advantages of this are:

- no maintenance of storage facilities is required at site
- no software licenses are needed on-site for storage

The disadvantages are:

- communications can go down for extended periods of time resulting in loss of data
- the bandwidth of the communication infrastructure can be overloaded
- the number of points and frequency can be restricted by the communication bandwidth
- access may not be allowed due to a companies Information Technology department restrictions

#### Local Storage

Local storage of data advantages/disadvantages are the inverse of remote storage.

#### Hybrid Local/Remote Storage

By using a mixture of the two techniques we can produce a more robust bandwidth friendly version. This assumes we are allowed remote access to the site, though even when this is not possible, data can be transferred via USB key in the post, by email or a File Transfer Protocol (FTP) site. Effectively we have remote access with a much longer update time when direct remote access is denied. The benefits of a hybrid solution include

- no loss of data on extended communication failure
- reduced bandwidth since only diagnostic and summary data information are transmitted on a regular basis
- specific high resolution data can be downloaded as required when drilling down lo look at a specific problem
- full high resolution data can be transferred on USB keys at longer intervals such as every two months



- any live data connection to site can be shared amongst all users as it is channelled through a central server
- information is always available directly on-site

#### **3.3 Distributing Data**

We want to get the turbine data to a point in the organisation where the existing infrastructure makes it easily available. For example, we can connect over normal phone links to sites and bring information back to a central server which them makes it available on the internal network and over the internet with appropriate security safeguards as shown in figure 1.

Figure 1- Example of a Monitoring and Diagnostics System Architecture



This structure means that many people all through the organisation can examine what has happened to the turbine and experts can be called in to help resolve problems when required. Often there are one or two people whose prime responsibility is to look after the turbine. These people are the ones that use the monitoring and diagnostic system the most.

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#### 4. Diagnostics

There are many techniques for capturing knowledge about gas turbines, producing a spectrum of diagnoses from the detection that something is abnormal through to the complete diagnosis of a fault. The embedded knowledge depends on the appropriate sensors being available. Even with few sensors (for example 80 analogs from a Speedtronic Mk IV) it is possible to detect and diagnose many problems. Note that in some cases it is not possible to distinguish between faults from the sensor input. Often site information is needed to resolve the cause of observed behaviour in the monitoring and diagnostic system.

The kinds of embedded knowledge include

- Limit checking
- Rule Bases
- Performance models for heat rate and power
- Compressor Efficiency Models
- Measuring NOx Levels Against Targets
- Factored Running Hours and starts
- Qualitative Fuel System Models
- Neural Net Combustion Models
- Vibration analysis

It is important to have concise summaries of diagnostics that can be explored in depth if necessary. We can look at the diagnostics produced in a number of ways and cross relate these to highlight specific areas of interest. For example, we can use the importance or severity of the diagnostic. A sample classification is

- critical needs immediate attention
- fault will not stop the turbine running, but needs to be addressed
- warning abnormal behaviour detected, likely to be a fault
- event status of the turbine has changed or minor abnormal behaviour detected
- information diagnostics or digital changes occurring in the normal course of running
- controller messages process and diagnostic messages and alarms from the controller itself

We can provide structure to the information presented by examining

- complete time listing of every diagnostic
- number of occurrences each different message shown once in the listing accompanied by the number of times it has occurred in the query time period
- currently abnormal diagnostics that have triggered out with the time period but are still indicating an issue
- top level if the diagnostics are organised in a hierarchical way, then we can present the top level of that hierarchy and drill down into it to see more detail



An example of hierarchical classification is when the monitoring and diagnostic system takes a set of messages in a given time span and recognises that they form a known pattern that is attributable to a specific fault. The classification splits the messages into various categories

- determined by why the main fault was concluded
- accounts for other diagnostics that are a consequence of the fault
- other messages in the same area as the main diagnostic for background information

In addition to the structures above, we can group the diagnostics into predefined areas such as fuel, combustion, generator or vibration. These can help isolate issues. An example of area classification is shown below in table 1.

gas compressor	seal oil
gas scrubber	shutdown
turbine	lp speed
electrical	transformer
cranking	cranking motor
fuel control	temperature control
digital	alarm
bearings	gas fuel
compressor inlet	generator
exhaust temp	wheelspace
speed control	flame detection
lube oil	grid
diesel start	compressor disch
combustion	liquid fuel
turbine power	controller
enclosure	boiler
water wash	cooling water
hydraulic	diesel speed
	gas compressorgas scrubberturbineelectricalcrankingfuel controldigitalbearingscompressor inletexhaust tempspeed controllube oildiesel startcombustionturbine powerenclosurewater washhydraulic

Table 1. – example of area classification for diagnostics

When turbines are being continuously monitored there is a need to know about particular problems that have previously been reported and if plans to rectify the problem have been put in place. This information needs to be available at the time the message is displayed. The monitoring and diagnostic system can attach notes to messages indicating that further information is available. These notes are available to all users. The system can also link diagnostics directly into the turbine manual pages.

The presentation of the diagnostics is important as often digital tags will change in the normal running of the turbine. We don't necessarily want to ignore these as they may be relevant additional information if an abnormality occurs, but in the normal running we want to be able to suppress them. Filtering messages so that they do not appear in a normal diagnostic query allows faster interpretation of the diagnostic list and makes new messages more obvious.



#### **<u>5. Monitoring Activities</u>**

There are three different types of monitoring activities

- frequency based checking typically daily
- event based checking investigating an incident or specific request
- summarising typically quarterly reports

Generally we find that gas turbines are reliable. The control systems usually have redundancy built in and problems develop over time. This means that checking on what has happened on a daily basis is usually enough to spot and track problems as they develop.

Sometimes though, an event occurs that needs immediate attention. For example, after a trip or on a start-up for a machine that is normally run constantly on base load.

Over time a number of faults are identified, not all of which can be fixed immediately. It is important to record the history of the turbine and know what outstanding problems exist. Providing summary reports facilitate this. Typically we find that producing a summary report every quarter is sufficient. In addition, summary reports can be produced before an outage.

#### 5.1 Frequency Based Checking

The checking of a turbine on a daily basis benefits hugely from assistance from a monitoring and diagnostic system.

Consider if only a data historian is used, the staff will have to check each tag, cross check relevant ones and potentially apply some form of comparison function by eye. If there are 200 analog tags, then this process can take a long time and since on any given day nothing much will have happened, staff soon loose interest and keeping them motivated is a big issue. Add to this the fact that some turbine knowledge is needed to review the data then you find you have a situation where you have skilled staff not applying their skills to their full potential and staff retention is a problem.

Using monitoring and diagnostic software to identify and keep track of problems with the turbine maximises the time of skilled staff. Certain functionality contributes to the working environment such as

- using diagnostics as the primary means to identify abnormalities and fault
- attaching notes to diagnostics to indicate the status of the issue especially with respect to notifying and feed back from site
- filtering diagnostics that already have been notified and a resolution proposed
- automatically showing data for a rolling historical period on graphs, typically a week is enough for a daily check
- Customised automated reports generated in word to allow adjustment and comments to be added



Monitoring a turbine on a daily basis over a period of years builds up a context for the machine. This context is very valuable in deciding whether a particular diagnostic is significant enough to report to site. Site just really wants to know what is new that they have to deal with. This context and the subsequent filtering of the diagnostics is facilitated by attaching notes to a diagnostic message indicating its status. In addition, the notes allow transferring of the context from one member of the diagnostic monitoring team to another.

The daily checking is a repetitive task, so we want the software to make it easy to look through the relevant data for the day. Setting up automated reports with all the relevant diagnostic queries and graphs is one way to do this. The problem with reports is that they are not interactive. A better solution is to provide a tool set of diagnostic and graph windows driven by the monitoring and diagnostic software that allows exploration of each tool instance. This allows instant

- drilling down for more detail
- viewing of attached notes
- manipulation of the active message filters

The tool set can open many windows with a single click and once the data has been viewed, each window is closed with a single click. If the windows are on top of each other then no mouse movement is required, only a set of clicks. Optimization of these types of of operational detail are important when an activity is carried out repetitively. Typically we find that we have 20 windows for a daily check for a given turbine.

#### 5.2 Event based checking

Events have a spectrum of severities from a sensor beginning to fail though to a turbine trip. They can be identified in the course of daily monitoring or be notified to staff using the monitoring and diagnostic system in a number of ways

- problem is flagged via a status screen on the monitoring and diagnostic system
- email or SMS message is sent to staff by the monitoring and diagnostic system
- phone call from site staff is received

Often time is of the essence in determining what has happened and in particular if it is safe to restart the turbine.

A scenario detailing activities in investigating an incident is given below:

- an incident is notified to monitoring and diagnostic staff via an SMS message on a mobile phone
- site is contacted to ascertain any background information and to notify them that the monitoring and diagnostic team are investigating sometimes the cause of the incident is out with the turbine and associated systems, for example a lightning strike taking out the generator



- a toolset with the current diagnostics and summary weekly trend graphs is loaded and the time span for the incident is determined
- the once-per second data for around the time of the incident is downloaded from site
- the data is replayed through the system as if it were live, allowing examination of screens and displaying of once-per second graphs
- the diagnostics are examined in detail with filters turned off we want to see everything that happed, including faults that have been identified before and currently abnormal conditions that apply at the start of the data period
- diagnostic hierarchy and groupings are explored
- individual diagnostics are examined by bringing up notes, once per second graphs and weekly trends of the turbine tags used in the diagnostic the system identifies automatically what these are
- historical searches of particular diagnostic occurrences are performed over all known data for the turbine to see of it has occurred before this can stretch back for many years and is dependent for its effectiveness on an efficient searching mechanism
- predefined toolsets for once-per-second graphs and historical trends are examined
- longer term trends over years are set up for specific tags of interest
- specialised engineering resources are called in to assist in resolving the fault
- site is informed and a plan of action determined
- a report is produced by the remote monitoring and diagnostic team

#### 5.3 Reporting back to site

Ideally, the monitoring and diagnostic system should be available on-site allowing staff there to investigate any incident. For remote monitoring and diagnostic situations we find that lack of staff resources on-site mean that they rely on remote analysis.

Reports will typically consist of an explanation followed by relevant diagnostics, graphs, trends and schematic screens. These images will come from automatically generated reports and from screen captures. These are produced in Microsoft Word, converted to PDF and uploaded to an FTP site. All interested parties are then sent a link to the document. We do not send the document by email as it is typically large due to the images it contains.

Reports on a per incident basis accumulate over the months. We need to provide a status and history that is easily referenced. Quarterly reports and status reports prior to outages provides summary reports that are easily actionable by the site. Quarterly reports can also show long term trends and performance measurements going back years. We include engineering and site comments in the quarterly reports, these often indicate why the observed behaviour occurred and what the proposed fix might be, with attendant timescales.



#### 6. Examples

The following examples are in the appendices

- 1. Status summary for a GE frame 5 turbine
- 2. Incident report for "ID 1" on the status summary in Appendix 1
- 3. Sample pages from an automated report for a GE frame 6 turbine

#### 7. Conclusion

We have examined the process of remote monitoring and diagnostics for power generation gas turbines. This includes the software infrastructure, staffing structure, skills required, support provided by software and details of tasks carried out.

Daily monitoring is carried out by a number of staff and this forms only part of what they do. Investigating incidents uses engineering expertise from throughout the organisation. Summaries are produced quarterly and prior to outages.

Diagnostic software assistance in the monitoring process greatly enhances staff productivity. We have examined how such software is used and what information technology infrastructure is needed to facilitate this.

The overall effect is to increase turbine availability and reliability and to maximise outage activities.



ID	DESCRIPTION	ANALYSIS	PA	RECOMMENDATI
			GES	ON
1.	Vibration spikes on generator vibration transducers	Since 7th March 2009, diagnostics has indicated possible problems with the generator DE vibration transducer on the turbine. There are intermittent periods when the transducer indicates frequent spiking. As there is only one transducer on each bearing, it is not possible to be certain if this is a real vibration problem, or a symptom of intermittent transducer faults. However, there are no significant transient events observed on any of the other key turbine parameters coincident with these events, so this indicates that the problem is more likely to be due to transducer problems.	23, 24, 25, 36, 43	Change out.
2.	Flame detector dropouts & alarms	Since 10th March 2009, there have been occasional dropouts on flame detector B, but not on A. This normally occurs during periods of reduced turbine power.	25, 26, 45	Change out/clean.
3.	Exhaust temperature spread changes	On 10 <sup>th</sup> March 2009 there was also an increase in exhaust temperature spread, from a low level of 12 Deg C to about 25 Deg C. Although this level was still quite low, it doubled during this period, and unusually increases during a time when other turbine parameters are fairly stable. There is also an increase in the temperature difference between the two 2nd stage aft wheelspace thermocouples, which is most likely caused by the increased spread. The spread increase appears to be caused by a fall in the combustion temperatures on combustion can 3 and 4. This problem has not re-occurred to date.	25, 26, 27, 29	Check Tx floating seals.

Appendix 1. Example - Frame 5 Status Summary



#### Remote Monitoring and Diagnostics for Power Generation Gas Turbines

ID	DESCRIPTION	ANALYSIS	PA GES	RECOMMENDATI ON
4.	Inlet guide vane position	This problem continues to occur during turbine startups for a few seconds as the turbine	34, 41	Calibrate.
	trouble	reaches full speed no load.		
5.	Minor negative	This problem has occurred on several shutdowns, for a few seconds before the	35	Check and adjust set
	turbine power	generator breaker opens.		points.
6.	High generator stator temperatures	A generator breaker trip, followed by a shutdown on March 28 <sup>th</sup> 2009 may have been caused by a thermocouple fault on stator slot temperature thermocouple GDF20, which began spiking at very high temperature levels. No other turbine parameters exhibited significant transients at the same time, so the sensor fault probably caused the generator stator high temperature alarm followed by the generator stator high temperature trip breaker alarm.	37, 38, 39	Renew & calibrate.
		This sensor broke on 28 <sup>th</sup> March 2009. It has not indicated high temperatures since that time, but is still broken.		
7.	Low hydraulic supply pressure alarm	This alarm has occurred during 3 shutdowns, including the most recent on 16 <sup>th</sup> April 2009.	44	Adjust VR.
8.	Exhaust thermocouple 8 failure	This thermocouple failed on 28 <sup>th</sup> March 2009, but was fixed on 14 <sup>th</sup> July 2009 and is currently working.	45	



#### Remote Monitoring and Diagnostics for Power Generation Gas Turbines

ID	DESCRIPTION	ANALYSIS	PA GES	RECOMMENDATI ON
9.	High wheelspace stage 1 aft outer 1 and 2 thermocouple temperature divergence	The differential temperature between the two thermocouples has stayed at about 30 Deg C throughout the report period, when the turbine is running on load. This is higher than would normally be expected.	33, 48	Refit.
10.	High load gear temperature	On 13th and 20th August 2009, two high load gear temperature alarms were detected. As expected, these coincided with higher load gear temperatures. The higher load gear temperatures appeared to be related to higher ambient temperatures. Unfortunately, the ambient temperature readings were not available from the turbine controller. However as there is an inverse relationship between turbine power and ambient temperatures when the turbine is on temperature control, this can be inferred from turbine power levels being lower when the alarms occur. This may indicate a developing problem with the lube oil cooling system. This alarm continues to occur intermittently when the turbine is running. The last occurrence was on 26 <sup>th</sup> August 2009.	50, 51, 52	Check oil cooler efficiency.
11.	Compressor trouble trip	Several turbine compressor trouble trips have occurred immediately after turbine trips and during turbine shutdowns. These trips are normally a side effect of the initial trip, and should not be a problem.	32, 40	No action needed.
12.	Low gas fuel supply pressure	Gas fuel pressure is often quite low, and this is indicated by the gas fuel speed ratio valve running at a high level, often being more than 90% open.	30	Increase supply pressure. Use a gas fuel compressor.

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#### Remote Monitoring and Diagnostics for Power Generation Gas Turbines

ID	DESCRIPTION	ANALYSIS	PA GES	RECOMMENDATI ON
13.	Compressor bleed valves slow to actuate	Compressor bleed valves are quite slow to open during trips and shutdowns. The delay can be up to 17 seconds.	32, 40	Fit latest version. Relocate outside of GT enclosure.
14.	Low lube oil pressure on turbine run down	Low lube oil pressure digital activates when the emergency lube oil pump stops just after the trip and clears when the emergency lube oil starts up when the turbine has stopped. So far, there have been no low load oil pressure alarms occurring as a result.	33	Recalibrate pressure switches and oil supply regulator.



#### Appendix 2. Example – Frame 5 Tiger Incident Report

#### **Bearing Vibration Levels**

On 7<sup>th</sup> March 2009, diagnostics indicated possible problems with the generator DE vibration transducer on the turbine. There are periods when the transducer indicates frequent spiking. As there is only one transducer on each bearing, it is not possible to be certain if this is a real vibration problem, or a symptom of intermittent transducer faults. However, there are no significant transient events observed on any of the other key turbine parameters coincident with these events, so this indicates that the problem is more likely to be due to transducer problems.

## Diagnostics query of vibration diagnostic messages with critical, fault, warning and event severities by occurrence for 7<sup>th</sup> March

[605] Maximum bearing vibration - derived (C\_BB\_MAX) too high. Limit 8.00 mm/s

- [605] Generator De Vibration (V39V\_4) too high. Limit 8.00 mm/s
- [437] Turbine bearing transducer 12 spike detected

[818] Turbine bearing transducer 12 vibration - significant decrease

[794] Turbine bearing transducer 12 vibration - significant increase

#### **Trend Graphs for March 2009**

MAX of all bearing vibration transducers indicates that all are normal except for generator DE vibration transducer which has episodes of high vibration





MIN/MAX of generator DE vibration transducer indicates that during the episodes of high vibration, the level is constantly changing

🚰 Trend Graph For Alarm Server 0	7:59:47 07/	/03/2009,	11.23	V39V_4(MAX) [mm/s] Gene	rator De Vibration		
Ў⋊⋕⋈ ⊾∎∎⊜ ◀		+ X	II D	XX XX 👔 X Xn Xn	m 3.58 11.41		
							,
10							
5							
07/03/2009		08/0	3/2009	09/03	/2009	10/03/2009	
Tag Name	Min	Value	May	Description	Turbine	State	
V39V 4(MAX)	3.782	11.309	11.408	[mm/s] Generator De Vibration	GT1	DEFAULT	
V39V_4(MIN)	3.584	3.596	4.154	[mm/s] Generator De Vibration	GT1	DEFAULT	

#### **Data Graphs for March 2009**

Generator DE vibration transducer indicates that during the episodes of high vibration, the level is constantly spiking. This may indicate a transducer fault



Graph of all vibration transducers indicates that during spiking on the generator DE vibration transducer the other vibration transducers are not affected. This also indicates a possible transducer fault







#### Appendix 3. Example – Frame 6 Daily Automated Report Sample Pages

#### 7-day Trend Report 24Hr Diagnostics Long Term Performance

#### Report Generated on 30/01/2008 at 10:56:52

#### **Table of Contents**

(note that the page numbers do not refer to this appendix – this is a sample)

OIL TEMPERATURES	3
Power & Max Compressor Inlet Flange Temperature	3
BEARING METAL TEMPERATURES	5
Turbine	5
Reduction Gear	5
Thrust	6
Generator	6
Power & Max Compressor Inlet Flange Temperature	7
WHEELSPACE TEMPERATURES & COMPRESSOR DISCHARGE TEMPERATURE 1 & 2	8
Power, Max Compressor Inlet Flange Temperature & Compressor Discharge Pressure	9
VIBRATION	11
Power (DWATT & DVAR) & Lube Oil Header Temperature	11
POWER & MAX COMPRESSOR INLET FLANGE TEMPERATURE.	12
SPEED BIASED TEMPERATURE CONTROL REFERENCE & EXHAUST TEMPERATURE MEDIAN CORRECTED BY AVERAGE	13
EXHAUST SPREADS	13
FLAME VECTOR	14
FLAME VECTOR ANGLE.	14
FUEL	16
Gas Fuel Stop Valve Open & Liquid Fuel Stop Valve Closed	16
POWER, MAX COMPRESSOR INLET FLANGE TEMPERATURE, INTERVALVE GAS FUEL PRESSURE INPUT, STEAM INJECTION FLOW, FUEL FLOW & LIQUID FUEL FLOW	GAS 18
COMPRESSOR EFFICIENCY	19
DRY CORRECTED POWER	20
DRY CORRECTED HEAT RATE	21
TURBINE POWER DAILY AVERAGE & COMPRESSOR INLET TEMPERATURE DAILY AVERAGE	22
DIAGNOSTICS	23
Currently Abnormal	23
Number of Occurrences	24





#### Oil Temperatures

#### Power & Max Compressor Inlet Flange Temperature







#### Power (DWATT & DVAR) & Lube Oil Header Temperature





#### Dry Corrected Power





Turbine Power Daily Average & Compressor Inlet Temperature Daily Average





#### **Diagnostics**

Currently Abnormal

Currently abnormal diagnostics for turbine GT 1 with tag:all message:all severities:all alarms:all with filter

10:56:52 30/01/2008 Control panel temperature high (L26CTH\_ALM) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Exhaust thermocouple trouble (L30SPTA) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Primary split above safe limit at high load (L3GSVM) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Turbine compartment vent fan #1 - undercurrent rel (L51BT1) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Above fast load rate T\.d. (L60DWR2Y) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Lube oil tank level high (L71QH) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Lube oil level trip (L71QT) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Directional trip to primary - servo not (L94FXP1) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Turbine temperature-wheelspace 3rd stg fwd outer (TTWS3FO2) too high. Limit 445.00 degC Highest Value: 508.77 Current Value: 508.53

10:56:52 30/01/2008 Turbine temperature-wheelspace 3rd stg fwd outer (TTWS3FO1) too high. Limit 445.00 degC Highest Value: 487.86 Current Value: 487.52

10:56:52 30/01/2008 Generator electrical trouble (L78GS\_ALM) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Lube oil level high (L71QH\_ALM) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 T\.d. hydraulic supply pressure low (L63HQ1LY) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Gas compartment vent fan #1 - undercurrent relay (L51VL2) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Access compartment vent fan #2 - undercurrent rela (L51BA2) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Wheelspace temperature high (L30WSA2) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 Combustion trouble (L30SPA) not in expected state (actual 1 expected 0)

10:56:52 30/01/2008 DLN Premix Combustion

10:56:52 30/01/2008 Wheelspace 3rd stage fwd outer differential temperature (C\_WS3FODIFF) too high. Limit 20.00 degCR Highest Value: 21.36 Current Value: 21.01 10:56:52 30/01/2008 Turbine is running in high load range

10:56:52 30/01/2008 Compressor inlet air flow (AFQ) too low. Limit 100.00 kg/sec Lowest Value: 0.00 Current Value: 0.00

