Discussion Database

- Platform To Integrate & Share Knowledge of Working Professionals
- Problems are Common – Therefore ONE solution for MANY !!
- Facilitate Faster Corrections
- RETAIN... Information

On Line Certifications

- Online course study- University Certificate Confirms the Acquired Knowledge
- Promote Knowledge of Codes & Standards

Lesson Learnt

- Every Project Initiates New Learning / Lessons
- Facilitate Corrections in Future Specifications

Benefits

- If learners don't understand something? No problem, they can retake certain parts as many times as they need to.
- Free flow of ideas encourages innovation and improves efficiency.

Benefits

- Learners can present all ideas and information through a common interface. This will meet the large requirement of trained personnel for operation and maintenance of plants, reduce O&M costs, reduce damage to plant, increase plant life and reduce training time.

- Till date, such Process Instrumentation & Control Online Certificate Course and I&C training programs are presently being taught in North America at two locations: in the United States at the University of Kansas Continuing Education (www.continuinged.ku.edu) and in Canada at the Dalhousie University Continuing Education (http://collegeofcontinuinged.dal.ca).

LANCO
INSPIRING GROWTH

THANK YOU

SAFETY INSTRUMENTED SYSTEM IN FERTILISER PLANT

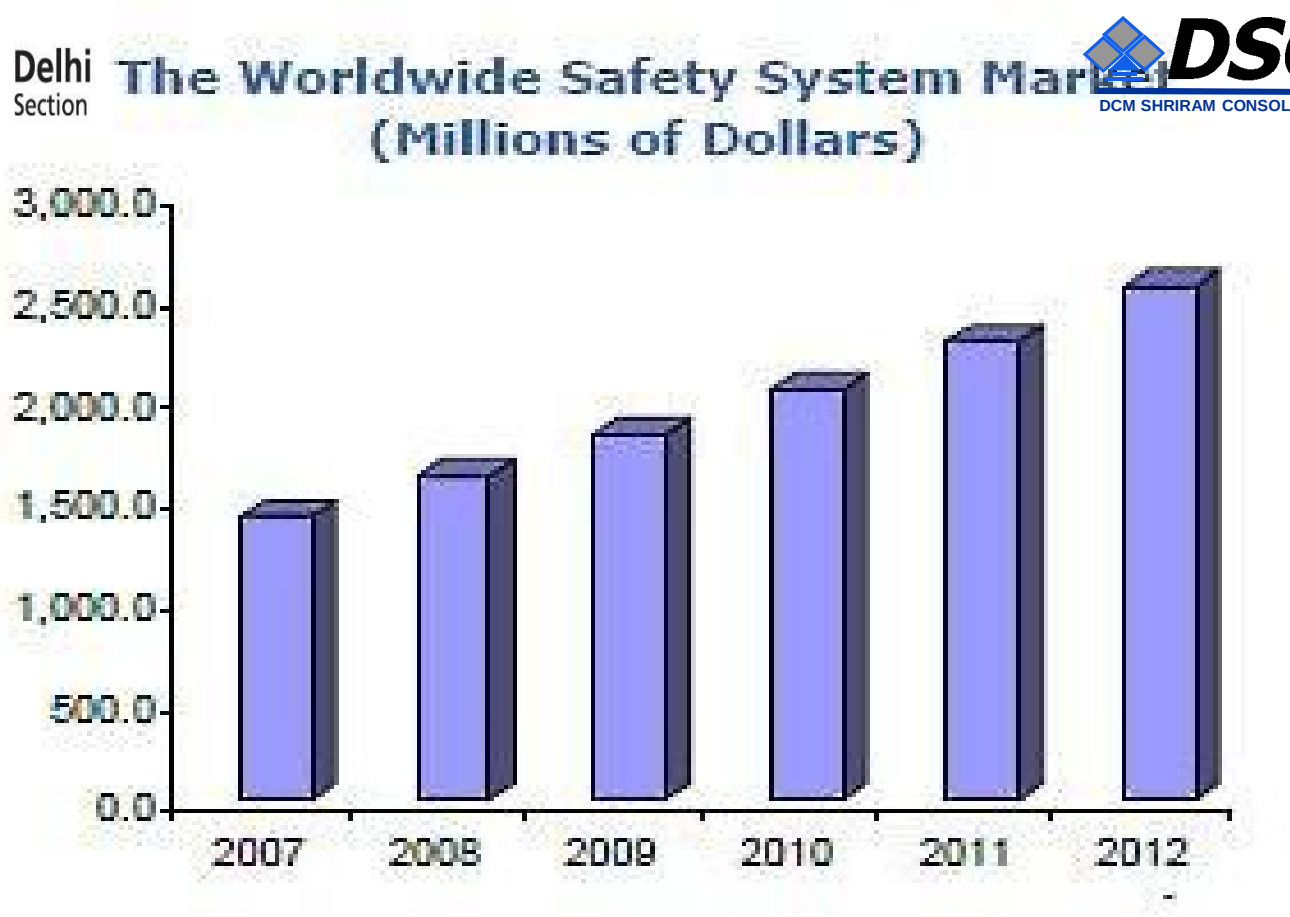
VIVEK GUPTA

SHRIRAM FERTILISERS & CHEMICALS: KOTA

ISA(D) POWAT-2010
Mumbai, 28th & 29th May 2010

"It could all be a coincidence, Barry, but we haven't had an accident-free day at the plant since you were hired."

- SIS WOULD BE THE BETTER OPTION!!



- WORLD SAFETY MARKET INCREASING DAY BY DAY

ISA Delhi Section

DSCL
DCM SHRIRAM CONSOLIDATED LTD

What is SIS ?

- **SIS-SAFETY INSTRUMENTED SYSTEM**

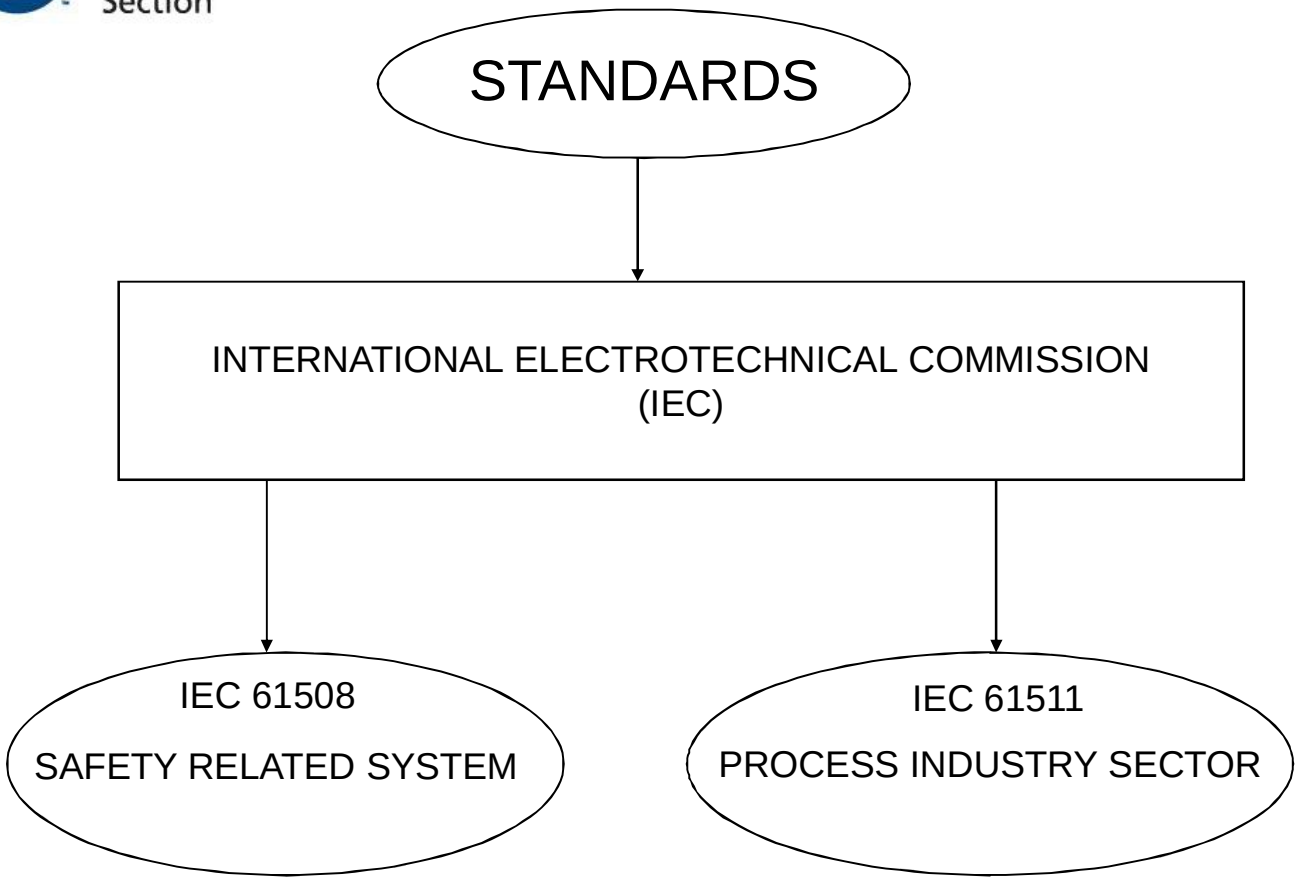
  A SIS is designed to prevent or mitigate hazardous events by taking processes to a safe state when predetermined conditions are violated.

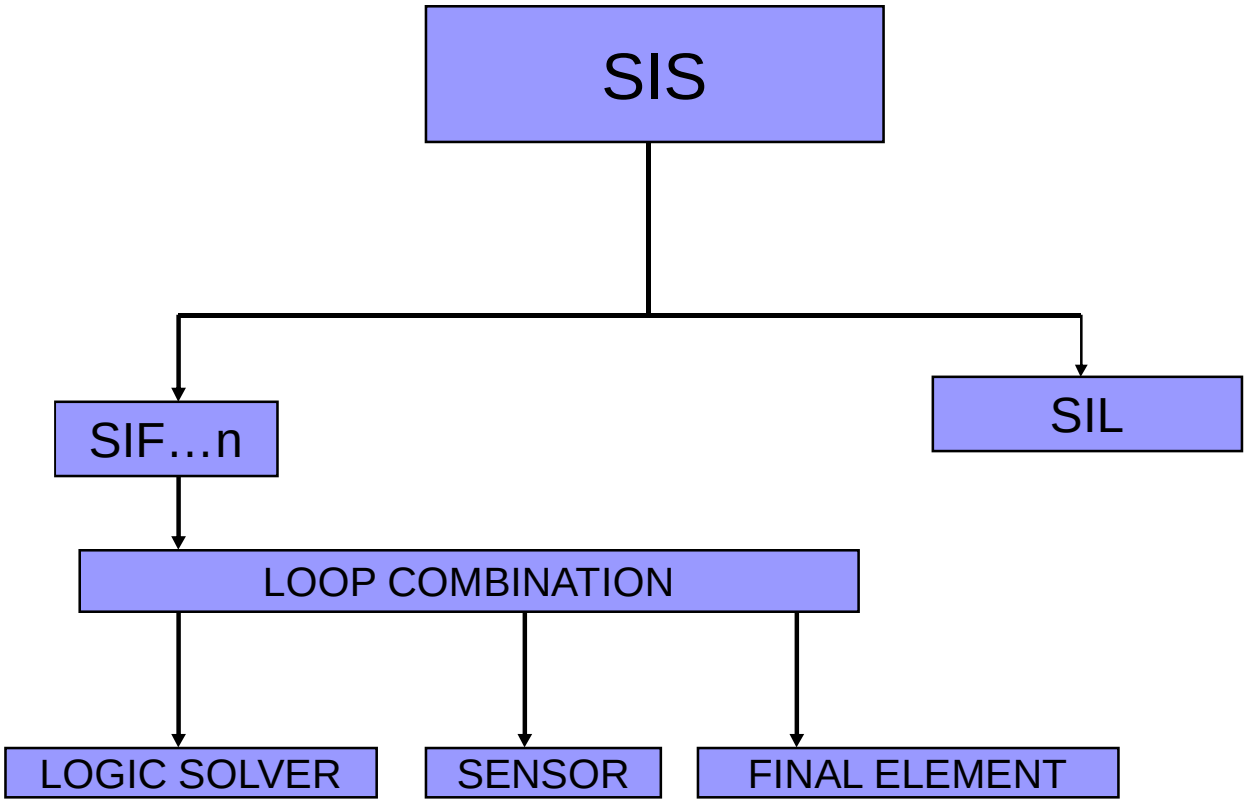
- **WHAT SIS CAN DO?**

  Emergency Shut Down

  Safety Shut Down

  Safety Interlocks


STANDARDS
INTERNATIONAL ELECTROTECHNICAL COMMISSION
(IEC)
IEC 61508
SAFETY RELATED SYSTEM
IEC 61511
PROCESS INDUSTRY SECTOR


SIS
SIF…n
SIL
LOOP COMBINATION
LOGIC SOLVER
SENSOR
FINAL ELEMENT

FUNCTIONAL SAFETY

Functional Safety is the safety that control systems provide to an overall process or plant.

CONCEPT FOR FUNCTIONAL SAFETY:

Developed in response to the growing need for improved confidence in safety systems.

SIF-SAFETY INSTRUMENTED FUNCTIONS:

Actions taken by a SIS to bring the process & equipment under control to a Safe state.

REQUIREMENT FOR FUNCTIONAL SAFETY:

- Safety Function Requirements – Hazard Analysis
- Safety Integrity Requirements – Risk Assessment

SAFETY INTEGRITY LEVELS

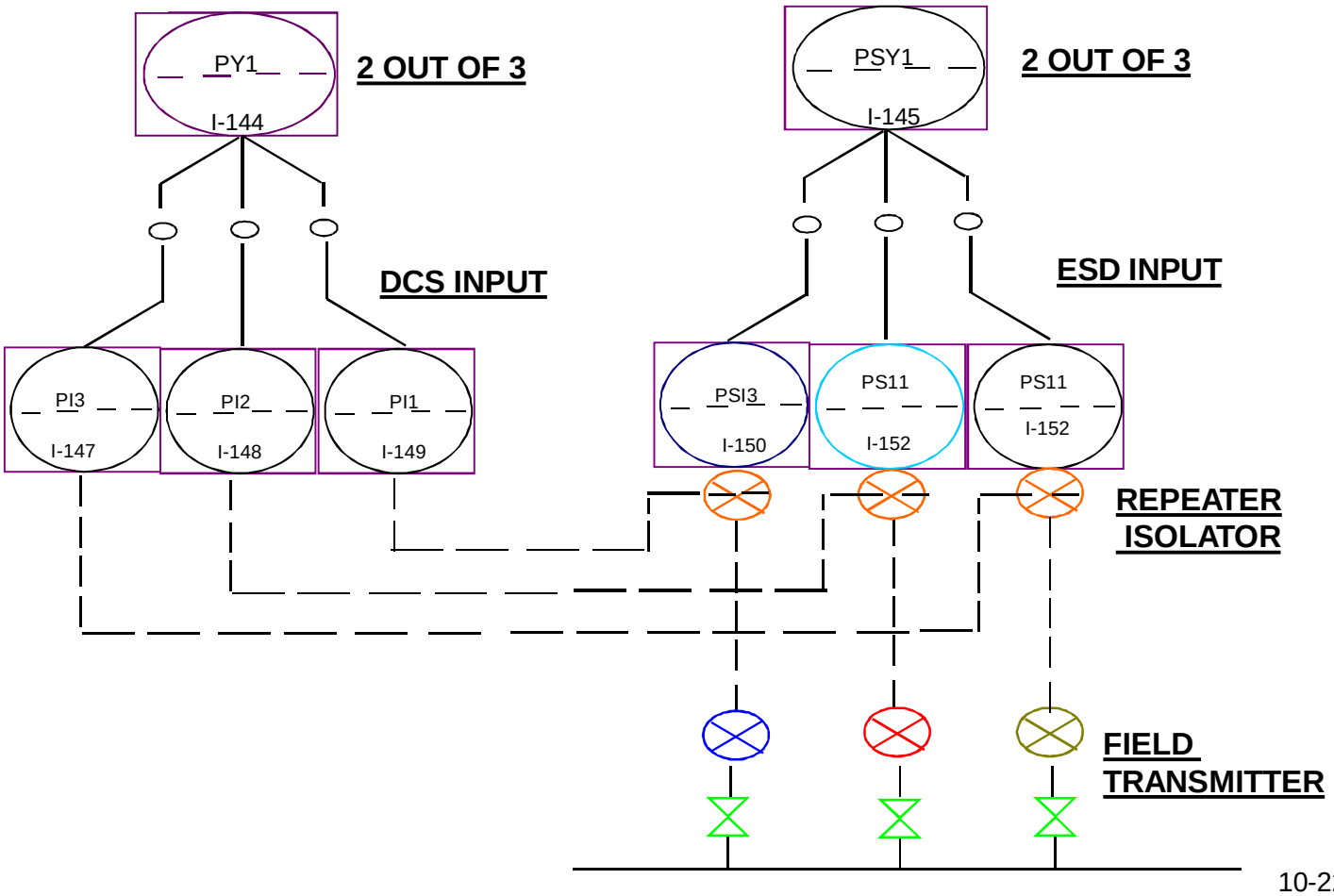
The higher the level of safety integrity, lower is the likelihood of dangerous failure.

Safety Integrity Level	Risk Reduction Factor	Probability of Failure on Demand (PFD)
SIL 4	100,000 to 10,000	10^{-5} to 10^{-4}
SIL 3	10,000 to 1,000	10^{-5} to 10^{-4}
SIL 2	1,000 to 100	10^{-5} to 10^{-4}
SIL 1	100 to 10	10^{-5} to 10^{-4}

DESIGN GUIDELINES FOR SAFETY INSTRUMENTED SYSTEM (SIS)

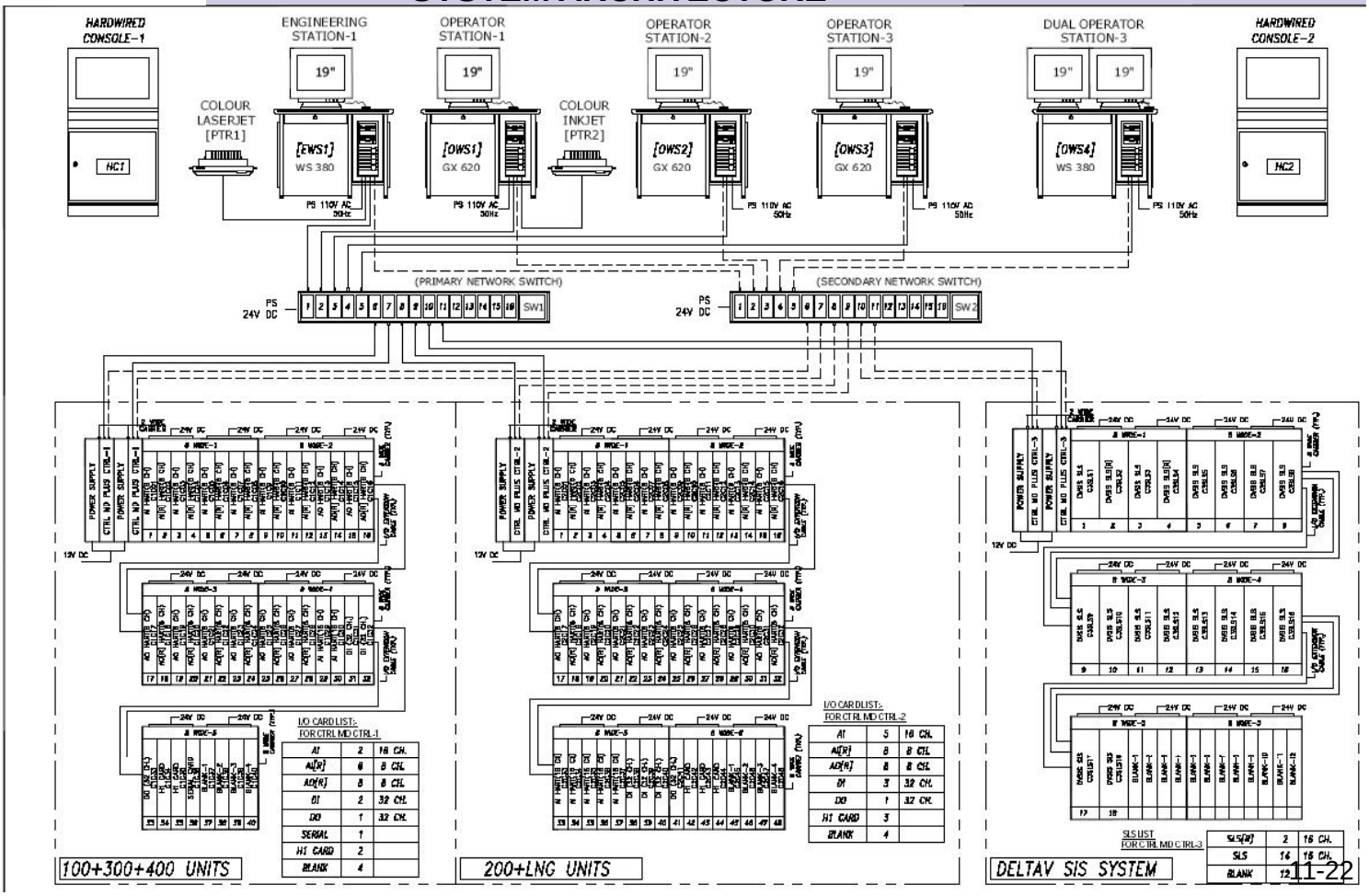
- Separation of SIS and DCS
- Identical or Diverse Separation
- Field Sensors
- Final Elements
- Wiring
- Hardware Fault Tolerance
- Physical Separation

STANDARD ALGORITHM – 2 OUT OF 3 VOTING



SIS AT AMMONIA PLANT

SYSTEM ARCHITECTURE



SIS LOGIC MODULE 1(2oo3)

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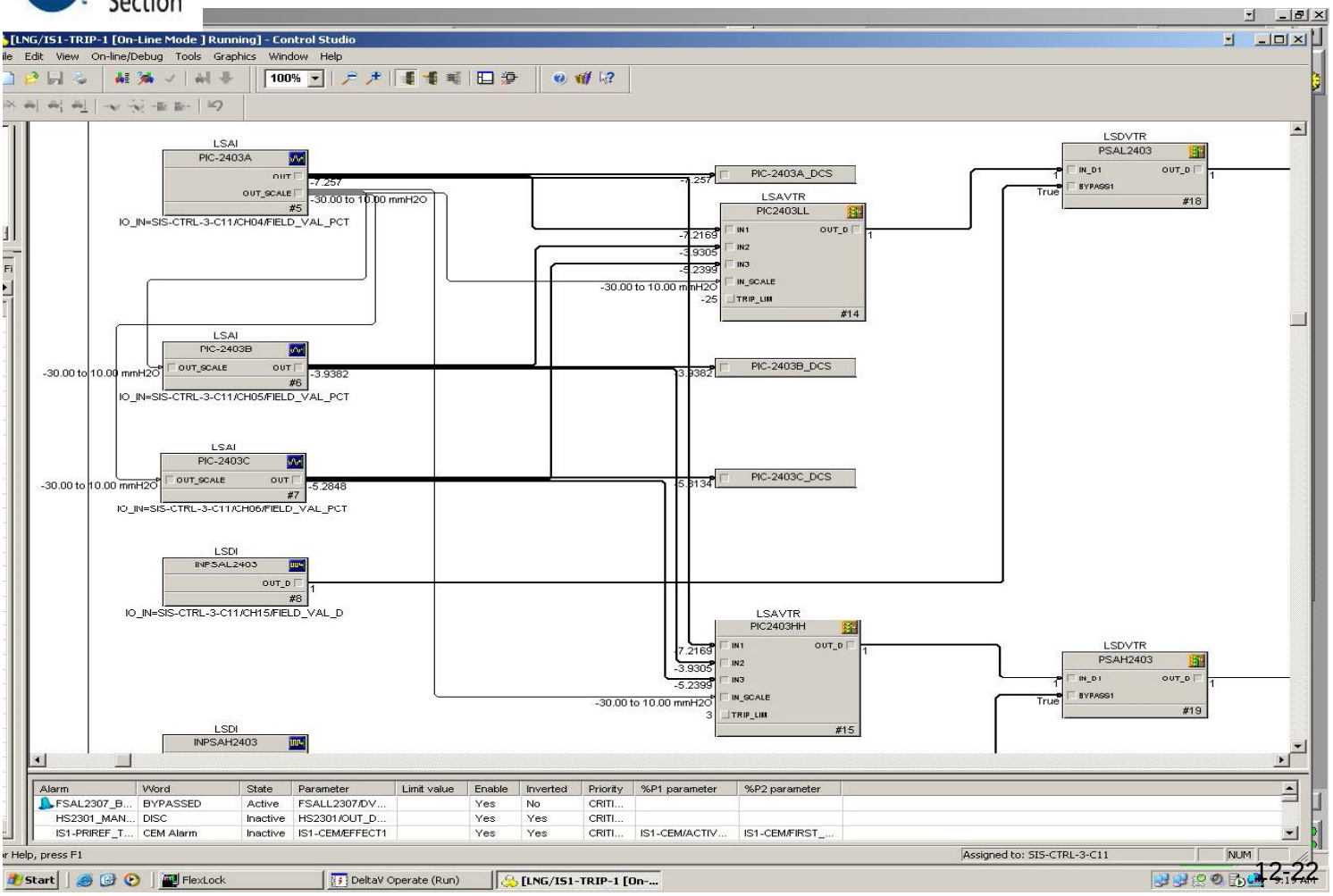

SIS LOGIC MODULE 2(2oo3)

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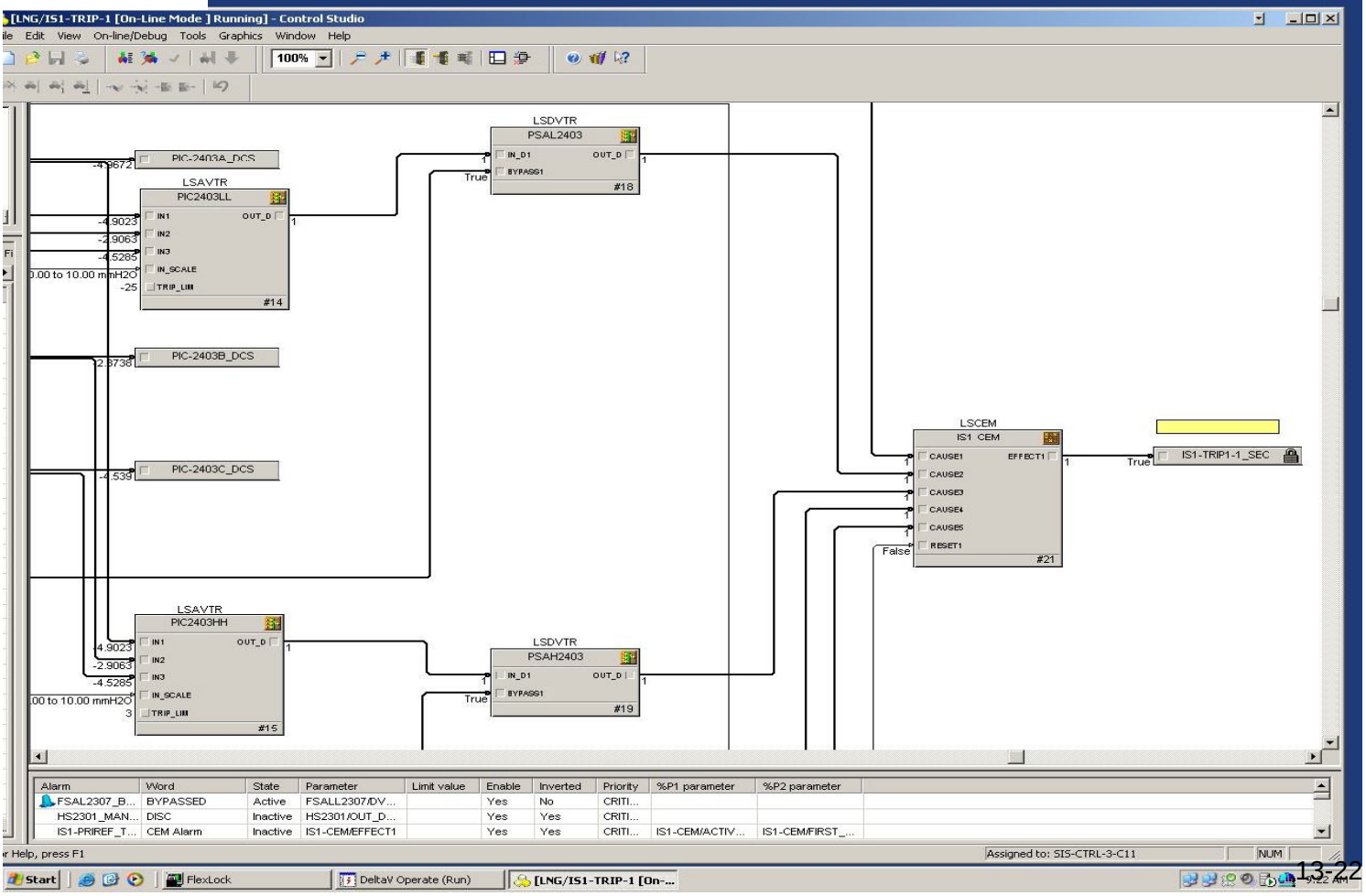
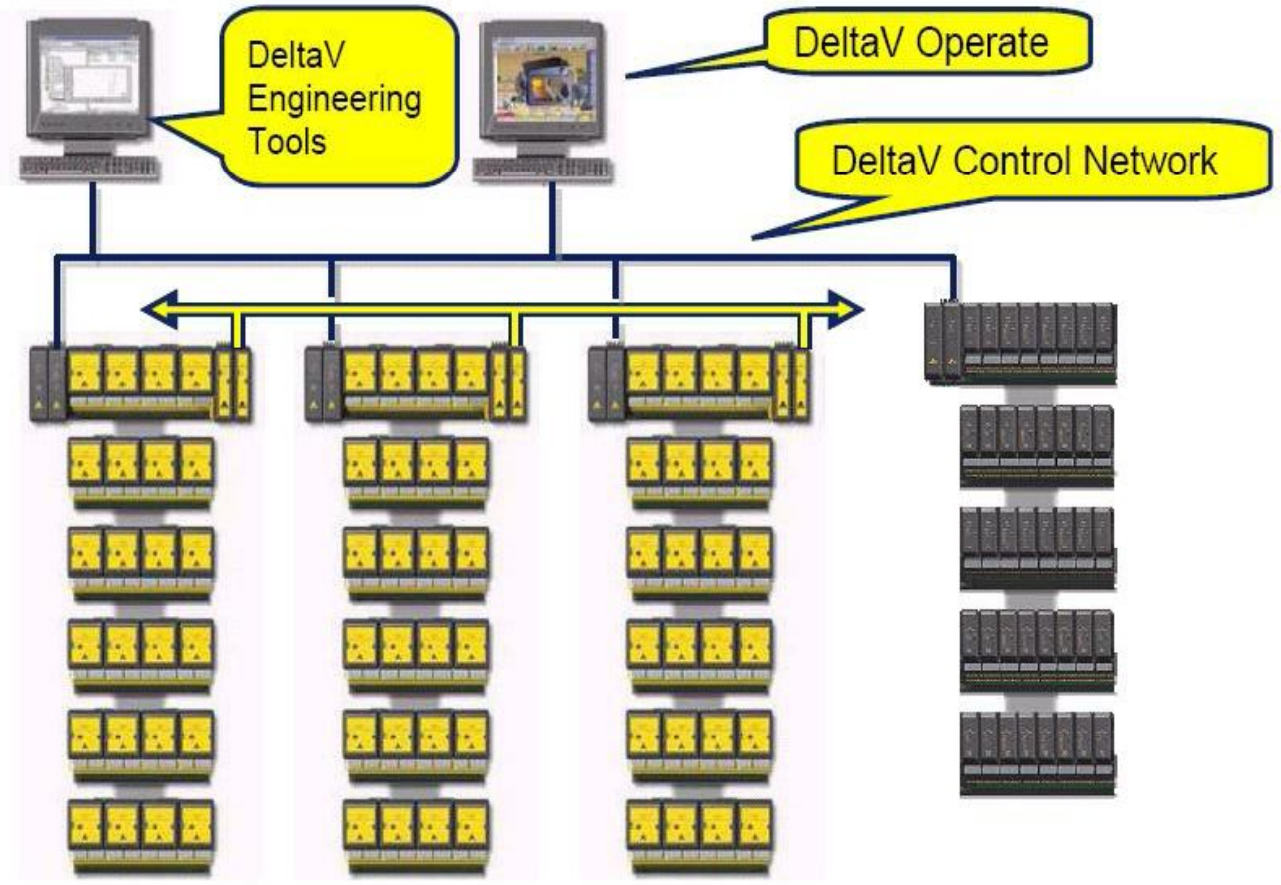


DELTA – V SIS, ENGINEERING ASPECTS AT SFC, KOTA:

- State of the Art expandable system
- Fault Tolerant & triple redundant system
- Hot swappable capabilities.
- Separate system with common platform for engineering
- Redundant at Output Level
- Redundant Power Supplies
- Redundant Communication
- 2oo3, 2oo2 & 1oo1 logic selection
- First out cause detection (Sequence & Event)
- Faster Scan Rate (50 mS)
- SIL-3 Approval
- Analog I/P & through Barriers
- DI & DO through Interposing Relays (SIL-3)
- Hart Compatibility for analog Inputs Equipped



DeltaV SIS overview

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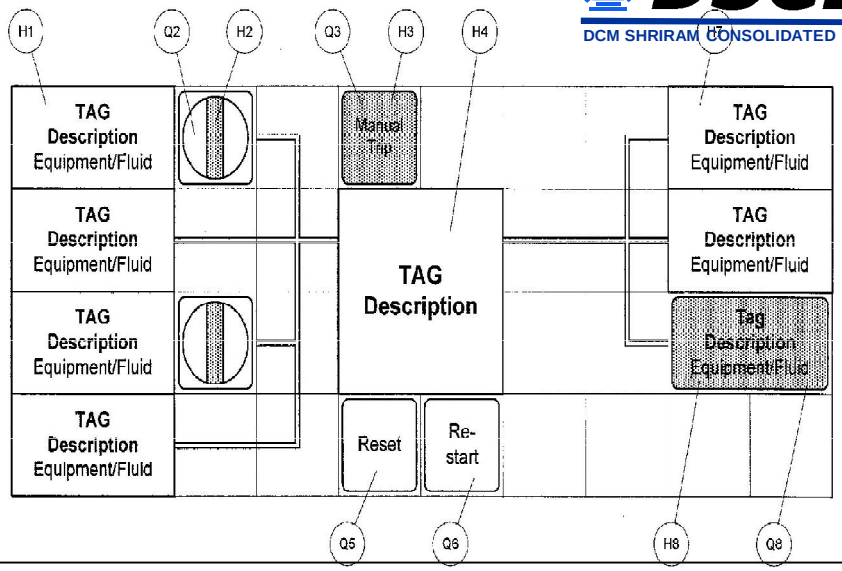
LOGIC SOLVER

CAPABILITIES:

- SEQUENCE OF EVENTS
- PROVIDE INTERFACE TO 16 I/O i.e. DI,DO&AI
- UNIQUE REDUNDANCY METHODOLOGY
- EACH LOGIC SOLVER HAS DUAL CPU
- ONLINE ADDITION OF MODULE CAN BE DONE

TYPICAL SHUTDOWN ARRANGEMENT



Components:
Switches
Q2 Inactivation (used when required only)
Push Buttons
Q3 Manual Trip
Q5 Trip Reset (common for all inputs)
Q6 Shutdown Group Reset
Q8 Output Reset (used when required only)
Status Lamps/Lights
H1 Trip Alarm. Normal OFF. Color RED
H2 Inactivation (used when required only). Normal OFF. Color ORANGE
H3 Manual Trip. Normal OFF. Color RED
H4 Shut down Group Trip. Normal OFF. Color RED
H7 Trip Action (without button). Normal OFF. Color WHITE
H8 Trip Action (with button). Normal OFF. Color WH

SPECIFICATIONS

- INPUT POWER 24VDC
- FIELD POWER 4A MAX
- EACH CHANNEL IS OPTICALLY ISOLATED FROM SYSTEM
- OPERATING TEMPRATURE -40 TO 70 ^{0}C
- SIMPLEX LOGIC SOLVER WIEGHT 0.625 KG
- HEAT DISSIPATION IS 16 WATT
- PROTECTION RATING IP20, NEMA 12

SHUTDOWN SEQUENCES

TAG NO.	DESCRIPTION
IS-1	PRIMARY REFORMER TRIP
I-201	I. D. FAN STOP
I-202	F. D. FAN STOP
I-203	NG PREHEATER FUEL STOP
SD-201	FSRU PREHEATER TRIP
SD-207	PROCESS AIR
SD-208	SECONDARY REFORMER
SD-209	RAW SYNTHESIS GAS
SD-301	METHANATOR
SD-302	HPC ABSORBER GAS PURGE
SD-303	HPC ABSORBER S/D
SD-304	SYNTHESIS GAS PURGE
SD-401	START-UP HEATER
SD-402	WASTE HEAT BOILER
PA-007	INSTRUMENT AIR
PWR FL	POWER FAIL

PRIMARY REFORMER SHUTDOWN

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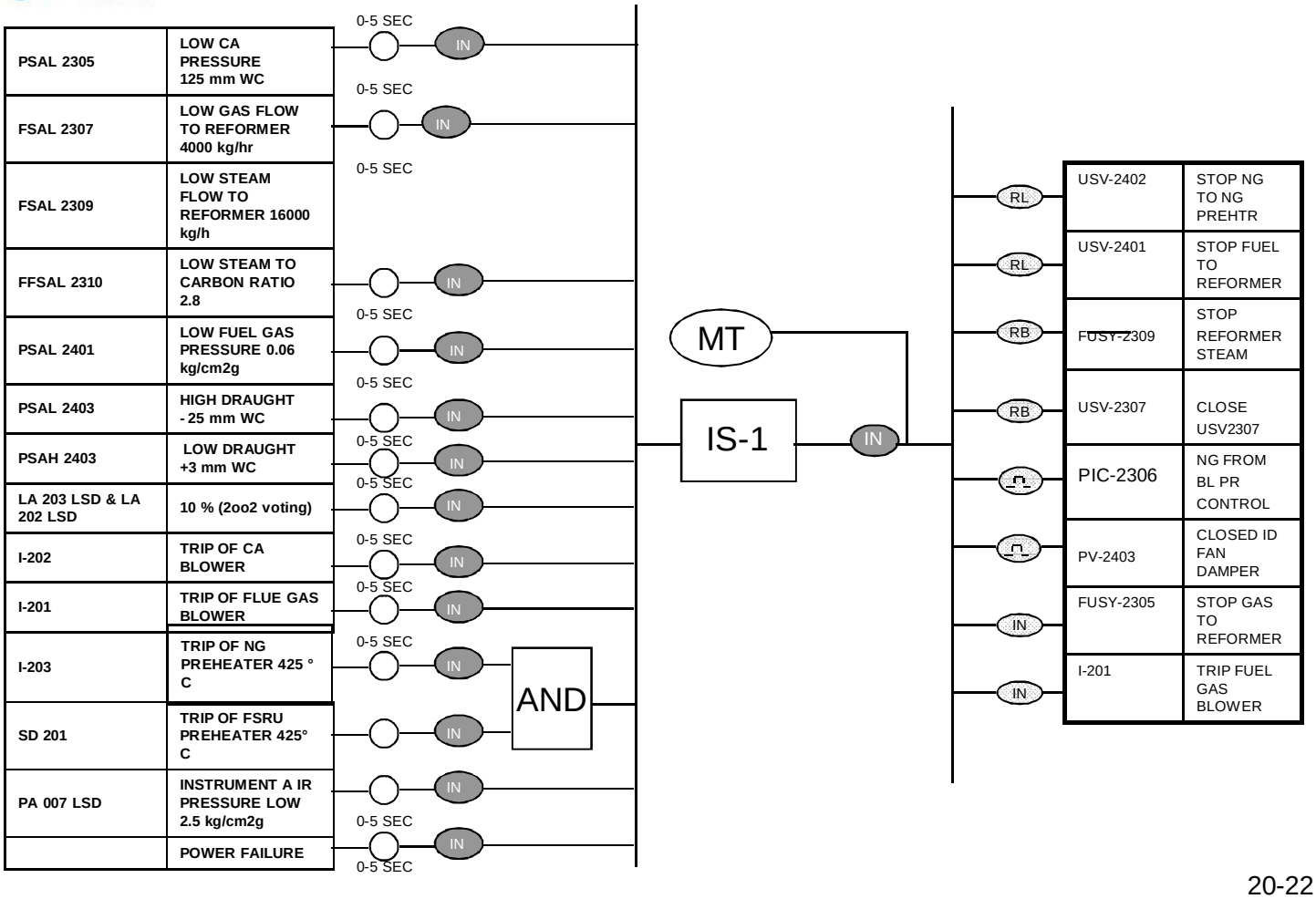

PSAL 2305	LOW CA PRESSURE 125 mm WC
FSAL 2307	LOW GAS FLOW TO REFORMER 4000 kg/hr
FSAL 2309	LOW STEAM FLOW TO REFORMER 16000 kg/h
FFSAL 2310	LOW STEAM TO CARBON RATIO 2.8
PSAL 2401	LOW FUEL GAS PRESSURE 0.06 kg/cm2g
PSAL 2403	HIGH DRAUGHT - 25 mm WC
PSAH 2403	LOW DRAUGHT +3 mm WC
LA 203 LSD & LA 202 LSD	10 % (2oo2 voting)
I-202	TRIP OF CA BLOWER
I-201	TRIP OF FLUE GAS BLOWER
I-203	TRIP OF NG PREHEATER 425 ° C
SD 201	TRIP OF FSRU PREHEATER 425° C
PA 007 LSD	INSTRUMENT A IR PRESSURE LOW 2.5 kg/cm2g
	POWER FAILURE

USV-2402	STOP NG TO NG PREHTR
USV-2401	STOP FUEL TO REFORMER
FUSY-2309	STOP REFORMER STEAM
USV-2307	CLOSE USV2307
PIC-2306	NG FROM BL PR CONTROL
PV-2403	CLOSED ID FAN DAMPER
FUSY-2305	STOP GAS TO REFORMER
I-201	TRIP FUEL GAS BLOWER

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BENEFITS

- INCREASED FOCUS ON OVERALL SAFETY
- INTEGRATION WITH CONTROL SYSTEM
- FLEXIBILITY & SCALABILITY
- LESSER HARDWARE & BETTER DIAGNOSTIC
- FASTER RESPONSE TIME
- INCREASED PROCESS AVAILABILITY
- REDUCED LIFE CYCLE COST

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Thank You

vivek_gupta@dscl.com

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Power Plant Rotating Machines - Vibration Analysis Increases Up Time !!

Tatsuro Tomoda & Mukesh Vyas
Shinkawa Japan & Forbes Marshall India

- **ISA (D) POWAT 2010**

Forbes Marshall

SHINKAWA

Introduction

- Forbes Marshall – US$ 120 Million – Instrumentation Company having Product Range of Shinkawa TSS & VMS , Insitu Gas Analyzers of Codel , SWAS , Flow Meters , AAQMS , Control Valves , DCS , Steam traps , Boilers……. With 23 Branches across India for Services.

- Shinkawa Japan – US$ 330 Million – Japan Based Company of On Line VMS & Other Instrumentation Packages. Key OEMs – MHI , Toshiba , Hitachi , Fujii , Shinippon , Ebara , Atlas Copco….

Forbes Marshall & Indian Power Industry

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- Shinkawa Vibration Monitoring system – More than 700 Customers and Used in 150 Large Power Plants above 250 / 500 / 600 MW…800 MW is just coming.
- Codel – Insitu Gas Analyzers – Changed the wave ….24 X 7 Working Analyzers for Sox , Nox & CO + Opacity Monitoring.
- SWAS – It is installed in almost all power plants of India.
- Ambient Air Monitoring System (AAQMS) – Plug & Play – Air pointer…No Need of Shelters !! A Revolution .
- Valves , Flow Meters , Level Measurement , Water Quality Analyzers….

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Power Plant Rotating Machine Vibration Monitoring

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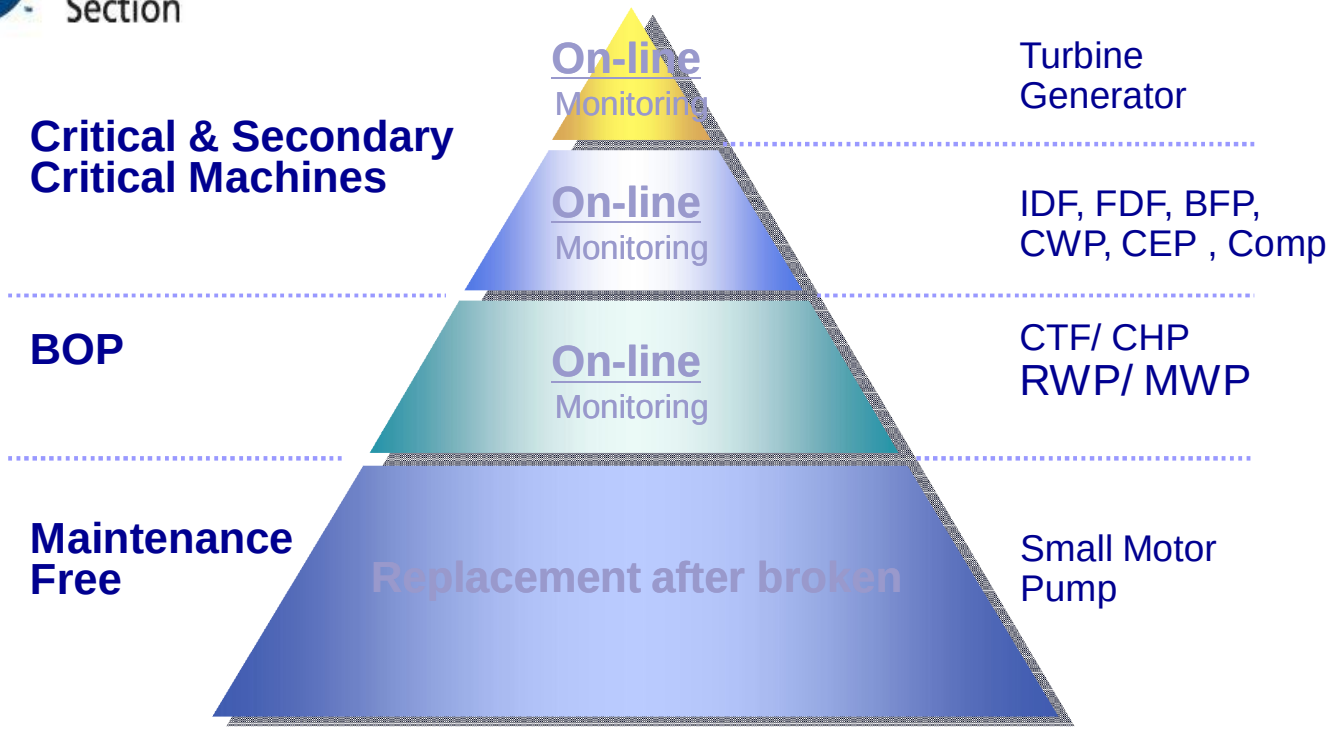
Category of VMS by Machine



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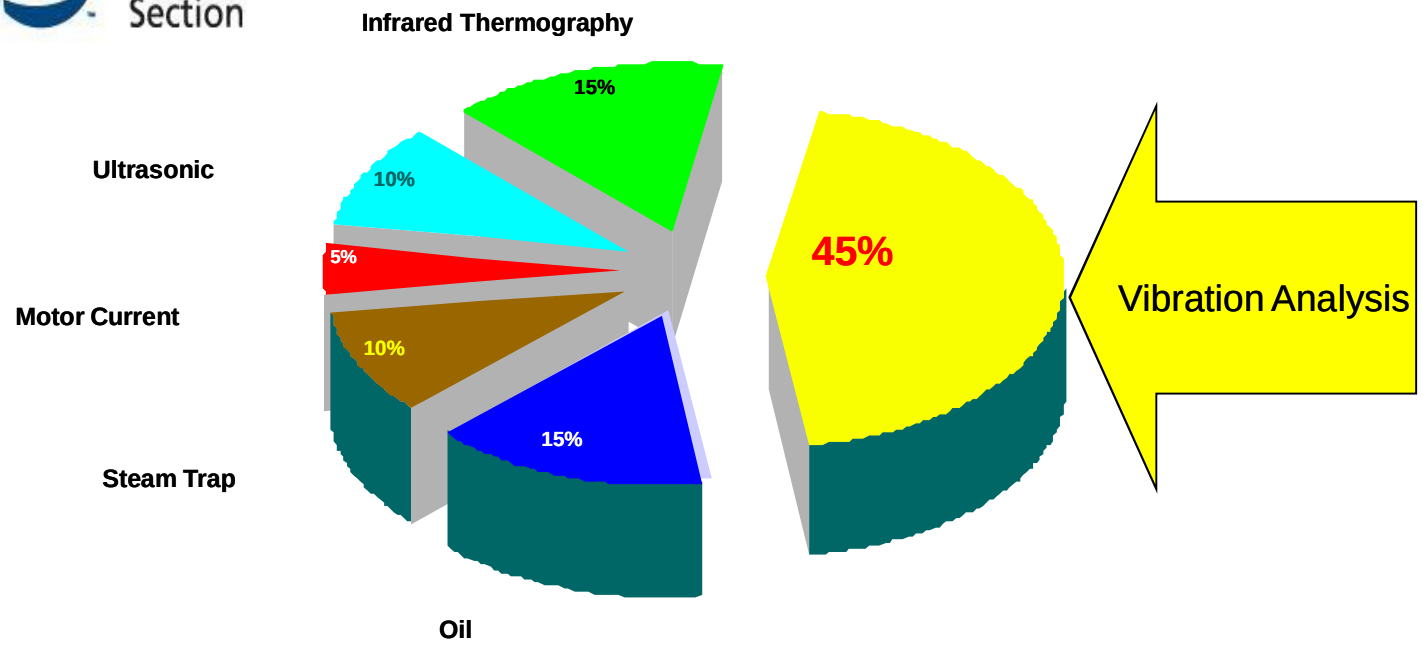

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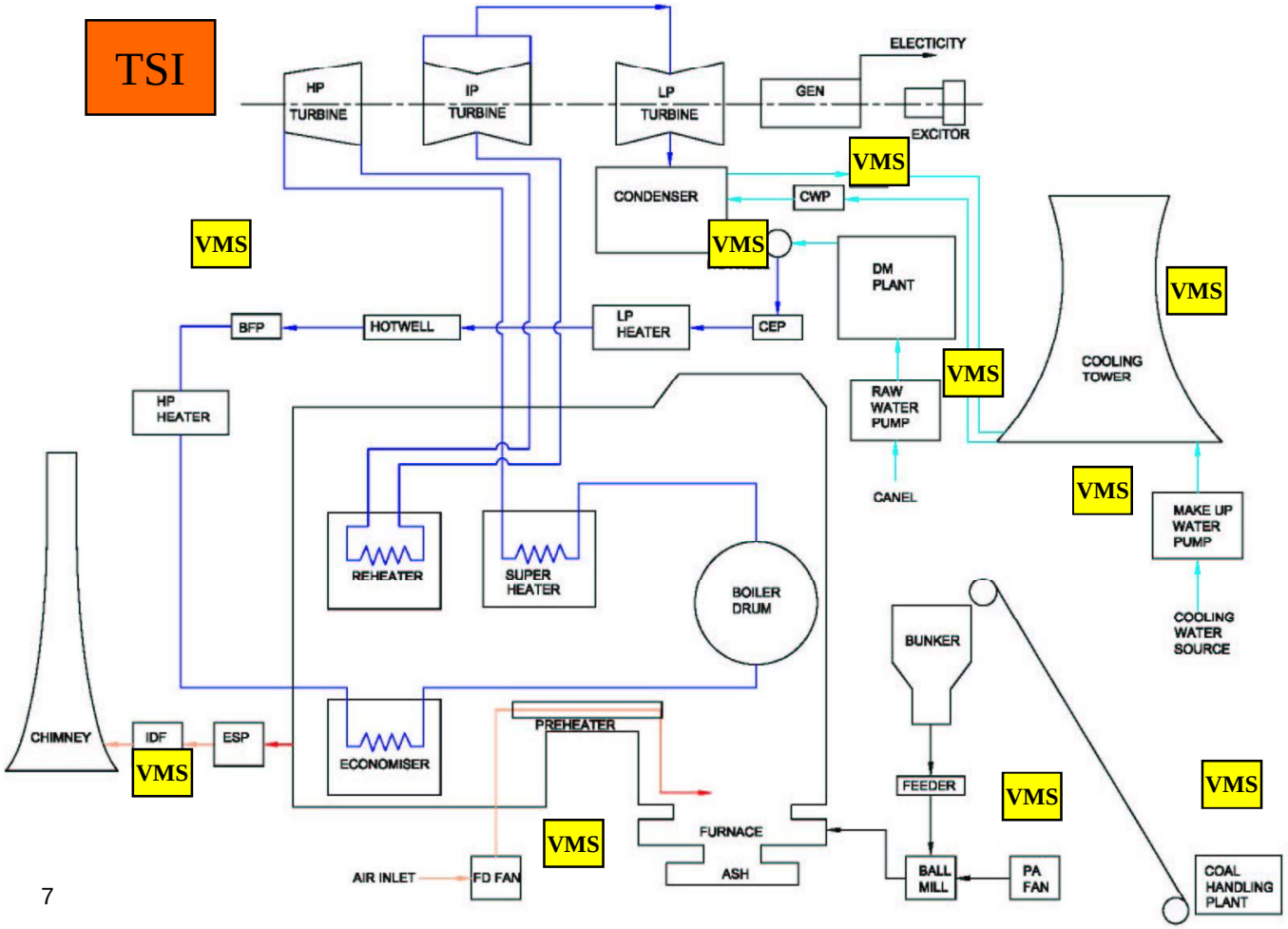
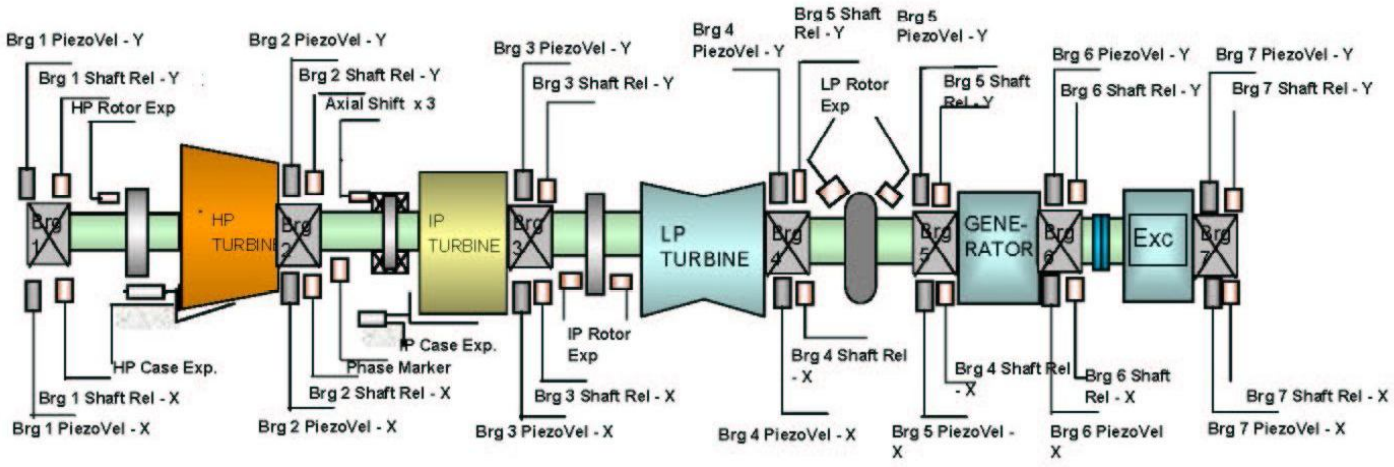
TYPICAL COAL FIRED POWER PLANT -SCHEMATIC



Typical Power Plant Rotating Machines

- **Critical Machine**
  - **Turbine & Generator**
- **Secondary Critical Machines**
  - **Boiler Feed Pumps & Motors**
  - **CE Pumps & Motors**
  - **CW Pumps & Motors**
  - **ID / FD / PA Fans & Motors**
  - **Mill Motors**
- **Balance of Plant Machines**
  - **Coal Handling Plants**
  - **Cooling Tower Fan & Motors**
  - **Make up Water & Raw Water Pumps**
  - **Compressors for Utility**


Brg 1 PiezoVel - Y
Brg 1 Shaft Rel - Y
HP Rotor Exp
Brg 2 PiezoVel - Y
Brg 2 Shaft Rel - Y
Axial Shift x 3
Brg 3 PiezoVel - Y
Brg 3 Shaft Rel - Y
Brg 4 PiezoVel - Y
Brg 5 Shaft Rel - Y
LP Rotor Exp
Brg 5 PiezoVel - Y
Brg 5 Shaft Rel - Y
Brg 6 PiezoVel - Y
Brg 6 Shaft Rel - Y
Brg 7 PiezoVel - Y
Brg 7 Shaft Rel - Y
HP TURBINE
IP TURBINE
LP TURBINE
GENE-RATOR
Exc
Brg 1
Brg 2
Brg 3
Brg 4
Brg 5
Brg 6
Brg 7
HP Case Exp.
Brg 1 Shaft Rel - X
Brg 1 PiezoVel - X
IP Case Exp.
Phase Marker
Brg 2 Shaft Rel - X
Brg 2 PiezoVel - X
IP Rotor Exp
Brg 3 Shaft Rel - X
Brg 3 PiezoVel - X
Brg 4 Shaft Rel - X
Brg 4 PiezoVel - X
Brg 4 Shaft Rel - X
Brg 5 PiezoVel - X
Brg 6 Shaft Rel - X
Brg 6 PiezoVel X
Brg 7 Shaft Rel - X
Brg 7 PiezoVel - X

Measuring Parameters for Turbine

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Measuring Parameters for TSI

Speed	Measure the running speed. Speed alarm may be used to change the alarm setting value of the vibration while start up and shut down.
Eccentricity	Measure the shaft bow, which is one of important conditions of the start up of the turbine. In some cased the alarm is required.
Casing Expansion	Measure the expansion of the turbine casing according to the temperature rise.
Differential Expansion	Measure the differential expansion between the casing and rotor which will be expanded by the temperature. This measurement is necessary to prevent the rubbing/contact accident of the casing and rotor.
Vibration	Measure the vibration of turbine, which may generate the alarms to shutdown the turbine.
Axial Position	Measure the position from the bench mark/base point of the axial shift.
Valve Position	Measure the opening position of a main steam control valve and/or a main stop valve.
Bearing Temperature	Measure the temperature of the bearings.

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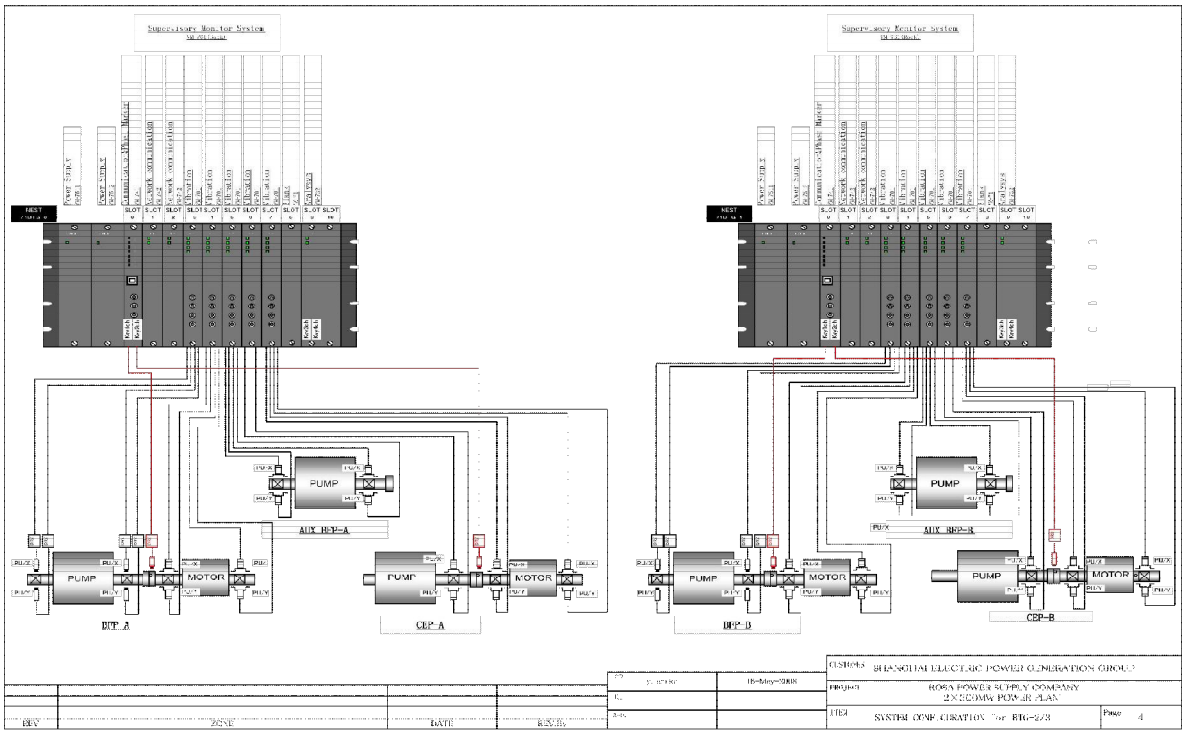
Pump / Fan / Motors / Mills



SHINKAWA Electric Of(shanghai) Co.Ltd

新柯河貿易(上海)有限公司

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Sensors & Monitors

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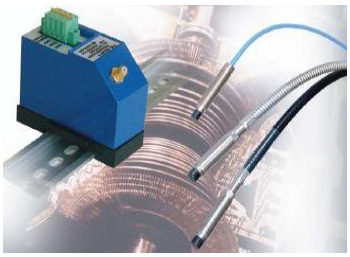
Vibration & Displacement Transducer



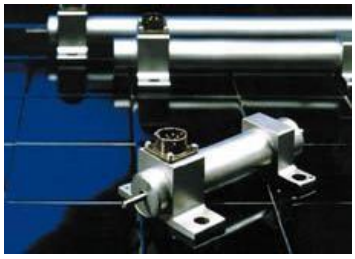
FK & VK Series
Vibration Transducer

CV & CA Series
Velocity & Acceleration Transducer

WK Series
2 wire Vibration Transmitter

RD Series
Tacho Driver

MS Series
Magnetic Pickup



LVDT Series
Differential Transformer

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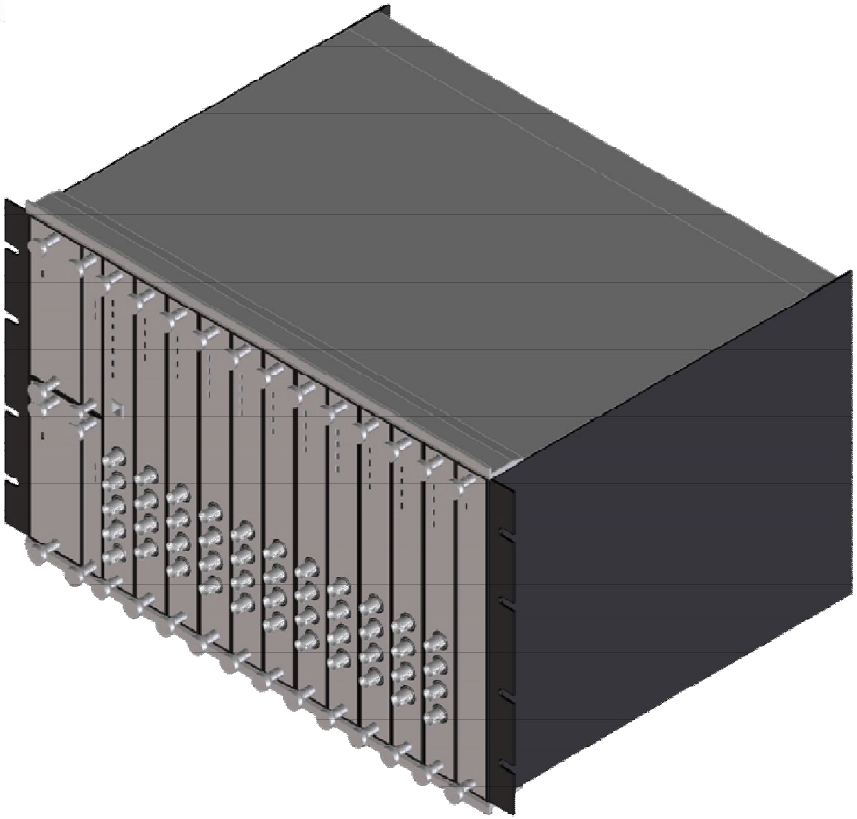
VM 7 MONITORING SYSTEM



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VM 7 Monitoring System – A New Generation Leader

- Each Monitor Has got Integrated Analysis (4 Ch)
- No Need of Separate Monitors in Rack for Analysis.
- High Resolution – 24 Bit Processor
- Integrated Relay in Each Monitors
- Integrated Display in Each Rack (Option)
- True Redundant Power Supply & Communications to DCS.
- All Parameter Measurement with 4 Types of Monitors
- Completely Field Configurable via Lap Top PC.

- **Proven Globally with 300 Racks in Field… India – 150 Racks in last 3 Years (Power & Oil & Gas)**

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SEC SHINKAWA

ISA Delhi Section

Vibration Analysis / Diagnosis / Remote Vib Monitoring

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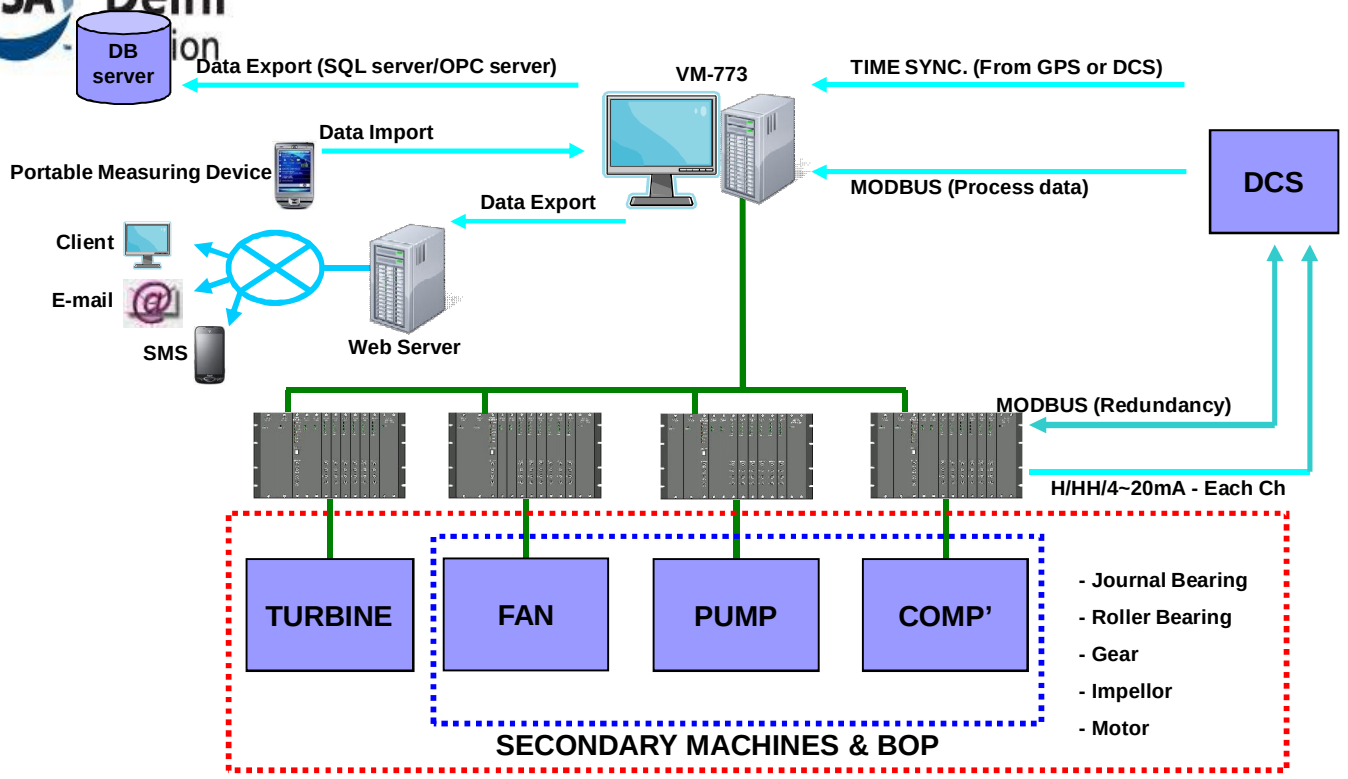
POWER PLANT WIDE ON LINE ANALYSIS & DIAGNOSIS



Net Work Architecture (Typical) for Plant Info.

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S-Station

Remote View Station
(Integrated Machine Condition Monitoring on demand)

* Detail Vibration Live Data can be observed on the S-Station.
* Alarm on-line Status is displayed contiguously
* Performance of the equipment will be shown In S-Station by the plant information from DCS and/or SIS as an option.

CCR

Vibration Live Data will be displayed on the Operator's console of DCS with alarm Status via MODBUS/TCP.

Router

C Factory

Ethernet

Security Server

LOCAL

Router

INTER-NET

B Factory

infiSYS View Station
(Data Collection and Analysis and Diagnostics)

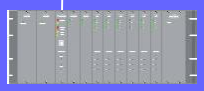
Ethernet

FFT Analyzing Processor

Machine Protection System

DCS

SIS



#1 Process

#2 Process

#3 Process

A Factory

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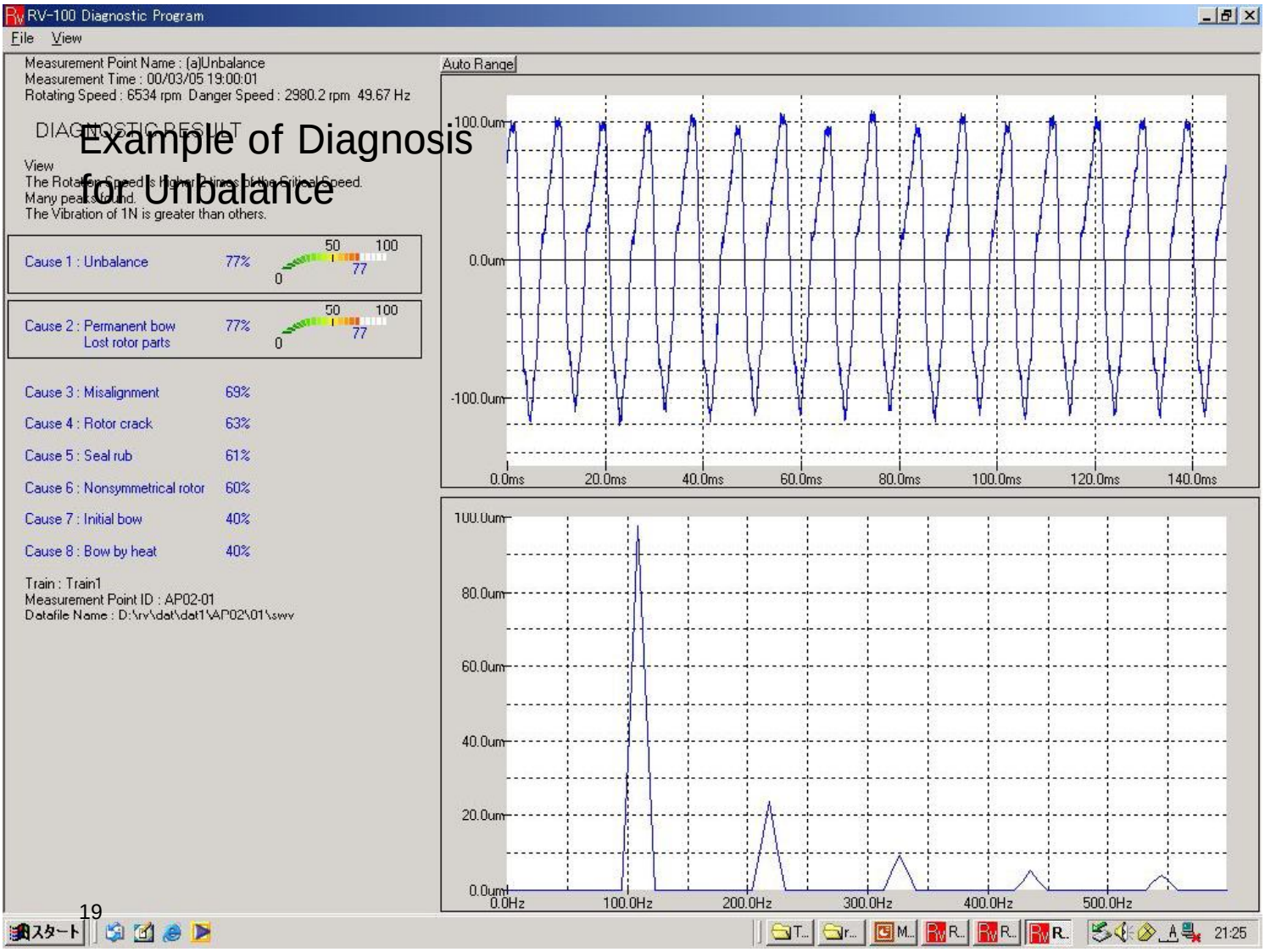
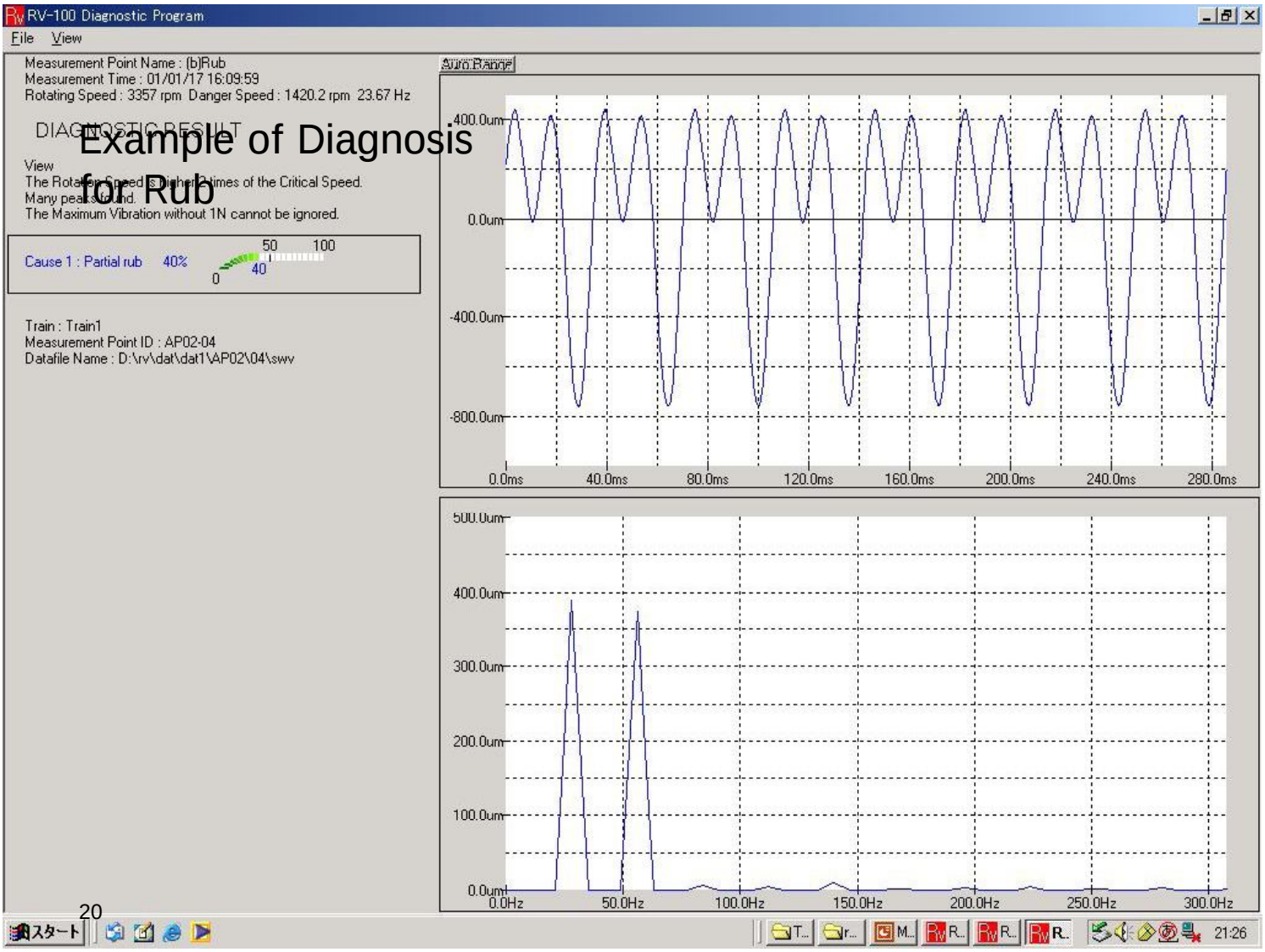
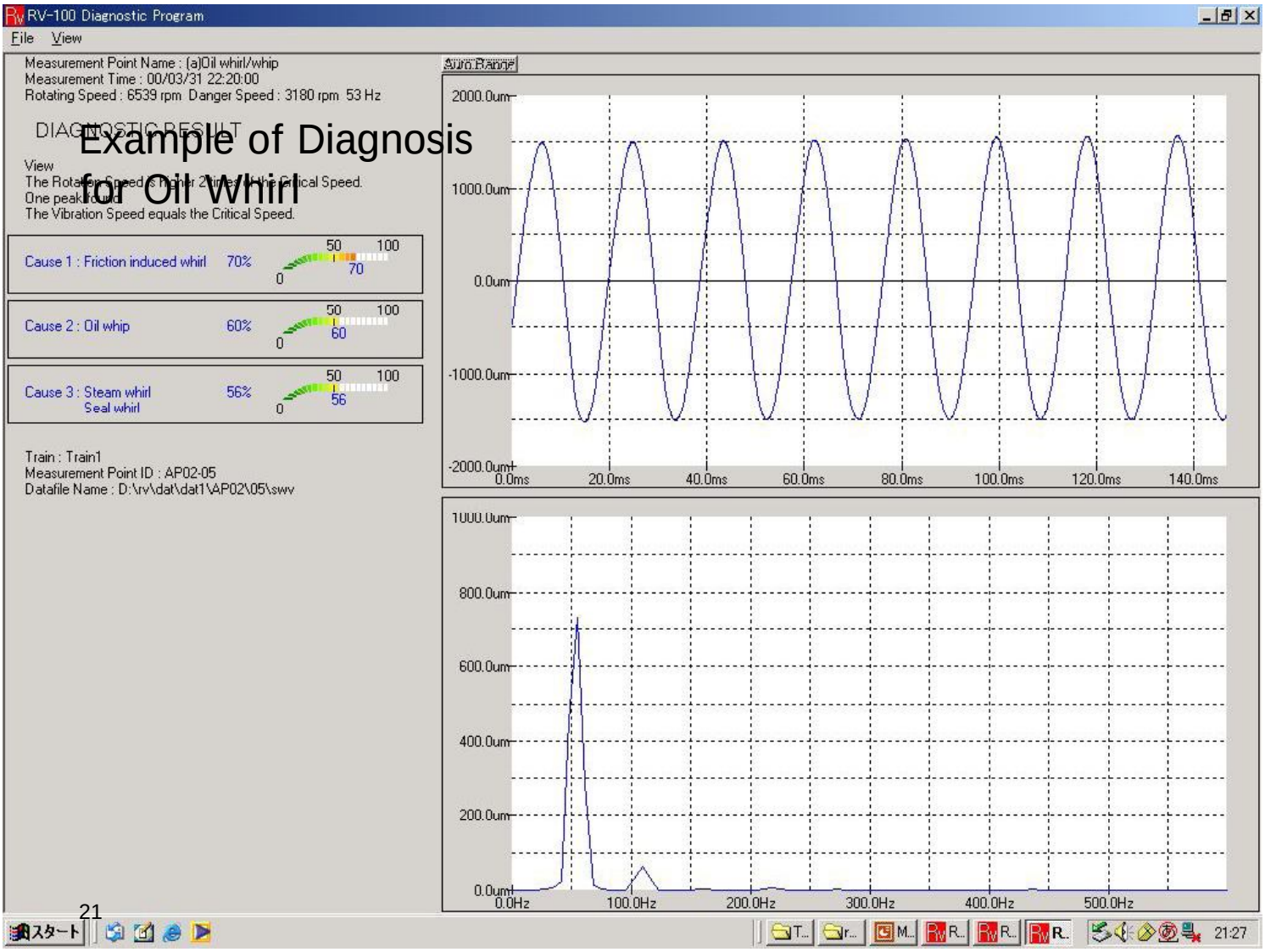
Example of Diagnosis for Unbalance



Example of Diagnosis for Rub



Example of Diagnosis for Oil Whirl



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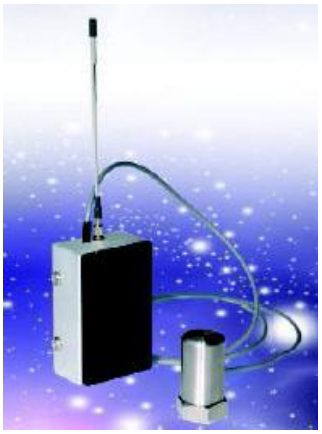
Coming

WIRELESS SYSTEMS i.e. SENSORS (ALL TYPES) AND MONITORS



PROXIMITY SENSORS WITH INTEGRATED DRIVERS for API 670

VMS Protection Monitoring System with Less Hardware and advanced display.

Remote Monitoring will be essential for upcoming projects being limited Experts.

On line Training for Product.

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Present Scanario – Power Plant Rotating Machine Vibration Monitoring.

- **New Power Projects : Most of Projects are 250 MW , 300 MW , 500 MW , 660 MW & 800 MW**
- **All are buying in different ways , getting diff systems from various OEMs. Some time there is duplication and some time multiple vendors in one locations…**
- **Here need to make standard approach to maintain complete plant VMS in long term.**
  - **Let Turbine Supplier Give Complete Monitoring System for all Machines and Sensors will be supplied as per API 670 by Respective machine OEMs.**
  - **Plant Owner may buy complete system for all the machines except TG Sets and integrate complete system by one VMS Vendor. Need to make sure all machine OEMs gives sensor mounting provision.**
- **VMS Selections must be standard and should be equal level.**
  - **API 670**
  - **Features / Tech Specs**
- **VMS Vendor Evaluation is key – Quality , Pre Inspection , Audit and right vendor product qualification test which include product life , support and so on.**

Conclusion

In Power Plant it is really required to consolidate and should have right Specifications , proper planning to avoid many variety of VMS System.

VMS Trainings to new Team Members are key for future.

Vibration Monitoring system is key and each user , consultant and suppliers must Look into details of specifications to have right solution rather than meeting just specs.

API 670 is key for right product specs

Vibration Analysis is must for Critical and Secondary critical machine to increase Plant uptime and reduce Inventory cost.

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Thanks for giving us valuable time .

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SHINKAWA

Delhi Section

imagination at work

RUB PHENOMENA IN ROTATING EQUIPMENTS

Amit Sharma- MDS Engineer
GE Energy Services- Optimization & Control,
Bently Nevada Asset Condition Monitoring

- **ISA (D) POWAT 2010 May 28-29, 2010, Mumbai**

Empowering 'Power' with Automation

ISA Delhi Section

imagination at work

GE

GE Infrastructure

GE Energy

GE Energy Services

Optimization & Control

Empowering 'Power' with Automation

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DETECTION AND IDENTIFICATION OF RUBS IN ROTATING MACHINES

1X Amplitude & Phase of Vibration, an important tool to confirm the Rub Phenomena

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Definition Of Vibration

Vibration is the oscillating,
or
back and forth periodic motion, of an object due to a force acting on it.

Empowering 'Power' with Automation

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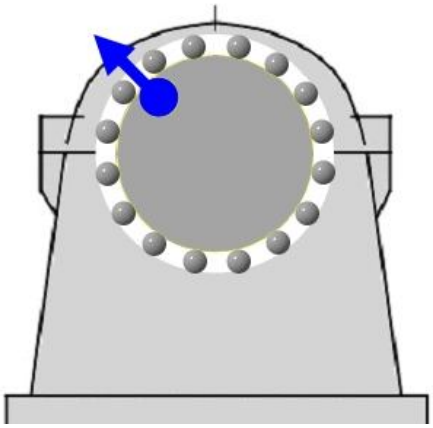
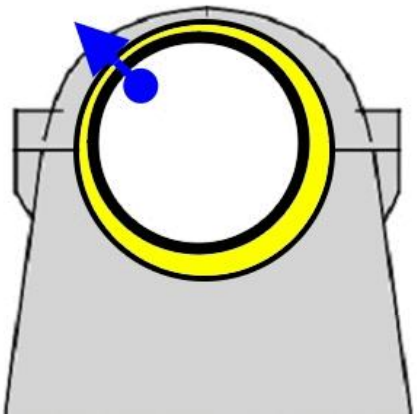
Machine Vibration

Introduction



Rolling Element Bearings



Fluid Film Bearings

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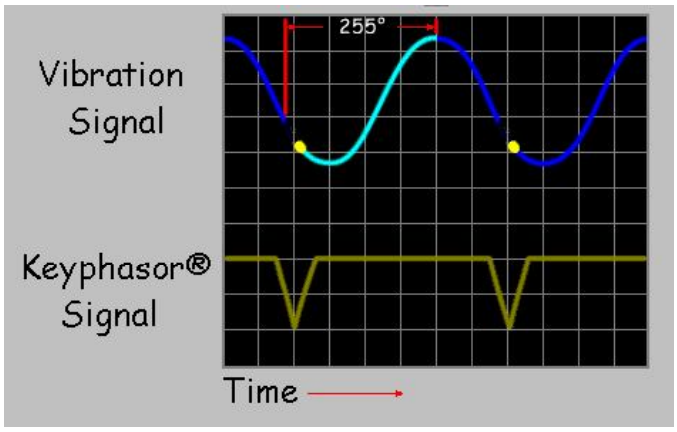

Absolute phase angle is measured for filtered, integer multiple frequencies of running speed. Such as 1X, 2X etc..

Absolute phase angle is measured between Keyphasor signal (pulse) and Filtered vibration signal.

Absolute phase is the angle measured in degrees between Keyphasor pulse (superimposed on vibration cycle- typically as blank & bright spot) to the first positive peak in vibration signal. I.e the angle between blank spot (start of Keyphasor event) to first positive peak (high Point/ maximum vibration event)

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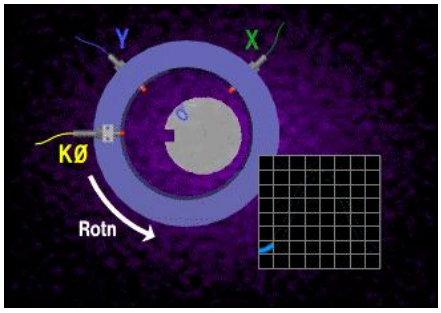
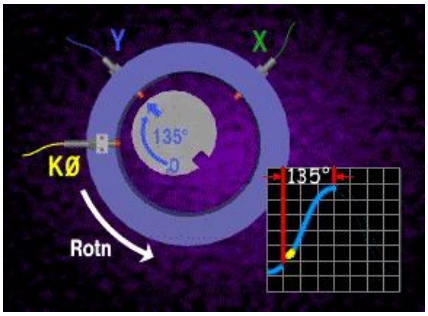


0-degree phase angle is the blank spot and is representing the point on rotor directly under the reference transducer (X or Y) when Keyphasor probe is aligned with Keyphasor notch.

This means the phase angle is calculated with respect to transducer and not the Keyphasor notch.



From 0 degree reference, Absolute phase angle is measured at a point on rotor, which is closest to reference transducer or say is showing maximum positive peak in vibration signal. This is lagging phase angle and is identified in the direction opposite to direction of rotation.

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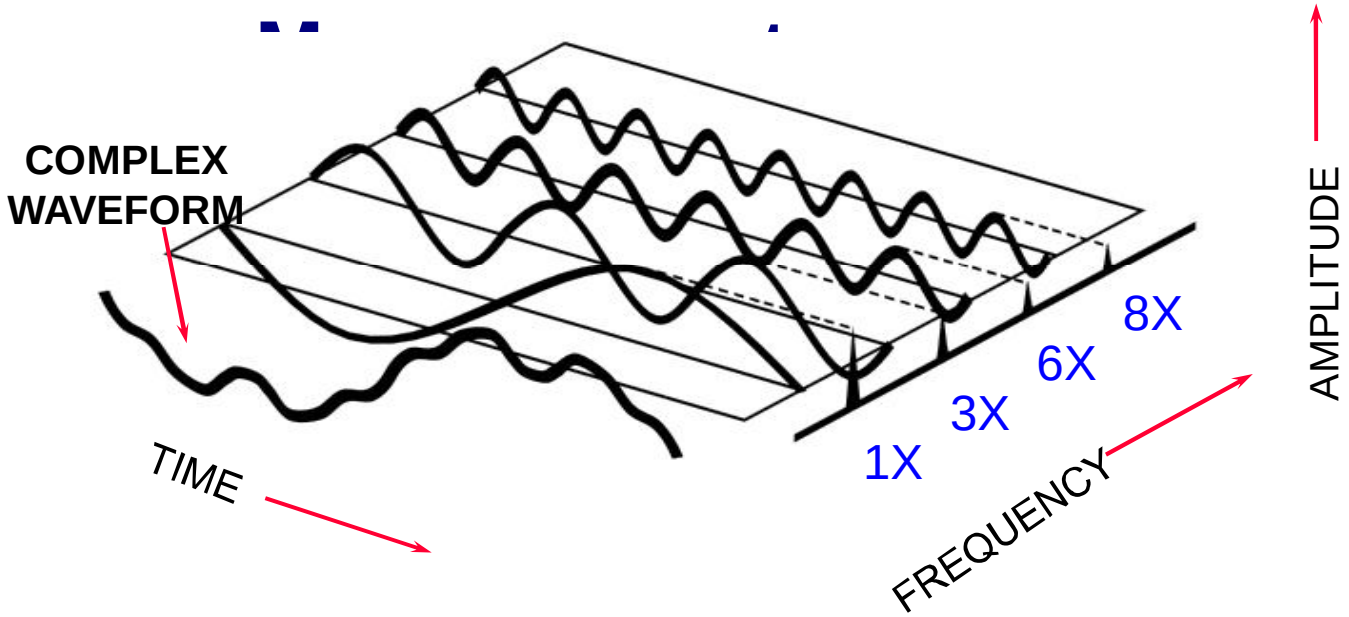
Vibration



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Scenarios with Cyclic Amplitudes in Rub Situation

A. Cyclic Amplitude Variations with almost no phase shift

B. Cyclic Amplitude Variations with almost 360 degrees phase shift

C. Cyclic Amplitude Variations with almost Resonance effect at running speed

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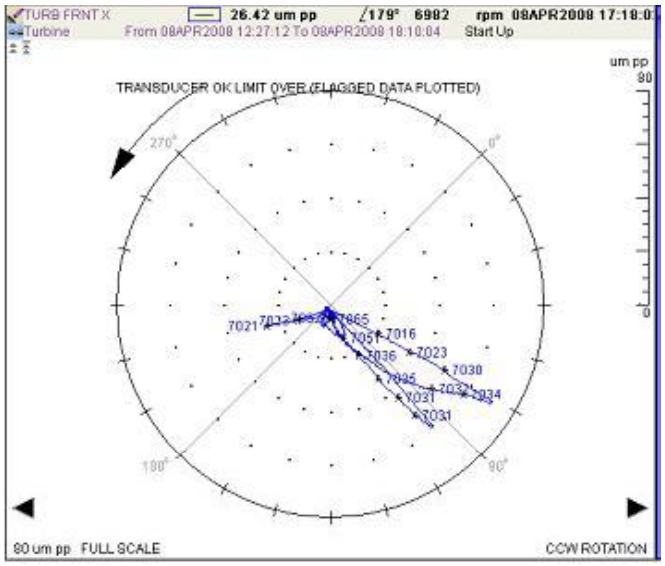
Case- A

Cyclic Amplitude Variations with almost no phase shift



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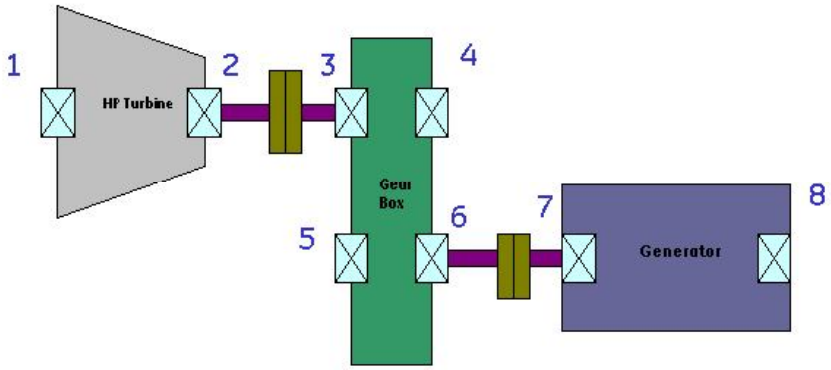
35 MW STG Machine

HPT - @ ~105 KG/Cm2

Critical speed of

HP Rotor: 3500 RPM



1. Cyclic Vibration observed at Front Bearing (Brg#1) of Steam Turbine from past few months.
2. Machine tripped several times when the spike amplitudes reached Danger level.
3. Rise & Reduction in amplitudes takes around 15-20 minutes, frequency of spikes is not repeatable.
4. Load reduction, Drain opening etc were tried to avoid tripping, but it could work sometimes.
5. The frequency of these cyclic vibration has increased from the last few days.

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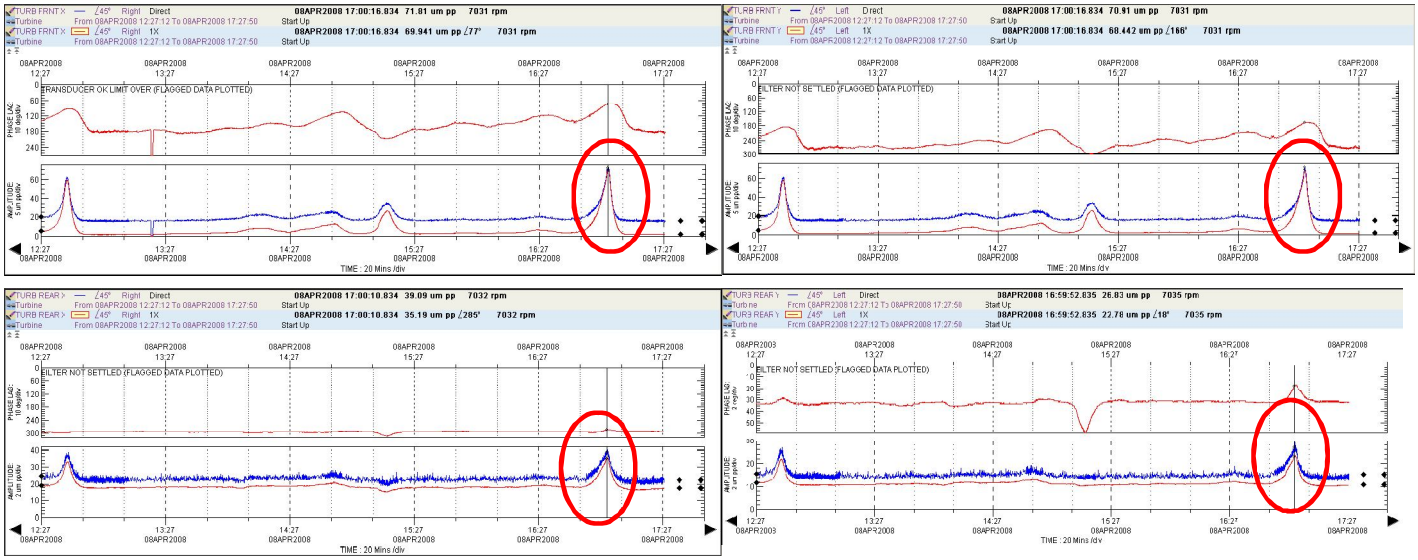

Rise in direct/1X amplitudes can be seen with different amplitude levels on both Turbine Front & Rear Bearings

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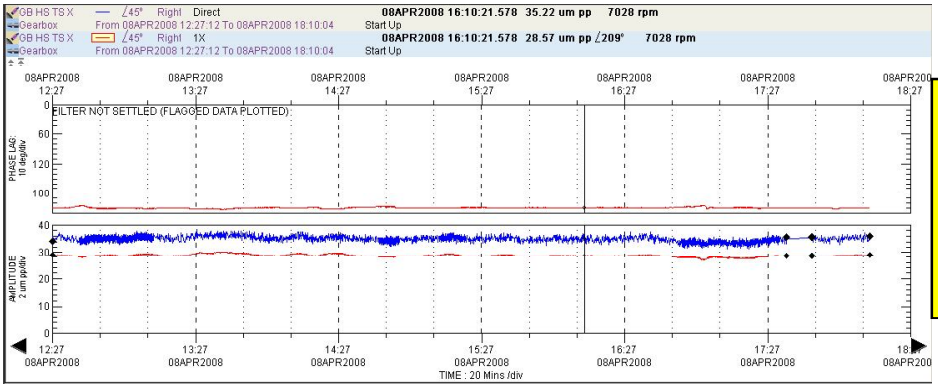
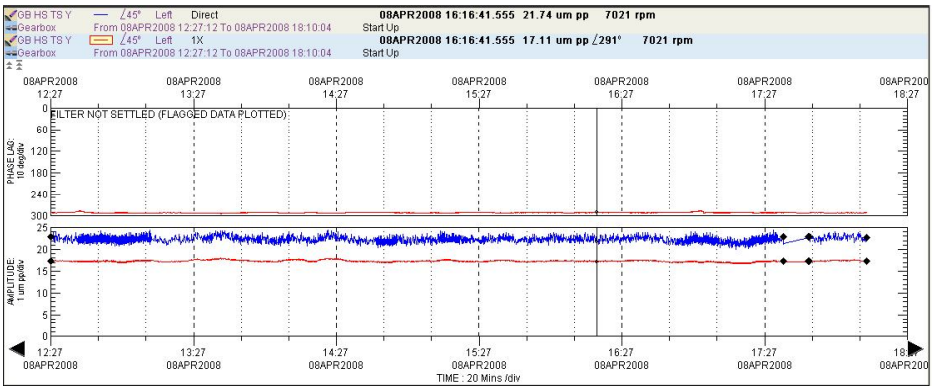


HS GB bearing does not show these symptoms



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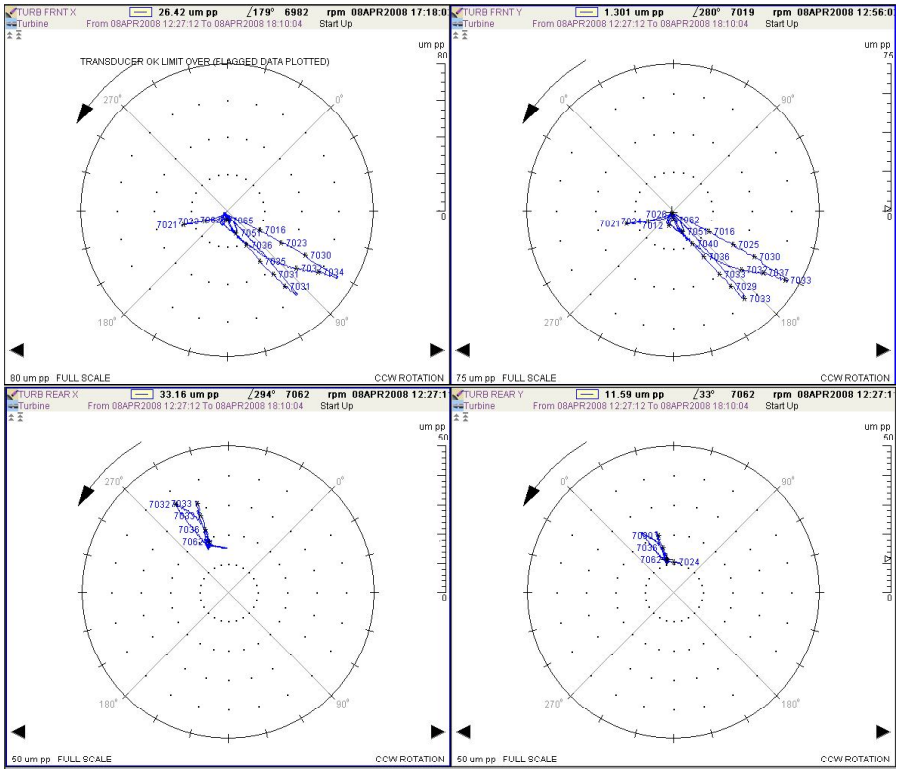

Rise & Reduction of 1X amplitudes at the ~ same phase angle observed. 3 complete cycles occurred at different phase angles. Similar phenomena resent at Rear Bearing also with

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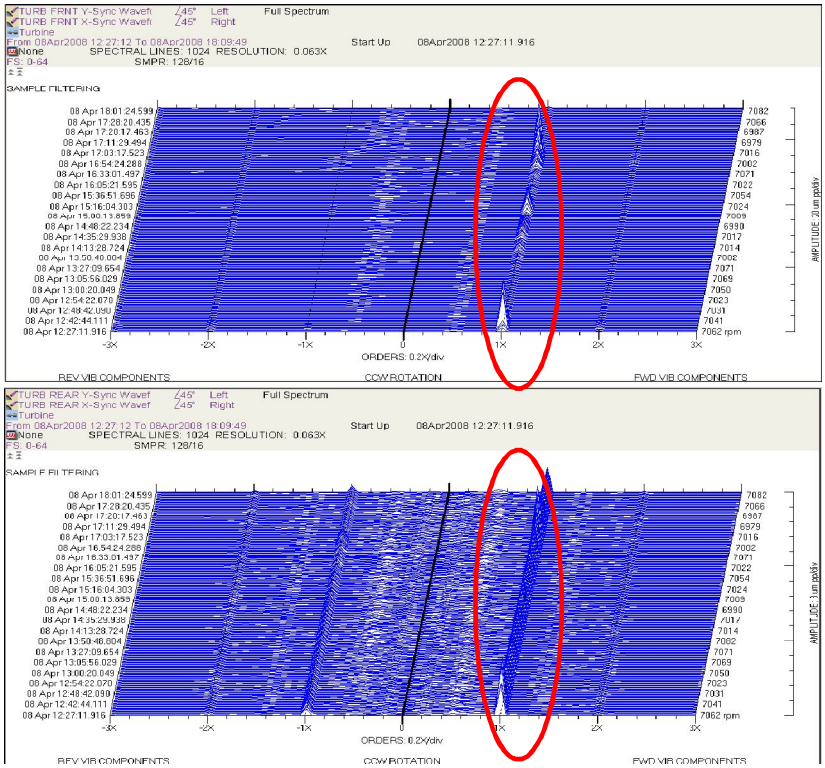

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Conclusion of Observations

$$Synchronuous\ \ response\ \ motion\ (d) \equiv \frac{UnbalanceForce}{DynamicStiffness}$$

- **Temporary unbalance/bow condition only seems to be the cause of rising 1X amplitudes at same phase angle.**

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Possible Causes of Temporary Bow/Unbalance

- **Oil Coking due to Leaky Oil Seals**
- **Rub at Gland Seal due to Steam Condensation or uneven expansion of casing/bearing jousing**

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Findings After Machine Inspection

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Similar Finding in another Machine

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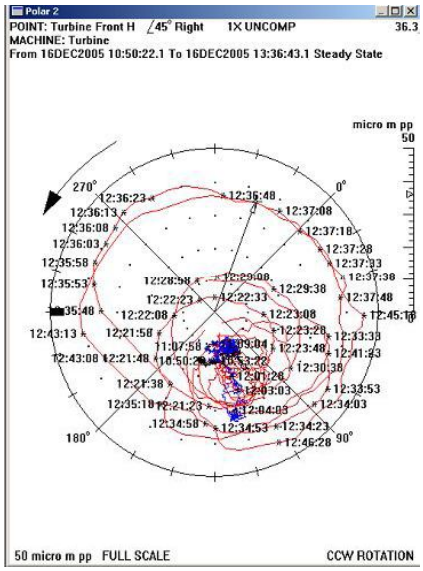
Case- B

Cyclic Amplitude Variations with almost 360 Degrees phase shift



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35 MW STG Machine Details :-

- Mfgd. Year: 1997
- Speed: 3000 RPM
- Inlet Pressure: 86.5 ATA
- Exhaust Pressure: 0.07 ATA
- No. of Stages: 20
- Inlet Temperature: 494 C

Machine tripped several times during operation on high vibration. Initially tripped at 800rpm & then tripped at 3MW,5MW, 10MW & 17MW at different occasions

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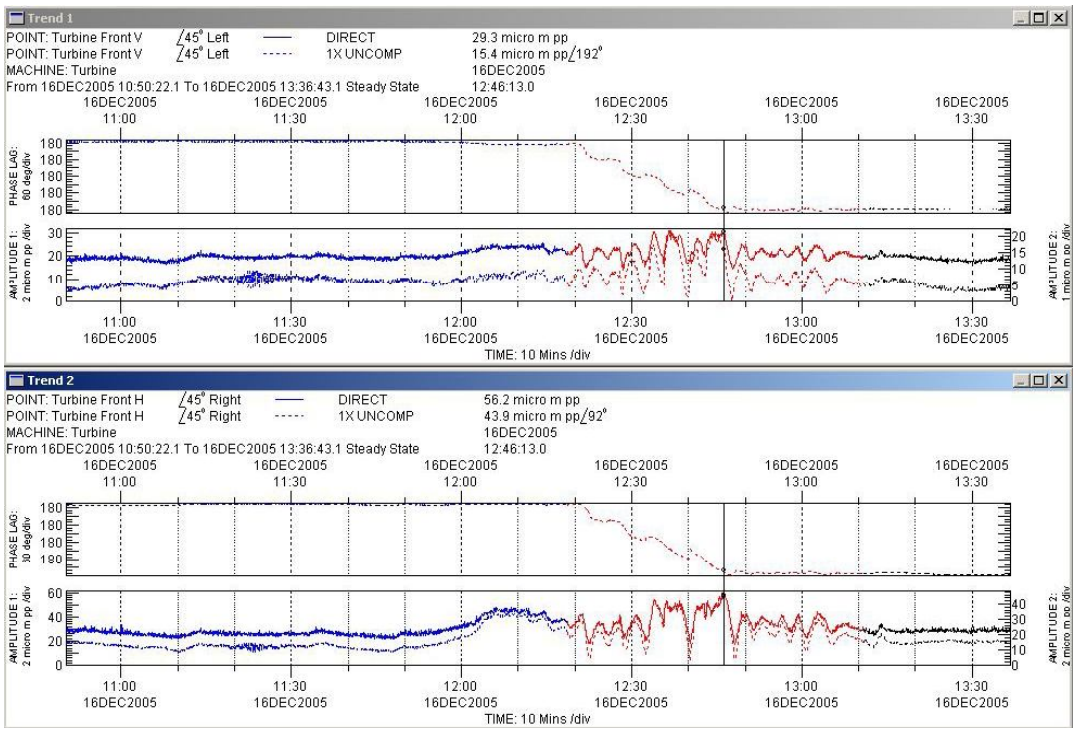
Trend Plots (Turbine Front Bearing)



Fluctuations in direct/1X amplitudes with significant change in 1X phase can be seen here

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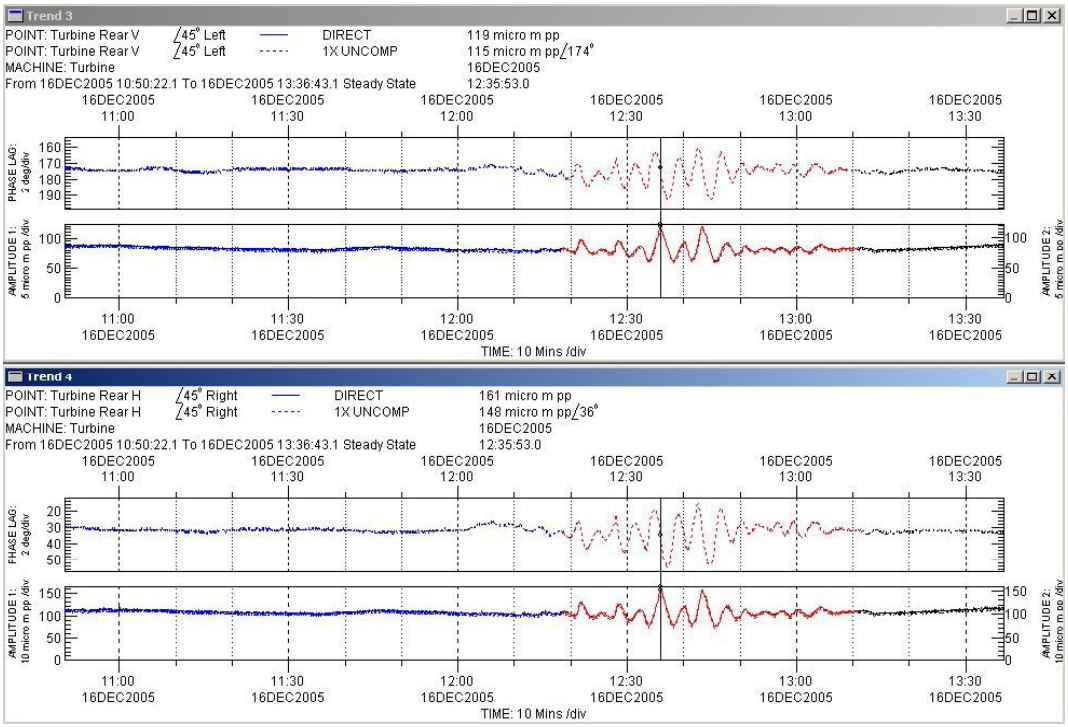
Trend Plots (Turbine Rear Bearing)



Fluctuations in direct/1X amplitudes with change in 1X phase can be seen here

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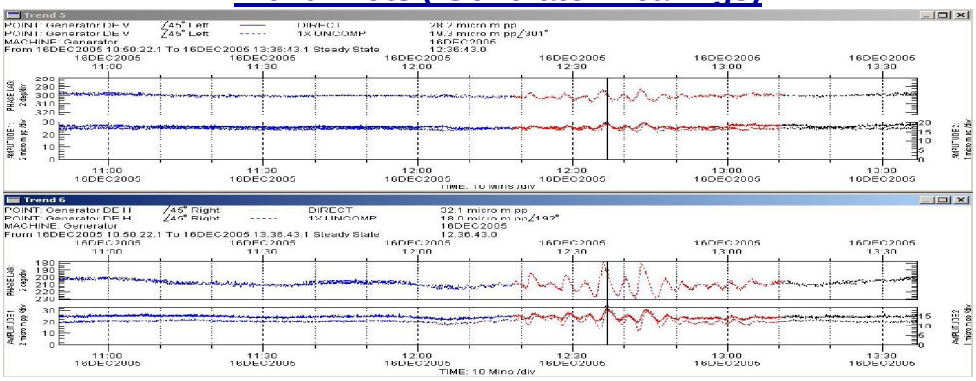
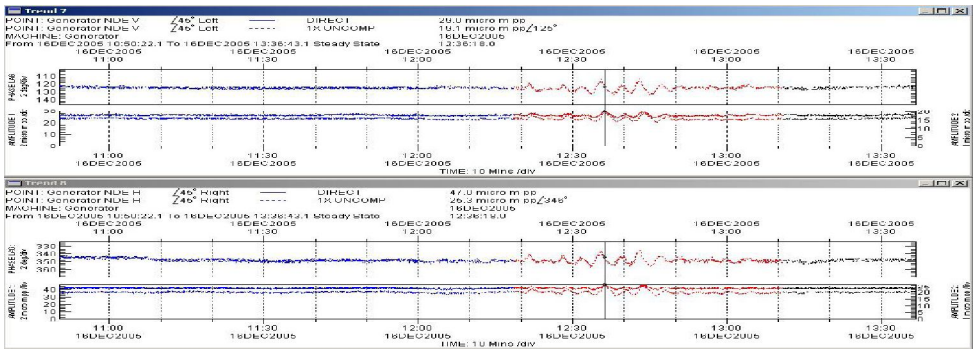
Trend Plots (Generator Bearings)





Similar symptoms can be observed in the Generator bearings also.

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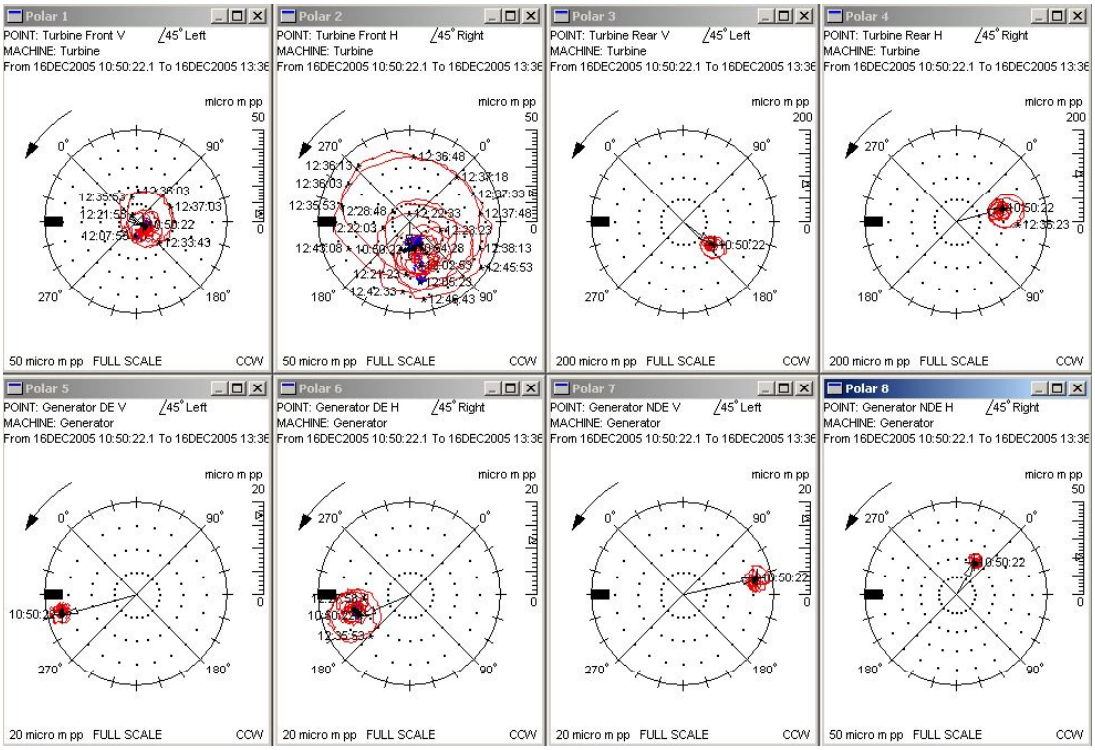
1X Polar Plots



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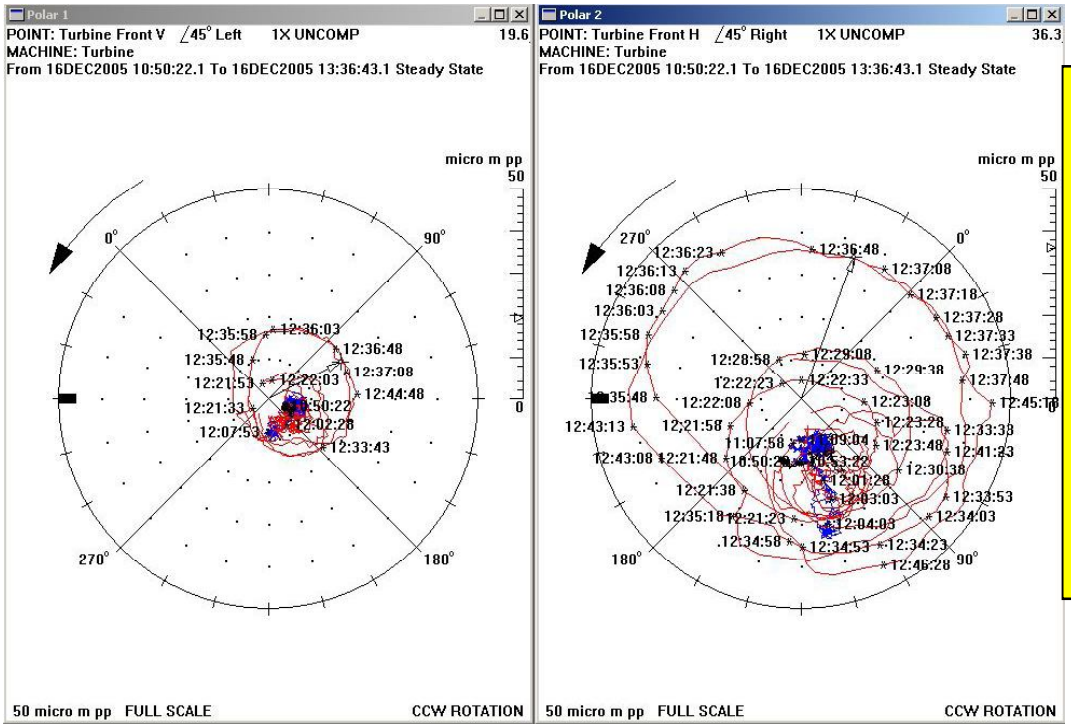
1X Polar Plots (Turbine Front Bearing)



Turbine Front Bearing clearly shows the 360 degrees phase shift in both of the probes indicating towards full annular lubricated rub condition at low clearance area.

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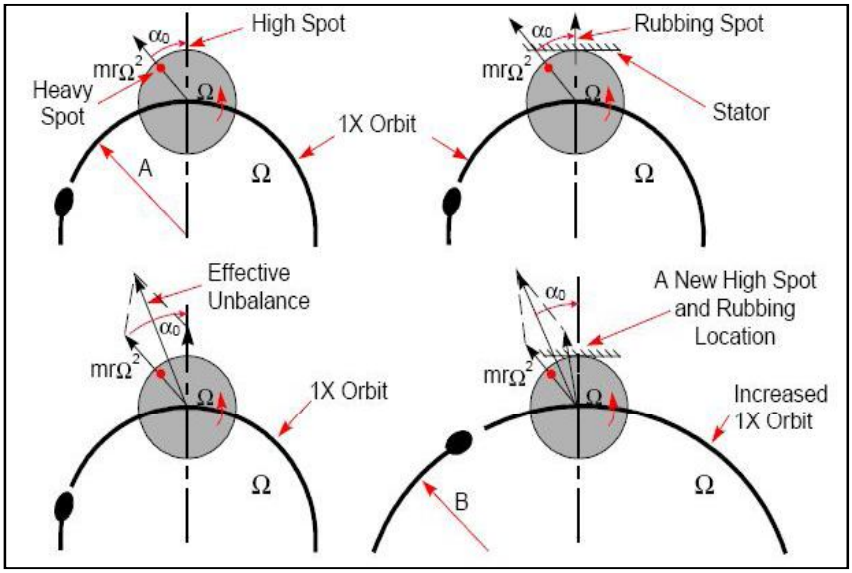
Reason for Changing 1X Amplitude & Phase during Full Annular Rubbing



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Observations & Conclusion of the Case

1. During COLD Start Up, heat soaking was not done properly & also loaded very fast without thermal stabilization.

2. Machine tripping at 800 rpm and low load were on account of high differential expansion of rotor and/ or thermally bowed rotor leading to Rub situation.

3. Root cause of the rub was uneven expansion of the turbine case resulting in to rub during sudden load increments. Whenever load increment was gradual, vibrations didn't increased.

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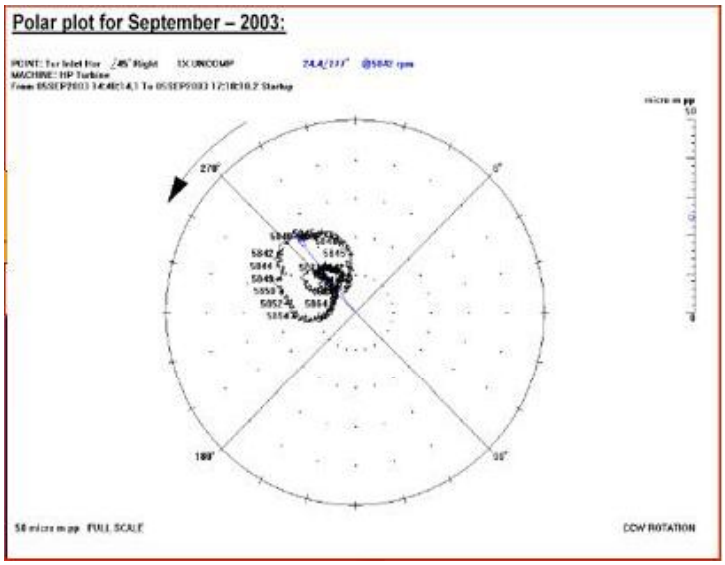
Case- C

Cyclic Amplitude Variations with almost Resonance Effect at Running Speed



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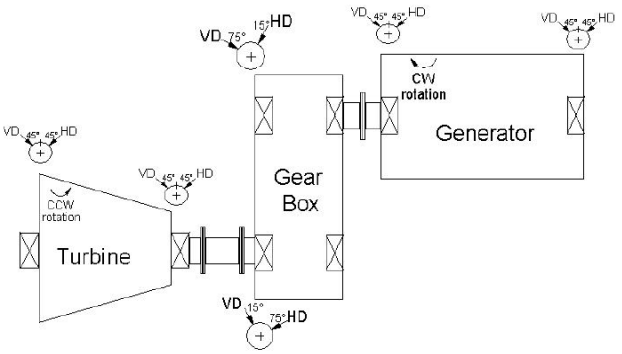
Machine Details



Type of Driver Machine: - Turbine

Rated Output	53.5 MW
Speed	5867 RPM
Direction of rotation	Counter Clock wise (Looking from Driver)
Type of Bearing	Plain Cylindrical Bearings
Type of thrust bearing	Tilting Pads
Bearing Clearance	500 um
Inlet Temperature	482 degrees
Inlet Pressure	63 bar abs
Rotor Weight	7 MT
Type of seal	Labyrinth seal

Gear Box

Rated Power	60,000 KW
Rated Speed	5867 / 3000
Service factor	1.1
Total weight	14000 Kgs
Oil Viscosity	ISO VG32
Oil flow	950 lb/min
Oil Inlet Pressure	1.5 bar
Number of teeth (Gear Ratio)	88 / 45
Type of gearing	Helical

Type of Driven Machine: - Generator

Rated Output	53500 KW
RPM	3000 RPM
KVA Rating	11000
Exciter System	Brushless
Bearing clearance	300 um
Excitation Volts	141 V

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Problem Statements

1. Cyclic Changes in Vibration Amplitudes were happening at High Speed Shaft with Low speed shaft showing no such variations.
2. Oil leakage was observed from Turbine Inlet bearing housing but the location of leakage was not established.

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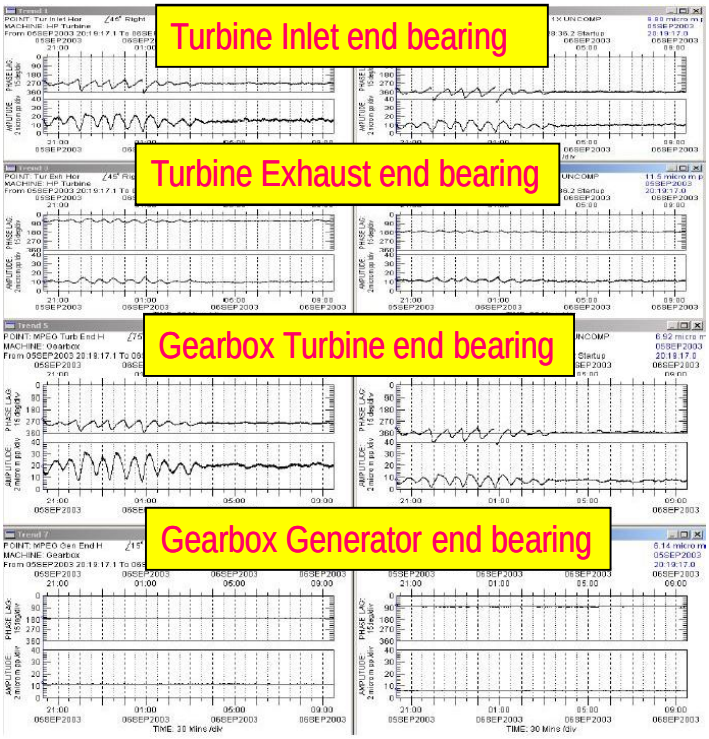

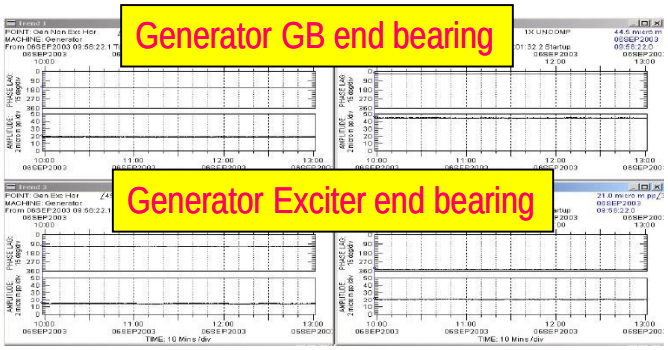

Abrupt cyclic vibration changes were

Present only on High speed shafts and Low speed Shafts weren't showing any Influence by it.

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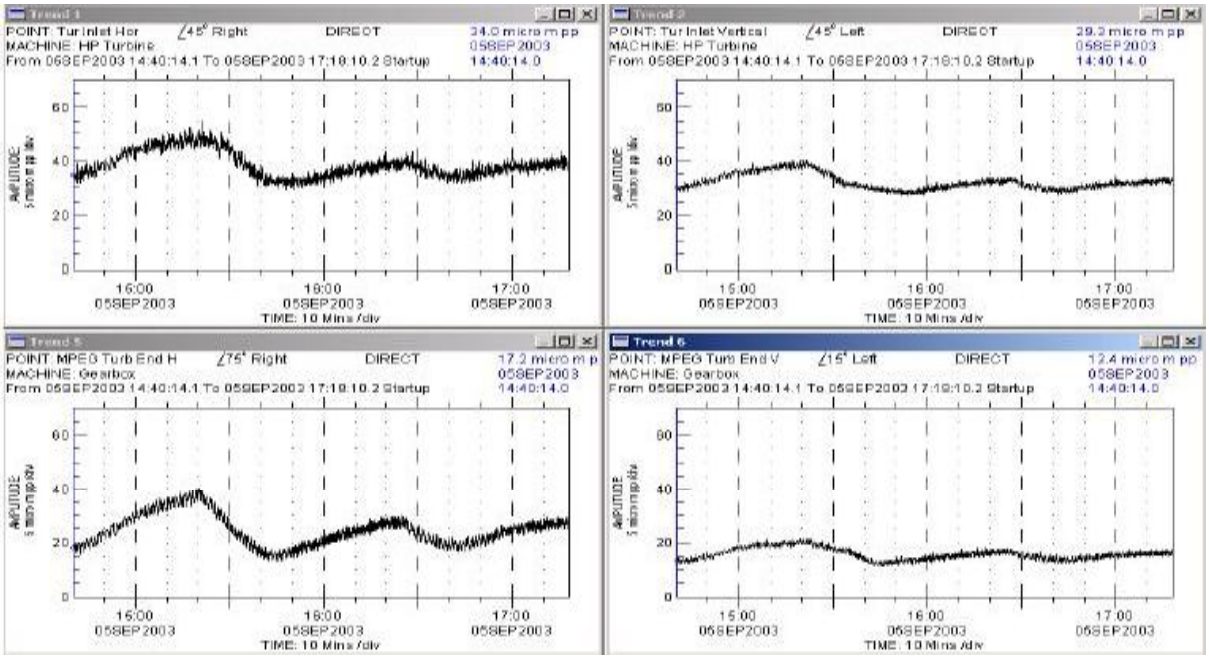

Cyclic vibrations were on account of varying 1X vibrations

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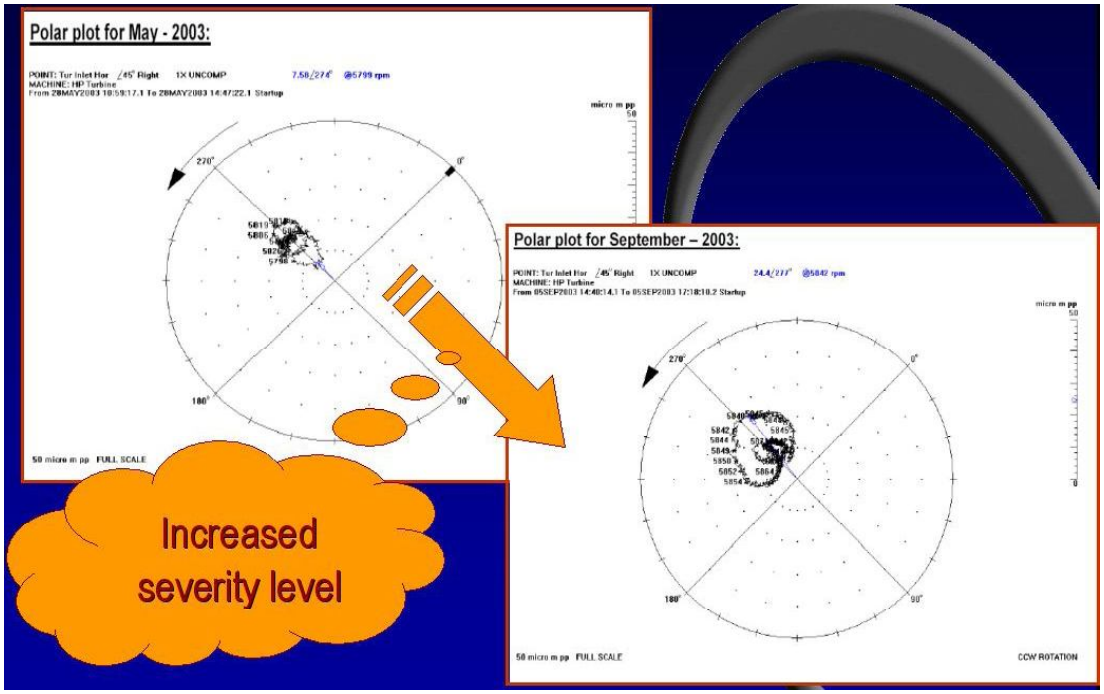
Polar Plots- Turbine End Bearing



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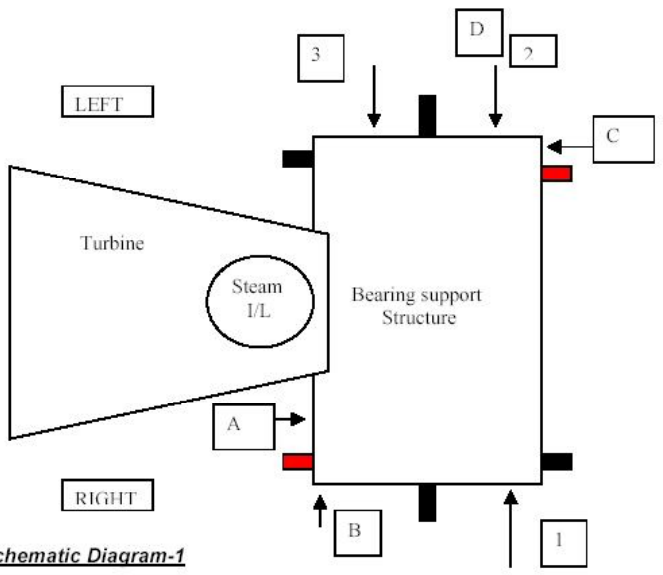
Reason for Cyclic Resonance

Jack bolt location and condition during Sep 03:



Schematic Diagram-1

There are totally six jack bolts. The red ones were found tight.

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Theory Behind Cyclic Vibration

Resonance of a rotor is expressed with below shown relation:

$$\Omega = \sqrt{\frac{K}{M_r}}$$

Where:

Ω -: Resonance speed
K -: Dynamic spring stiffness of rotor system
M_r -: Mass of rotor

It is clear form the above relation that any change of rotor stiffness or the mass of the rotor will have direct impact on the resonance of the rotor. Whenever there is any rub occurs in a machine the spring stiffness will increase and 1x amplitude & phase will start varying in a periodic manner.

It is communicated that this rotor of the steam turbine has a resonance at 4120 rpm. While there is any rubbing taking place, the K in the above equation tends to increase, increasing the Ω. And if the Ω approaches the operating speed of 5800 rpm, the machine starts showing symptoms of resonance at normal operating speed.

Resonance is always associated with change of 1X amplitude and phase and the amount of the change depends on how close the machine is operating to the resonance speed.

While the doing data acquisition during May 2003 it was noticed by Bently Nevada that there was cyclic change of over all vibration amplitude and further drill down of the data revealed that there was 1X amplitude and phase change taking place. The phase showed further increase of angle (from around 30 degree to 90 degree) during September 2003 audit. This was showing that the machine condition was moving from bad to worse.

Coming to the reason for this kind of phenomena, this actually happens on account of some light rub or any other phenomena causing stiffening of the system. To explain the present scenario, there was some kind of abnormal expansion or obstruction to expansion was happening at the turbine front bearing, which was resulting in rub and they're by increasing the stiffness. This was supported by the bearing pedestal movement, which was showing up in the form of decreased gap between the pedestal jack bolts provided for alignment. This was noticed during May 2003 audit and recommendation was made to keep proper gap between the jack bolt and the bearing pedestal. It was corrected at an available opportunity and during the September 2003 audit it was again seen that the bolts were touching the bearing pedestals.

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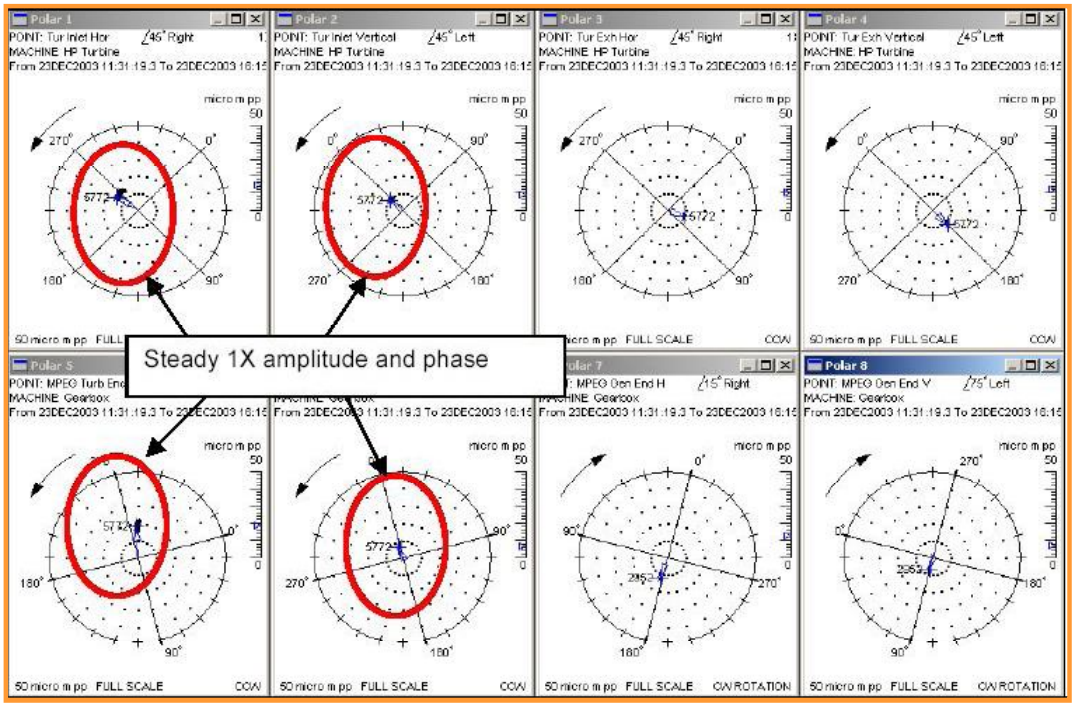
Post Maintenance Plots



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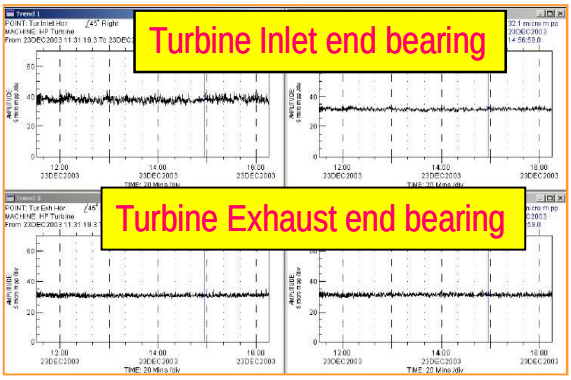
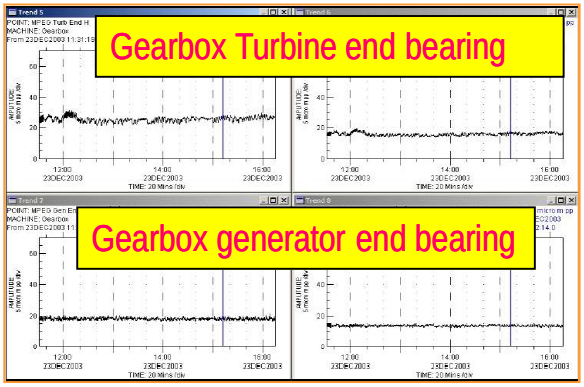
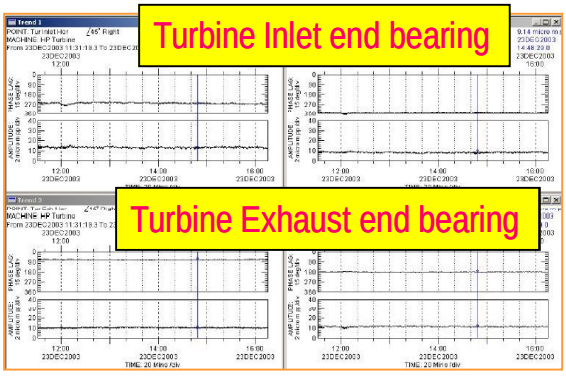
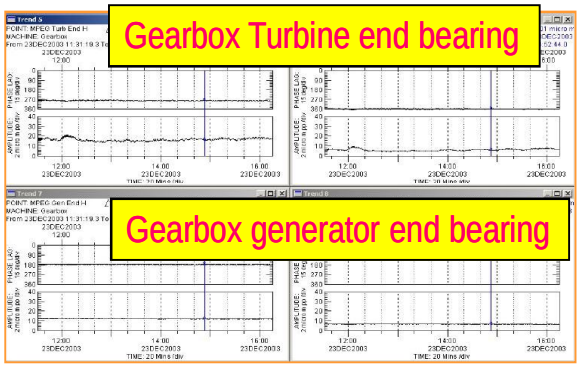


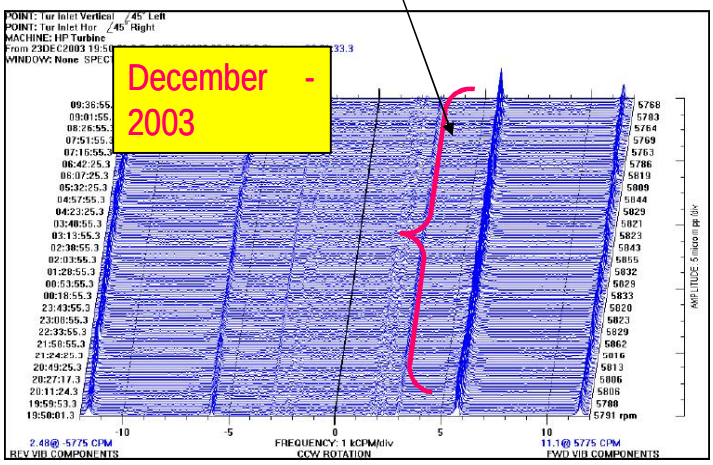


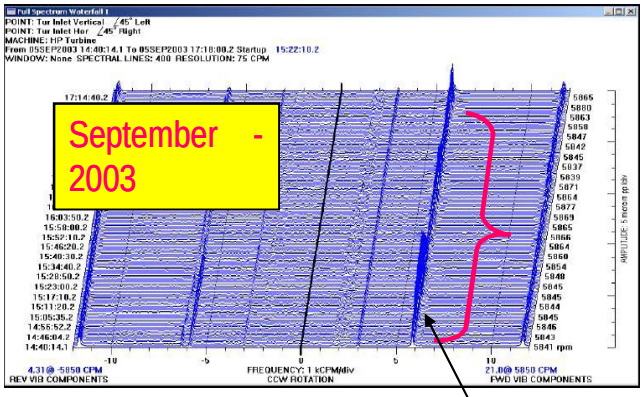




Full Spectrum Plots Comparison

Constant 1X





Varying 1X

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Conclusion