

Implementation of Control Systems for Cyclotrons at VECC: A Status Report

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Introduction



- Sub-systems
 Control of SCC
- Diagnostic systems
- Modernisation of Control
- Future plans
- Conclusive Remark





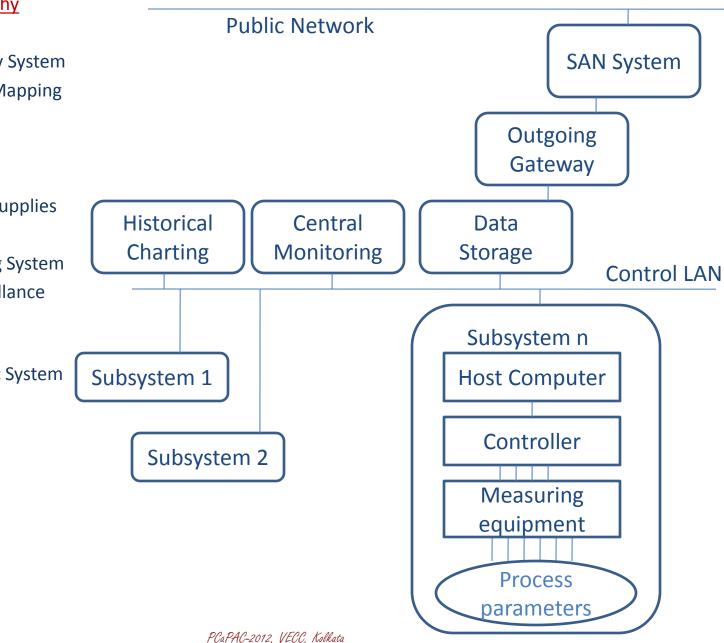
- Control Philosophy
- Control Network
- Cryogen Delivery System
- Magnetic Field Mapping
- ECR Ion Source
- RF System
- Vacuum System
- Magnet Power Supplies
- LCW System
- Trim Coil Cooling System
- Radiation Surveillance Monitors
- Central Console
- Beam Diagnostic System

Superconducting Cyclotron



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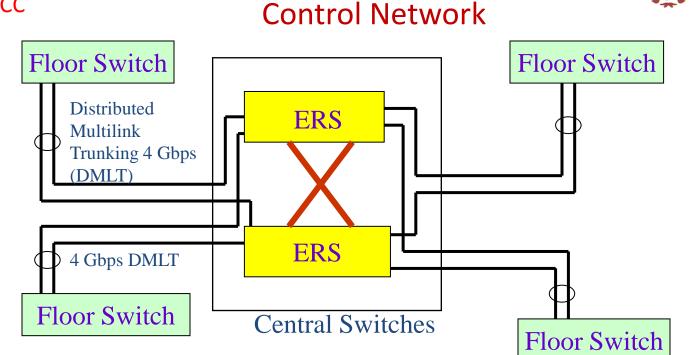
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Monitoring and Control Philosophy

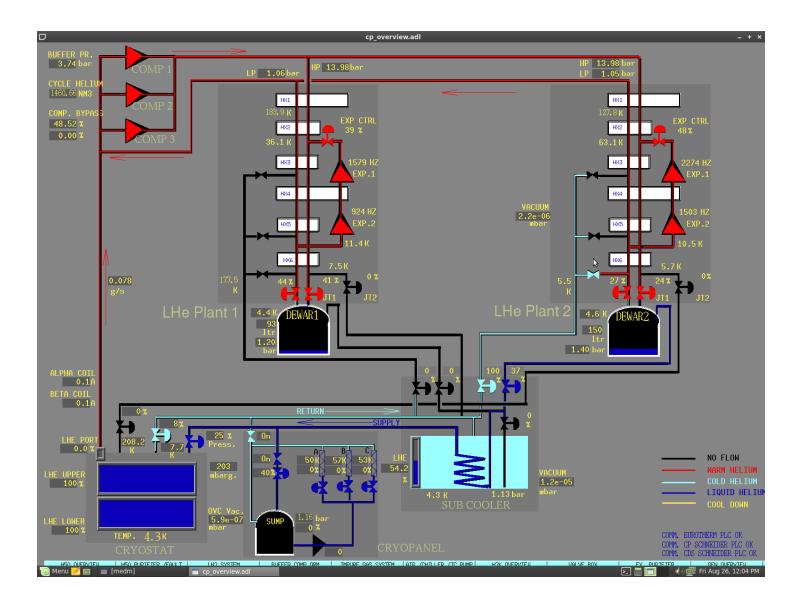
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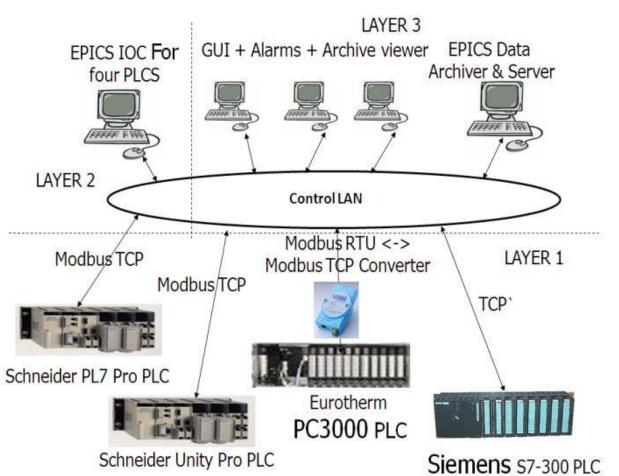
- Isolated from VECC Office LAN.
- Star topology: 2-Tier Design
- Fiber Gigabit Backbone and end-to-end connectivity
- Node level speed: 100 Mbps.
- Service zone: CAT5E UTP Cabling
- Tolerant to single switch / link failure
- Network Management Software (NMS)

TOTAL CRYOGENIC PROCESS

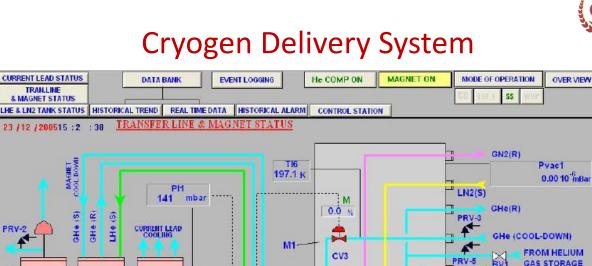


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Overview of cryogenic plant control system

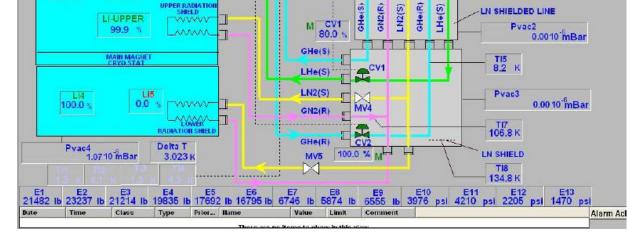


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LHe(S)

LN SHIELDED LINE



- Vacuum jacketed cryogenic transfer lines
- Liquid nitrogen shielded cryogenic transfer line
- **Distribution manifolds**

PRV-2

4.0 %

LII

0.0 %

LI-UPPER

L16

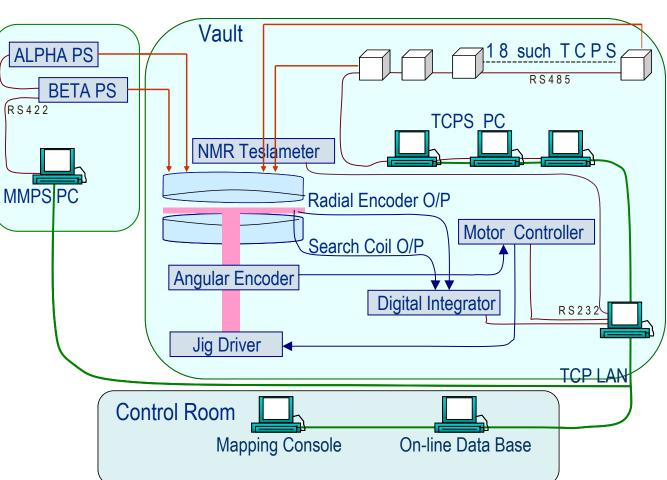
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UPPER RADIATION

HIELD

www

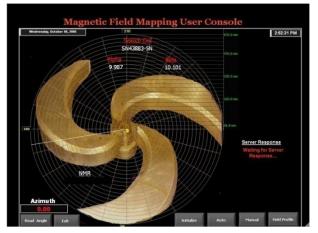
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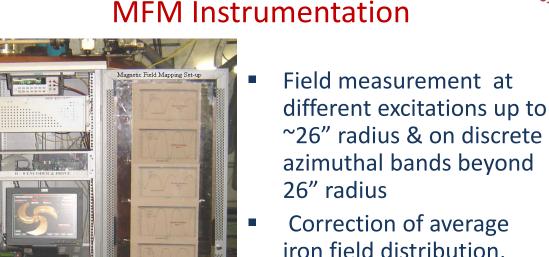




Magnetic Field Mapping

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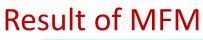
- iron field distribution,
 Minimization of first harmonic component,
- Coil centering by support link force balance
- Automated High speed data taking - ~ 90 min per 100K Data Points
- 70 micron radial encoder resolution
- 0.004 deg. Angular Encoder resolution

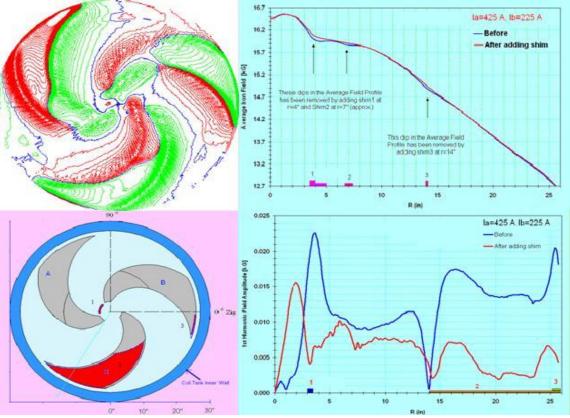
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- Deviation from three fold symmetry Contour Plot
- Shimming to Correct Average Field Profile
- Shimming for First Harmonic Field Correction
- First Harmonic minimization by adding iron shims



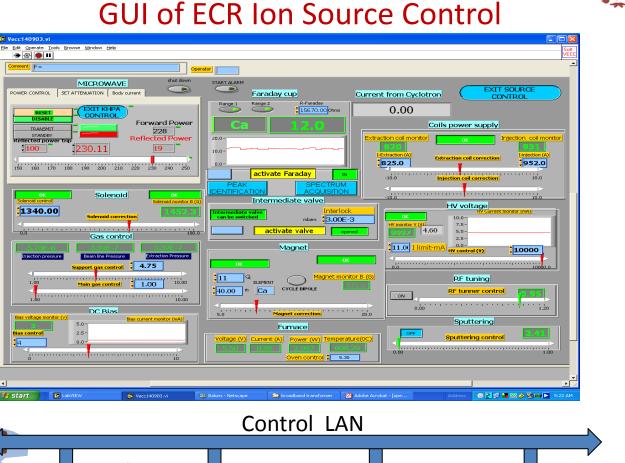
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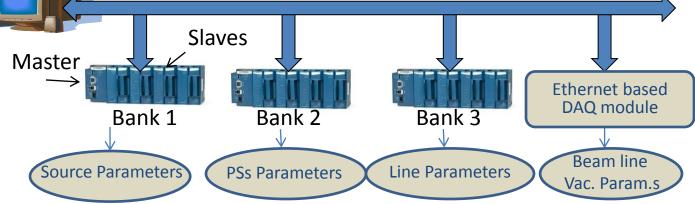
ECR Ion Source & Injection Line



- Power Supplies for different units such as ECR coil, solenoid, extraction electrode, analyzing and bending magnets
- Vacuum Pumping modules, Gate valves and Gauges.
- Beam diagnostic elements like Faraday cup, collimator, slits etc.

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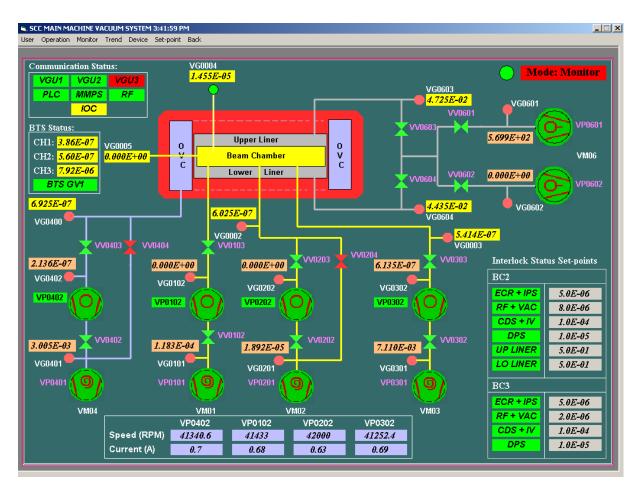




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Vacuum Control



- Beam chamber : 10⁻⁸mbar
- Liner : 10⁻²mbar
- Turbo-pumps backed by Scroll pumps, Rotary pumps, VPI valves, gauges





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Loop Control in SCC Vacuum System

- Control logic for operational sequence of roughing pump during sudden pressure rise SCC beam chamber
- If pressure $BC2/3 \ge 1x10^{-4}$ mbar
 - HV gate close
 - TMP ON

If pressure $BC2/3 \ge 2x10^{-4}$ mbar

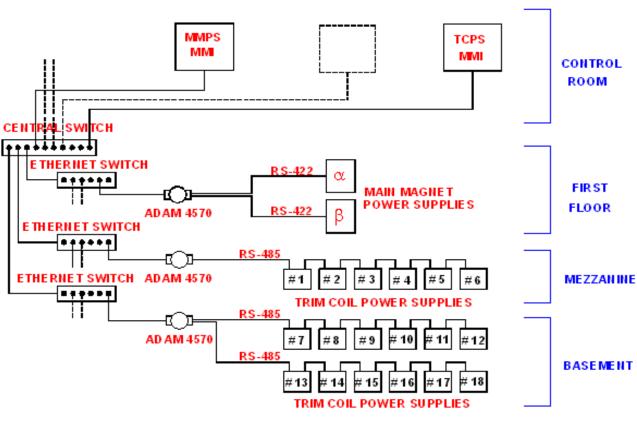
- Scroll pump start
- If pressure $BC2/3 \ge 5x10^{-2}$ mbar
 - Roughing valve open
- If pressure BC2/3 < 5x10⁻²mbar
 - Roughing valve close
 - HV gate valve open

If pressure BC2/3 < 5x10⁻⁴mbar

- Scroll pump switch off

Pressure Falling					Pressure Rising				
IL	SP	RV	GV		GV	RV	SP	IL	
				5x10 ⁻² mbar					
			-	3x10 ⁻² mbar					
				5x10 ⁻⁴ mbar		8. 1	2		
4		1		2x10 ⁻⁴ mbar		93	1		
				1x10 ⁻⁴ mbar		<u></u>	2		
				8x10 ⁻⁵ mbar		.	-		

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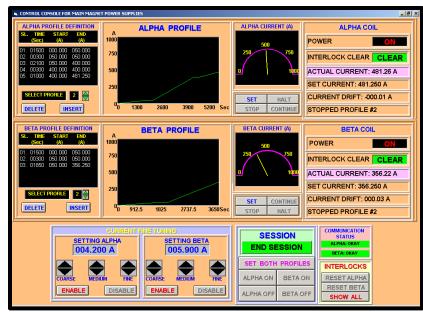
- Main Magnet Power Supplies (Nos. 2)
 - 20 V, 1000 A, 10 ppm
- Trim Coil Power Supplies (Nos. 18)
 - 400 A, 10 ppm
- Windows based GUI developed in VB 6
- PS with intelligent controllers and serial interfaces



Control Architecture of MPSs

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GUI of MMPSs & TCPSs

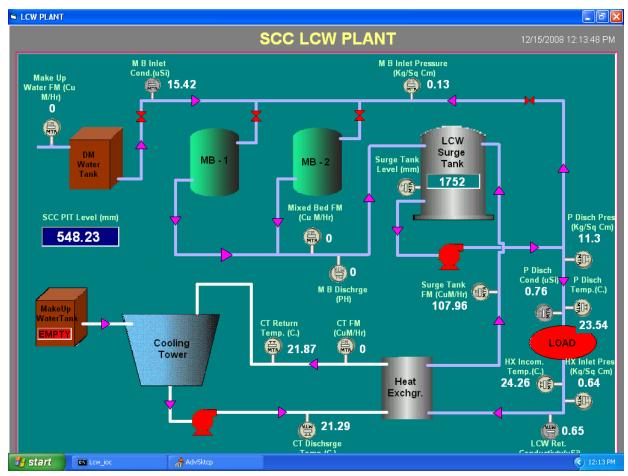


🖦 CONTI	ROL PANEL FO	IR TRIM COIL POWER SUPP	LIES							_ 8
	ACTUAL	SET	SET	SET	SET	HIST	CALC.	I/L	STAT	POL
0	010.0					10.0000			ON	٠
1A	-007.0					-07.0000			ON	-
18	013.0	013.0				13.0000			ON	•
10	-007.0					-07.0000			ON	-
2	009.9					10.0000			ON	•
3	010.0					10.0000			ON	+
- 4	001.0					10.0000			ON	•
5	010.0					10.0000			ON	+
6	009.1			009.1		09.1000			ON	•
7	010.0					10.0000			ON	+
8	000.0					10.0000			OFF	•
9	010.0					10.0000			ON	+
10	008.9		009.0			09.0000			ON	+
-11	010.0					10.0000			ON	+
12	010.1					10.0000			ON	+
13A	-				008.5	08.5000			ON	٠
13B	-					12.5000			ON	+
130	012.5					12.5000			ON	+
		COARSE MEDIUM	COARSE MEDIUM	COARSE	COARSE MEDIUM		DE /alley Coil		ND SESS	SION
		FINE	C FINE	O FINE	• FINE	•	frim Coil		INTERLO	CKS
									SAVE	1
2906.2										

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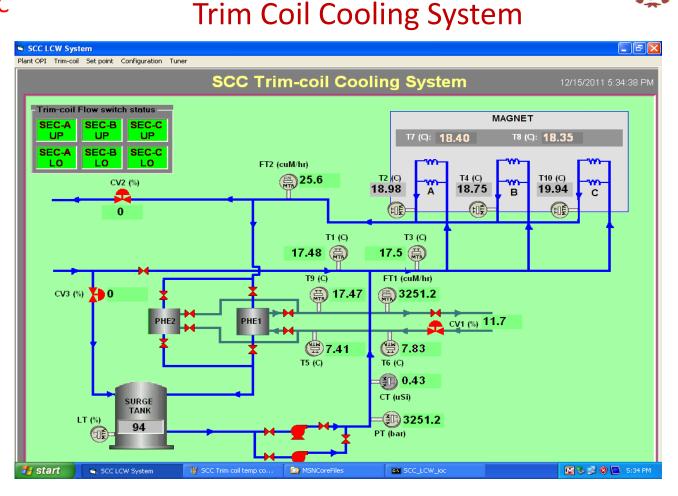
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LCW Plant





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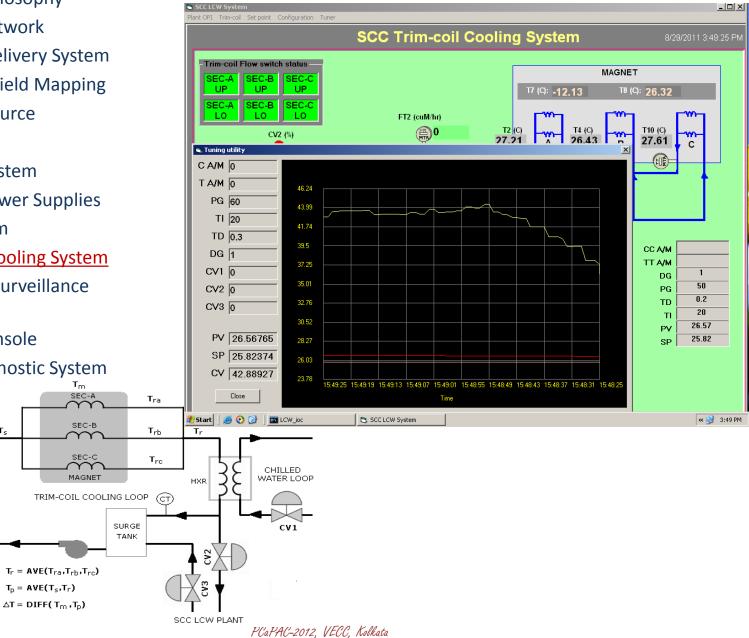
1/30/2013

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Тs

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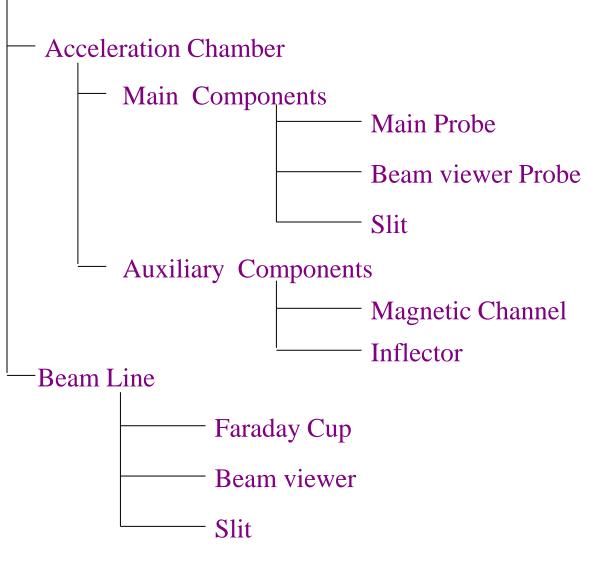




- LAN based two layer architecture
- PC based soft meters for monitoring of all parameters
- Assignable soft knobs for controlling multiple parameters
- On-line numerical trending of important parameters
- MySQL Database for control parameter logging and historic analysis

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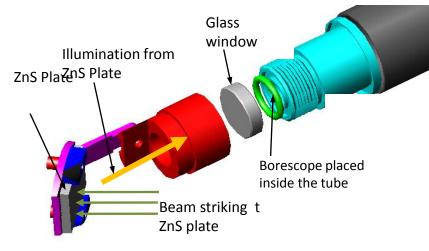
Beam Diagnostic Components

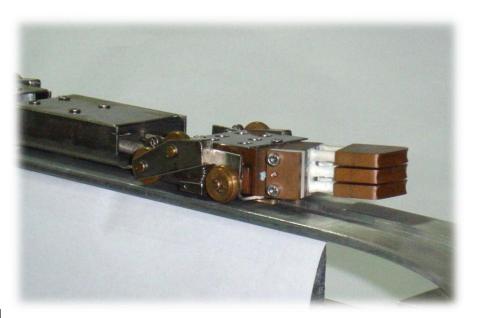


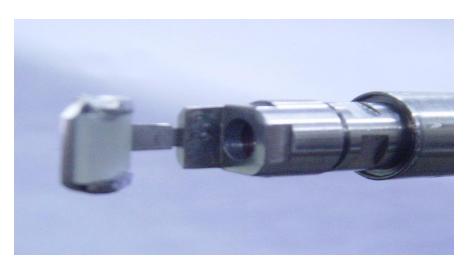
- Diagnostic Component
- Probe Control
- Profile

Internal Beam Diagnostics Components





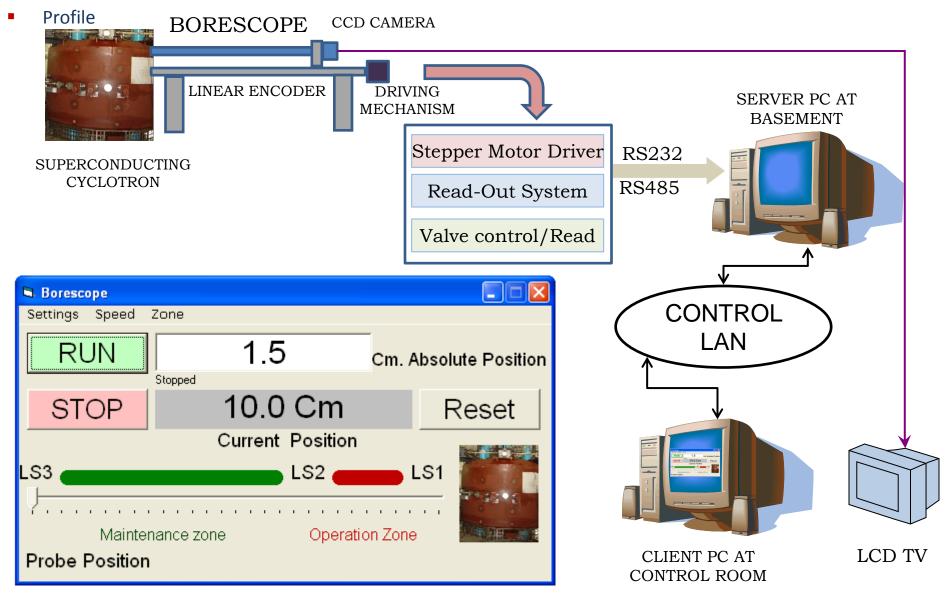




- Diagnostic Component
- Probe Control

Viewer Probe Control





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Diagnostic Component

Probe Control

Profile

Internal Probe Control

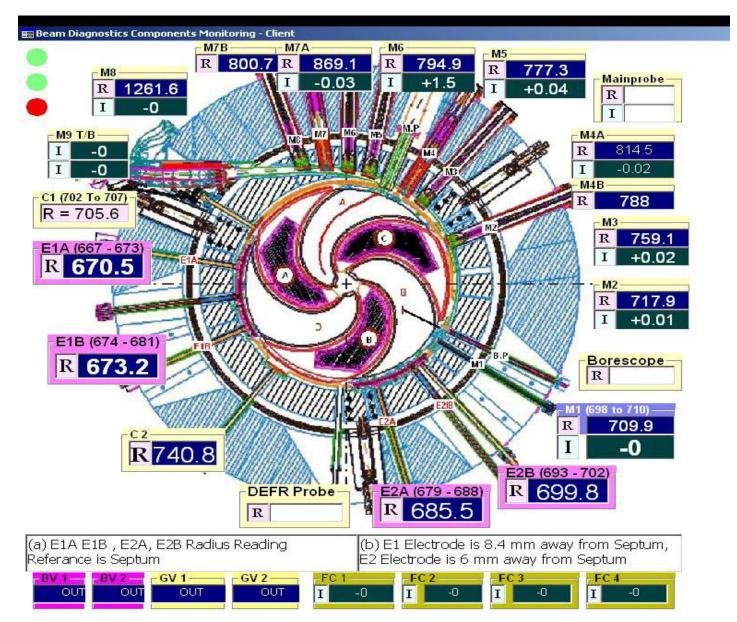


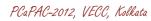
OPERATING POINT LOCATION - 0 > 1/29/2012 3:30:06 AM lon: N2+ , h= 2 , 14 MHz, 31.9 kG, 4.5 MeV/u 350.01 A 459.12 A BoreProbe Monitor : Connected - 🗆 × Position-Probe Position nterlock Status Set Linear Position -From Driver END LS 100.27 100.31 698.9 MID LS Mm P 5 Motor Stopped START LS Set R 699.3 GV Open GV Close -Probe Current (nA)-MOVE Read Range – Bot Ch7 🗹 Boreprobe Ch4 🗹 Top Ch5 🛛 🗹 Mid Ch6 STOP SAVE 200 nA 20 uA M1 Ch10 🗹 DR Probe Ch8 🛛 🗹 Def Probe Ch9 Flow SW Foggle Refresh - 🗆 × E1 Exit- Ch5 - ----- Ch7 ---Ch9 C Probe MID Ch6 -Delta R Ch8 M1 Ch10 -0.02 0.01 0.01 -0.01 n C-Probe Mid Current Time scan -Probe Data Main Probe Current Vs. Radius 180 R H 7:1 V 1:1 597.9 50 140 et 603.4 100 MOVE Read 50 100 150 200 250 Time (Sec) 100 150 200 250 300 Time (Sec) 60 Curr STOP SAVE 20 E1-Exit Probe Time Scan M1 Current Time scan \frown Graph -20 Refresh H 1:1 V 16:1 640 600 610 620 630 650 660 670 680 690 Probe Position 0.05 EndLS (Cyclotron) Operation Zone MidLS 2 >> .0.1 100 150 200 250 300 Time (Sec) 100 150 200 250 Time (Sec) • mm 👻 Message from Driver Set Linear Position-Command-Movement-Interlock Status 125.45 esent Linear **Reset Position** END LS TRACK IN GV OPEN 6 In - Out MID LS GV CLOS Track IN Motor Stopped START LS 🛋 Absolute Position of MainProbe 📃 🗖 🗙 604.26 Radial distance of Mainprobe from Cyclotron centre (mm) 125.36 Magnetic Channel 🏄 Start 🛛 🛃 🧮 🗐 🎉 🙆 🦉 🛃 🖄 OPERATING POINT LO... 🛛 🎎 Main Probe Monitor 🔰 💓 14.0015MHz.bmp - Paint 🛛 📅 BoreProbe Monitor : Co... 🛛 🗱 Magnetic Channel Posit... 🛛 😭 Absolute Position of ... 📜 10:17 AM

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- Diagnostic Component
- Probe Control
- Profile





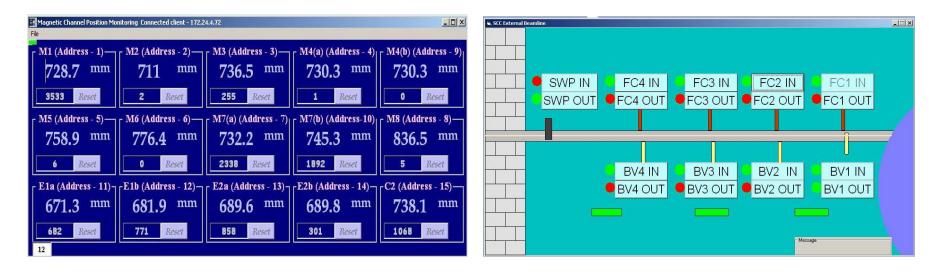


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- Diagnostic Component
- Probe Control
- Profile

Probe Monitoring and Control

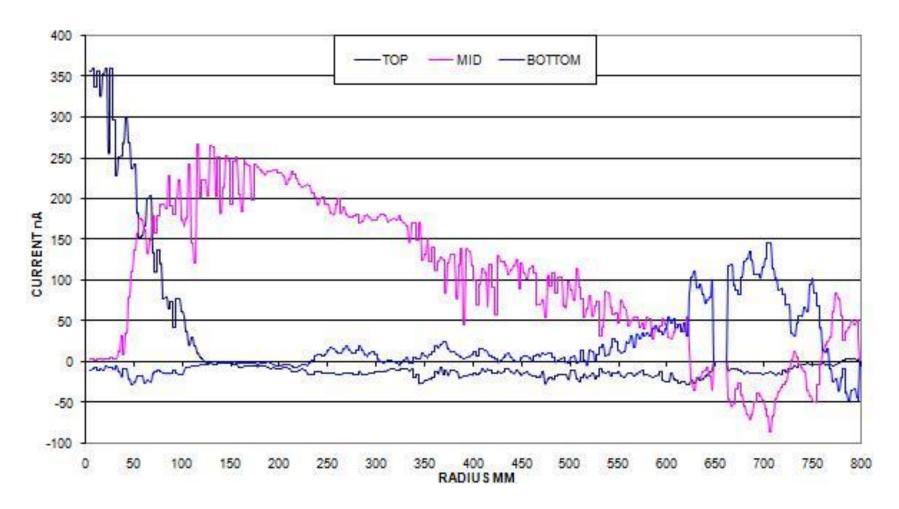




- Diagnostic Component
- Probe Control
- <u>Profile</u>



Three Finger Probe Profile

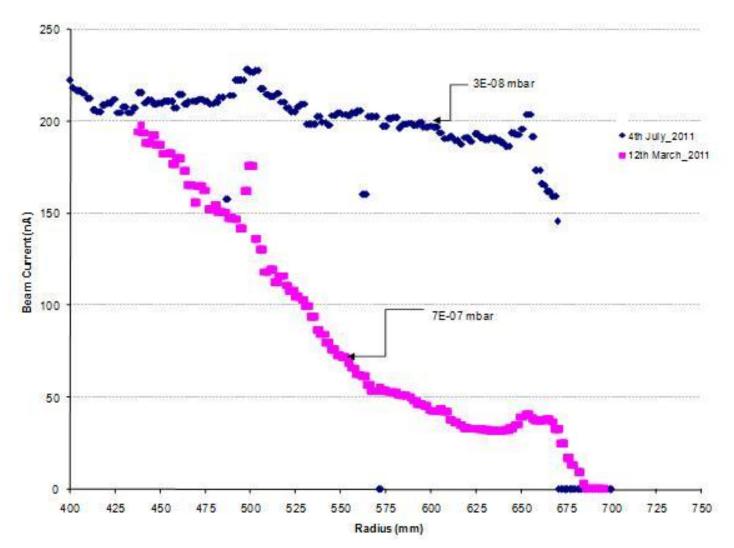




Probe Control

<u>Profile</u>

Internal Beam Profile



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- <u>EPICS</u>
 <u>Implementation</u>
- Supervisory
 Control
- VEC MPSs Control
- VEC Vacuum Control
- Central Console of VEC
- Control DB
- Secured Access

EPICS Implementation

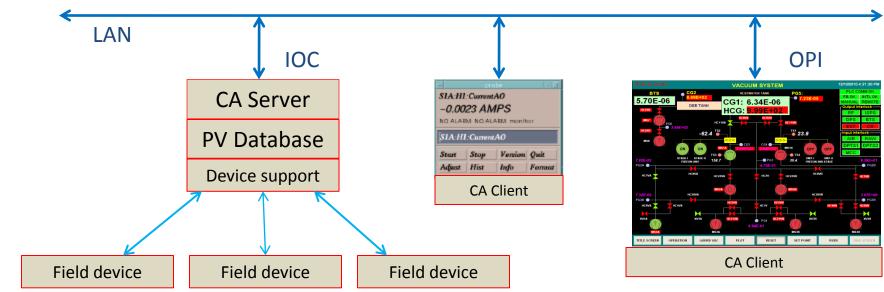
- Vacuum System
- MPS
- LCW System
- Beam Diagnostic

- EPICS Implementation
- <u>Supervisory</u>
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Supervisory Control System - EPICS

- Underneath protocol
 - Channel Access (CA)
- Network transparent protocol
 - Hides communication intricacies of field devices from GUI
 - Unique PV names
 - to bridge link between CA server & CA client
 - Access security

- to protect access of crucial parameters
- Event based notification
 - Value is changed

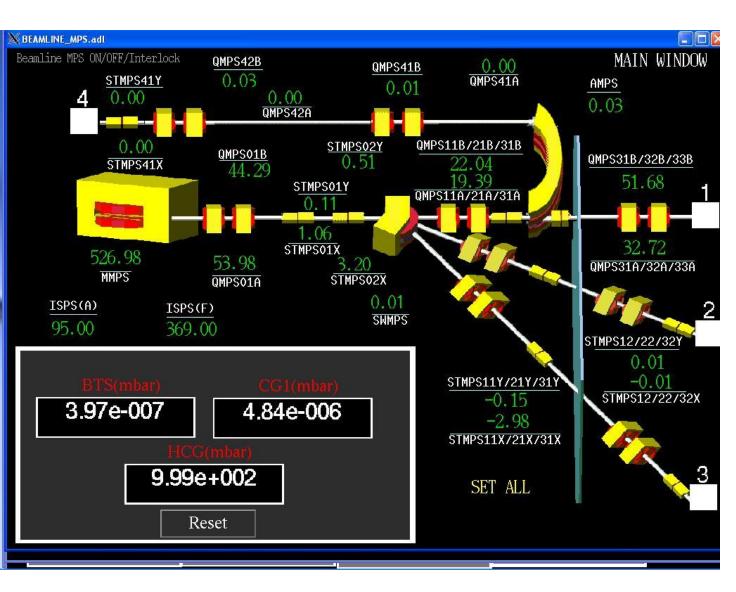


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- EPICS
 Implementation
- Supervisory Control
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VEC MPSs Control

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PLC Based RTC Vacuum System

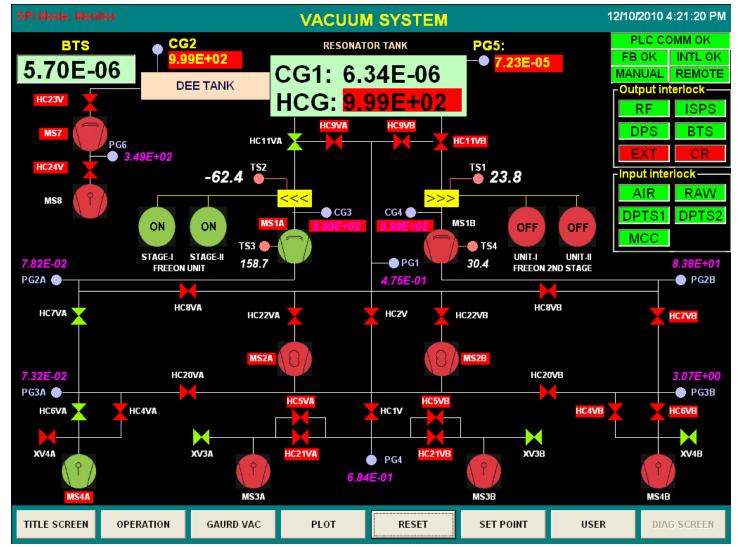
Basic requirement

- Desired vacuum level 2 x 10⁻⁶ Torr at Resonator tank, DEE tank and Beam lines
- Volume of Resonator tank & DEE tank– 23 m3 approx.

Basic features

- Commissioned around 1975
- Available technology Oil Diffusion Pump, Freon cooled chevron baffle, Roots pump, Rotary pump
- Hot-cathode, cold-cathode & thermocouple gauge
- Redundant pumping system to support from Roughing to Backing
- Relay based Manual Control Logic
- Renovated in 2009
 - Replacement of fifteen crucial gate valves for better isolation
 - Use of new state-of-the-art Pirani , Combination gauges & RTD
 - Replacement of Freon unit & chevron baffles
 - Up gradation of Control system to modern PLC based system

- EPICS Implementation
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VEC Vacuum Control

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New look of Central Console of VEC



- EPICS
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- <u>Central Console of</u> <u>VEC</u>
- Control DB
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- Unlock and Mode Selected Soft -Knobs coarse settin Selection Buttons Protect Sensor array sheath
- Direct measurement by individual cable
- Push buttons, toggle switches, multiturn pots, selector switches
- DPMs, analog meters, measuring instruments and indicator lamps for display
- Manual multiplexing

Implementation of Control Database for SCC & VEC with Secured Access

What it does?

•Archiving a large number of control parameters of different subsystems e.g. Cryogenic, Magnet Power Supply, RF system, Vacuum, ECR, Beam Diagnostic etc.

•Provide snap shot view of correlated control parameters over time

- •Integration of SCC and VEC control LAN
- •Secured access of control parameter from office LAN
- •Facilitate archiving of EPICS and non-EPICS system parameters

Important features

- •EPICS tool for interfacing database •Developed in VECC
- •Supports polling & event driven types of data logging
- •Auto configuration of database
- •Inbuilt web server for online distributed viewing
- •Historic data analysis
- •Graphical comparison among archived data
- •Web based online Addition/ Removal/ Modification of data

🖲 VEC Live Status - Hozilla Fi	irefox		
Ele Edit View History Book	narks Ijols Help		
VEC Live Status	× D'Linear Technology - Design Smulation an × +		
(+) http://10.200.9.10	D(nannadrine.php	👚 - C 😽 - kpice download	<i>p</i> 🔒

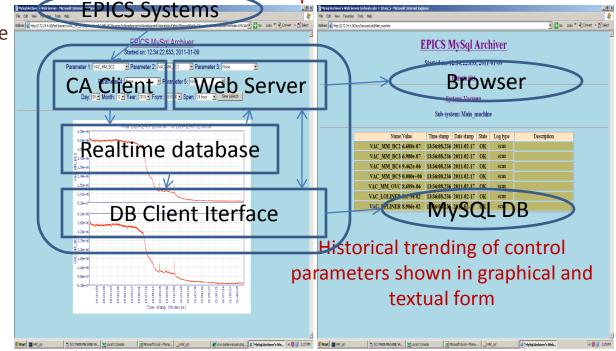
VEC Live Status

25-4-2012, 02:58pm

Current Status Trim coil Power Supply Beam line Power Supply Deflector Power Supply Vacuum

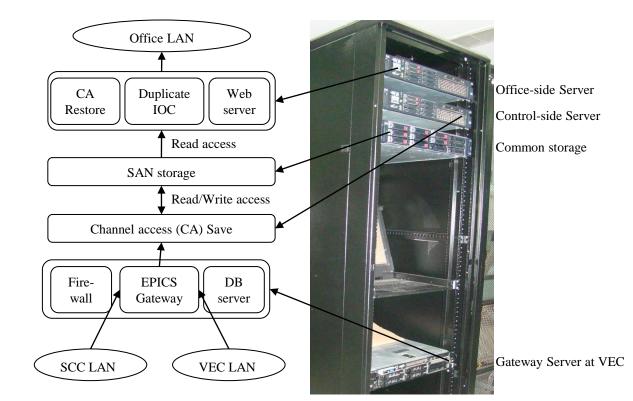
Main Magnet(Ampere)	842.5	
Dee Voltage(kVolt)	0	
Filament Current(Ampere)	381	
Arc Voltage(Volt)	379	
Arc Current(Ampere)	0.5	
Gas Flow(sccm/s)	7.41	
Gas Type	Helium	

Live monitoring of control parameters of VEC from office LAN



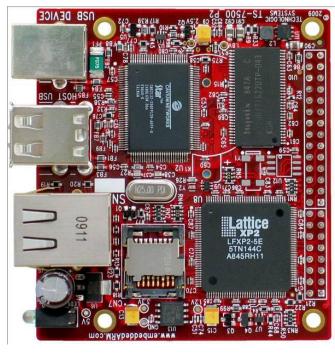
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- <u>Epics Enabled</u>
 <u>Controller</u>
- In-house Design
- EPICS
 Performance
 Analysis
- Concluding Remark

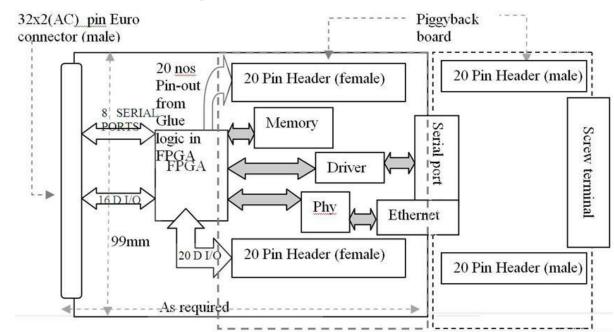
Epics Enabled Controller



- 250MHz ARM9 CPU, 64MB DDR-RAM, 4MB Flash, Micro SDHC Card slot
- Customizable 5K LUT OpenCore FPGA
- Ethernet, UART, DIO, SPI and I2C interfaces, Watchdog Timer
- Small size, Low power
- Prebuilt Linux 2.6 kernel loaded on micro sd card/flash and boots in than seconds
- Full featured Linux including GNU C/C++ embedded development environment installed in the SD Card



In-house Design of Embedded EPICS Controller





Future Plans

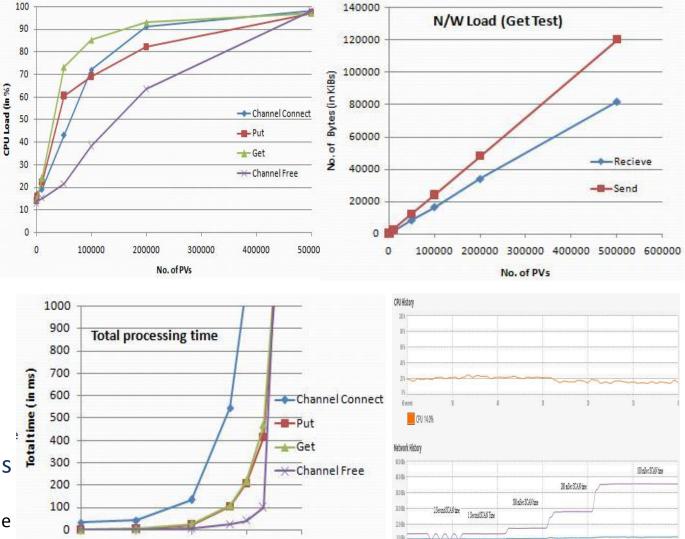
- Epics Enabled
 Controller
- In-house Design
- <u>EPICS</u>
 Performance
 Analysis
- Concluding Remark

PCaPAC-2012, VECC, Kolkata



EPICS Performance Analysis

- Epics Enabled
 Controller
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Performance analysis

- CPU Load
- Server Processing Time
- Network Load
- Database Performance

10000

No. of PVs

100000

1000000

f) amin

Receiving

Total Received

100

1000

46.2 KiB/s

653.1 MiB

1

2.1 KiB/s

975.9 MiB

A Sending

Total Sent

- Epics Enabled
 Controller
- In-house Design

EPICS Performance Analysis

<u>Concluding</u>
 <u>Remark</u>

I/O Channels requirement

System Data Statistics	SCC (No. of Parameters)	VEC (No. of Parameters)
Internal Beam Diag.	16	6
External Beam Diag.	40	20
Magnet Power Supply	34x8	40x8
Vacuum (Main & Beam Line	214	216
LCW Cooling	42	34
Radiation Surveillance System	32x6	40x6
Temperature Monitoring		25

EPICS

Analysis

Remark

Epics Enabled
 Controller

In-house Design

Performance

Concluding

Components used for Control/Monitor

- System Components
 - Pump

- Valve
- Motor
- Encoder
- Camera
- Process Variables
 - Vacuum/Pressure
 - Temperature
 - Level
 - Flow
 - Current
 - Voltage
 - Position
 - Status Flag

- Control H/W Components
 - PLC
 - Controller
 - DAQ Module
 - Field point module
 - Measuring devices
 - Multiplexer
 - Converter
 - Filter
- Supervisory Control S/Ws
 - EPICS
 - LabView
 - VB
 - Proprietary





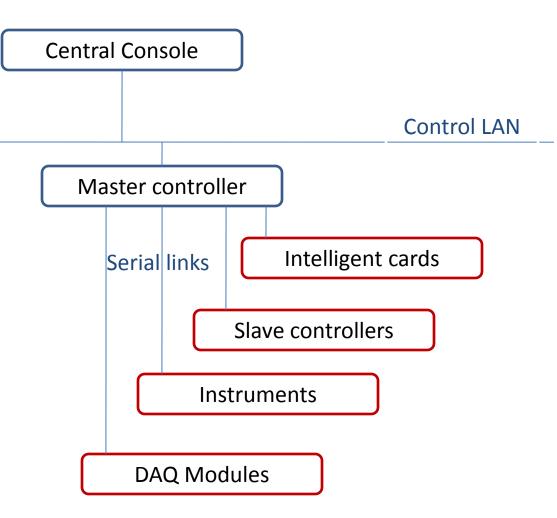




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Embedded Controller Scheme





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Future Plans

- Epics Enabled Controller
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Concluding Remark

The simple equation :-

Reliability of HW/SW

- + Availability of HW/SW (cost effective)
- + Maintainability of HW/SW (openness)
- + Upgradability of HW/SW (openness)
- = LONG-LIVED CONTROL SYSTEM



Acknowledgement

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Thank You!