Operational Security – Contd.
EMERGENCY TRIP

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origin

The Emergency Trip system is not to be used unless advised to do so by the Duty Operator.

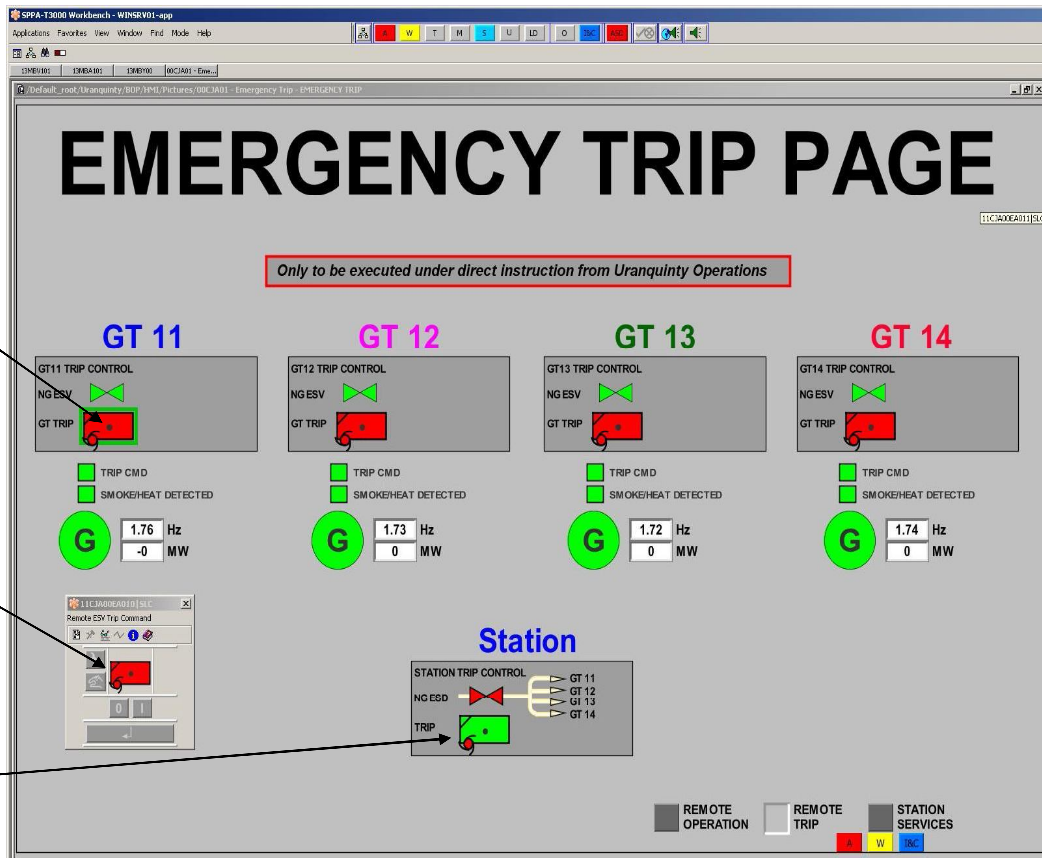
Only under extreme circumstances will the Duty Trader need to use this page.

This page should not be opened or used except for it's intended purpose.

Double click on SLC as previously shown to open faceplate

By activating this function will shutoff gas to the unit and the unit will trip.

Alternatively if the whole station is to be tripped off the main Gas ESD will need to be shutdown via here.



Physical Security

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Power Stations and Control Rooms

- Physical Lockout and Swipe Card Access
- Operator Alarm

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origin

Centralised Remote Operations - Tangiblle Benefits and security threats

Tangible Benefits of remote operations setup

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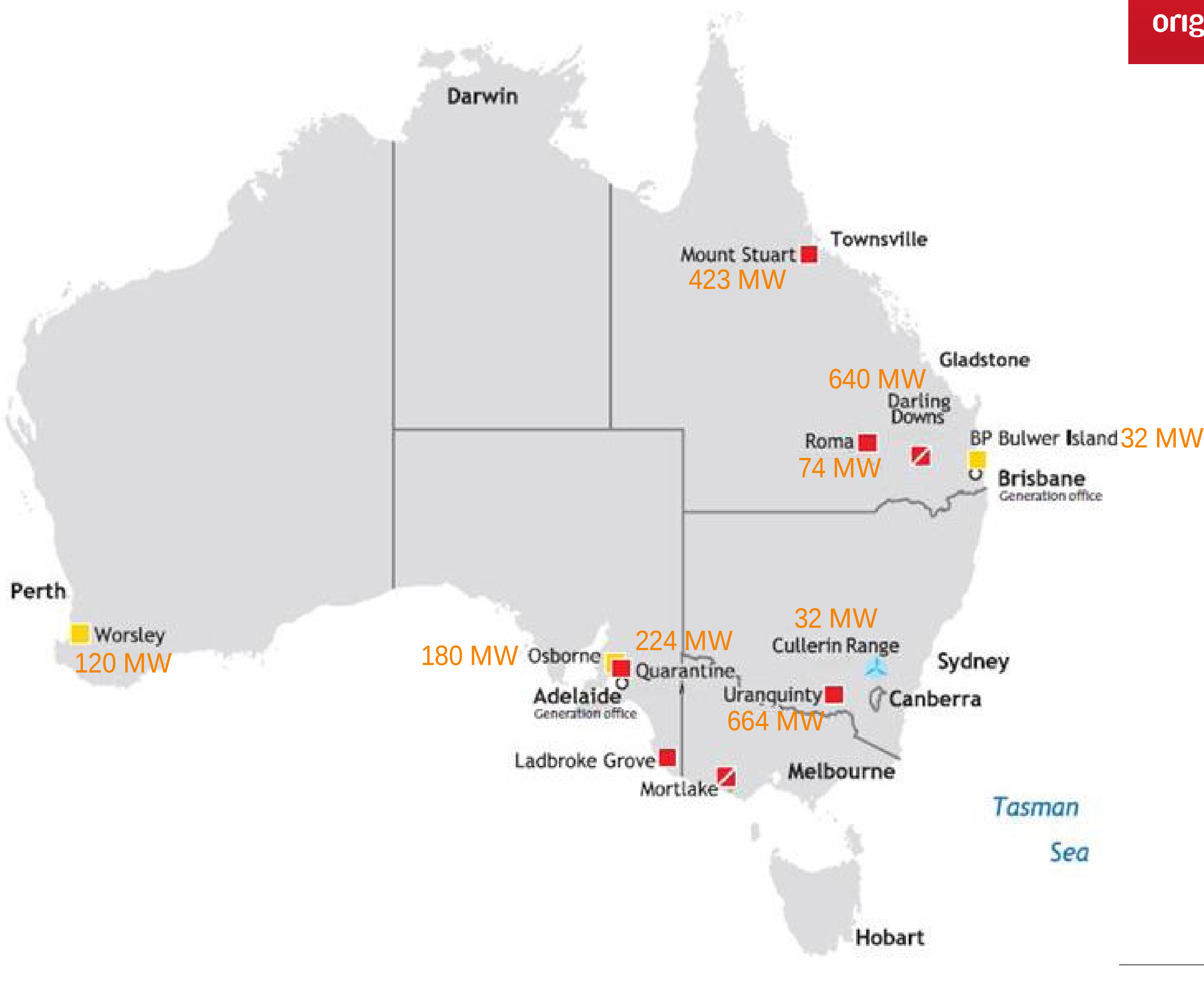
origin

- Significant Cost Saving
- In-house skill uplift
- Scalability
- Competitive Advantage
- Monitoring and Support Centre Project Evolution

Centralised Remote Operations and Monitoring

origin



Benefits of Centralised Operations

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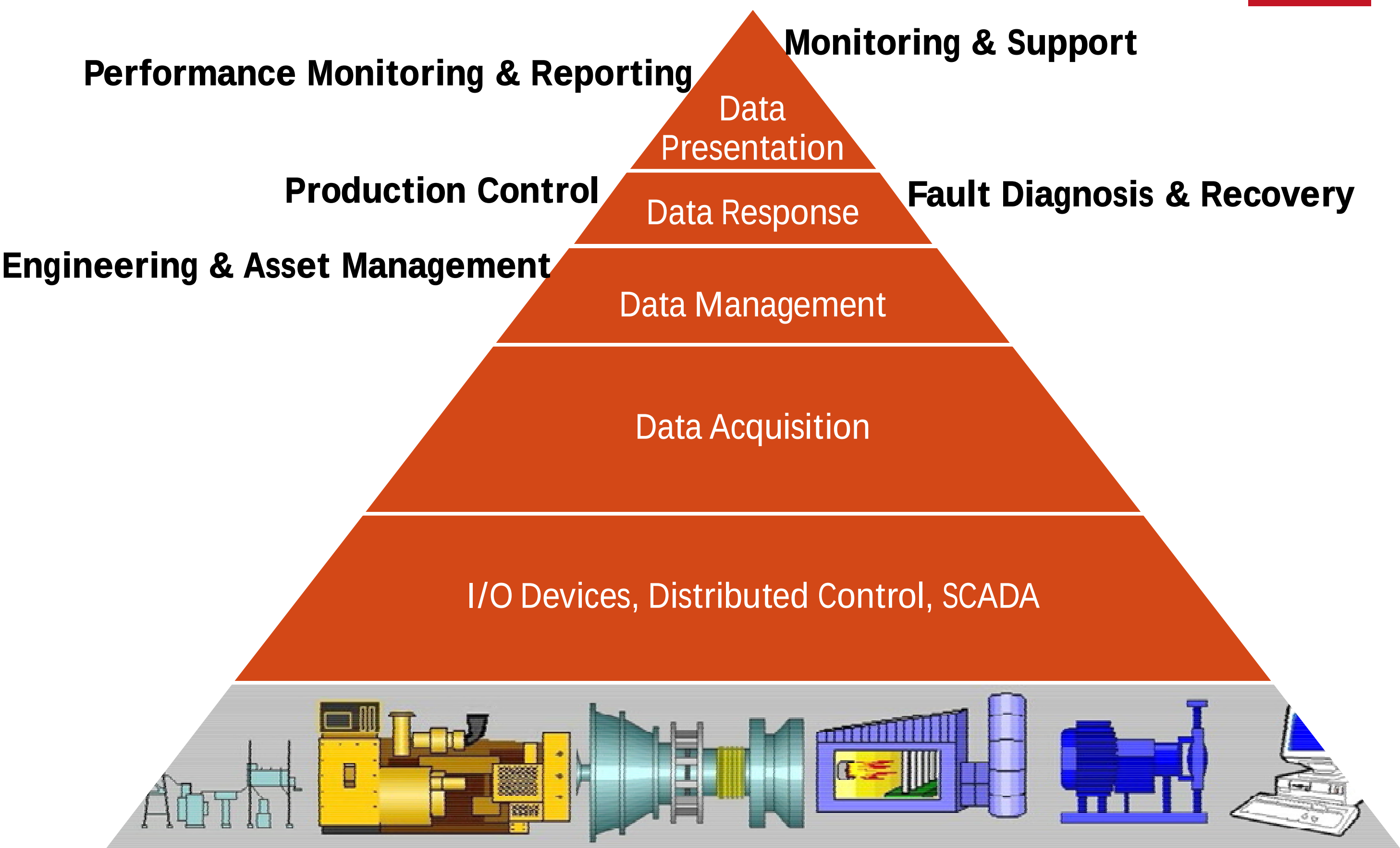

Security Threats of Centralised Remote Operations and Monitoring

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origin

- Data Warehouse at Centralised location
- Vulnerable to cyber attack – prime energy sector
- More transparency across business to multitude of stakeholders - possible misuse of info
- Physical security threat
- More prone to human errors due to similarity of displays across different sites
- Linkage between IT and Control network
- Potential of exposing information to external world
- Easy propagation within integrated modules with SSO (Single Sign On) model

SCADA/DCS installed at Origin Generation sites

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origin

Generation Site	
Mt Stuart Power Station	Mitsubishi Netmation & GE Mark VIes
Roma Power Station	Citect/Triconex
Darling Downs Power Station	GE Mark VIes
Uranquinty Power Station	Siemens T3000
Mortlake Power Station	Siemens T3000
Ladbroke Grove Power Station	Citect/Woodwards
Quarantine Power Station 1-4	ABB Advant
Quarantine Power Station 5	GE Mark Vies
Cullerin Range Wind Farm	Citect/Foxboro

Origin

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Questions?

OUTPUT LOSS ANALYSIS (OLA)

A tool to monitor Real time performance losses of a CCGT power station

D. Kaushik
V.P. Singh

NTPC Limited, NOIDA

ISA(D) POWAT-INDIA 2012, New Delhi January 13th -14th, 2012

PRESENTATION OVERVIEW

- OLA – Output Loss Analysis
- PI System & its implementation in NTPC
- OLA – The Software
- OLA – Process Flow
- OLA – Losses Details
- OLA - Additional Performance Monitoring
- OLA - Benefits
- OLA - Future Roadmap & Conclusion

OLA – Output Loss Analysis

- The problem of output loss with time is a inherent feature of gas turbines.

- A part of this loss could be irrecoverable owing to mechanical reasons, but rest of it is possible to recover.

OLA – Output Loss Analysis

- OLA provides the breakup of machine output losses in real time in MW as well is in Rs/hr under various loss heads.

- PI server based application running on PI Process Book.

OLA – Output Loss Analysis

- The application works on the base data derived from

- station PI server
- registered data specific to the station (e.g. targets etc.)
- transaction data from SAP (e.g. fuel GCV….)

OLA – The Software

- The OLA application has been prepared using PI tools of PI-ACE & PI MDB on .Net platform.

- The application is scheduled to run at a predefined interval; writes output back to station PI for trending & archiving.

- OLA software is common across all CCGT stations.

PI System implementation

PI System implemented in NTPC at

- 15 Coal stations
- 7 Gas stations
- Corporate office

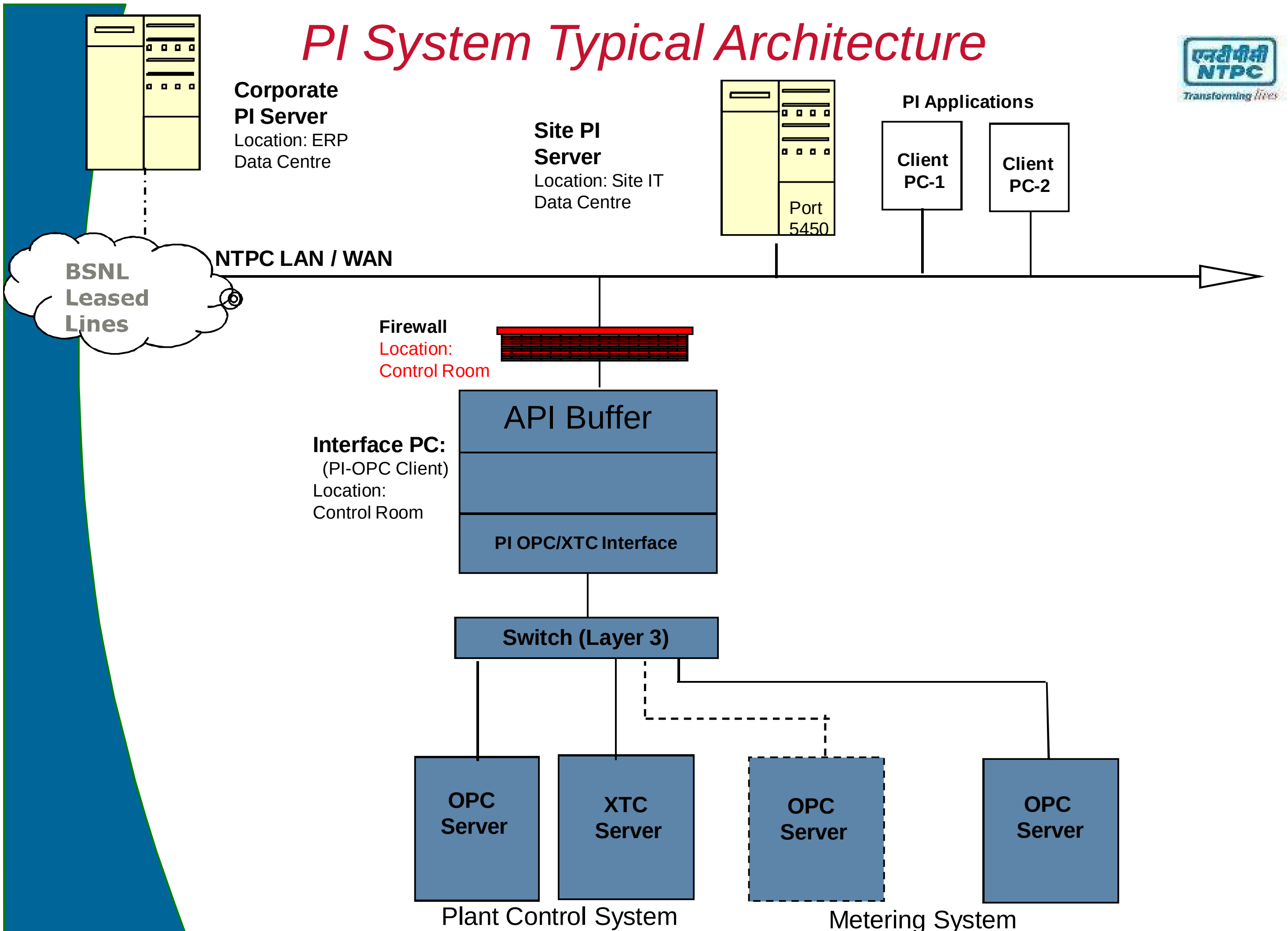
Brief about the PI System

PI = Plant Information

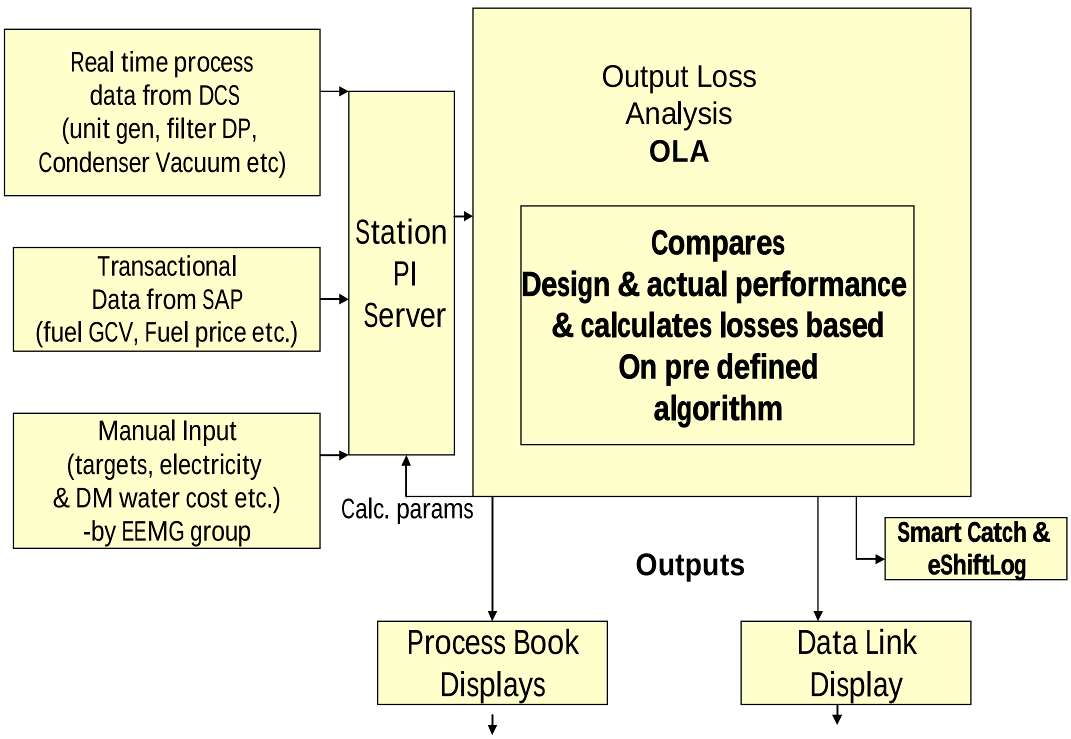
The PI System is a set of Server-and-Client-based software programs designed to fully automate the collection, storage and presentation of plant information.

PI becomes the main link from the Plant Control Room to the Office.

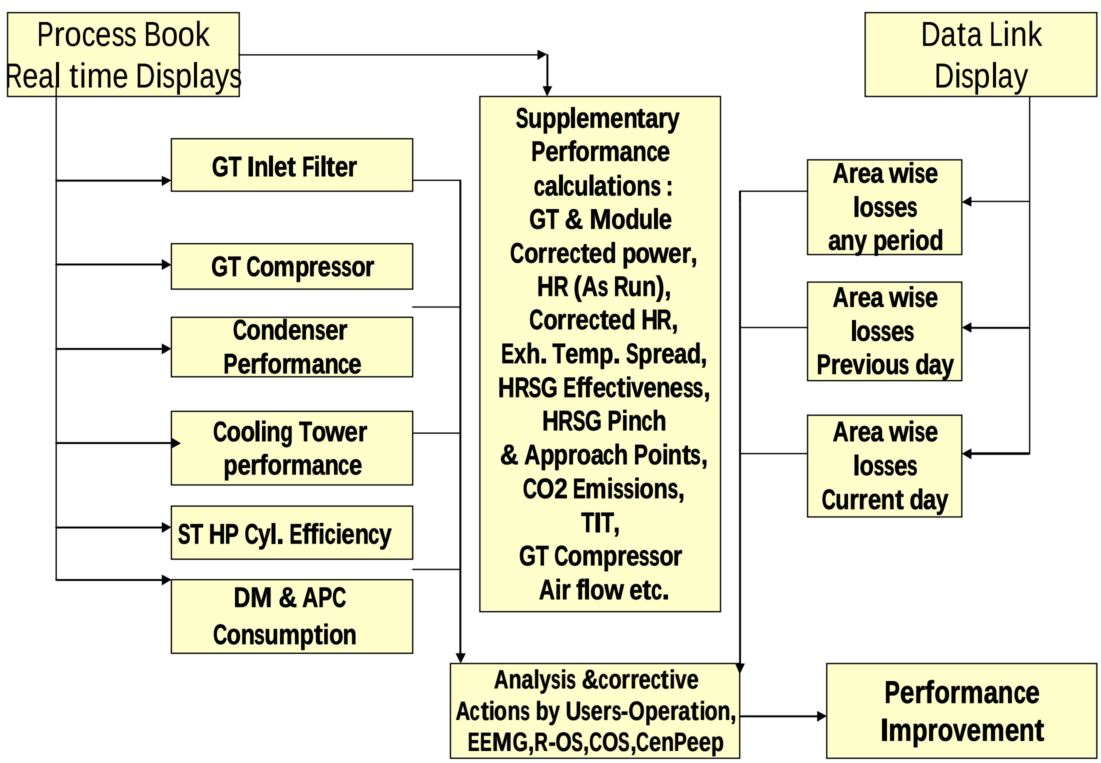
PI System Typical Architecture



OLA-Process Flow



OLA-Process Flow



OLA – Losses Covered

Uncontrollable losses

- Ambient temperature
- Ambient pressure
- Ambient RH
- Grid frequency

Controllable losses

- Higher GT Inlet Air filter DP
- GT compressor efficiency deviation
- Condenser Back Pressure deviation
- Excessive DM water consumption
- HP cylinder efficiency deviation
- Aux power consumption deviation
- Cooling tower performance deviation

OLA – Additional Performance

- GT & Module actual/corrected output, heat rate, GT Gross efficiency & GT Compressor Efficiency.

- HRSG overall efficiency, section wise effectiveness, Economizer approach, Evaporator pinch point & Stack CO_2 Emissions

- ST HP cylinder efficiency & Heat Rate

- Loss Reports for a period

- OLA Help

OLA Benefits

- Improved Operation /Performance engineer awareness of critical plant performance KPI's

- Identification of loss areas aids decision making process for targeting resources to specific problem areas

- Losses can be targeted prior to the monthly efficiency reports

- Archiving facility for all loss data

OLA Benefits

- Allows operators to make critical cost effective decisions based on evaluated plant conditions

- Cumulative Impact on machine performance of operator’s actions for a problem helps choosing best course of action at that point of time

- Maintenance effort can be quantified based on pre & post work cost of losses

OLA Future Roadmap

- Advice for GT Inlet air filter replacement based on filter replacement cost & output loss due to high filter DP.

- Indicators for GT Inlet temperature & mass flow in GT Performance

- Alerts for GT compressor wash based on GT compressor performance

- Completing OLA roll out at all NTPC CCGT stations

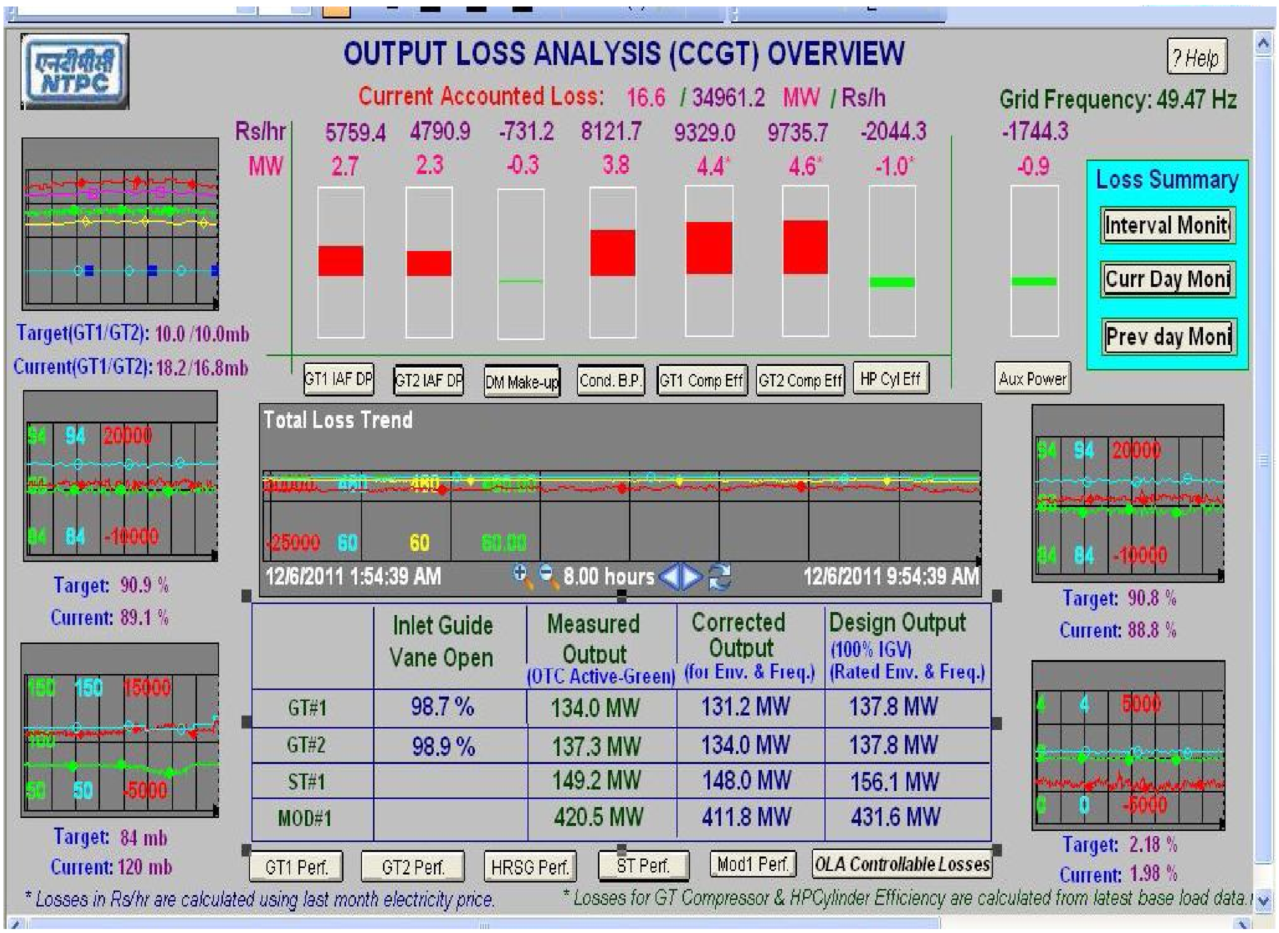
Conclusion

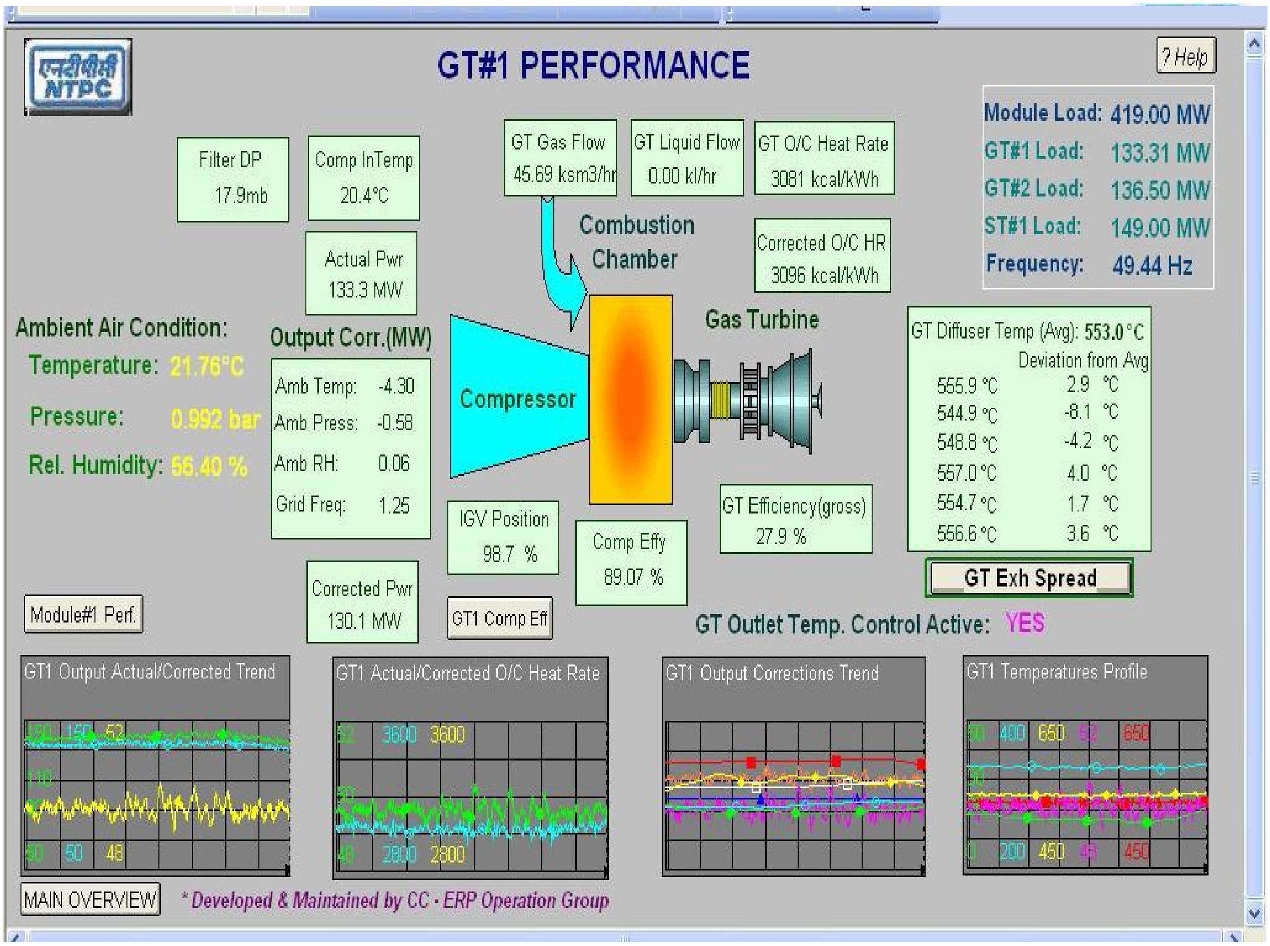
- Implementation of Performance enhancing applications has given a new dimension to the level & quality of information available within the plant as well as outside it.

- Using these applications, the operator have an advisory tool with them to optimize station performance with quantified support to validate & justify his actions.

- The demand for more applications of such nature & addition of new features in existing applications is increasing by the day.

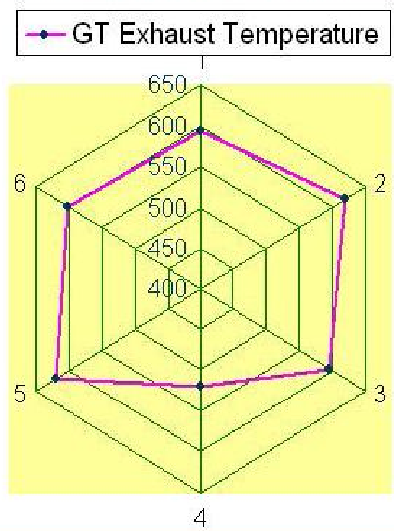
THANKS


OUTPUT LOSS ANALYSIS (CCGT) OVERVIEW
? Help
NTPC
Current Accounted Loss: 16.6 / 34961.2 MW / Rs/h
Grid Frequency: 49.47 Hz
Rs/hr 5759.4 4790.9 -731.2 8121.7 9329.0 9735.7 -2044.3 -1744.3
MW 2.7 2.3 -0.3 3.8 4.4* 4.6* -1.0* -0.9
Loss Summary
Interval Monit
Curr Day Moni
Prev day Moni
Target(GT1/GT2): 10.0 /10.0mb
Current(GT1/GT2): 18.2/16.8mb
GT1 IAF DP
GT2 IAF DP
DM Make-up
Cond. B.P.
GT1 Comp Eff
GT2 Comp Eff
HP Cyl Eff
Aux Power
Total Loss Trend
12/6/2011 1:54:39 AM
8.00 hours
12/6/2011 9:54:39 AM
Target: 90.9 %
Current: 89.1 %
Target: 90.8 %
Current: 88.8 %
Inlet Guide Vane Open
Measured Output (OTC Active-Green)
Corrected Output (for Env. & Freq.)
Design Output (100% IGV) (Rated Env. & Freq.)
GT#1 98.7 % 134.0 MW 131.2 MW 137.8 MW
GT#2 98.9 % 137.3 MW 134.0 MW 137.8 MW
ST#1 149.2 MW 148.0 MW 156.1 MW
MOD#1 420.5 MW 411.8 MW 431.6 MW
Target: 84 mb
Current: 120 mb
Target: 2.18 %
Current: 1.98 %
GT1 Perf.
GT2 Perf.
HRSG Perf.
ST Perf.
Mod1 Perf.
OLA Controllable Losses
* Losses in Rs/hr are calculated using last month electricity price.
* Losses for GT Compressor & HPCylinder Efficiency are calculated from latest base load data.

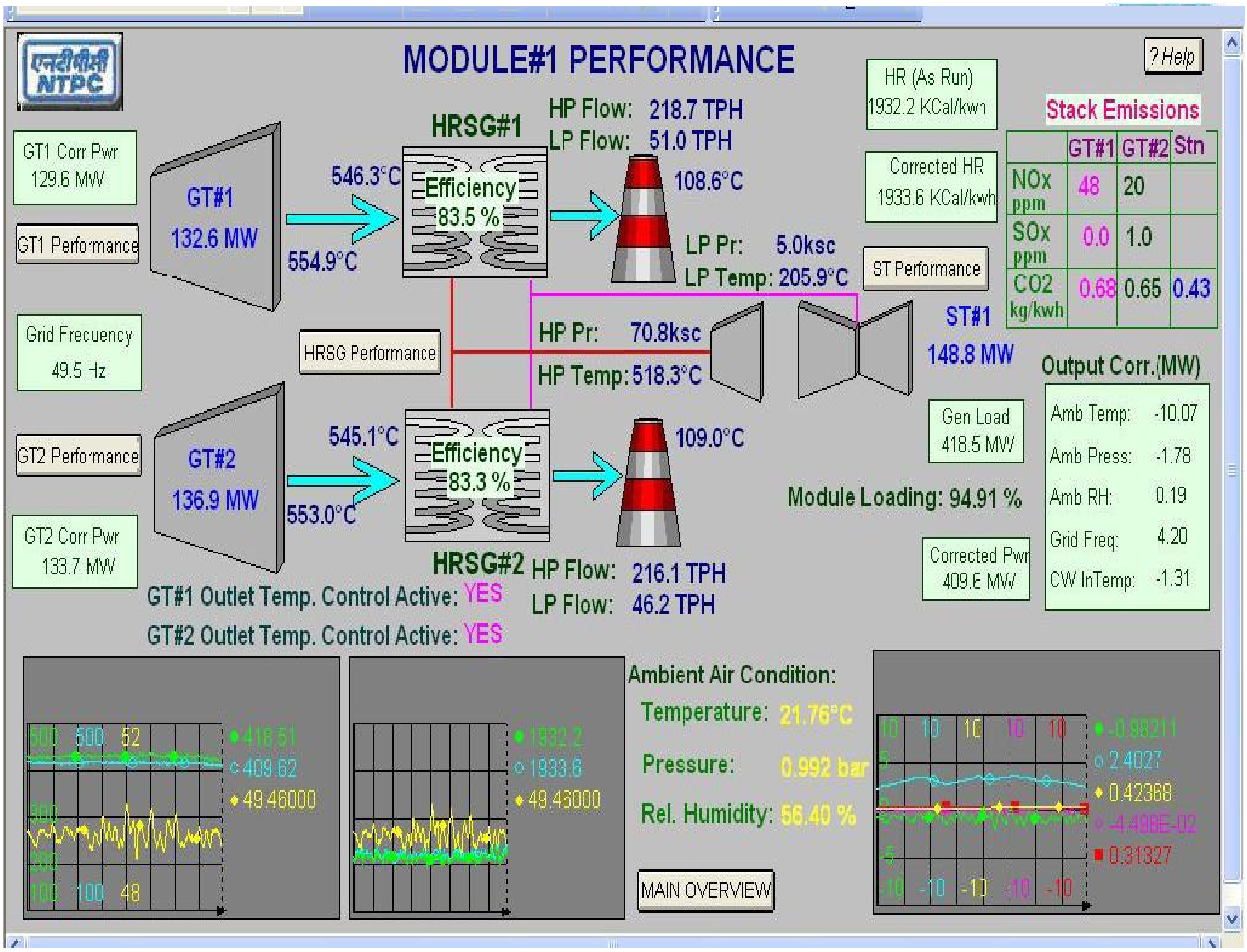

GT#1 PERFORMANCE
? Help
NTPC
Filter DP 17.9mb
Comp InTemp 20.4°C
Actual Pwr 133.3 MW
GT Gas Flow 45.69 ksm3/hr
GT Liquid Flow 0.00 kl/hr
GT O/C Heat Rate 3081 kcal/kWh
Corrected O/C HR 3096 kcal/kWh
Combustion Chamber
Gas Turbine
Compressor
Module Load: 419.00 MW
GT#1 Load: 133.31 MW
GT#2 Load: 136.50 MW
ST#1 Load: 149.00 MW
Frequency: 49.44 Hz
Ambient Air Condition:
Temperature: 21.76°C
Pressure: 0.992 bar
Rel. Humidity: 56.40 %
Output Corr.(MW)
Amb Temp: -4.30
Amb Press: -0.58
Amb RH: 0.06
Grid Freq: 1.25
IGV Position 98.7 %
Comp Effy 89.07 %
GT Efficiency(gross) 27.9 %
GT Diffuser Temp (Avg): 553.0 °C
Deviation from Avg
555.9 °C 2.9 °C
544.9 °C -8.1 °C
548.8 °C -4.2 °C
557.0 °C 4.0 °C
554.7 °C 1.7 °C
556.6 °C 3.6 °C
GT Exh Spread
Corrected Pwr 130.1 MW
Module#1 Perf.
GT1 Comp Eff
GT Outlet Temp. Control Active: YES
GT1 Output Actual/Corrected Trend
GT1 Actual/Corrected O/C Heat Rate
GT1 Output Corrections Trend
GT1 Temperatures Profile
MAIN OVERVIEW
* Developed & Maintained by CC - ERP Operation Group

GT Exhaust Temperature Spread

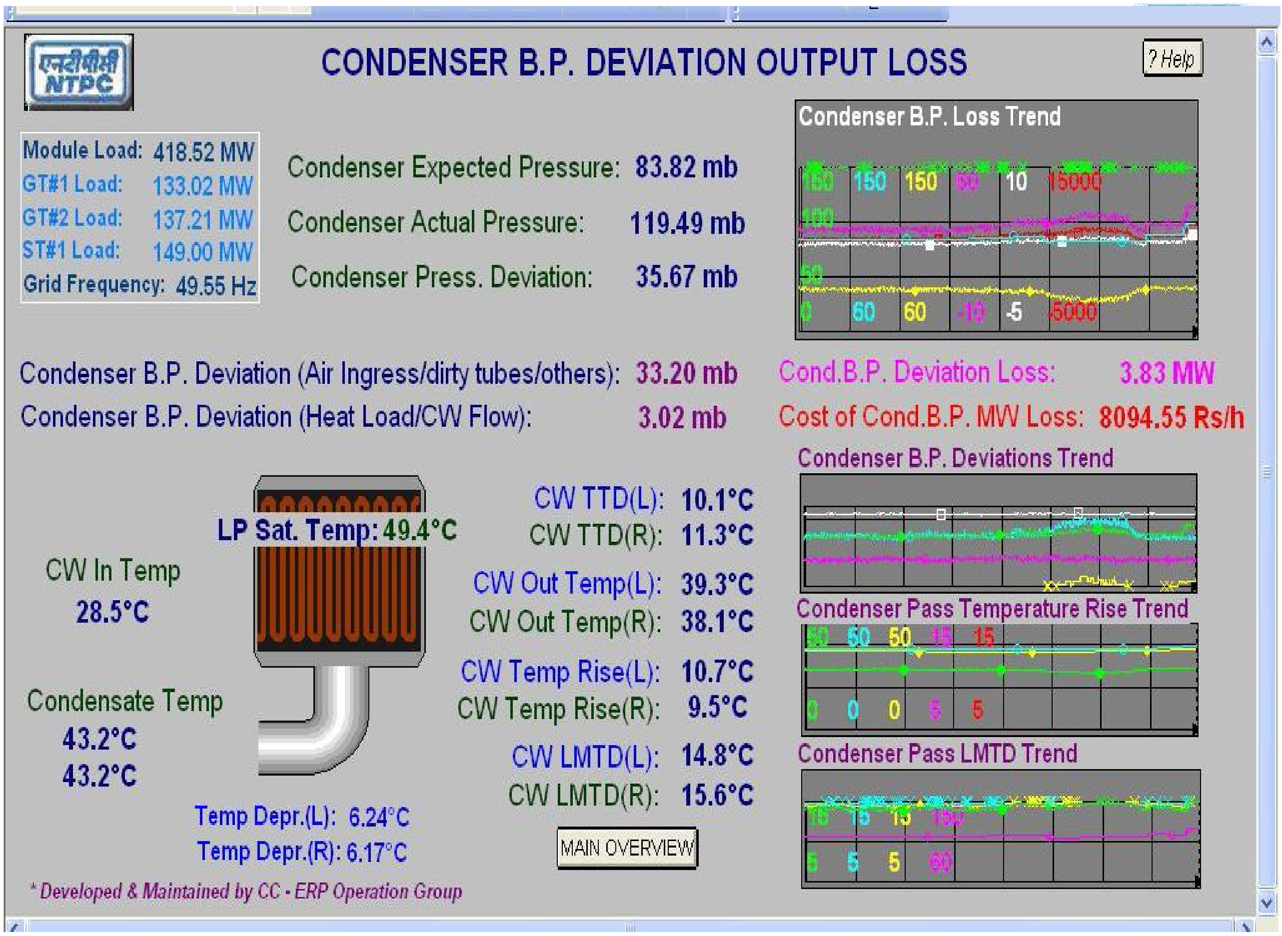
Enter GT No.=>	**2**			12/6/2011 9:55
GT Exhaust Thermocouple	**Temp. Value**	**Temp. Deviation**	**Deviation from Avg**	GT Output (MW)
GT Exhaust Temperature 1	593.01	GT Exh. Temp. Dev. 1	1.67	136.60
GT Exhaust Temperature 2	620.51	GT Exh. Temp. Dev. 2	29.17	
GT Exhaust Temperature 3	595.54	GT Exh. Temp. Dev. 3	4.20	
GT Exhaust Temperature 4	519.97	GT Exh. Temp. Dev. 4	-71.37	
GT Exhaust Temperature 5	617.65	GT Exh. Temp. Dev. 5	26.31	
GT Exhaust Temperature 6	601.37	GT Exh. Temp. Dev. 6	10.03	
GT Avg Exh Temp	**591.34**	**GT Exh Max Spread**	**100.54**	



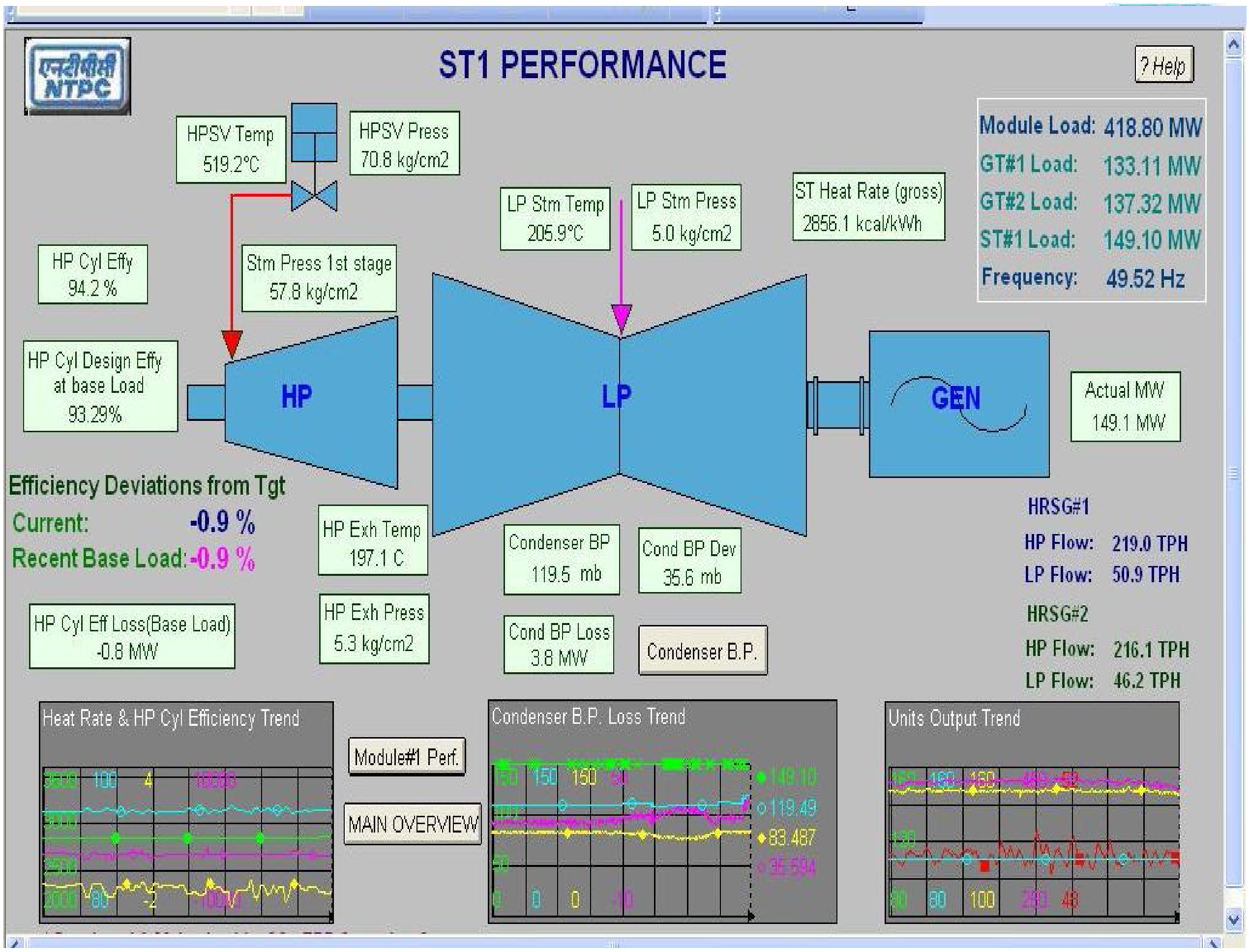
Sheet1 Sheet2 Sheet3



MODULE#1 PERFORMANCE
NTPC
? Help
HR (As Run) 1932.2 KCal/kwh
Corrected HR 1933.6 KCal/kwh
Stack Emissions
GT#1 GT#2 Stn
NOx ppm 48 20
SOx ppm 0.0 1.0
CO2 kg/kwh 0.68 0.65 0.43
GT1 Corr Pwr 129.6 MW
GT1 Performance
GT#1 132.6 MW
546.3°C
554.9°C
HRSG#1
Efficiency 83.5 %
HP Flow: 218.7 TPH
LP Flow: 51.0 TPH
108.6°C
LP Pr: 5.0ksc
LP Temp: 205.9°C
ST Performance
ST#1 148.8 MW
HP Pr: 70.8ksc
HP Temp: 518.3°C
Grid Frequency 49.5 Hz
HRSG Performance
GT2 Performance
GT#2 136.9 MW
545.1°C
553.0°C
Efficiency 83.3 %
109.0°C
HRSG#2
HP Flow: 216.1 TPH
LP Flow: 46.2 TPH
GT2 Corr Pwr 133.7 MW
Gen Load 418.5 MW
Module Loading: 94.91 %
Corrected Pwr 409.6 MW
Output Corr.(MW)
Amb Temp: -10.07
Amb Press: -1.78
Amb RH: 0.19
Grid Freq: 4.20
CW InTemp: -1.31
GT#1 Outlet Temp. Control Active: YES
GT#2 Outlet Temp. Control Active: YES
Ambient Air Condition:
Temperature: 21.76°C
Pressure: 0.992 bar
Rel. Humidity: 56.40 %
MAIN OVERVIEW
418.51
409.62
49.46000
1932.2
1933.6
49.46000
-0.98211
2.4027
0.42368
0.31327



NTPC
CONDENSER B.P. DEVIATION OUTPUT LOSS
? Help
Module Load: 418.52 MW
GT#1 Load: 133.02 MW
GT#2 Load: 137.21 MW
ST#1 Load: 149.00 MW
Grid Frequency: 49.55 Hz
Condenser Expected Pressure: 83.82 mb
Condenser Actual Pressure: 119.49 mb
Condenser Press. Deviation: 35.67 mb
Condenser B.P. Loss Trend
Condenser B.P. Deviation (Air Ingress/dirty tubes/others): 33.20 mb
Condenser B.P. Deviation (Heat Load/CW Flow): 3.02 mb
Cond.B.P. Deviation Loss: 3.83 MW
Cost of Cond.B.P. MW Loss: 8094.55 Rs/h
Condenser B.P. Deviations Trend
LP Sat. Temp: 49.4°C
CW In Temp
28.5°C
Condensate Temp
43.2°C
43.2°C
CW TTD(L): 10.1°C
CW TTD(R): 11.3°C
CW Out Temp(L): 39.3°C
CW Out Temp(R): 38.1°C
CW Temp Rise(L): 10.7°C
CW Temp Rise(R): 9.5°C
CW LMTD(L): 14.8°C
CW LMTD(R): 15.6°C
Condenser Pass Temperature Rise Trend
Condenser Pass LMTD Trend
Temp Depr.(L): 6.24°C
Temp Depr.(R): 6.17°C
MAIN OVERVIEW
* Developed & Maintained by CC - ERP Operation Group


ST1 PERFORMANCE
? Help
NTPC
HPSV Temp 519.2°C
HPSV Press 70.8 kg/cm2
LP Stm Temp 205.9°C
LP Stm Press 5.0 kg/cm2
ST Heat Rate (gross) 2856.1 kcal/kWh
Module Load: 418.80 MW
GT#1 Load: 133.11 MW
GT#2 Load: 137.32 MW
ST#1 Load: 149.10 MW
Frequency: 49.52 Hz
HP Cyl Effy 94.2 %
Stm Press 1st stage 57.8 kg/cm2
HP Cyl Design Effy at base Load 93.29%
HP
LP
GEN
Actual MW 149.1 MW
Efficiency Deviations from Tgt
Current: -0.9 %
Recent Base Load: -0.9 %
HP Exh Temp 197.1 C
Condenser BP 119.5 mb
Cond BP Dev 35.6 mb
HRSG#1
HP Flow: 219.0 TPH
LP Flow: 50.9 TPH
HP Cyl Eff Loss(Base Load) -0.8 MW
HP Exh Press 5.3 kg/cm2
Cond BP Loss 3.8 MW
Condenser B.P.
HRSG#2
HP Flow: 216.1 TPH
LP Flow: 46.2 TPH
Heat Rate & HP Cyl Efficiency Trend
Module#1 Perf.
MAIN OVERVIEW
Condenser B.P. Loss Trend
Units Output Trend

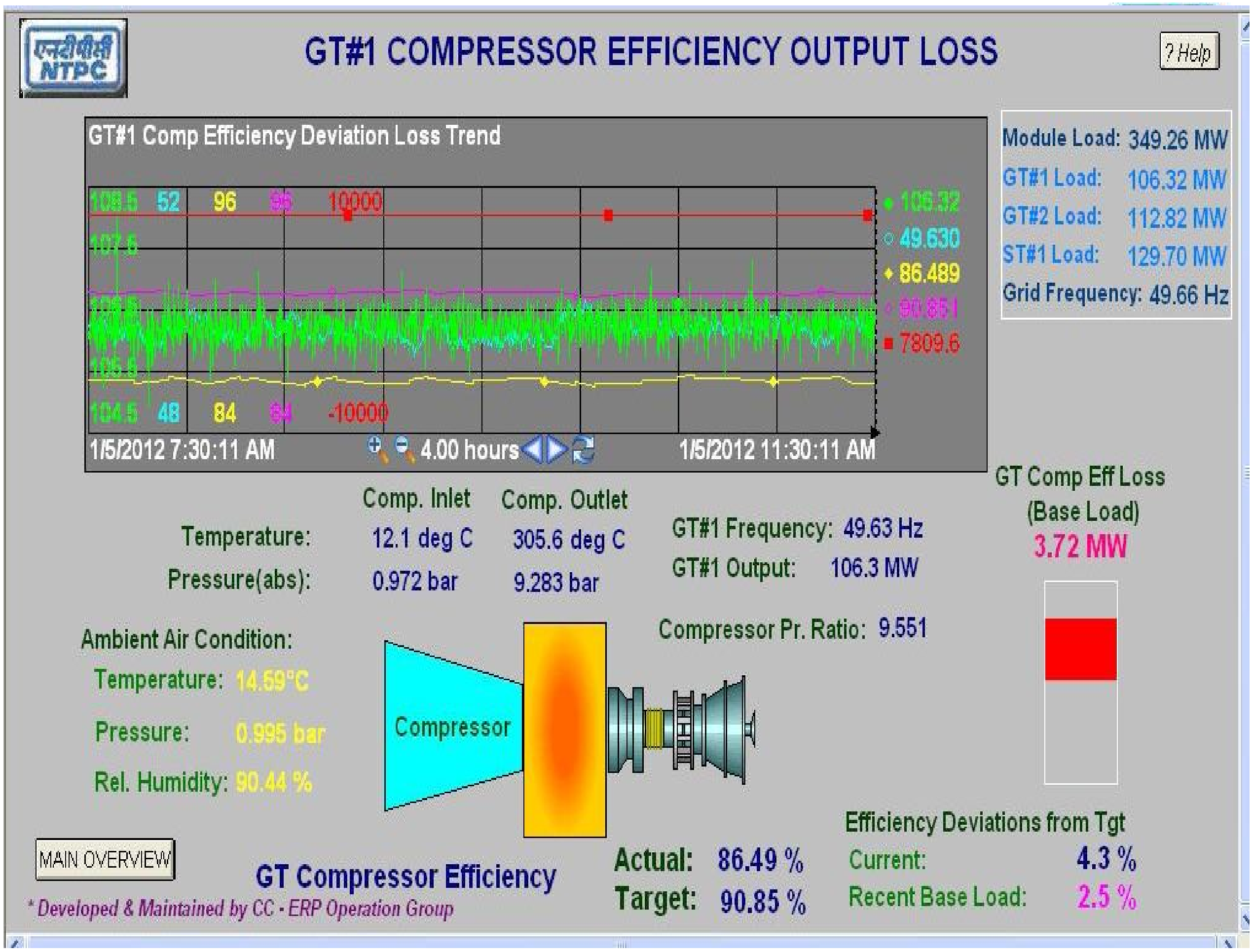
S.N.	Parameter Description	GT#1	GT#2	ST#1	Station	Loss Cost (Rs)
	Interval Start Time	06/12/11 08:58	06/12/11 09:58	Interval End Time		

Time Interval Loss Monitor

* The monitor gives ***true representation of losses for base load operation*** of the station. At part loading also, trending of losses can be done to monitor degradations.*Other losses include ***partial losses due to grid,fuel & planned restrictions*** also.

S.N.	Parameter Description	Time Interval Loss (MW)				Loss Cost
		GT#1	GT#2	ST#1	Station	(Rs)
1	*Uncontrollable Parameters*					
	Output Loss due to:					
1.1.1	Ambient Temperature	-4.876	-5.032	-1.964	-11.872	
1.1.2	Ambient Pressure	-0.608	-0.593	-0.714	-1.915	
1.1.3	Ambient RH	0.057	0.053	-0.057	0.053	
1.1	**Environment Total**	**-5.427**	**-5.572**	**-2.734**	**-13.734**	
1.2	**Grid Frequency**	**1.144**	**1.124**	**0.917**	**3.184**	
	Sub Total Uncontrollable	**-4.284**	**-4.448**	**-1.818**	**-10.550**	
2	*Controllable Parameters*					
	Output Loss due to:					
2.1	GT High Inlet Air Filter DP	1.798	1.390	1.811	4.999	10762.83
2.2	GT Poor Comp Efficiency	2.839	3.004	3.277	9.119	19171.08
2.3	Deviation in Aux Power Cons				-0.947	-1987.13
2.4	Deviation in DM Make up Cons				-0.349	-733.04
2.5	Condenser Pressure			3.358	3.358	7049.17
2.6	ST HP Cyl Efficiency Deviation			-0.832	-0.832	-1688.97
	Sub Total Controllable	**4.637**	**4.394**	**7.614**	**15.349**	**32573.95**
	Average Gross Gen	136.205	139.471	149.955	**425.631**	
	Installed Capacity	137.758	137.758	156.070	**431.586**	
	Total Gap	**1.553**	**-1.713**	**6.115**	**5.955**	
	Total Accounted Loss	**0.353**	**-0.054**	**5.796**	**4.799**	
	Other Losses	**1.200**	**-1.659**	**0.319**	**1.156**	
	Corrected Heat Rate	**3063.5**	**2907.7**	**2849.5**	**1927.3**	
	OTC Control Active Time (hrs)	1.00	0.92			

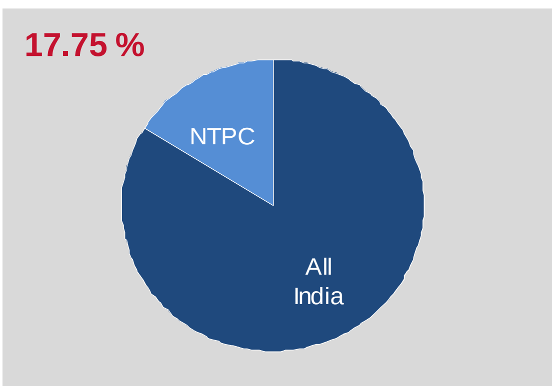
Sheet1 Sheet2 Sheet3


GT#1 COMPRESSOR EFFICIENCY OUTPUT LOSS
? Help
GT#1 Comp Efficiency Deviation Loss Trend
1/5/2012 7:30:11 AM
4.00 hours
1/5/2012 11:30:11 AM
Module Load: 349.26 MW
GT#1 Load: 106.32 MW
GT#2 Load: 112.82 MW
ST#1 Load: 129.70 MW
Grid Frequency: 49.66 Hz
GT Comp Eff Loss
(Base Load)
3.72 MW
Comp. Inlet
Comp. Outlet
Temperature: 12.1 deg C 305.6 deg C
Pressure(abs): 0.972 bar 9.283 bar
GT#1 Frequency: 49.63 Hz
GT#1 Output: 106.3 MW
Compressor Pr. Ratio: 9.551
Ambient Air Condition:
Temperature: 14.59°C
Pressure: 0.995 bar
Rel. Humidity: 90.44 %
Compressor
MAIN OVERVIEW
GT Compressor Efficiency
Actual: 86.49 %
Target: 90.85 %
Efficiency Deviations from Tgt
Current: 4.3 %
Recent Base Load: 2.5 %
* Developed & Maintained by CC - ERP Operation Group

About NTPC

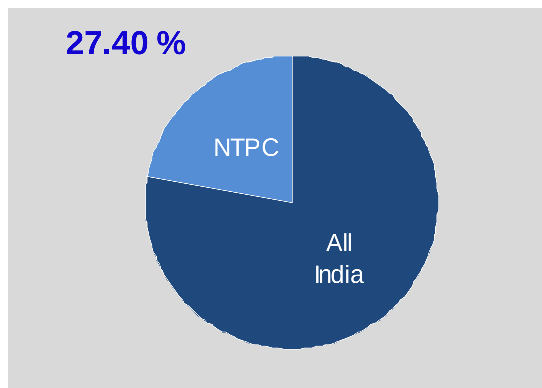
Total Capacity

36,014 MW



Generation

220.54 BU



NTPC Contributes More Than One-fourth of India's Total Power Generation with Less Than One-fifth Capacity

- Set up in 1975 with 100% ownership by government of India
- The largest power generation company in India, with comprehensive in-house capabilities in building and operating power projects
- Target of 1,28,000 MW capacity by 2032
- Installed 2490 MW of new capacity in 2010-11

About NTPC

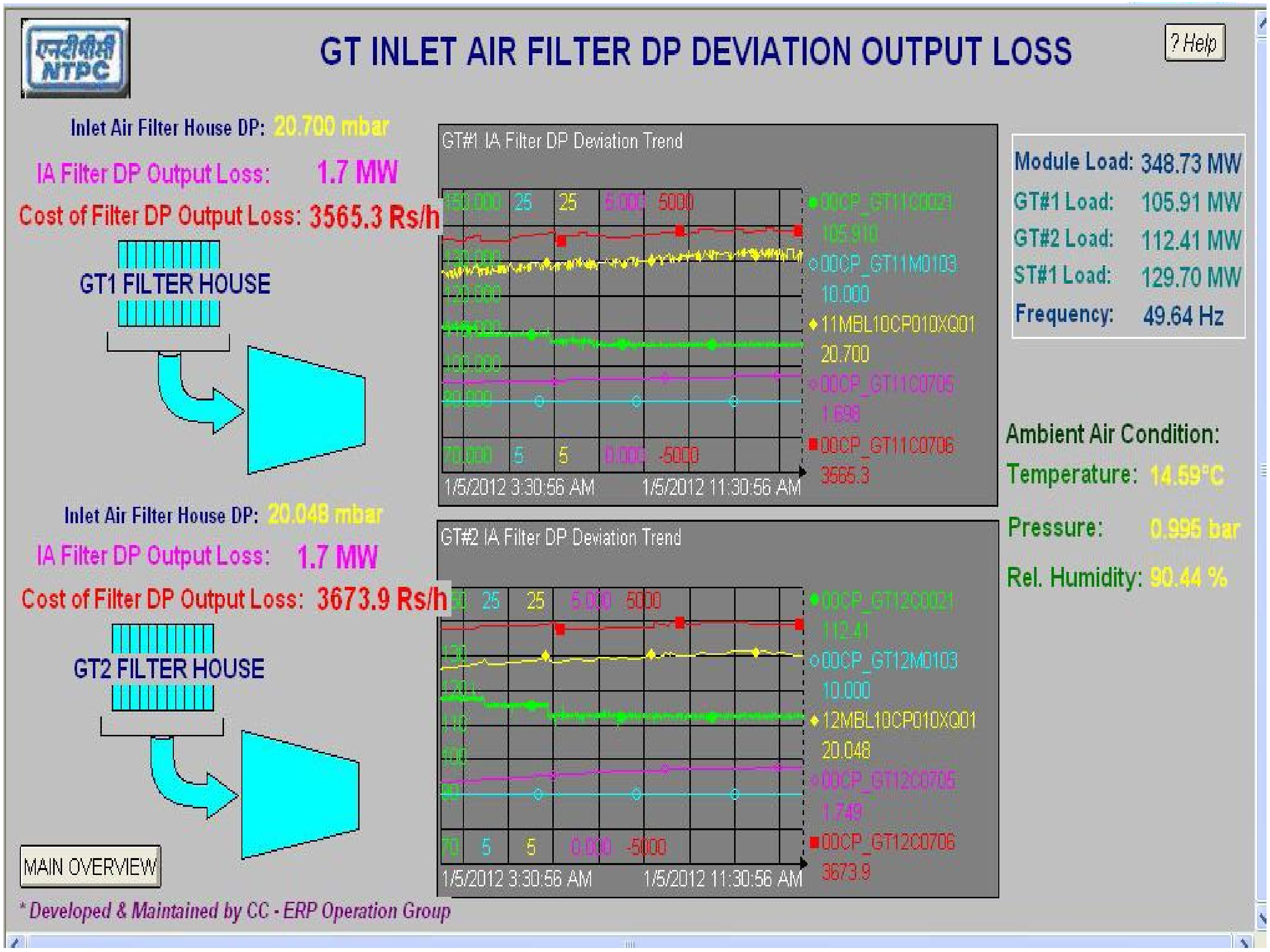
Stature

- Awarded “Maharatna” status in May 2010
- No.1 Independent Power Producer in Asia and 2nd globally in the Platts Top 250 Global Energy Company Rankings
- Excellent MOU Rating by GOI for the fiscal 2011
- Ranked 348th largest company in the world as per Annual Ranking of top 2000 companies in the world by Forbes
- Good Corporate Citizen award – 2011 by PHD Chamber of Commerce for outstanding works in CSR & Corporate Governance.

About NTPC

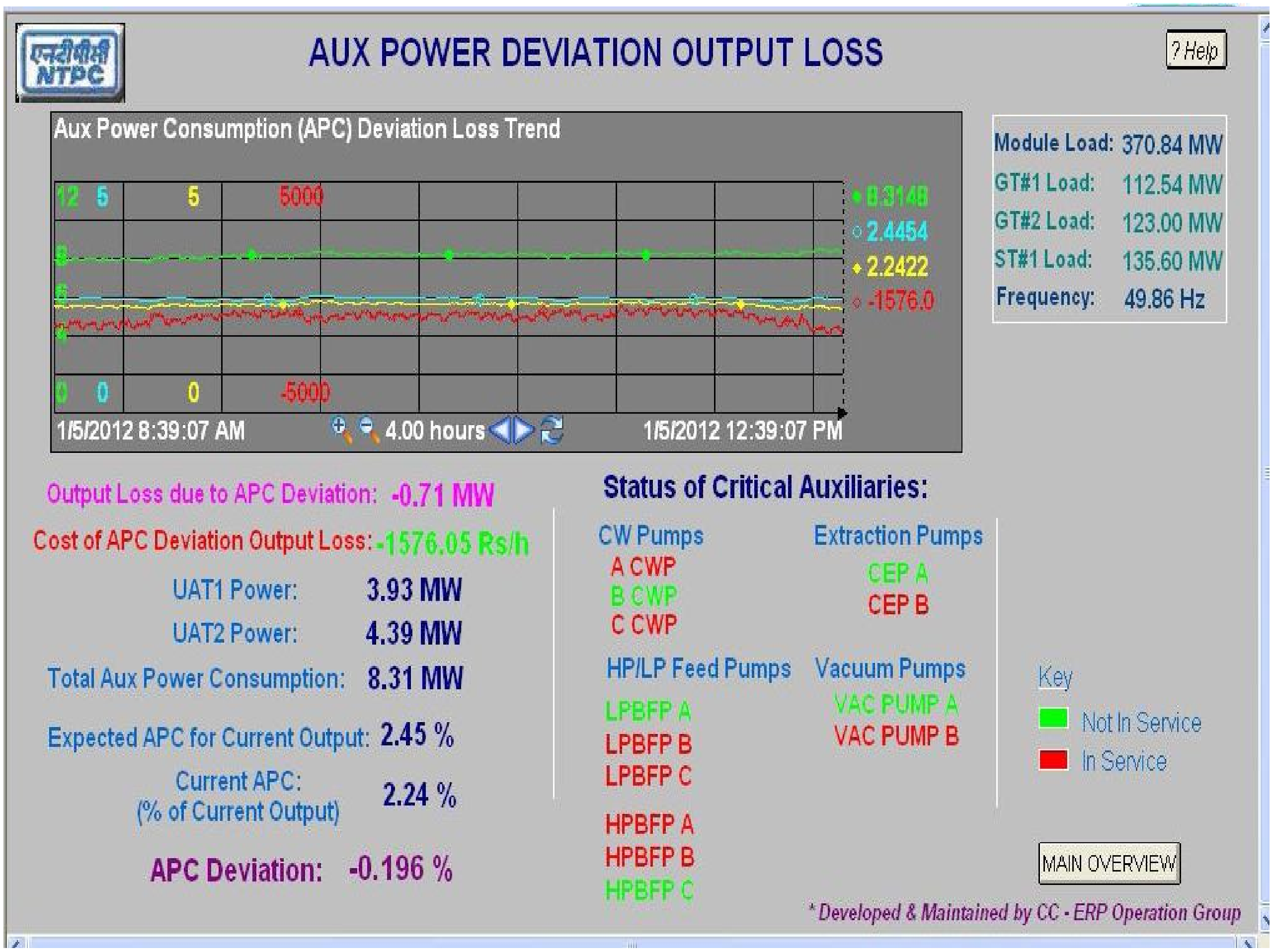
Operational Performance

- Generation from NTPC units increased by around 1% to 220.54 BUs in 2010-11 from 218.84 BUs in 2009-10.
- 7 NTPC stations figure among the top 10 stations in the country in terms of highest Plant Load Factor(PLF) in 2010-11.
- Average PLF of NTPC coal stations was 88.29% & that of gas stations was 71.77% in 2010-11.
- Coal stations of NTPC achieved an Availability of 91.6% in 2010-11 against 91.4% achieved in 2009-10.



GT INLET AIR FILTER DP DEVIATION OUTPUT LOSS
? Help
Inlet Air Filter House DP: 20.700 mbar
IA Filter DP Output Loss: 1.7 MW
Cost of Filter DP Output Loss: 3565.3 Rs/h
GT1 FILTER HOUSE
GT#1 IA Filter DP Deviation Trend
00CP_GT11C0021
105.910
00CP_GT11M0103
10.000
11MBL10CP010XQ01
20.700
00CP_GT11C0705
1.698
00CP_GT11C0706
3565.3
1/5/2012 3:30:56 AM
1/5/2012 11:30:56 AM
Module Load: 348.73 MW
GT#1 Load: 105.91 MW
GT#2 Load: 112.41 MW
ST#1 Load: 129.70 MW
Frequency: 49.64 Hz
Ambient Air Condition:
Temperature: 14.59°C
Pressure: 0.995 bar
Rel. Humidity: 90.44 %
Inlet Air Filter House DP: 20.048 mbar
IA Filter DP Output Loss: 1.7 MW
Cost of Filter DP Output Loss: 3673.9 Rs/h
GT2 FILTER HOUSE
GT#2 IA Filter DP Deviation Trend
00CP_GT12C0021
112.41
00CP_GT12M0103
10.000
12MBL10CP010XQ01
20.048
00CP_GT12C0705
1.749
00CP_GT12C0706
3673.9
1/5/2012 3:30:56 AM
1/5/2012 11:30:56 AM
MAIN OVERVIEW
* Developed & Maintained by CC - ERP Operation Group

Output Loss Analysis (OLA) Help
Choose from menu below to view relevant area:
Gas Turbines
Loss due to GT Inlet Air filter DP
Loss due to GT Compressor
Loss due to GT partial loading
Loss due to higher (than design) Ambient Temperature
Loss due to higher (than design) Ambient Humidity
Loss due to higher (than design) Ambient Pressure
Loss due to lower (than design) grid frequency
Loss due to GT Exhaust Temperature deviation
Waste Heat Recovery Boiler (WHRB)
WHRB Outlet Temperature
Boiler Tube Leakages
Steam Turbine
Done
My Computer
100%



AUX POWER DEVIATION OUTPUT LOSS
? Help
Aux Power Consumption (APC) Deviation Loss Trend
1/5/2012 8:39:07 AM
4.00 hours
1/5/2012 12:39:07 PM
8.3148
2.4454
2.2422
-1576.0
Module Load: 370.84 MW
GT#1 Load: 112.54 MW
GT#2 Load: 123.00 MW
ST#1 Load: 135.60 MW
Frequency: 49.86 Hz
Output Loss due to APC Deviation: -0.71 MW
Cost of APC Deviation Output Loss: -1576.05 Rs/h
UAT1 Power: 3.93 MW
UAT2 Power: 4.39 MW
Total Aux Power Consumption: 8.31 MW
Expected APC for Current Output: 2.45 %
Current APC: (% of Current Output) 2.24 %
APC Deviation: -0.196 %
Status of Critical Auxiliaries:
CW Pumps
A CWP
B CWP
C CWP
Extraction Pumps
CEP A
CEP B
HP/LP Feed Pumps
LPBFP A
LPBFP B
LPBFP C
HPBFP A
HPBFP B
HPBFP C
Vacuum Pumps
VAC PUMP A
VAC PUMP B
Key
Not In Service
In Service
MAIN OVERVIEW
* Developed & Maintained by CC - ERP Operation Group

REDUCING UNCERTAINTY IN FUEL GASE MEASUREMENT BY MASS SPECTROMETRY

Pete Traynor
Product Manager, Process Mass Spectrometers

The world leader in serving science

Presentation Overview

- Executive Summary
- MS Operating Principles
- Performance Attributes
- Measurement Uncertainty
- Performance Assessment
- Design for Reliability
- Maintenance Procedures
- Summary
- Questions

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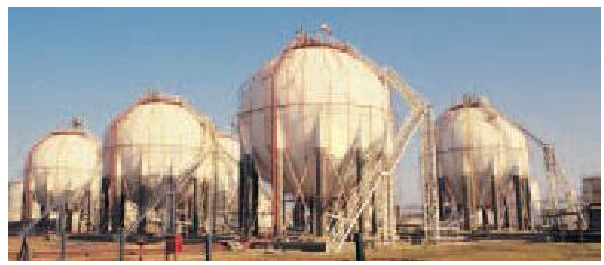
MS vs. Alternative Technology: Executive Summary



- Mass specs are fast
  - 10 to 30 seconds per sample stream compared with several minutes for GC
- Mass specs typically provide a complete composition analysis
- Mass specs are software configured and adaptable
  - Whereas GCs are configured with hardware
- Mass specs are usually multi-stream in fuel gas measuring applications
- Mass specs provide the best available precision and stability
- When compared one-for-one, mass specs are more expensive than GCs or calorimeters but most multi-stream MS installations are less expensive to buy and own and they are far more effective in most cases

Modern Process Mass Spec Design Criteria

- A true next-generation process mass spec will provide the following features:
  - Simplified setup and operation
  - Rugged construction
  - Fault-tolerant design with uptime close to 99.9%
  - Rapid fault identification and correction
  - High analytical precision (<<0.1% relative precision over 24 hours)
  - Extended calibration interval (months not weeks)
  - Extended 3-year PM interval
  - Simplified maintenance (2-hours or less)
  - Comprehensive 3-year warranty and performance guarantee

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Process MS:
Operating Principles

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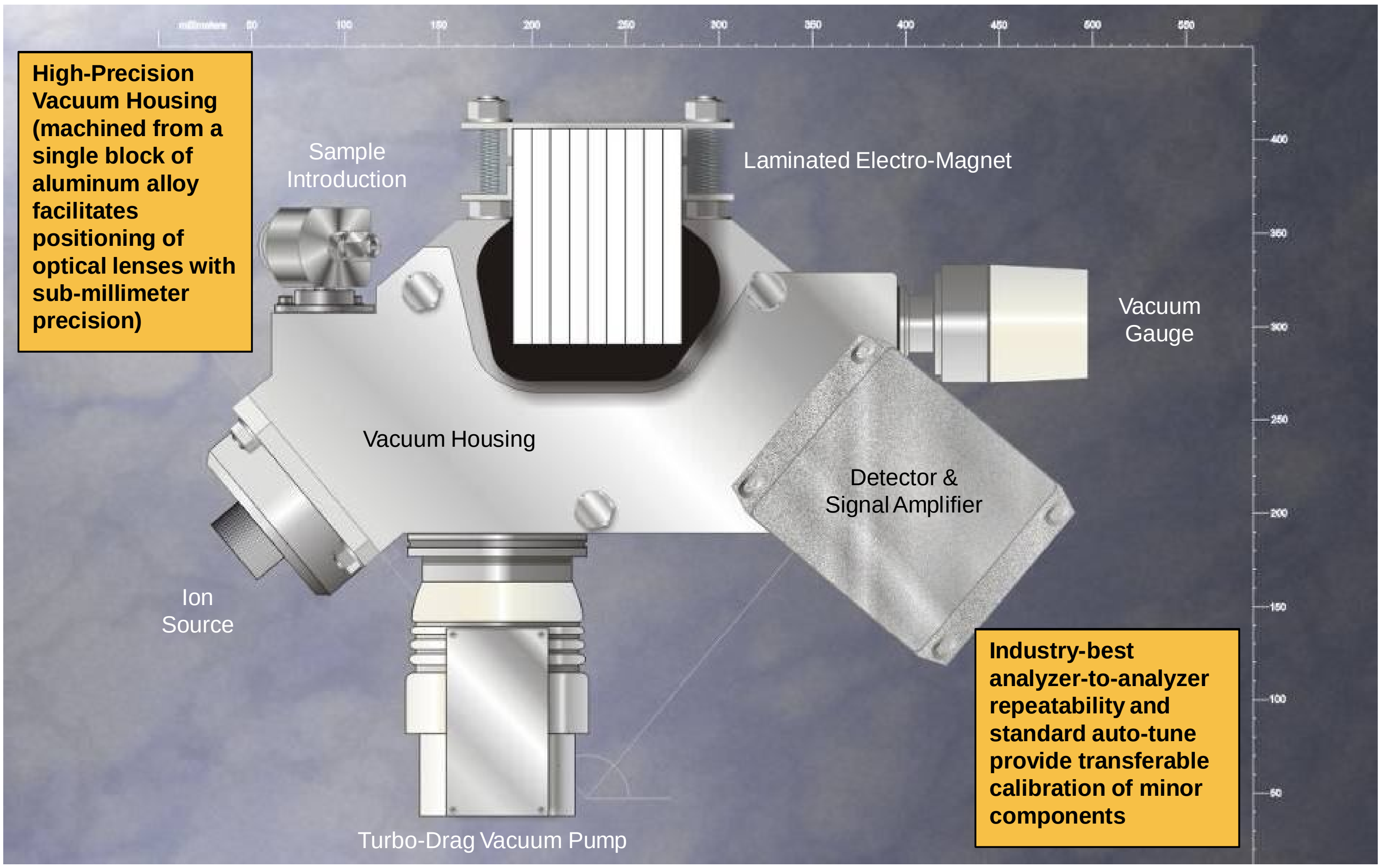
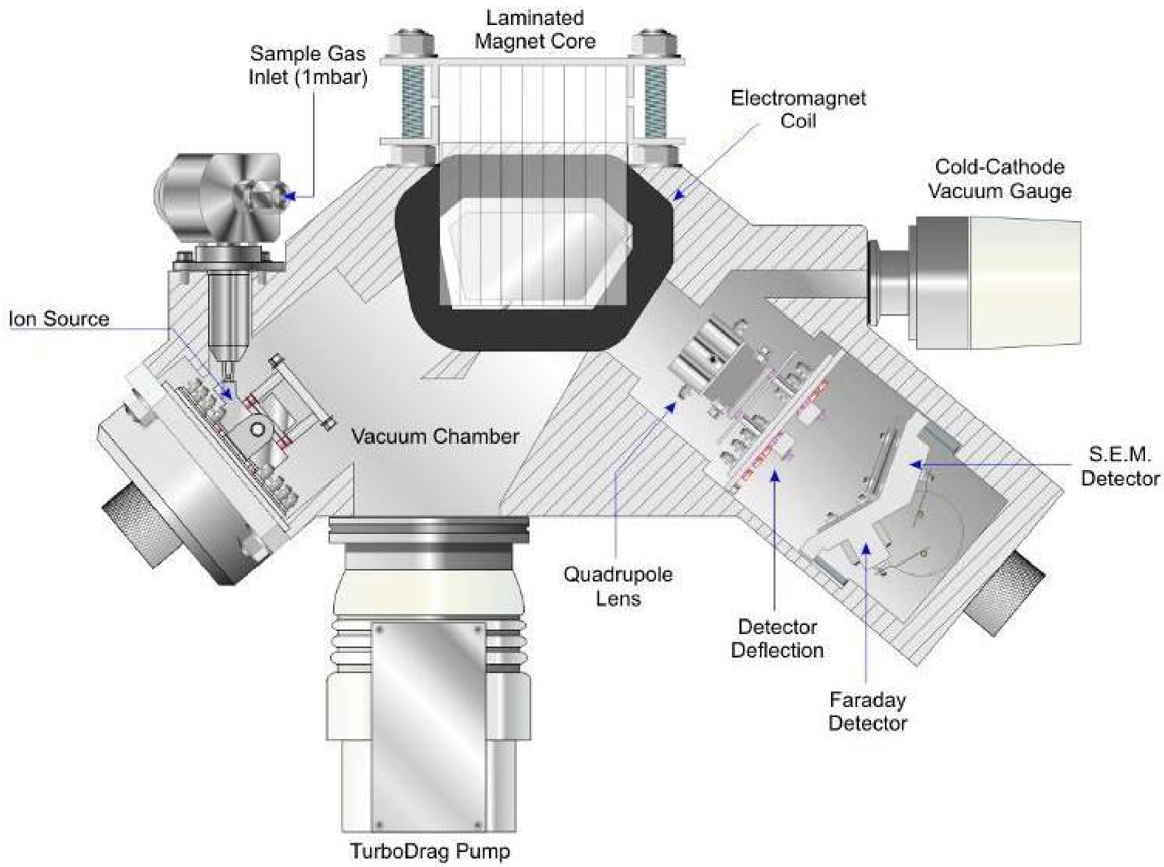
All-New Scanning Magnetic Sector Mass Spectrometer



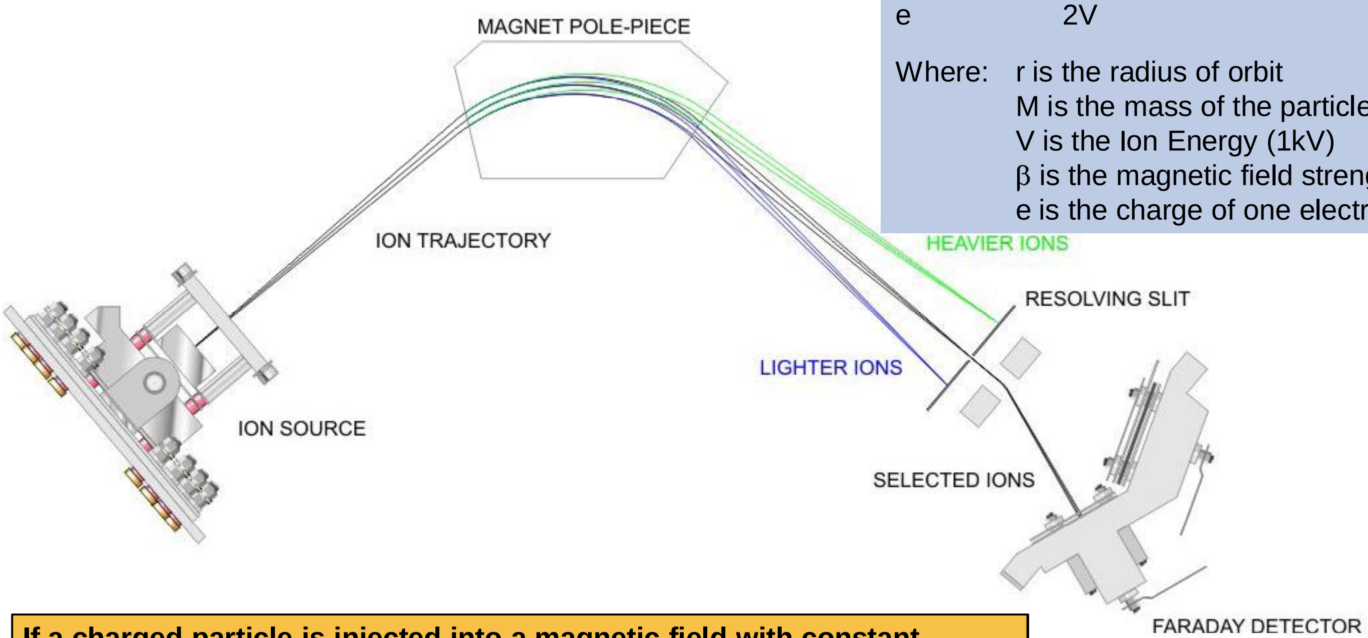
Magnetic Sector Principle Components



Magnetic Sector Principles of Operation

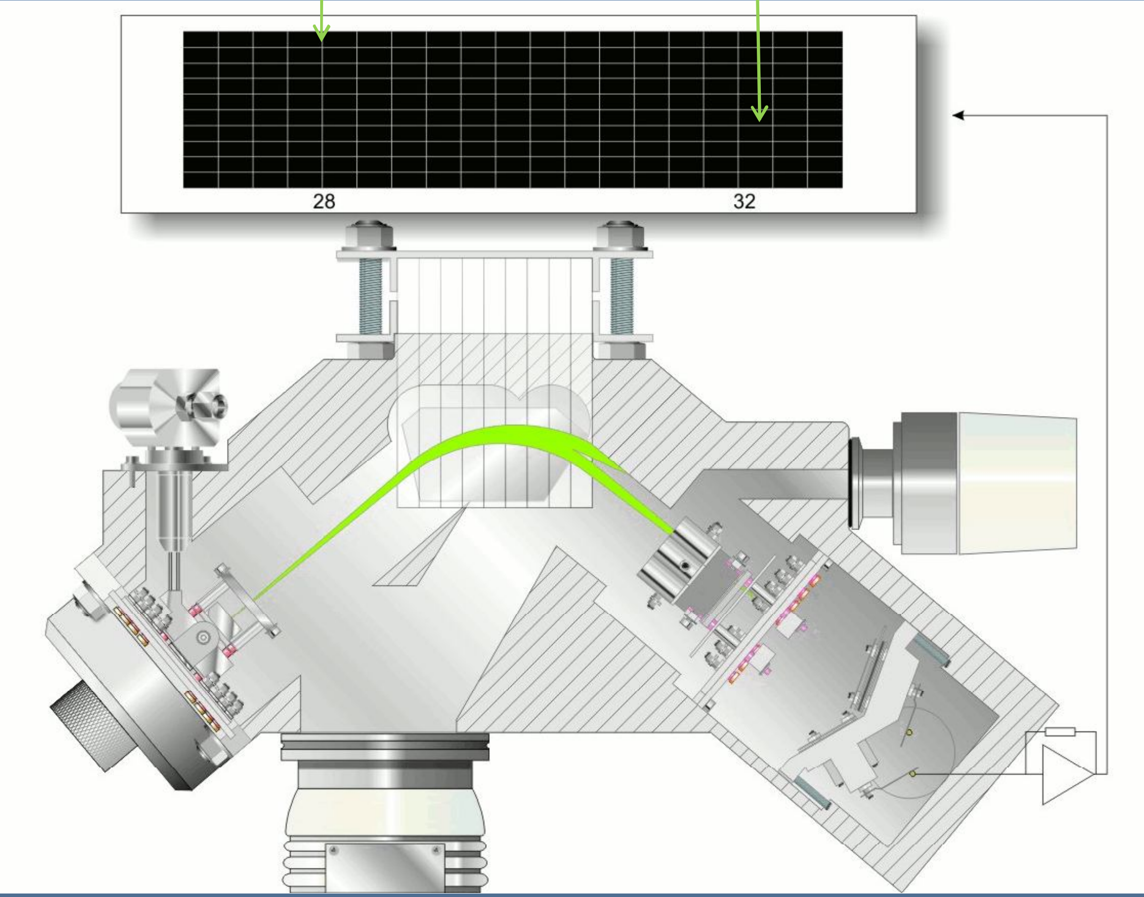
$$\frac{M}{e} = \frac{\beta^2 \times r^2}{2V}$$

Where:
- r is the radius of orbit
- M is the mass of the particle
- V is the Ion Energy (1kV)
- β is the magnetic field strength
- e is the charge of one electron

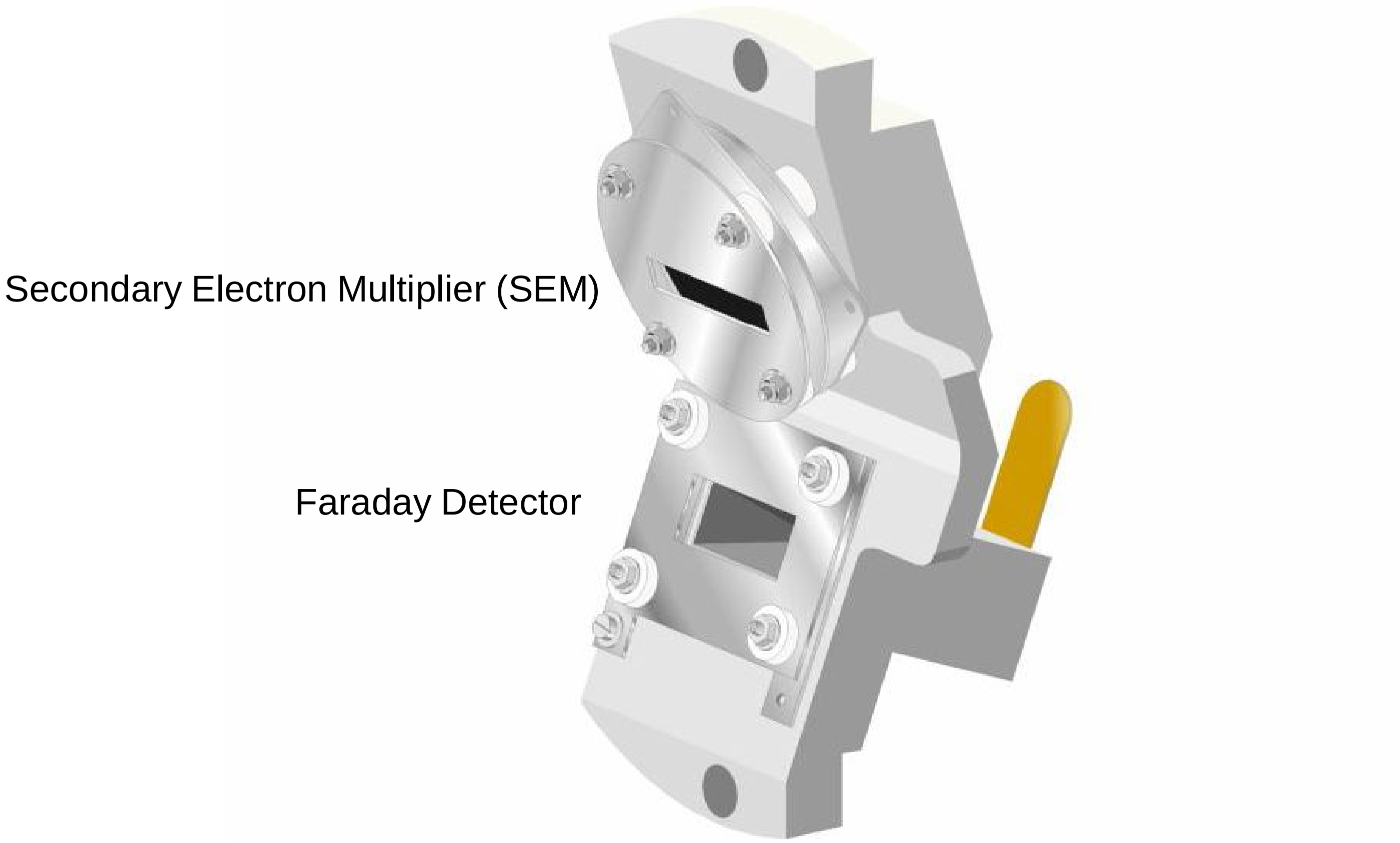


If a charged particle is injected into a magnetic field with constant velocity, the Lorentz force will act on the particle and cause it to move in a circular orbit of constant radius. The radius of orbit is dependent upon the velocity of the particle and its mass, and is also governed by the strength of the magnetic field and the charge on the particle.

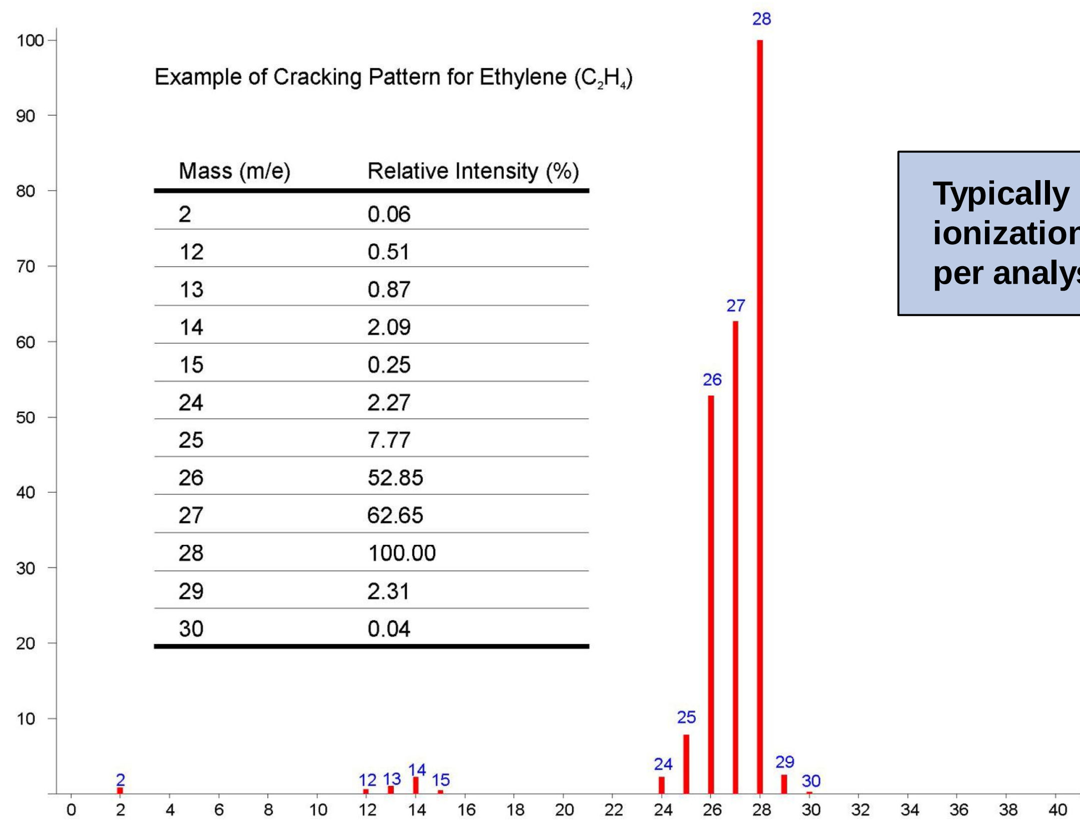
The abundance of selected ions is directly proportional to peak height. It is not necessary to measure the peak in the dead center (i.e. quadrupole MS). The entire peak top yields the same result.



Prima PRO MS Detector Assembly



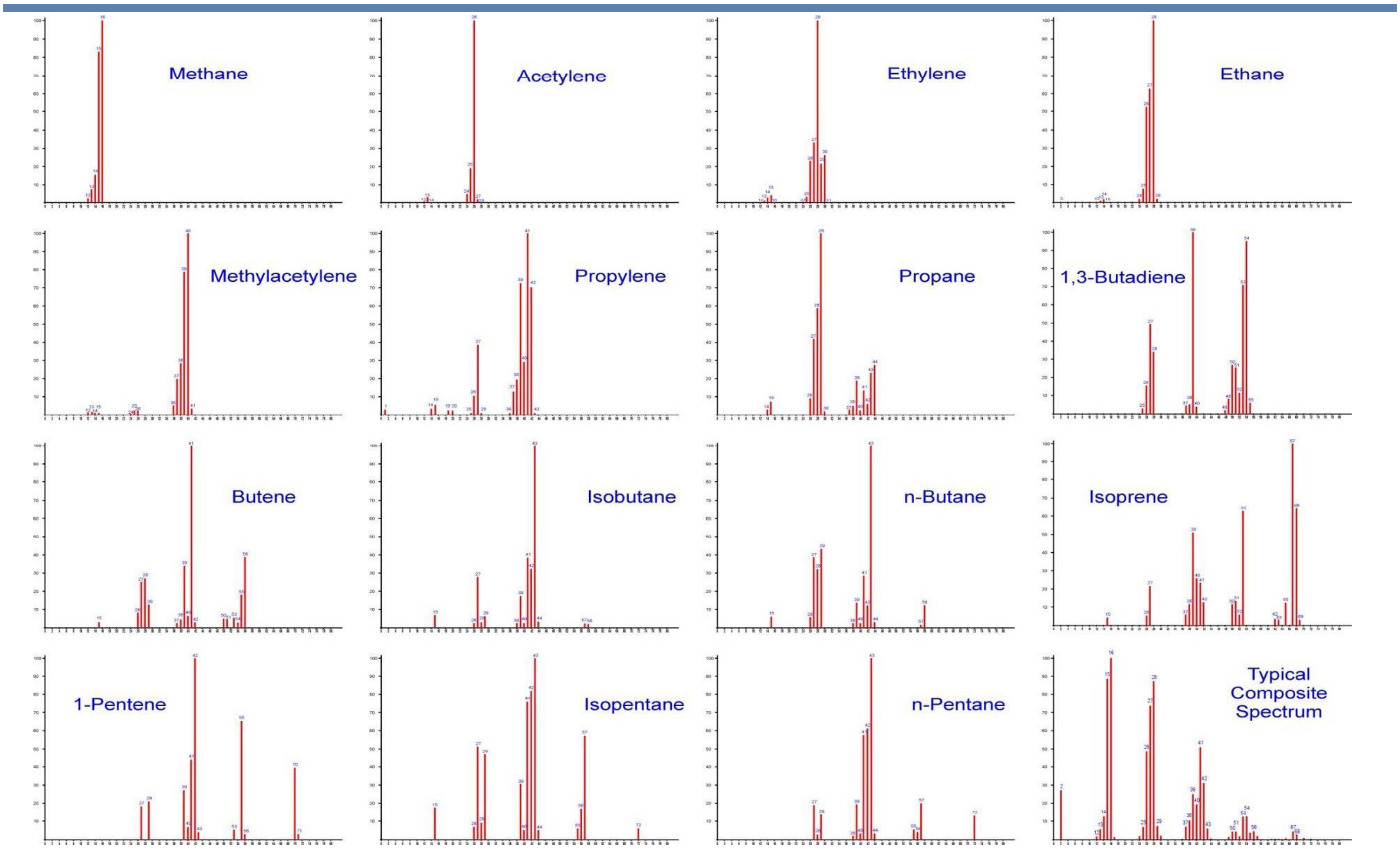
Ethylene Spectrum



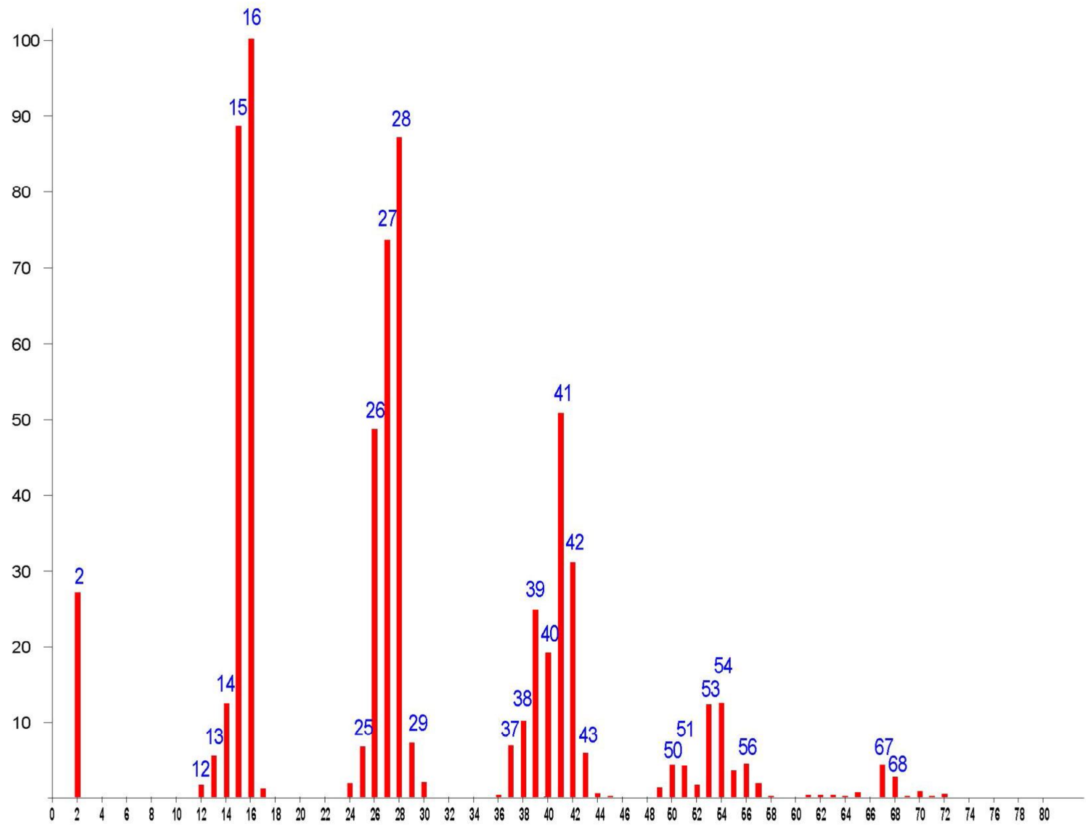
Mass (m/e)	Relative Intensity (%)
2	0.06
12	0.51
13	0.87
14	2.09
15	0.25
24	2.27
25	7.77
26	52.85
27	62.65
28	100.00
29	2.31
30	0.04

Typically $5x10^{10}$ ionization events per analysis

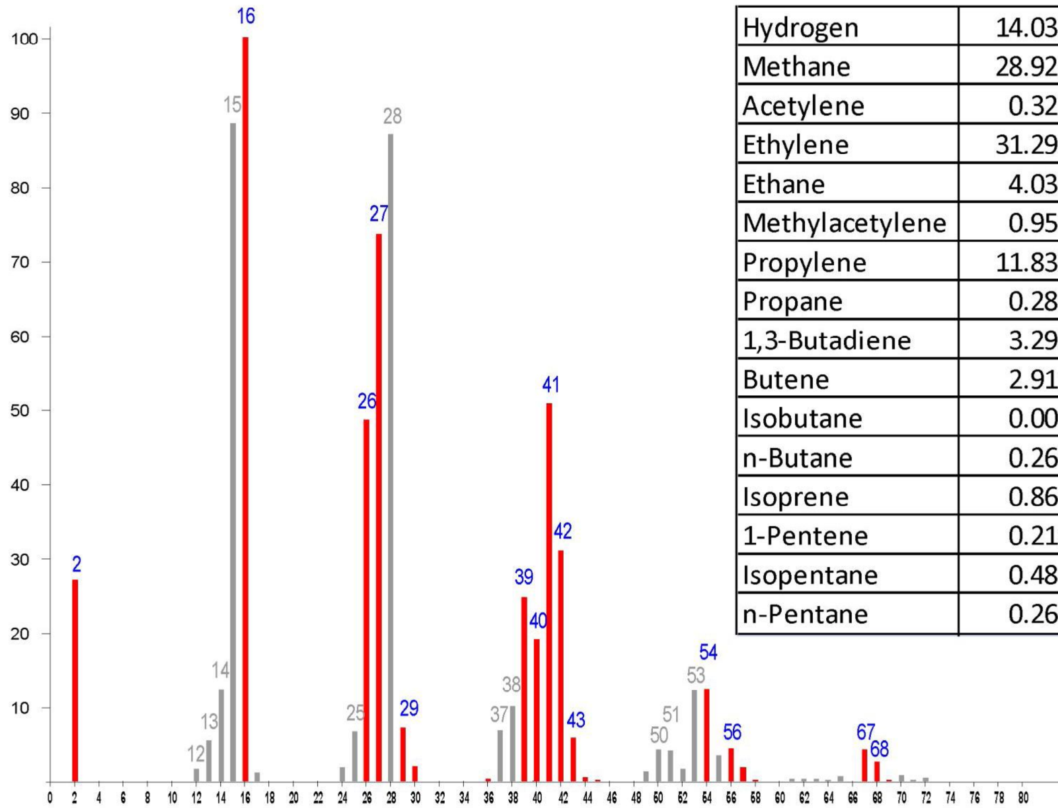
All Fuel Gas Spectra



Ethylene Furnace Effluent: Composite Spectrum

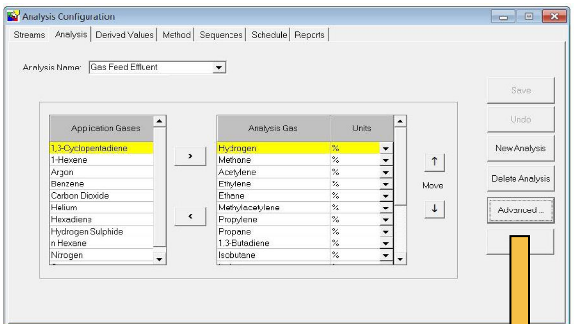


Composite Spectrum: Selected Peaks

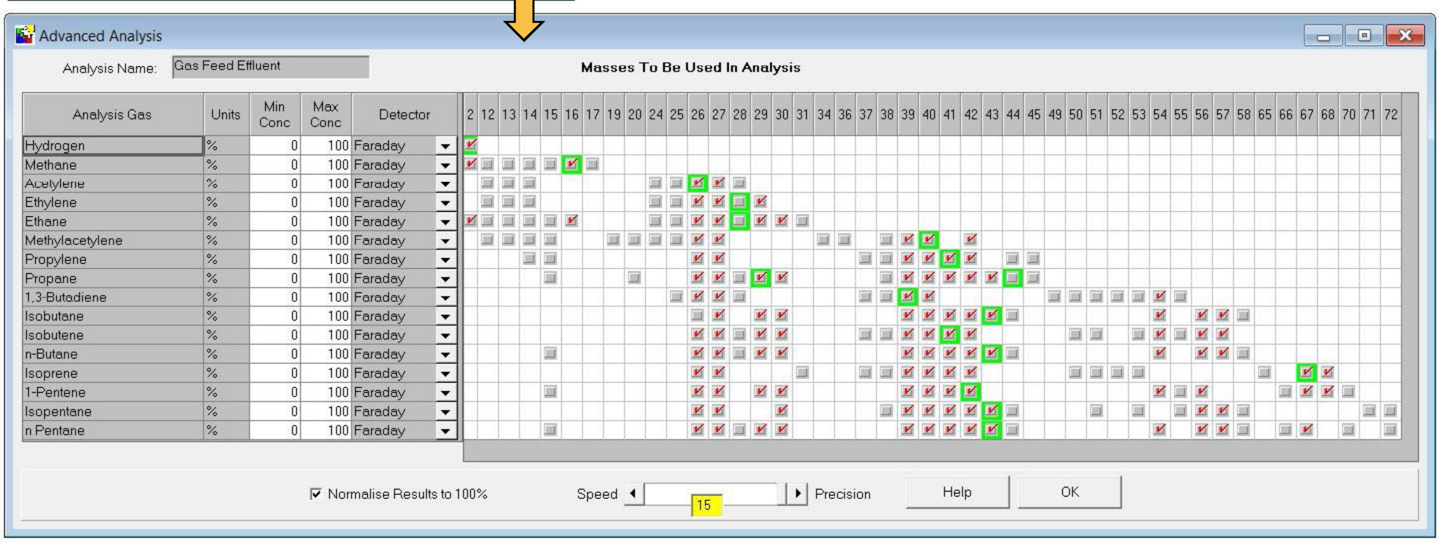


Hydrogen	14.0321
Methane	28.9266
Acetylene	0.3232
Ethylene	31.2908
Ethane	4.0326
Methylacetylene	0.9569
Propylene	11.8399
Propane	0.2893
1,3-Butadiene	3.2922
Butene	2.9118
Isobutane	0.0047
n-Butane	0.2667
Isoprene	0.8663
1-Pentene	0.2165
Isopentane	0.4846
n-Pentane	0.2658

Software: Method Configuration (Completed by our Startup Engineer)



1. In Analysis Configuration, move required components from the library to the application list.
2. Go to “Advanced” and select peaks to be measured and set the speed.



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Process MS: Performance Attributes and Measurement Uncertainty

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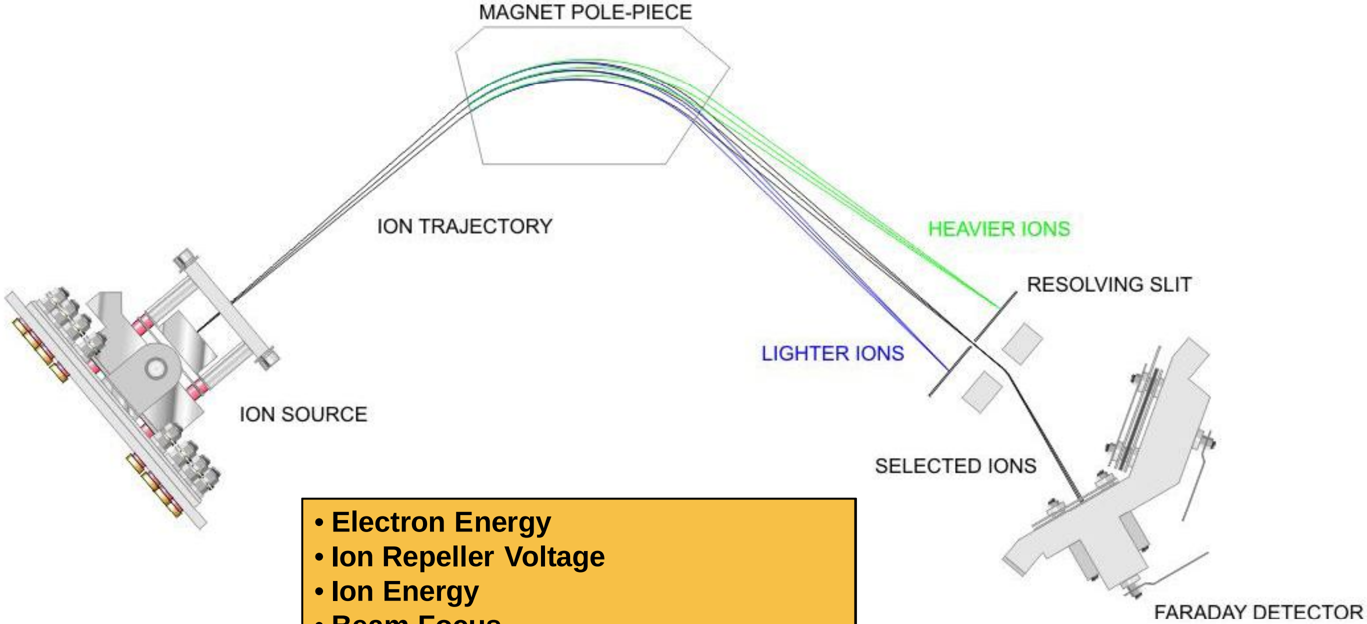
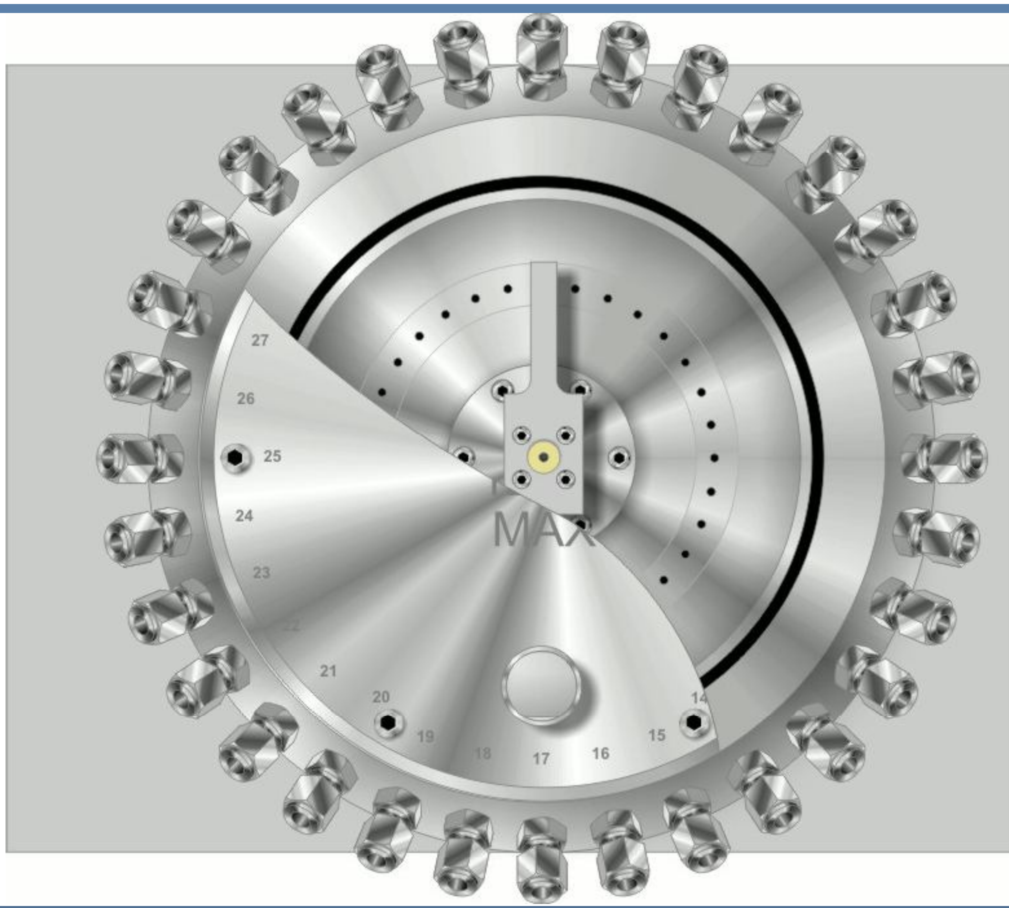
Magnetic Sector Performance Dependencies

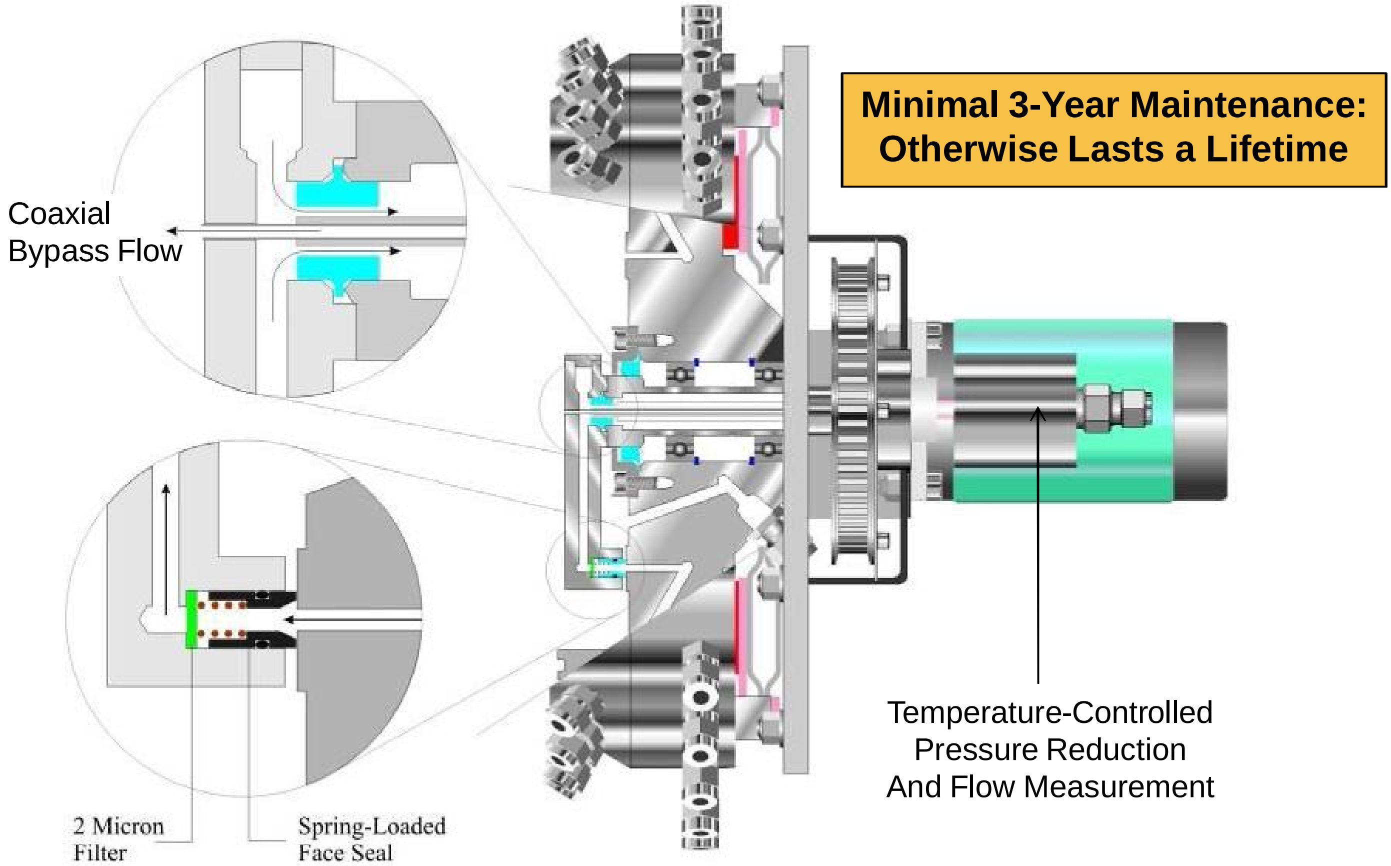


- **Electron Energy**
- **Ion Repeller Voltage**
- **Ion Energy**
- **Beam Focus**
- **Secondary Electron Suppression**

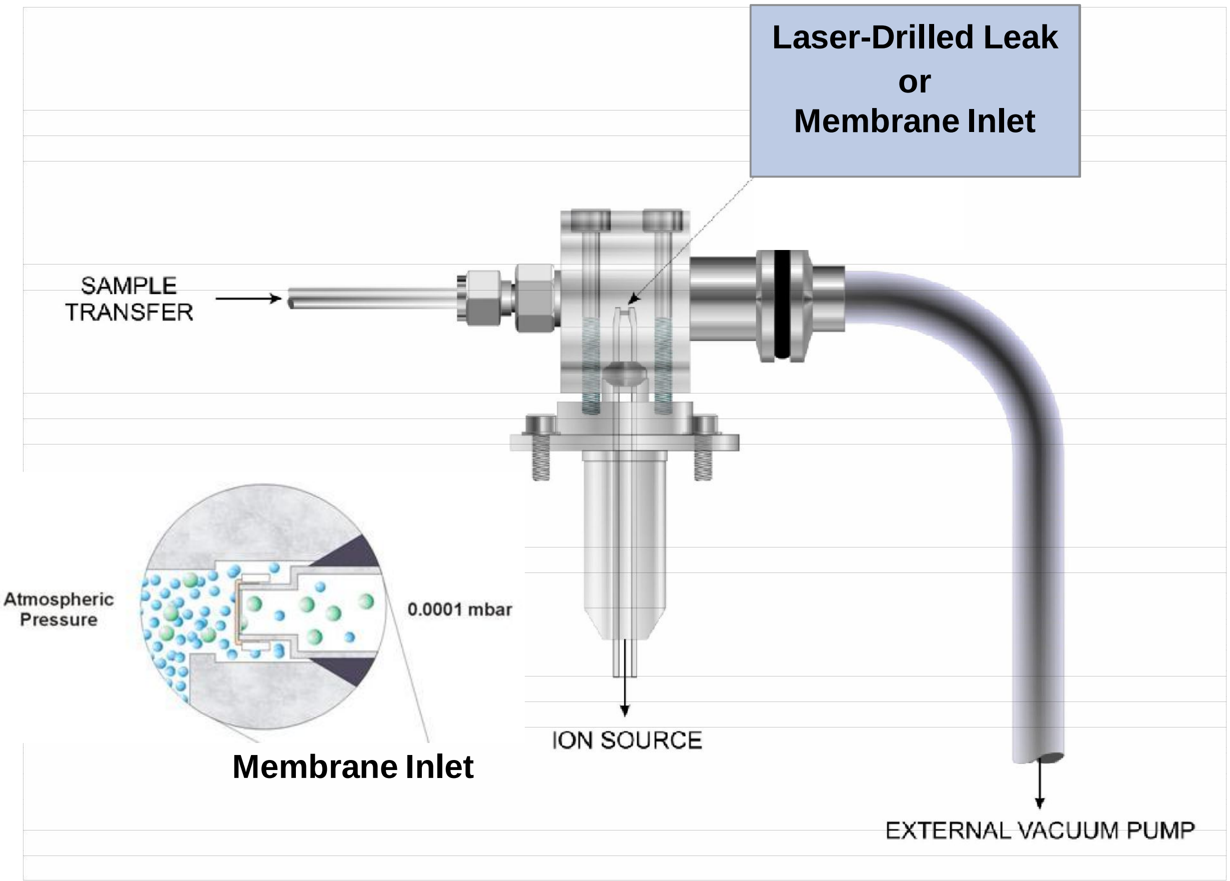
Rapid Multi-Stream Switching



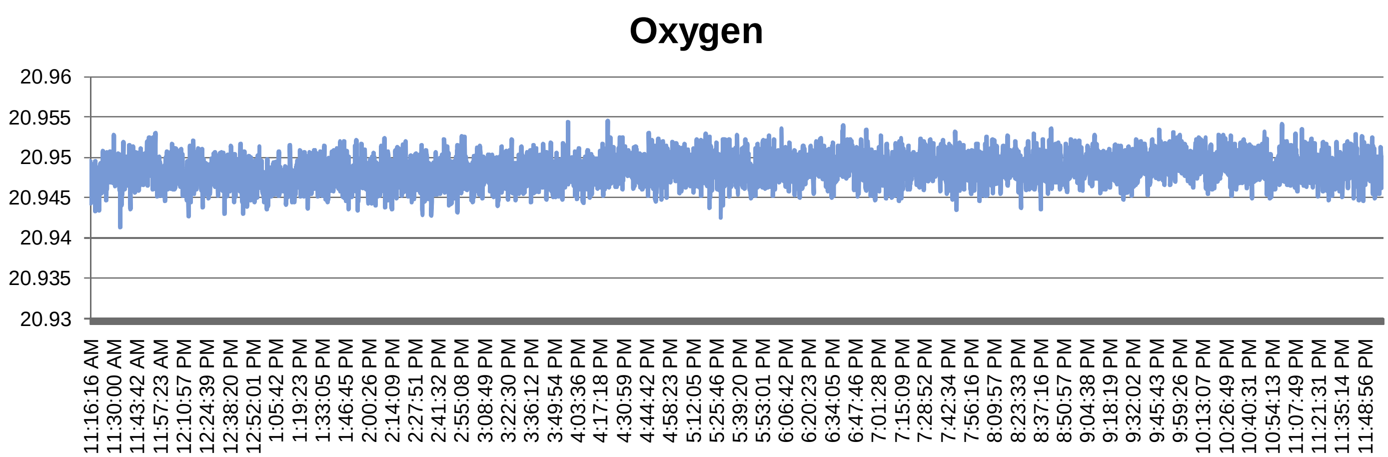
RMS Flow Path



Inlet Probe – Final Pressure Reduction



In-House Testing of Oxygen Precision & Stability



▪ Data Points:	5,245
▪ Sample Interval:	8 Seconds
▪ Mean Value:	20.9485%
▪ Standard Deviation:	0.001169%
▪ Relative Std. Deviation:	0.005581%

New mass spec four times faster or four times more precise when compared to predecessor models

Assessment Methodology

- Use ISO procedures to determine the analytical precision for each fuel gas component for several points representing the maximum possible concentration range
- Calculate the linearity expression for each component
- Use Monte Carlo methodology to combine precision, linearity and calibration uncertainty in order to determine any potential measurement bias in the generated data

Measurement Precision (accredited calibration lab)

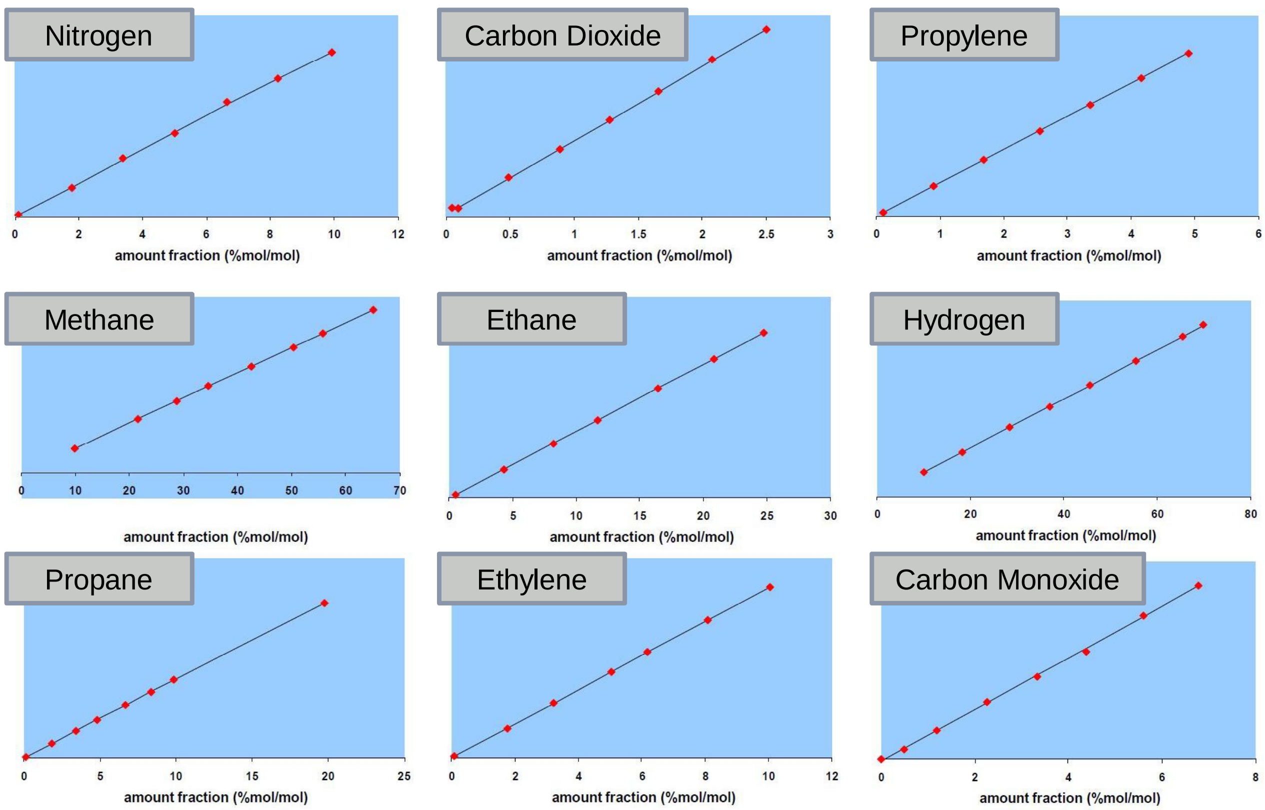
The precision was calculated at various concentrations in the simulated range using functions defined in ISO 15796*.
This is a measure of the true performance of the instrument.

		All values in mole%				
Nitrogen	Mean Concentration	0.1	2.56	5.02	7.48	9.94
	Measured Precision	0.0117	0.0169	0.0169	0.0171	0.0174
Carbon Dioxide	Mean Concentration	0.05	0.66	1.27	1.89	2.5
	Measured Precision	0.0006	0.001	0.0011	0.0011	0.0011
Methane	Mean Concentration	9.85	23.61	37.37	51.13	64.9
	Measured Precision	0.0037	0.0037	0.0037	0.0037	0.0037
Ethane	Mean Concentration	0.5	6.56	12.62	18.69	24.75
	Measured Precision	0.0001	0.0014	0.0026	0.0039	0.0051
Propane	Mean Concentration	0.11	5.01	9.91	14.81	19.72
	Measured Precision	0.001	0.0018	0.0026	0.0034	0.0042
Ethene	Mean Concentration	0.099	2.588	5.077	7.566	10.055
	Measured Precision	0.0024	0.0023	0.0023	0.0023	0.0023
Propene	Mean Concentration	0.099	1.3	2.502	3.703	4.904
	Measured Precision	0.0009	0.0009	0.0009	0.0009	0.0009
Hydrogen	Mean Concentration	10.013	24.682	39.351	54.021	68.69
	Measured Precision	0.0048	0.0048	0.0048	0.0048	0.0048
Carbon Monoxide	Mean Concentration	0.098	1.772	3.445	5.118	6.792
	Measured Precision	0.0366	0.0173	0.0171	0.017	0.0169

68.69%
0.0048%

*ISO 15796 gives guidance on how to estimate overall measurement uncertainty.

Linearity Data (accredited calibration lab)



Fuel Gas Physical Properties

In addition to providing a comprehensive analysis of the fuel gas, the MS also calculates the following properties:

- Gross Calorific Value (high heating value or real superior calorific value)
- Net Calorific Value (low heating value or real inferior calorific value)
- Carbon Dioxide Emission Factor (gross)
- Carbon Dioxide Emission Factor (net)
- Carbon Dioxide Emission Factor (quantity)
- Base Density
- Relative Density
- Molecular Weight
- Wobbe Index (real Wobbe number)
- Stoichiometric Air Requirement
- Combustion Air Requirement Index (CARI)

Density & Calorific Value Calculations

Density of Mixture =

- [Density of Pure $Component_1$ x Mole Fraction of $Component_1$] + [Density of Pure $Component_2$ x Mole Fraction of $Component_2$] + [Density of Pure $Component_3$ x Mole Fraction of $Component_3$] + etc
- The Specific Gravity is equal to the density divided by the density of the reference gas (normally air).

Calorific Value of Mixture =

- [Calorific Value of Pure $Component_1$ x Mole Fraction of $Component_1$] + [Calorific Value of Pure $Component_2$ x Mole Fraction of $Component_2$] + [Calorific Value of Pure $Component_3$ x Mole Fraction of $Component_3$] + etc

CARI & Wobbe Index

CARI = Stoichiometric Air Requirement / $(\text{Specific Gravity})^{0.5}$

Wobbe Index = Calorific Value / $(\text{Specific Gravity})^{0.5}$

- The Wobbe Index indicates the effective heating value of the fuel gas, correcting for the effect of increased flow for a lighter gas (for a given pressure drop).

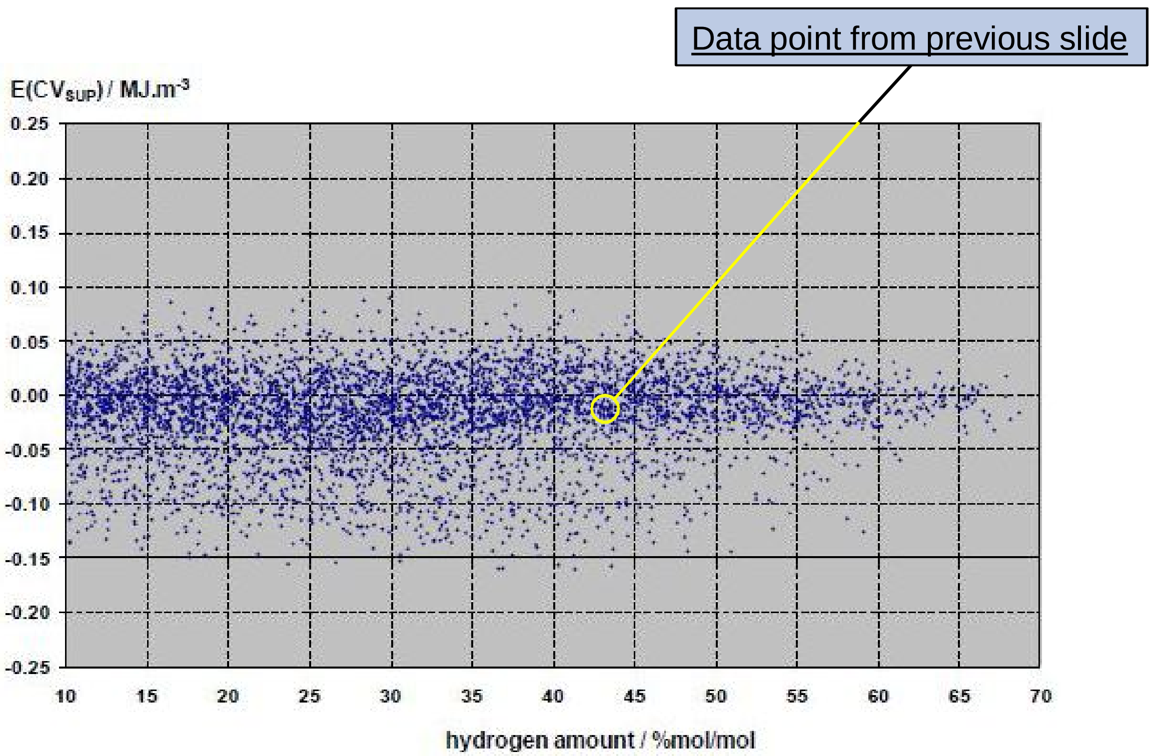
Evaluating Bias using Monte-Carlo Simulation

Randomly generated hypothetical calibration gas

Component	Cal Gas Actual mol%	Sample Gas Composition mol% actual	Measured	Measured normalized	Bias Error absolute mol%	Bias Error relative %
Nitrogen	9.007	5.02	5.1153	5.1105	0.0909	1.81
Carbon Dioxide	4.986	1.275	1.278	1.2706	-0.004	-0.327
Methane	9.013	37.44	37.4281	37.3933	-0.044	-0.117
Ethane	5.007	12.63	12.6792	12.6674	0.041	0.325
Propane	9.976	9.923	9.923	9.9138	-0.009	-0.088
Ethylene	5.004	5.079	5.0794	5.0747	-0.004	-0.075
Propene	4.987	2.502	2.4974	2.4951	-0.007	-0.28
Hydrogen	43.029	22.69	22.6864	22.6653	-0.028	-0.124
Carbon Monoxide	8.991	3.446	3.4125	3.4093	-0.036	-1.051
Gross CV MJm-3		40.25		40.238	**-0.014**	-0.034
Net CV MJm-3		36.62		36.607	-0.013	-0.035

Randomly generated hypothetical fuel gas

Bias Errors on Gross Calorific Value (5,000 Simulations)



Gross CV is shown as a function of increasing hydrogen content (10 – 70 %mol/mol)

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Process MS:
Design for Reliability

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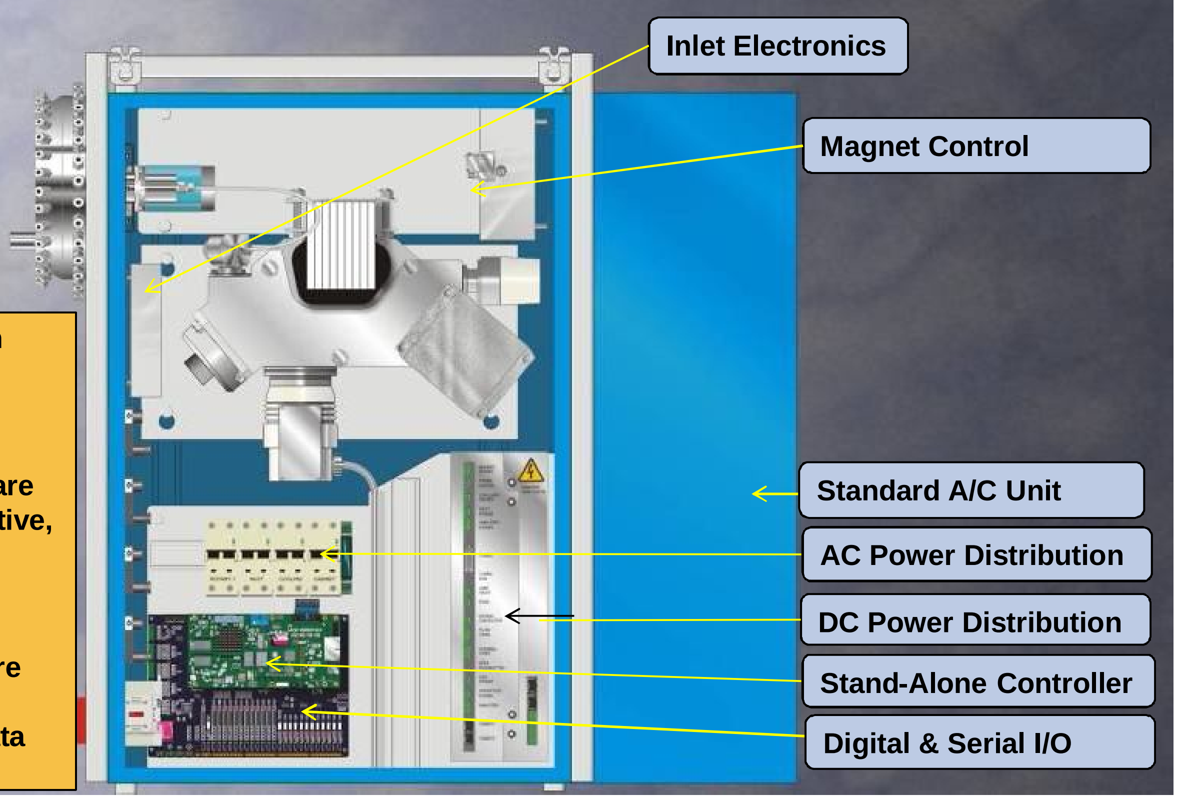
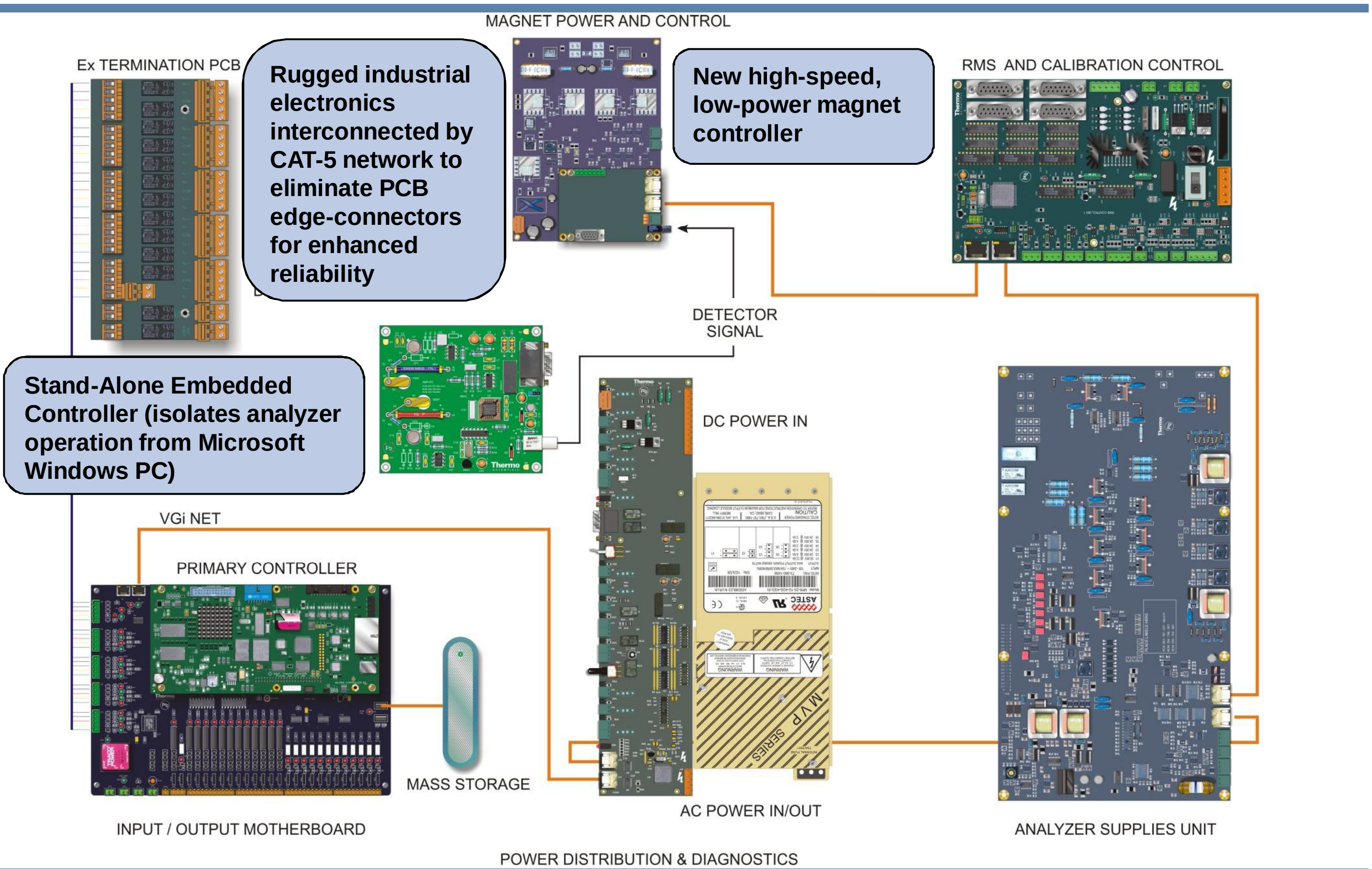
Prima PRO Temperature-Controlled Cabinet Layout



Fault-Tolerant Design Example:

- **Design out any aspects of performance that are temperature-sensitive, then control the temperature**
- **This ensures two modes of failure are required to cause deviation in the data**

Electronics Design Overview: Hot-Swap, Plug & Play



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Process MS: Maintenance Procedures

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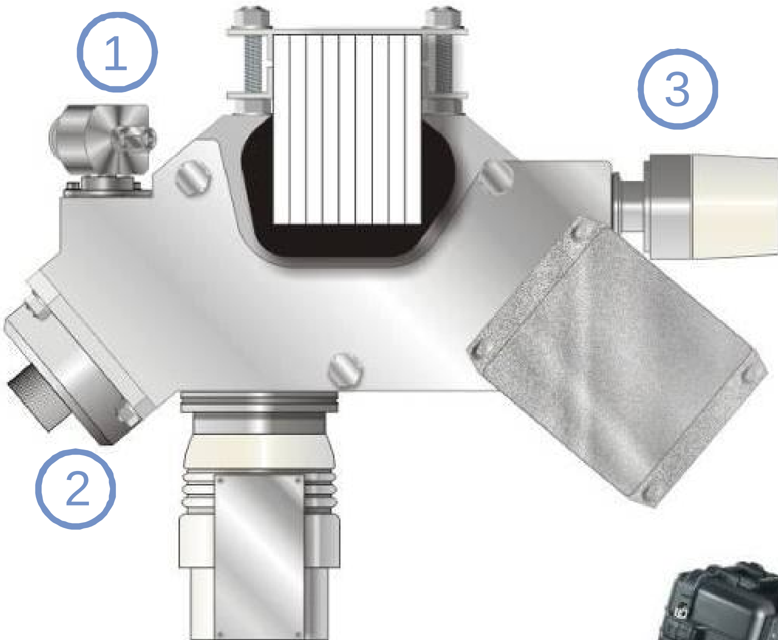
New Simplified Maintenance Procedures



New Service Procedure:
1. **Swap Inlet Probe & Capillary**
2. **Swap Ion Source**
3. **Swap Vacuum Gauge**
4. **Power Up – Wait 30 minutes**
5. **Run Auto-Tune**
6. **Run Calibration Routine**
7. **Upload/Download Data**
8. **Return Case to Factory**

Note: 3-year service interval on turbo-pump

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Presentation Summary

- MS provides the best available online, real-time analysis for tighter control of combustion
- ☑ Result: Maximizes energy recovery from fuel gas

- Extremely low total cost of ownership
- ☑ Result: Profitability optimized

Thank You For Listening

Q&A

Radiation Monitoring
in
Indian Nuclear Power Plants

ISA POWAT- 2012,

New Delhi

January 13th -14th, 2012

Vinayak Bendigeri

N. P. Panchal

N. S. Kaintura

Nuclear Power Corporation of India Limited,

Mumbai

OVERVIEW

- Nuclear Radiation Basics
- Radiation Sources in NPP
- Detection of Radiations
- Radiation Monitors in NPP
- Conclusion

RADIATION MONITORING SYSTEM

The consideration in reactor design is to keep radiation exposure of the public and of persons within the Nuclear Power Plant boundary AS LOW AS REASONABLE ACHIEVABLE (ALARA) in all operational and accidental conditions.

Radiation Monitoring System helps in controlling and minimising radiation exposure of the plant personnel and population.

NUCLEAR RADIATION

During the process of radioactive decay, the unstable nucleus gives out energy in the form of radiations.

Nuclear Radiations are of four types:

(1) Alpha	(α)	**(2) Beta**	(β)
(3) Gamma	(γ)	**(4) Neutron**	(${}_0n^1$)

The rate of emission depends on the half-life of that radioactive material. The unit of radioactivity is expressed in Becquerel (Bq).

Equivalent Dose (or dose in NPP) relates the absorbed dose in human tissue to the effective biological damage of the radiation. Its unit is Sievert (Sv).

TYPES 0F NUCLEAR RADIATIONS

α - radiations :

Alpha particle contains 2 protons and 2 neutrons. Hence it is also called Helium nucleus ($_2He^4$).

It can not travel more than an inch in air and very less in other materials .

β - radiations :

They are fast moving electrons of nuclear origin approaching the velocity of light that are emitted from nucleus of high neutron/proton ratio.

They can be stopped by plastic or Aluminum.

Even high energy β - particles can be stopped by ½ inch of plastic or plywood.

TYPES OF NUCLEAR RADIATIONS (Contd.)

γ - radiations :

They are electromagnetic radiations like light, X-rays, UV-rays. They are emitted from the nucleus of the atom when it moves from excited higher energy state to its ground state.

It is usually preceded by an α, or $\alpha-\beta$ emission.

Gamma radiation have high energy and high penetrating power.

Gamma ray can never be stopped completely.

Heavy shielding of materials such as concrete, lead, iron, several feet of water is required to bring down the intensity to an acceptable level.

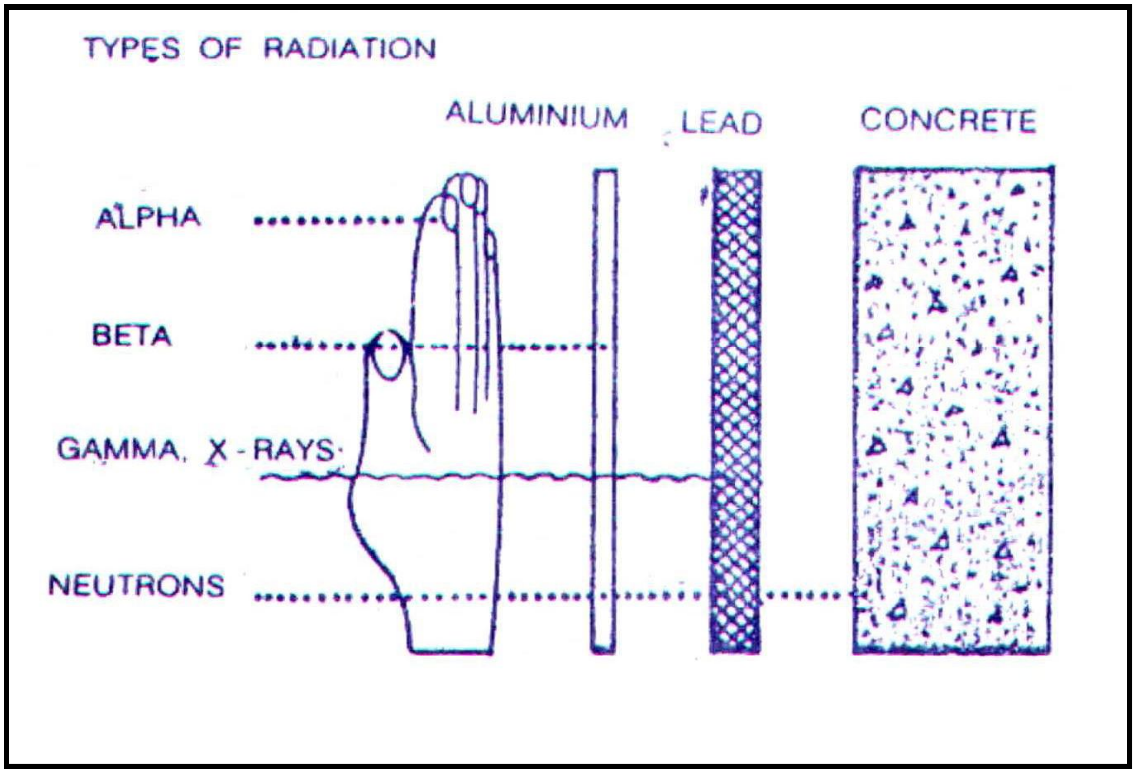
Neutrons :

They are slowly moving uncharged particles.

Neutrons are emitted by elements such as uranium and plutonium during fission (splitting of an atom).

Hydrogenous materials like water, paraffin, etc. can be used to absorb neutrons.

PENETRATION POWER OF NUCLEAR RADIATION



INTERACTION OF NUCLEAR RADIATIONS WITH MATTER

Directly Ionizing Radiations:

All charged particles such as α, β directly interact with the medium through which they pass by electrostatic interaction and produce ionization and excitation i.e. they split up the neutral atom into positively charged ion and negatively charged electron.

γ-rays also directly interact with the medium through which they pass by the following interactions and produce ionization.

i) Photo-Electric ii) Compton iii) Pair-Production.

INTERACTION OF NUCLEAR RADIATIONS WITH MATTER (Contd.)

Indirectly Ionizing Radiations:

Neutrons do not produce direct ionization in the medium through which they pass, however they transfer their energy to protons or α-particles by collision which in turn ionize the medium. Hence they are called indirectly ionizing radiations. In addition to this they interact with the nucleus of the atoms of medium and emit α, protons or γ-rays. These reactions are called Nuclear Reactions.

$$_5B^{10} + {}_0n^1 \longrightarrow {}_3Li^7 + {}_2He^4$$

$$_7N^{14} + {}_0n^1 \longrightarrow {}_6C^{14} + {}_1H^1$$

— **Transmutation**

$$_1H^2 + {}_0n^1 \longrightarrow {}_1H^3 + \gamma$$

— **Activation**

RADIATION SOURCES IN A NUCLEAR POWER STATION

Fission Products:

Each fission produces two fission fragments, which are simply intermediate sized nuclei, which are radioactive.

The fragments formed directly from fission and the daughters formed by the decay of the fragments are collectively called FISSION PRODUCTS.

Eg: I^{131}, I^{132}, Cs^{137}, Xe^{131}, Se^{133}, Xe^{135}, Ru^{103}, Ru^{106}, Kr^{85}, Zr^{95},Nb^{95}, etc.

RADIATION SOURCES IN A NUCLEAR POWER STATION (Contd.)

Activation Products:

Activation is the process by which a material is made radioactive by bombardment of Neutrons. These are mainly (β, γ) emitters.
Eg: N^{16}/O^{19}, Ar^{41}, H^{3}.

Corrosion products:

Corrosion products are activation products removed from the reactor or systems by chemical or electrochemical reactions.
Eg: Co^{60}, Mn^{54}, Fe^{56}, Zn^{65}, Ni^{64}, etc.

DETECTION OF NUCLEAR RADIATIONS

As all radiations are associated with energy, its presence can be detected using an *instrument* by its property of ionization / excitation of medium through which it passes.

In general a Radiation Instrument has the following :

- A sensitive volume of a suitable medium where radiation can produce ionization/excitation.

- A device to convert the output of ionization to electrical signal.

The above two units together make a DETECTOR.

- A Processing unit to process the electrical signal as per requirement.

Types of Radiation Detectors

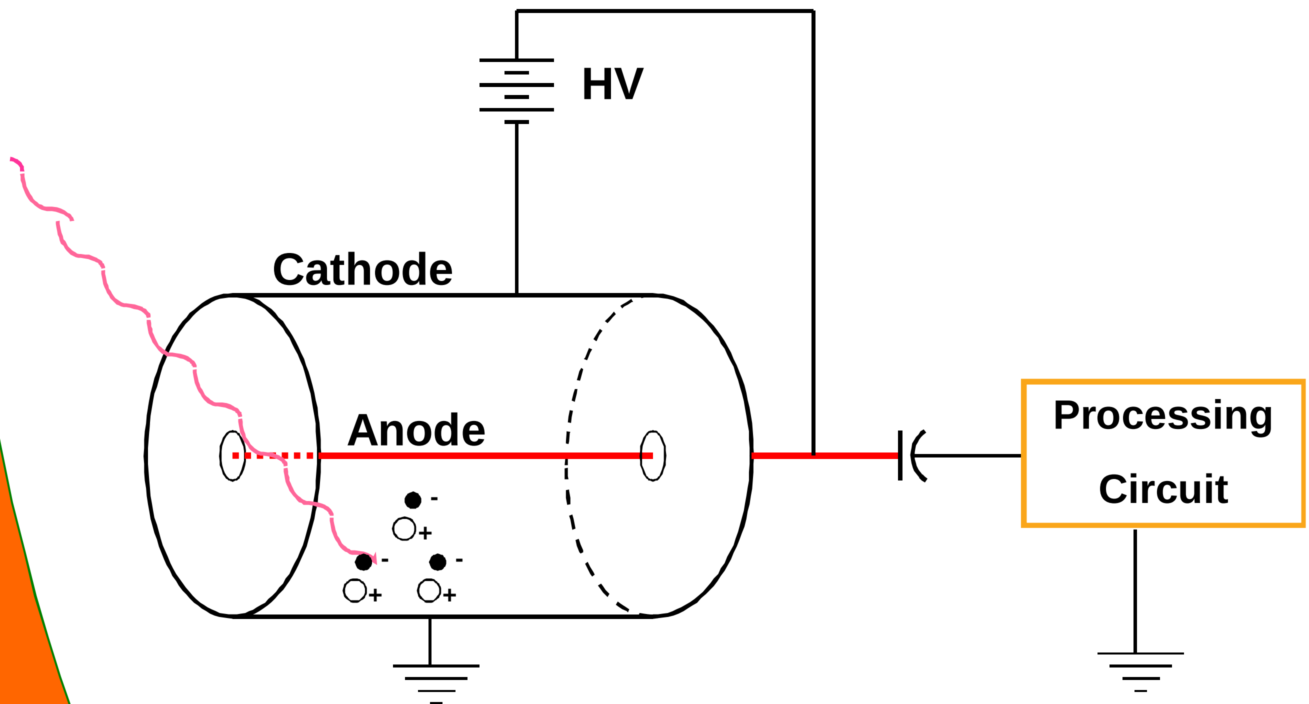
- **Gas Filled Type**
- **Scintillator Type**
- **Semiconductor Type**

Gas Filled Type :

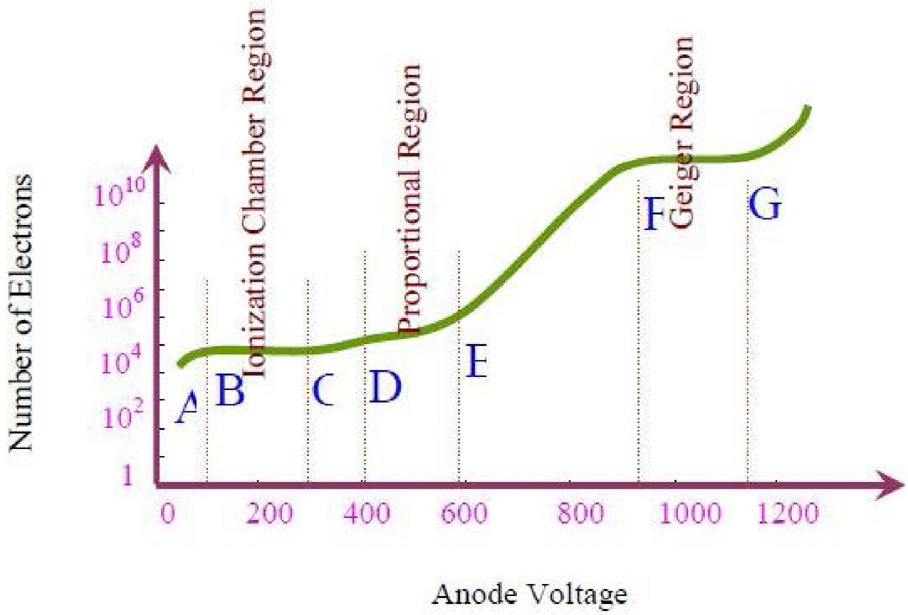
A gas filled detector consists of a chamber of volume ranging from 1 cc to 5 litre, filled with gaseous medium such as argon, nitrogen, air etc.

A pair of electrodes having high voltage (DC) of the order of 100-1000V across it collects the charge due to ionisation caused by radiation and produces electrical signal in the form of voltage pulse or current.

Simplified Representation of a Gas Filled Chamber Detector.



Various Regions of Gas Filled Detector



In theory, the same detector can be used as an ionization chamber, a proportional counter or a Geiger counter, depending on the applied voltage.

Various Regions of Gas Filled Detector

Ionization Region:

the number of ions pairs collected is equal to the number of primary ions pairs produced. Detectors working in this region are called Ion Chambers which are used for detecting high radiation.

Proportional Region:

the number of ions pairs collected is greater than the number of ion pairs produced initially. This is due to gas amplification phenomena. Detectors operating in this region are more sensitive and hence are used in detecting low level alpha, beta and neutron radiations.

Geiger Mueller Region:

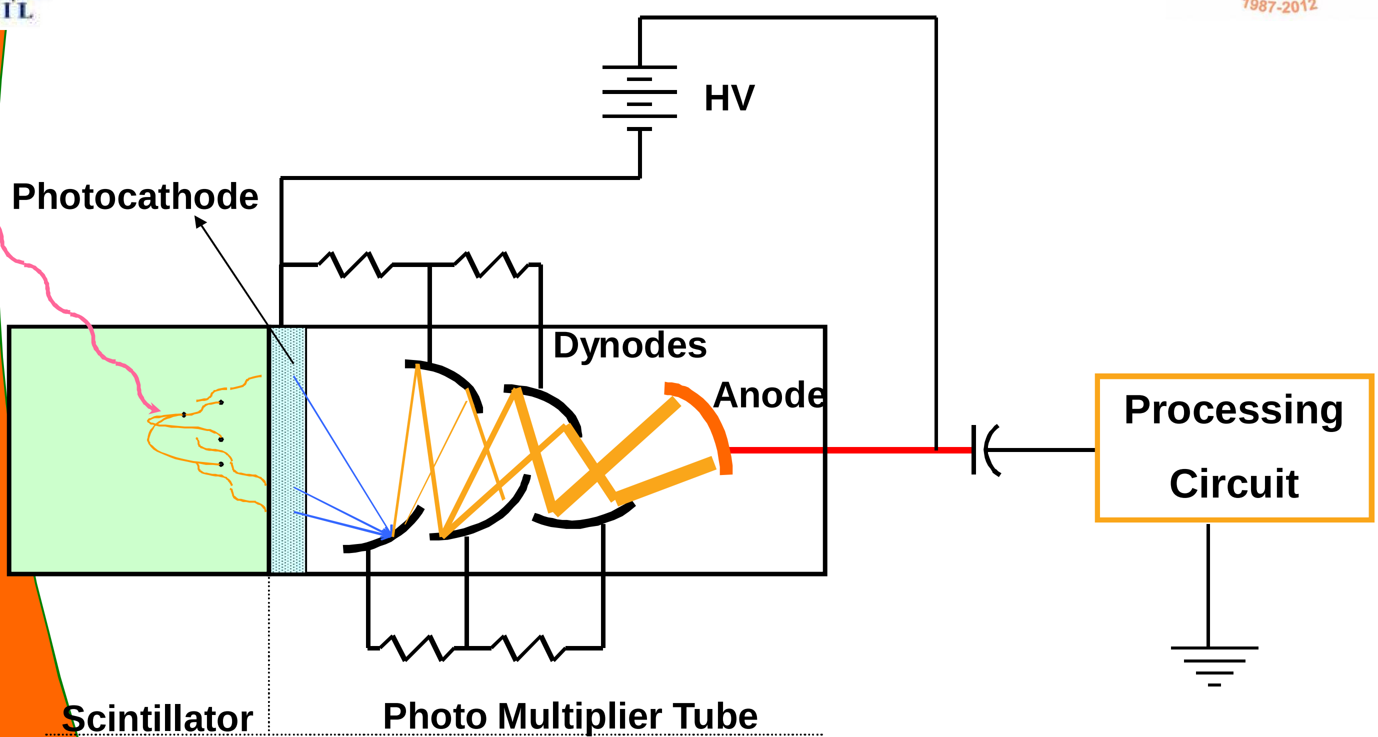
due to larger gas amplification factors a stage is reached eventually where the number of electrons remains pretty well constant. Detectors working in this area are called GM Detectors and are most sensitive to low radiation levels.

Scintillator Type :

Scintillator type detector consists of a small sensitive volume of material which emits light when radiation interacts with it.

Photo Multiplier Tube is used for converting light photons to electrical signal and its amplification.

Simplified Representation of a Scintillator based Instrument.

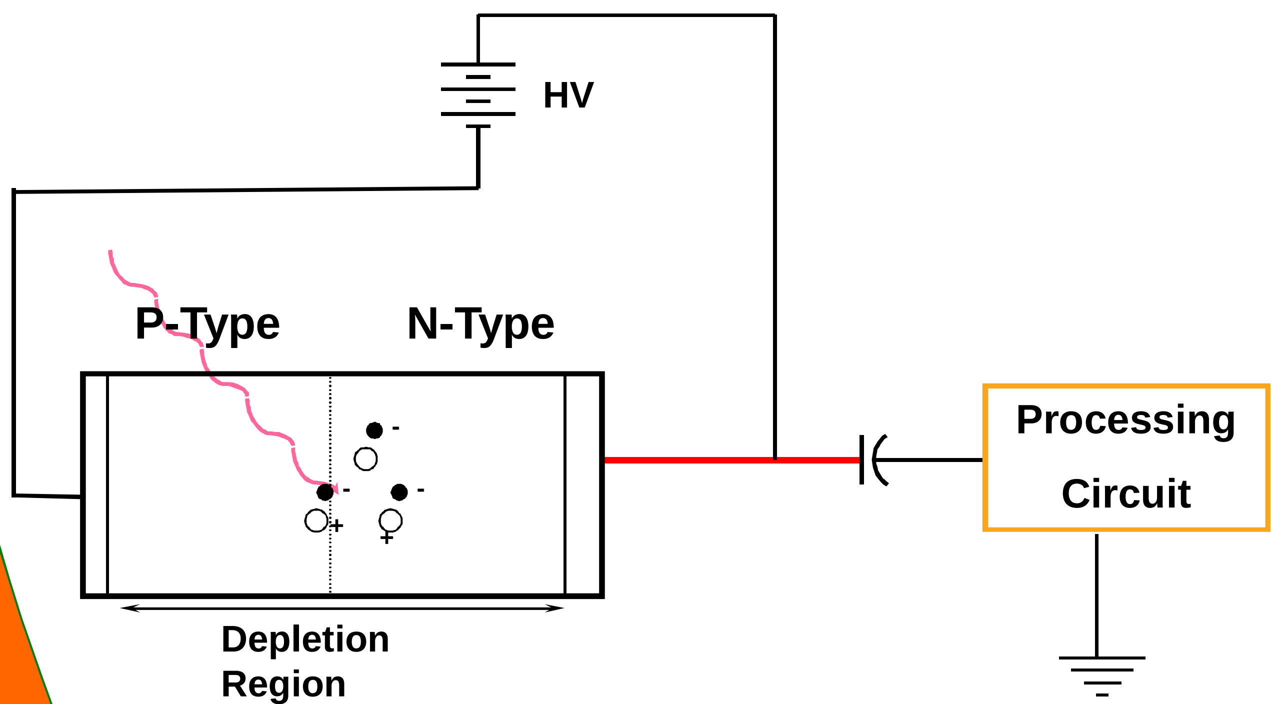


Semiconductor Type :

Sensitive Volume and Medium is a small volume (few cc) of semiconductor material (usually a PN junction) in which a depletion region can be created to produce an active volume using reverse bias.

Device to produce electrical signal is a pair of electrode having high voltage (DC) of the order of 1500V across it which collect the charge and produce electrical signal.

Simplified Representation of a Semiconductor Type Detector.



Processing Unit:

The processing unit consists of electronic circuitry and modules which amplifies and shapes the feeble electric signal obtained from the detector and passes it through various discriminators to gives output in any of the following form :

- **Rate of radiation - *Rate meters***
- **Integrated number of Radiations in a particular period - *Scalars***
- **Particular band of radiation energy - *Single or Multi channel Analyzers***

The above outputs are calibrated to directly read in Dose/Dose rate/ Activity etc.

RADIATION MONITORING SYSTEMS IN NUCLEAR POWER STATIONS

1. AREA RADIATION MONITORS (Low Range & High Range, ‘γ‘)
2. STACK ACTIVITY MONITORS (FPNG, Argon, Iodine, Particulate, ‘γ‘)
3. ENVIRONMENTAL RADIATION MONITORS (‘γ‘)
4. VENTILATION DUCT RADIATION MONITORS (‘γ‘)
5. TRITIUM MONITORS (‘β‘)
6. PROCESS WATER ACTIVITY MONITORS (‘γ‘)
7. CONTAMINATION MONITORS (FRISKERS) (‘β‘,‘γ‘)
8. HAND AND FOOT MONITORS (‘β‘,‘γ‘)
9. PORTAL MONITORS (‘β‘,‘γ‘)
10. RADIATION DATA ACQUISITION SYSTEM

LOW RANGE AREA RADIATION MONITOR

HIGH RANGE AREA RADIATION MONITOR

CONTAMINATION MONITOR (FRISKER)

HAND & FOOT MONITOR

PORTAL MONITOR

RADIATION DOSIMETERS

DIRECT READING DOSIMETERS (DRD)

THERMOLUMINISENCE DOSIMETER (TLD)

RADIATION DATA ACQUISITION SYSTEM (RADAS)

Data Acquisition and Control Room Operator Information System for Radiation Monitoring System and Heavy Water Leak & Loss Monitoring System.

Generates Alarm Messages and Displays the same on OIUs located in Control Room, Shift Charge Engineer's Room and Health Physicist's Room.

RADAS provides various Displays like:

> **System Status Table (SST), Graphical & Tabular Trend, Graphical & Tabular History, Diagnostic Display, Bar Graph, LCD Display, Hourly/Daily/Monthly Heavy Water Loss Display, Hourly/Daily/Monthly Stack Gamma Activity Release Display, Mimic Display.**

THANK YOU

Radiation Monitoring System in a Nuclear Power Plant is a vast subject. In this presentation a brief overview of the same has been covered.

For more details one has to refer other books and documents.

Thank You again and Happy New Year 2012 to You all

Power Control Requirements, Instruments and Techniques for Indian PHWRs

ISA POWAT- 2012,

New Delhi

January 13th -14th, 2012

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CONTENT

- Nuclear Reactor Basics
- Reactor Power Control Fundamentals
- Power Control Requirements
- Sensor Instrumentation
- Actuator Instrumentation
- Power Control Algorithm
- Conclusion

Nuclear Reactor Basics

•**Nuclear reactor is a device in which heat energy from nuclear fission reaction is released in a controlled and safe manner.**

$$U^{235} + Neutron \rightarrow FissionProducts + Neutrons + Energy(200Mev)$$

$$\text{Note : } 1Mev = 0.160x10^{-12}J = 0.160pJ$$
$$1ev = 0.160x10^{-18}J = 0.160x10^{-6}pJ$$

•**Heat energy released by nuclear fission is carried away by coolant to produce steam**

•**Steam is used to rotate conventional turbo generator set to generate electricity**

Nuclear Reactor Basics… contd.

Nuclear reactor can be classified in various ways

1) Based on Nuclear fuel used e.g. Uranium Reactor, Plutonium Reactor, Thorium Reactor

2) Based on kinetic energy of the neutrons causing most of the fission reaction e.g. Thermal reactor, Fast reactor

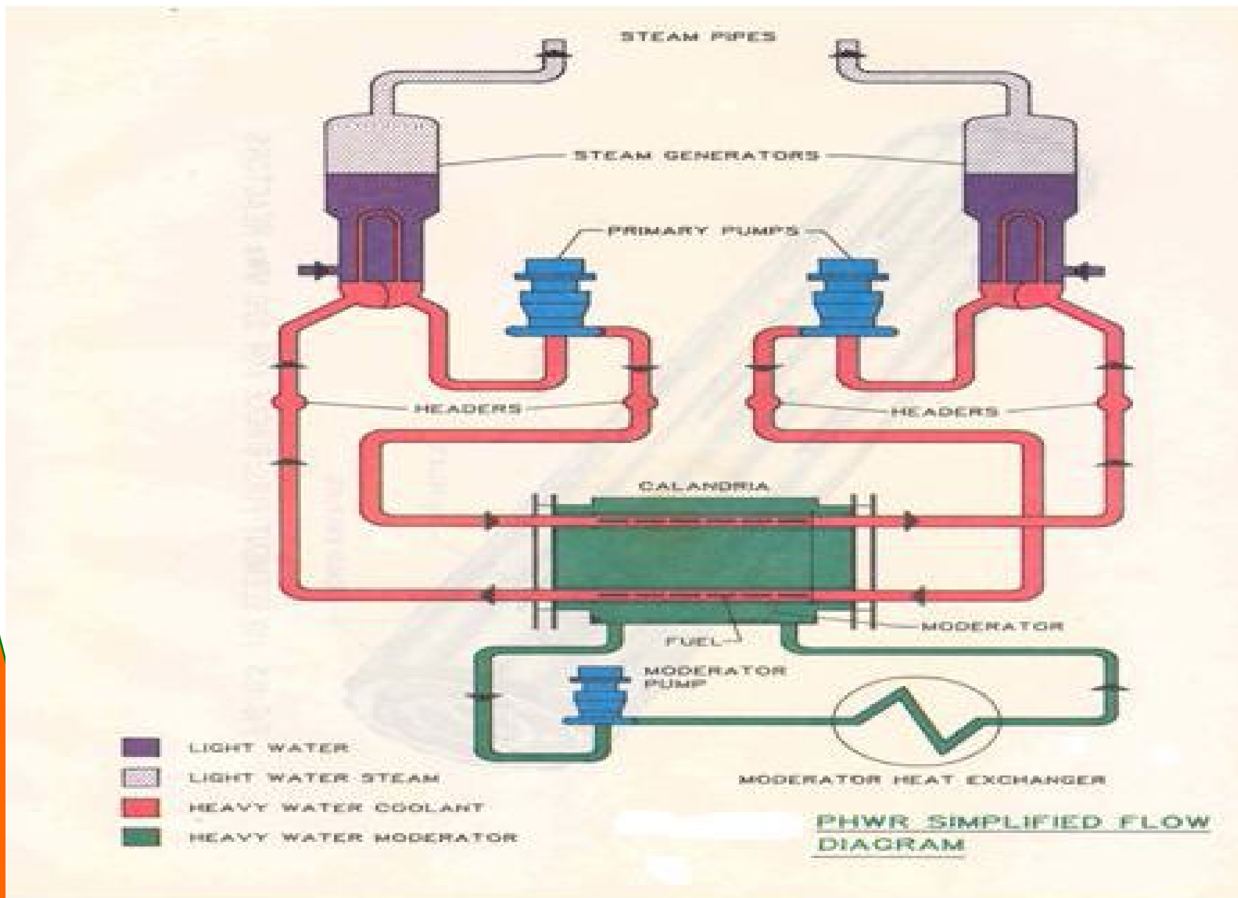
3) Based on the moderator and coolant used e.g. Light water reactor (LWR), Heavy water reactor (HWR)

4) Based on whether the coolant is pressurized or not e.g. Pressurized water reactor (PWR), Boiling water reactor (BWR)

Nuclear Reactor Basics… contd.

- Till date Indian nuclear power programme is essentially based on Pressurized Heavy water Reactors PHWRs (18 out of 20 running reactors are PHWR, remaining 2 BWR. 4 more PHWR and 2 more PWR under construction)
- PHWR uses natural uranium (not enriched) as fuel and heavy water as moderator and coolant.
- PHWRs are of horizontal pressure tube type core which is called calendria which contains fuel in the form of clusters .
- The fuel is cooled by high pressure high temperature circulating heavy water system called primary heat transport system (PHT).
- Heavy water is also used as moderator in a separate low temperature low pressure moderator systems.
- Refueling of the reactor is carried out "on power" using fuel handling system.
- The heat from the reactor is carried away by heavy water coolant and is given away to secondary side in the steam generator(SG).
- The steam from SGs are fed to turbine-generator for production of electricity.

Nuclear Reactor Basics… contd.



Reactor Power Control Fundamentals

- **Reactor power control essentially is achieving desired rate of fission inside the fuel**

- **The parameter which is measured for estimating the rate of fission is called neutron flux and defined as product of number of neutrons in unit volume and the average velocity of neutrons.**

- **Power level of a reactor at any instant is directly proportional to the neutron flux for a given fuel enrichment.**

- **It is said that neutron multiplication factor K is 1(one) if rate of fission reaction is constant in the ractor. If rate of fission is increasing then K becomes more than one, on the other hand if K is less than one, rate of fission is decreasing.**

- **Reactivity is defined as fractional deviation of neutron multiplication factor K from unity. For K>1 reactivity is positive and if K<1 reactivity is negative**

Reactor Power Control Fundamentals... contd.

Addition of positive reactivity increase netron flux and addition of negative reactivity decrease the netron flux

In most situations reactor power is controlled by measuring neutron flux and altering reactivity.

Three general methods are possible for changing the reactivity in a reactor, addition or removal of

1) **fuel**
2) **moderator**
3) **a neutron absorber (liquid poison or solid rod).**

Each of this method or a combination is used for reactor control. Most commonly especially in power reactor third option is used.

Control elements are generally referred as 'control rods' because often they are cylindrical rod in physical shape.

Power Control Requirements

•Automatic Control of Reactor Bulk Power (BP) to operator given set point and Power Manuevering in the range of 10^{-6}%FP to 110%FP in the Turbine-Follow-Reactor Mode.

•Maintain the neutron flux distribution close to its nominal design shape avoiding violation of bundle or channel power limits during full power.

•spatial power control to suppress Xenon induced oscillations with the help of inputs from Flux Mapping System and Zonal Thermal Power Measurement System

•Execution of Reactor Setback i.e., reduction of power with a rapid rate when any potential unsafe situation occurs. This functionality prohibits the unnecessary frequent actuations of reactor trip systems.

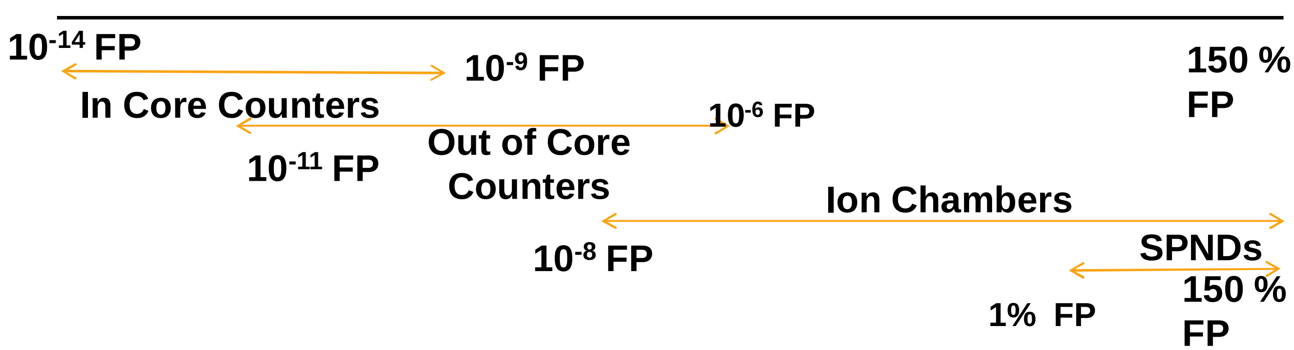
•Withdrawal of Shut off Rods sequentially under supervision of Operator during Reactor Start up

•Providing limited xenon over ride capabilities for quick restart of reactor after trip.

Sensor Instrumentation

- Reactor power control system monitors nutroic power level of the reactor over the full operating range which varies about 14 decades
- No single instrument can provide a satisfactory indication of the neutron flux over the whole possible range
- Whole range is divided into three sub range namely source range, intermediate range, and power range. Different kinds of neutron detectors are used for different range
- Adjacent range overlap by one or two decade for smooth switching from one type of instrument to another
- In-core Self Powered Neutron Detectors (SPND) are the only option for measuring zonal flux in power range.
- In Power range operation both thermal power and neutronic power is measured.

Sensor Instrumentation… contd.



Sensor Instrumentation… contd.

•The source range instrumentation is used from spontaneous fission power level approximately from 10^{-14} FP to 10^{-9} FP with one set of in-core detectors and from 10^{-11} FP to 10^{-6} FP with another set of out-of core detectors.

•This instrumentation system also used for fresh core start up as well as after a prolong shut down when normal flux measuring instruments are off scale.

• It also plays a dual role of reactor power control over the lowest power range and trip generation for reactor protection.

•In this range, the reactor is controlled manually by operator from control room with the help of neutron count recording instrumentation mounted in a mobile cabinet.

• Reactor trip is initiated when the count rate exceeds the set point or the rate of change is excessive.

Sensor Instrumentation… contd.

•Ion Chambers are used for the intermediate range and power range.

•Reactor Power Control System employs the ex-core ion chambers for total average reactor power measurement.

•These along with its amplifiers are calibrated to measure log neutron power (10^{-6} % FP to 150% FP), linear neutron power (0 to 150% FP) and rate of change of log neutron power (-20% to +20% of present power/sec).

•These ion chambers respond to both the gamma and neutron flux, rather than to fission power directly.

•Due to non-uniform shadowing effects of control rod movements, poison concentration etc. signals of these detectors are different from the actual fission power.

•Necessary correction of the detector signal is desirable based on indirectly measured bulk thermal power

Sensor Instrumentation… contd.

- In-core detectors are used for power range

- SPNDs are the only detector available for point flux measurement.

- SPND signals are used in a range from 5% to 150% FP.

- The output signals for some of the sensors are accurate but delayed (e.g. Vanadium, Rhodium). These are distributed throughout the core to map the neutron flux of the core.

- On the other hand some SPNDs (Cobalt) are prompt but inaccurate due to burn up and build up. These are placed zone wise to get zonal flux.

Sensor Instrumentation contd.

- **Reactor Thermal Bulk Power is measured by Instrumented channel monitoring System based on primary parameters i.e., differential temperature and flow values obtained from selected channels.**

- **Differential Temperature is measured using thermo well mounted RTD and flow is measured using venturimeter and flow transmitter.**

- **Channel power computation is done using following expression.**

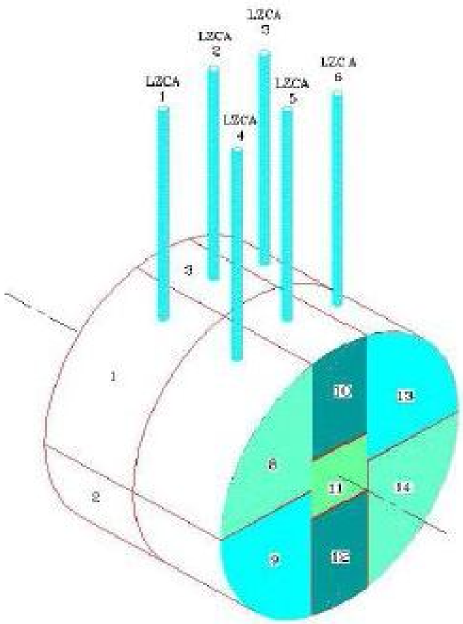
$$P_{channel} = M \times C_P \times \Delta T$$

- **The method followed for estimation of zonal thermal power and bulk thermal power is weighted summation of selected channels.**

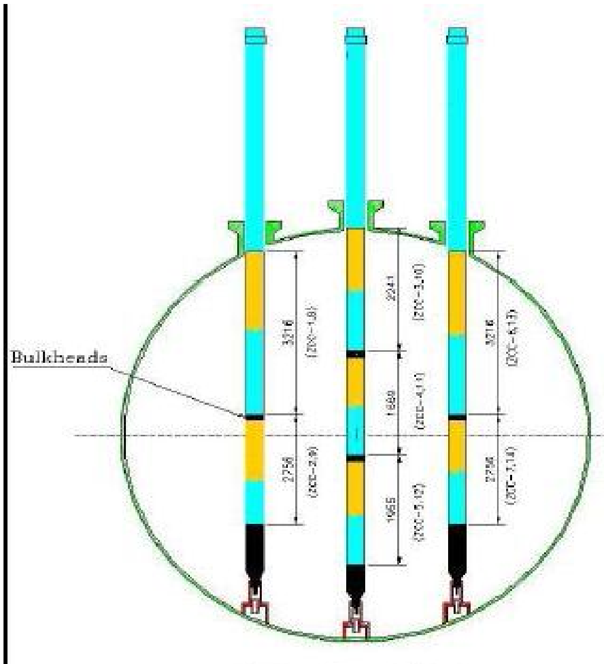
Actuator Instrumentation

- Actuators (Reactivity devices) are those devices which can alter neutron multiplication rate.
- **14 Zone Control Compartments (ZCC)** for slow, small, frequent variation of global neutron power and to achieve spatial power distribution by suppressing Xenon induced oscillation inside reactor core.
- **17 Adjuster Rods (ARs)** grouped in 8 banks are provided to shape the neutron flux for optimum reactor power, fuel burn up and to supply positive reactivity beyond control range of ZCC. These also help to achieve limited capability Xenon Override during fast Reactor Start up.
- **4 Control Rods (CRs)** grouped into two banks are provided for coarse reduction of power.
- **Moderator liquid poison** is used to augment the negative worth of the reactivity devices.
- On-Power **Refueling** to control long term bulk reactivity (through Fuel Handling System).

Actuator Instrumentation …contd.



Liquid Zone Control Assemblies and 14 Zones of 540 MWe PHWR



Section Through Reactor

Zone Control Compartments Layout

Power Control Algorithm

Representative Signal Generation

The reactor power control system is categorized as IB system (as per AERB SG-D1).

Lot of redundancy is provided in sensors, computers and actuators to immune the system from small process disturbance and measurement failure

Extensive diagnostic and validation algorithm like rationality check and median selection for analog input signals, 2 out of 3 criteria for digital input signals, feedback of analog output signals, read back of digital output signals, conditional and absolute switchover etc. are performed to ensure that faulty sensors, computers and / or actuators are discarded meeting single failure criterion and improving availability.

Power Control Algorithm… contd.

Bulk power and zone power estimation

- Bulk reactor power is determined by solely using ion chamber signal at low power level (up to 5% FP).

- Using Weighted average of cobalt SPND of each zone at higher power level (above 15%FP)

- Combining both the signal between 5% FP to 15%FP.

- Zone power is calculated using cobalt SPND signal separately for each zone.

- Reactor bulk power is continuously corrected by bulk thermal power and zone power is corrected by zone thermal power signal or correction factor from Flux Mapping System.

Power Control Algorithm… contd.

Demand Power Programme

Demand power programme generates reactor power set point on the basis of operator demand set point and the pre selected rate (Fast or normal).

Any setback condition overrides operator demanded set point and decreases the power set point at a pre decided rate depending on the set back parameter and ensure power is reduced to a level to clear the causing parameter.

A negative deviation limiter prevents the power set point from being more than 5% FP above actual bulk power to allow the reactivity devices to respond since saturation for maximum rate of raise is achieved at this error.

Power Control Algorithm… contd.

EFFECTIVE POWER ERROR CALCULATION

- Control loop is basically conventional output feedback Proportional Control except for the bulk power error term
- The bulk power error term calculated as following.
- Bulk Power Error Term = K_P x (log (BP)-log (DP)) + T_D x (Rate of log (BP) - Rate of log (DP))

Where,

K_P = Proportional gain
T_D = Derivative time
BP = Bulk Power
DP = Demand Power

Power Control Algorithm… contd.

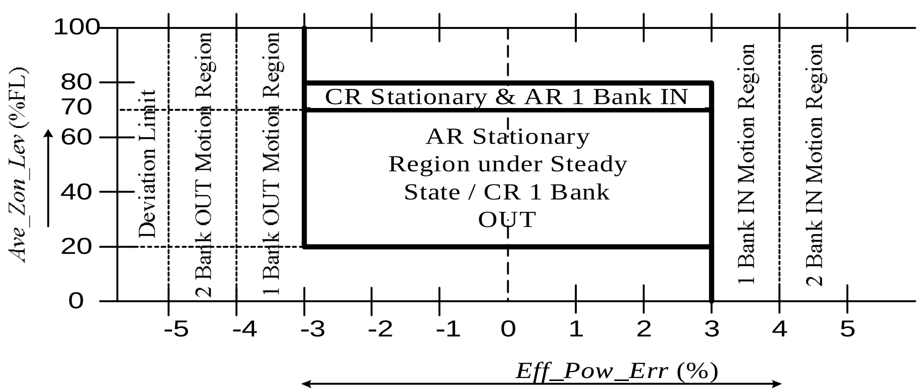
Reactivity Control Algorithm

The method of short term / fine reactivity control is by varying the light water level inside ZCC.

Normally adjuster rods are fully inserted, control rods are fully withdrawn and average ZCC level is in between 30% to 50%.

In case of shortage of negative reactivity / positive reactivity indicated by high / low ZCC level, Control Rods and Absorber Rods are driven in / out bank wise in a specific sequence. These are driven at a speed proportional to power error.

The reactivity mechanism control logic is summarized in following figure



Power Control Algorithm… contd.

Shutoff Rods Withdrawal Logic

Dropping of shutoff rods are executed by Shut Down System but withdrawal is controlled by reactor power control system.

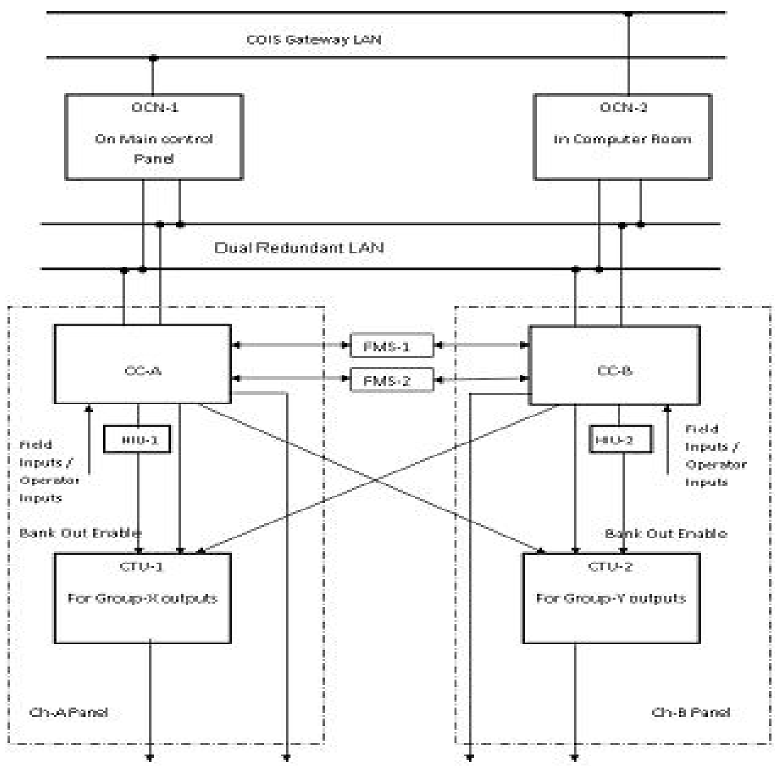
Withdrawal is inhibited until reactor trip signal is cleared. 28 SRs are grouped into two banks. Normally SRs are withdrawn one after another bank.

Withdrawal is stopped if power error or rate log power exceeds a specified limit.

Manual Control

Manual operation of rods/ZCC are limited during power operation to control the addition / removal of reactivity. Manual operation is liberalised during low power (<0.1%FP) operation for initial physics experiments.

Dual computer hot standby architecture



Dual computer hot standby architecture

The reactor power control algorithms are implemented on two independent but identical embedded computer referred as control computers (CC) using DCHS architecture.

The outputs of the two CCs are selected and sent to field through a Control Transfer Unit (CTU) to control the reactivity devices depending on the healthiness of the CCs.

Bank out commands are passed through a Hardware Interlock Unit (HIU). In case of unintended bank out commands generated by software, HIU detects the fault and restricts the addition of reactivity.

Conclusion

Earlier reactor power control system was made using multi-nodal architecture with dependency on network for the control. Now it is attempted to implement similar requirement with DCHS architecture independent of network for control purpose.

THANK YOU

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ISA Delhi Section

APPLICATION OF DART FOUNDATION FIELDBUS TECHNOLOGY IN POWER PLANTS

Arasu Thanigai

Pepperl+Fuchs Pte Ltd , Singapore

ISA(D) POWAT-INDIA 2012, New Delhi January 13th -14th, 2012

OVERVIEW

- Historical structure of explosion hazardous area protection
- Handling arcs, sparks and limited explosions
- Preventing arcing, sparking and hot surfaces
- Changing the paradigms – DART
- DART History
- Basic Operating Principles
- Using DART in Foundation Fieldbus
- Application in Power Industry
- Conclusion

Intention

BASF Ludwigshafen ammonium nitrate fertilizer explosion from 1921 killed 561 people, destroyed 900 buildings and left a crater of 100m in width and 20 m in depth

History

- Explosion hazardous area protection was first considered in the European mining industry at the beginning of the 20th century.
- Electricity as a major cause of ignitions became relevant in the first half of that same century.
- Considerable accidents lead to improved standards and to a multiple of various explosion protection methods.
- Intrinsic Safety is historically one of the newest methods.

Redefining IS – the general idea

- **If you want to make a vehicle stop safely you either limit it's speed or develop better brakes.**
- **If you want to safely control arcing and sparking you can either limit the energy to totally avoid arcing or develop methods to handle the sparks quickly and effectively before they do any harm.**
- **Whereas the first approach is static the second one adds a dynamic component to the explosion protection method.**

Handling sparks instead of avoiding them

- The idea is not really new as other methods of explosion protection also handle smallest explosions safely instead of completely avoiding them.
- As an example let's have a deeper look into the "explosion proof (ex-d)" - method.
- The basic method was invented in the mining industry for petroleum torches