

ITER & CODAC Status Update

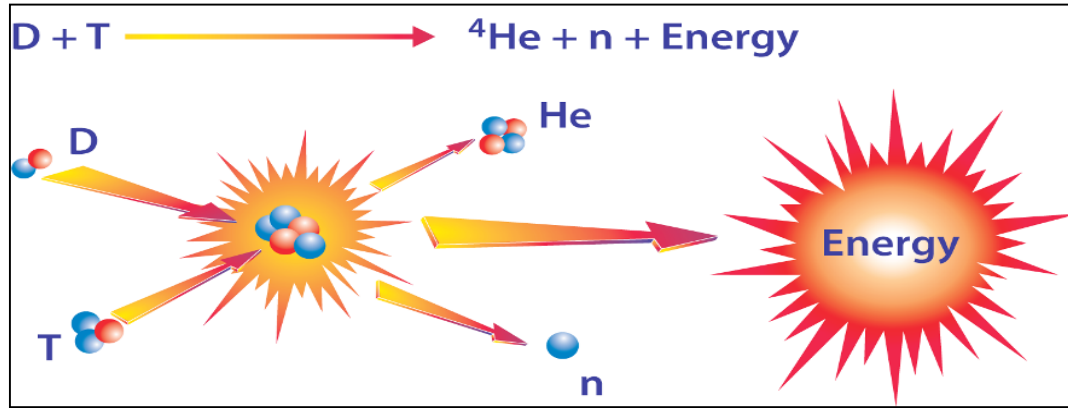
An aerial, wide-angle photograph of the ITER construction site. The image shows a large complex of buildings, including a prominent white structure with a large circular opening on the left. Numerous cranes are visible, some with red and white lattice structures. The site is surrounded by a hillside with sparse vegetation under a clear blue sky. The overall scene depicts an active and large-scale industrial construction project.

Anders Wallander
Control System Division
ITER Organization

Disclaimer: The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

Introduction

- Demonstrate technical feasibility of nuclear fusion as energy source



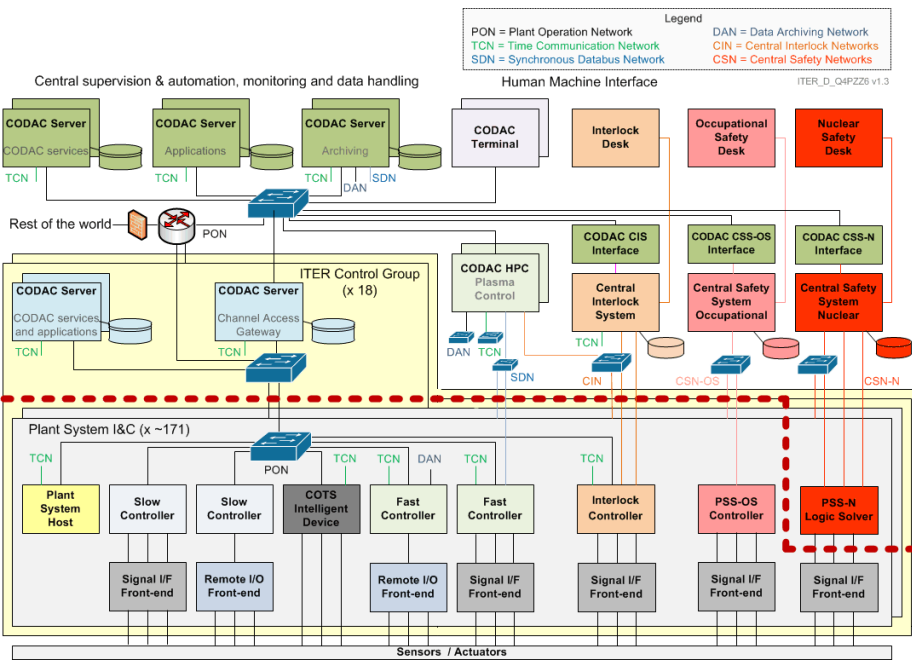
- Lawson criterion: Temperature * Density * Time > Big Number
- ITER is an international project based on in-kind contributions

The big news since last EPICS collaboration meeting:

**ITER Control System
started 24/7 operation on
January 26, 2019**

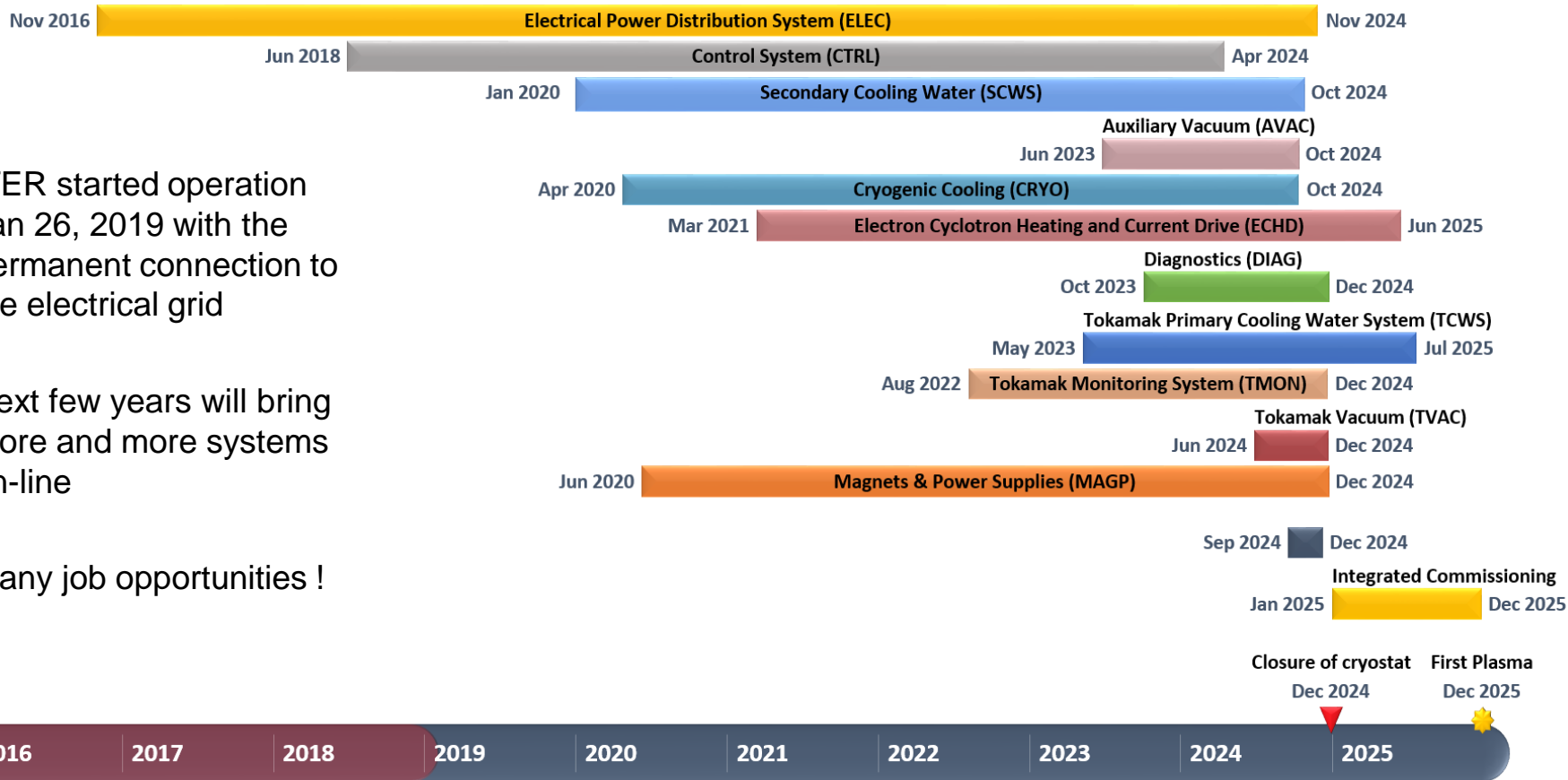
ITER Control System Architecture recap.

- 18 subsystems
- 171 local control system
- 101 in-kind suppliers
- Millions of PV's



- Our EPICS distribution is called CODAC Core System, released yearly (latest v6.1) and distributed to all in-kind suppliers
- We are starting exploring EPICS 7 for higher level applications

Commissioning Schedule



- ITER started operation Jan 26, 2019 with the permanent connection to the electrical grid

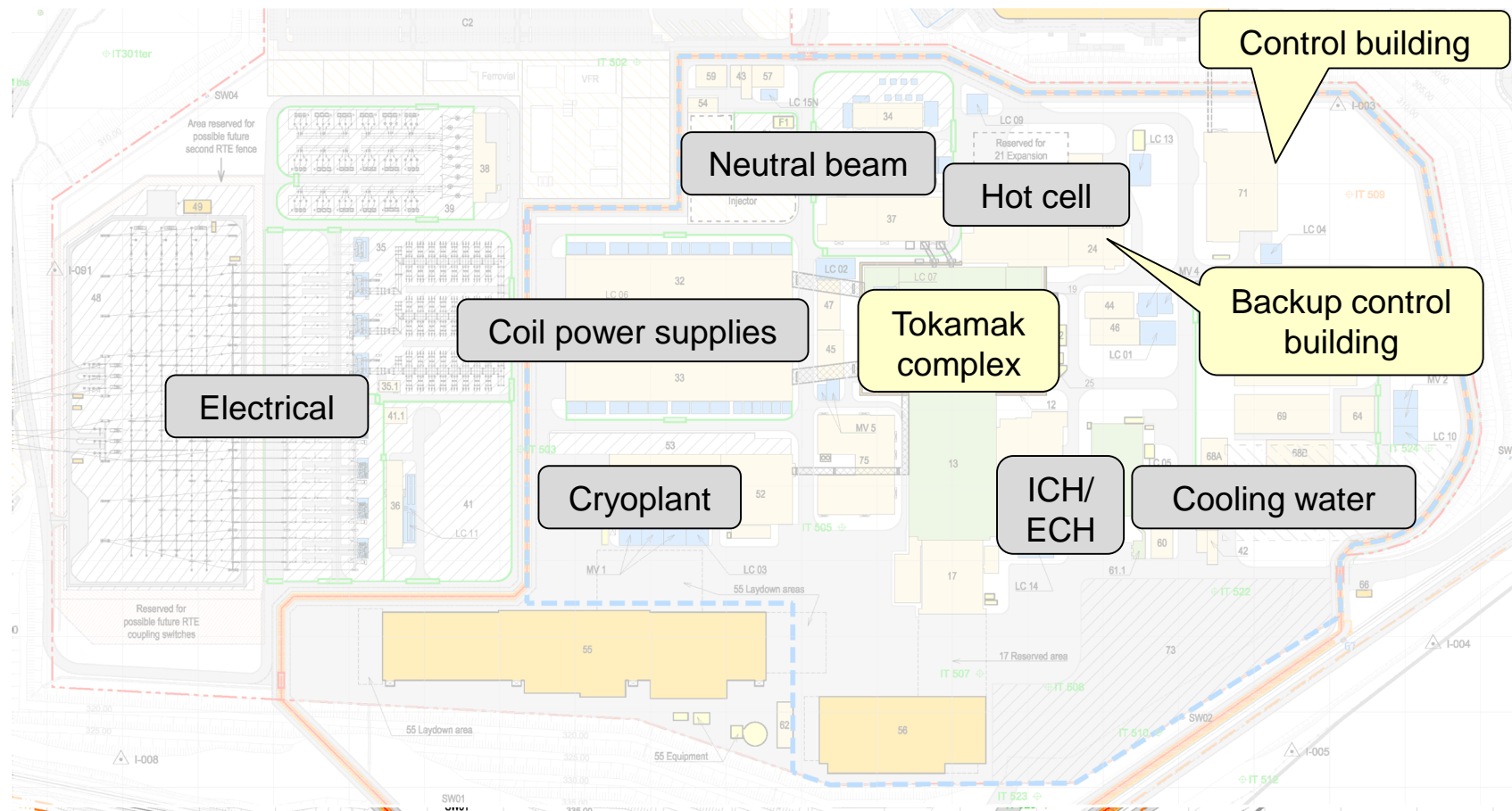
- Next few years will bring more and more systems on-line

- Many job opportunities !



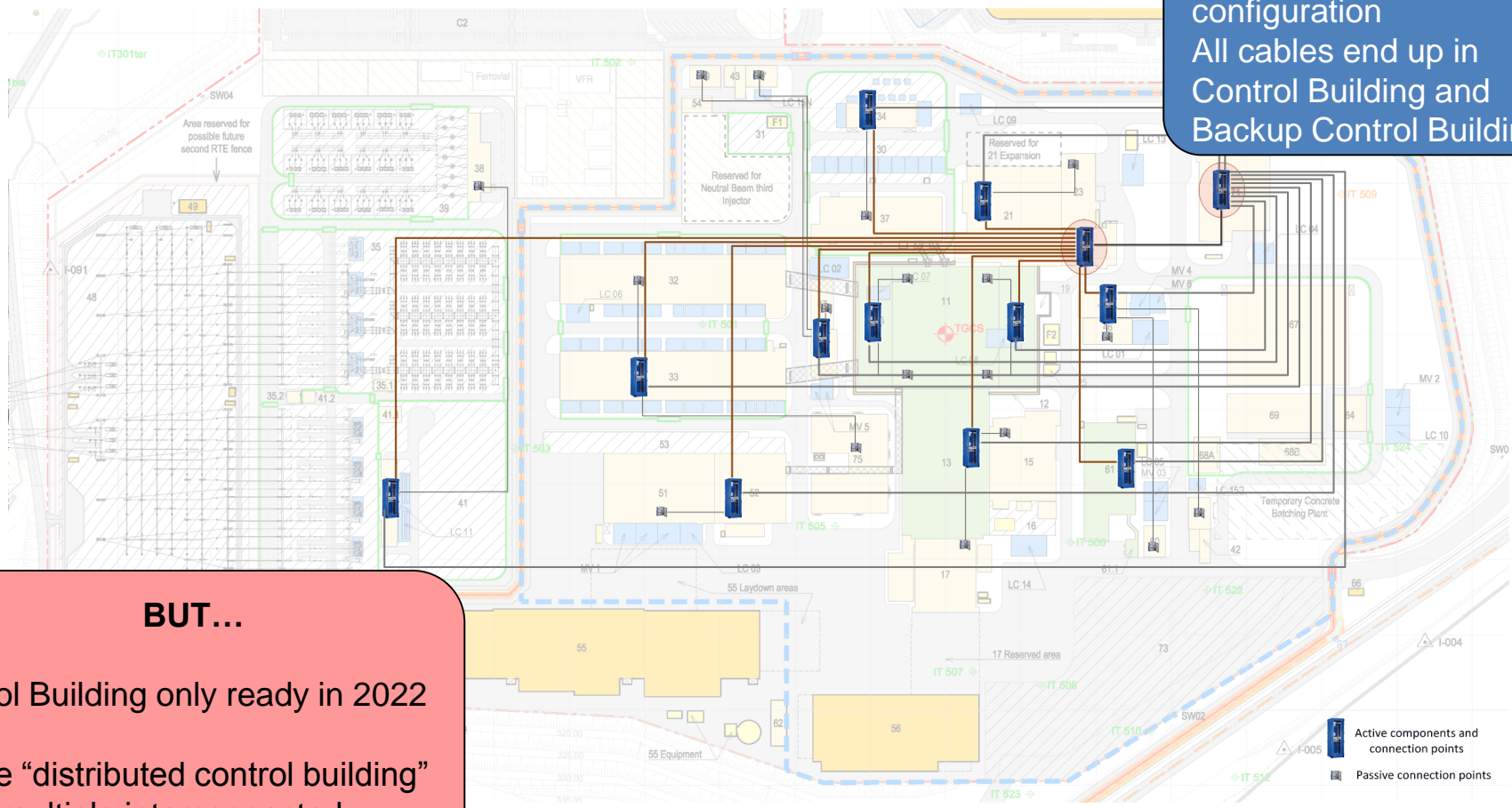
Today

Infrastructure



Infrastructure

Redundant dual star configuration
All cables end up in
Control Building and
Backup Control Building



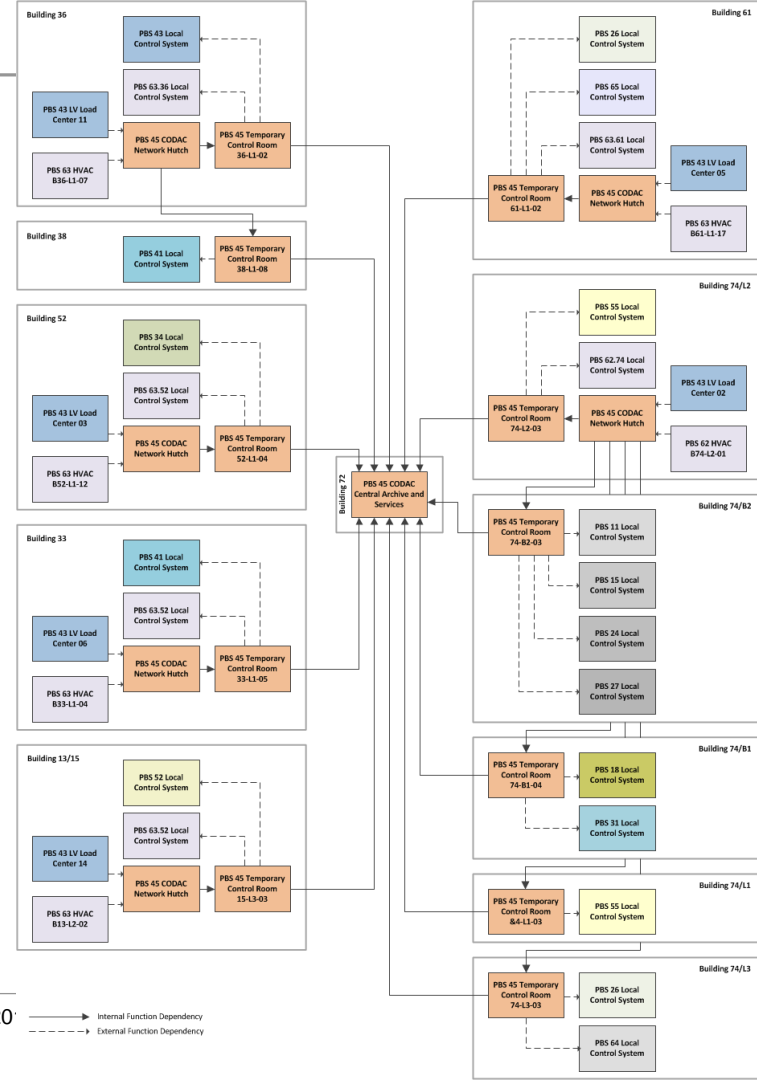
BUT...
Control Building only ready in 2022
Create “distributed control building”
using multiple interconnected
“Temporary Control Rooms”

Temporary Control Rooms

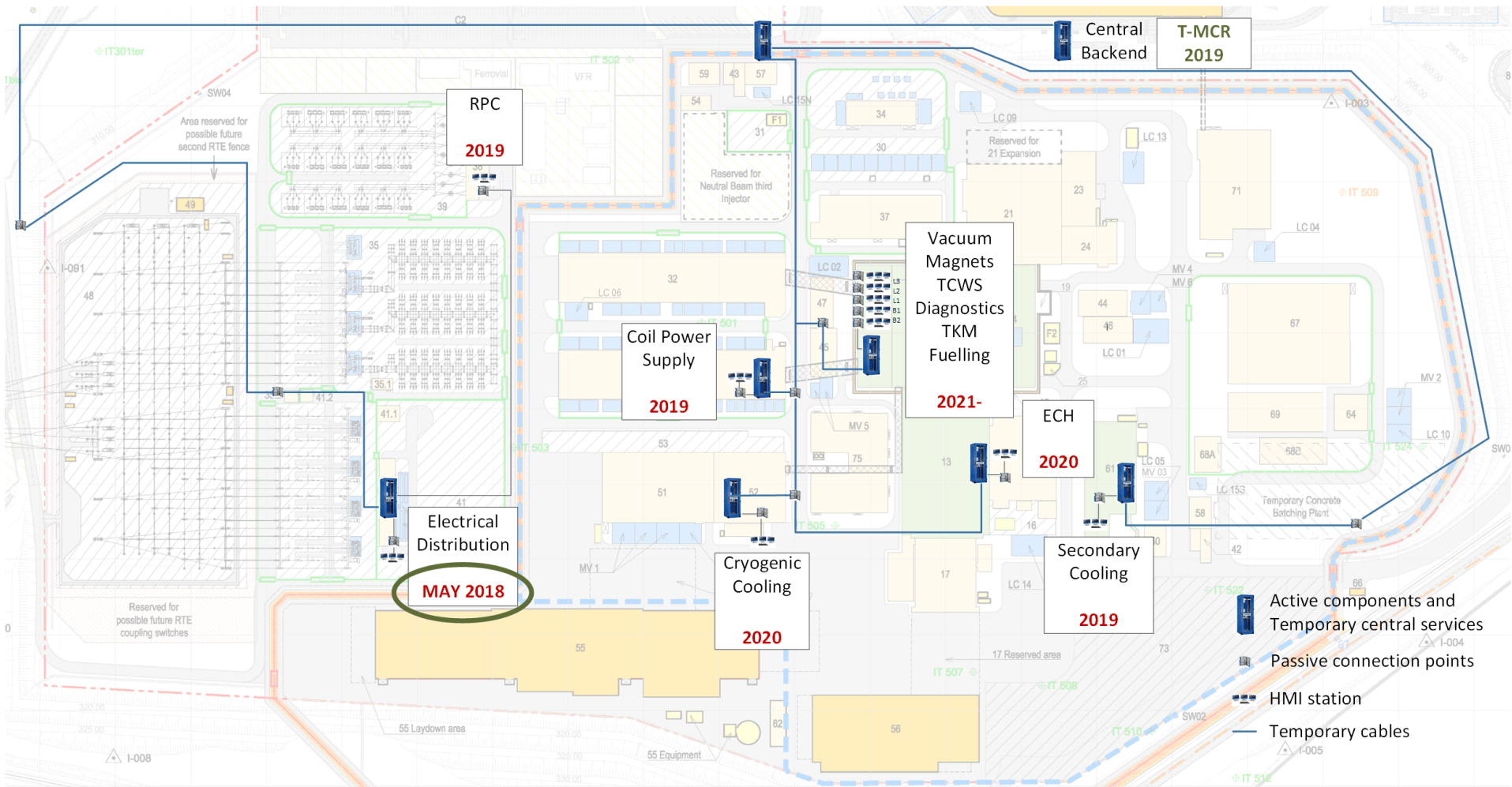
11 TCR's in 6 buildings interfacing all first plasma plant systems

Functions provided as services to the plant systems:

- Human Machine Interface
- Data handling including archiving, storage and access
- Inter plant communication
- Role based access control
- Alarm handling including notification
- Time synchronization
- Electronic logbook
- Access to central software repository and issue tracking (configuration control)
- Development stations for software updates (fast turn-around)
- Central supervision and monitoring
- Access to archived data from office



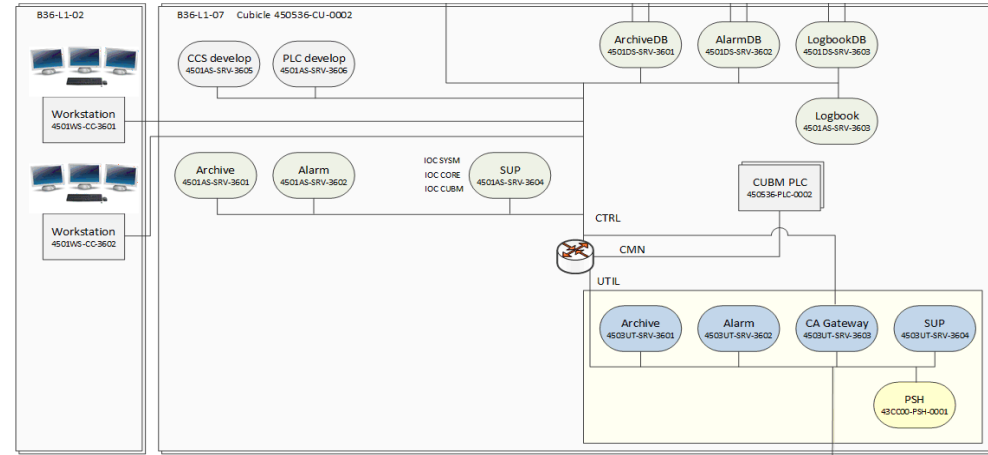
Temporary Control Rooms - Schedule



Electrical – First plant system

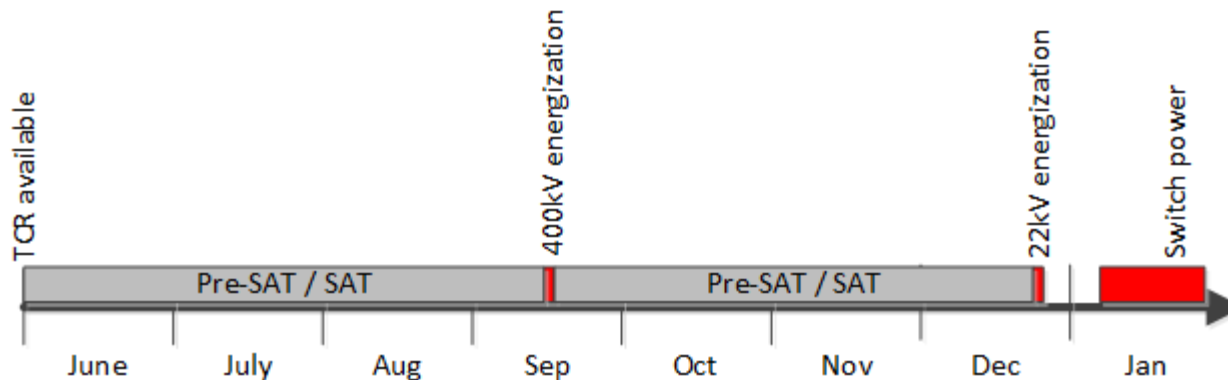
Central back-end in B07/B72 providing central archive, remote monitoring and alarm relaying

Temporary control room located in B36 with around 15 servers (VM) and two HMI workstations



UTIL-HV plant system comprising 88 Intelligent Electronic Devices (IED's) connected together by an IEC 61850 network using 21 switches and interfaced to CODAC via a WinCC-OA gateway using OPC-UA. It has a total of 6873 process variables, 2533 defined alarms and 35 Operator Interface (OPI) panels.

Electrical – First plant system in operation



Major milestones:

- Jun 1, 2018 – B36 TCR operational
- Sep 17/18, 2018 – 400 kV energization
- Dec 21, 2018 – 22 kV energization
- Jan 26, 2019 – Switch off CEA power

Many Actors:

- F4E I&C
- GTD
- Engage
- SSEN I&C
- CSD I&C and codac_adm
- TCS
- TB06
- TB06 subcontractors (Siemens etc.)
- SSEN client
- Commissioning and Operation

Electrical – First plant system

July 2018



July 2018



Sep 2018



Nov 2018



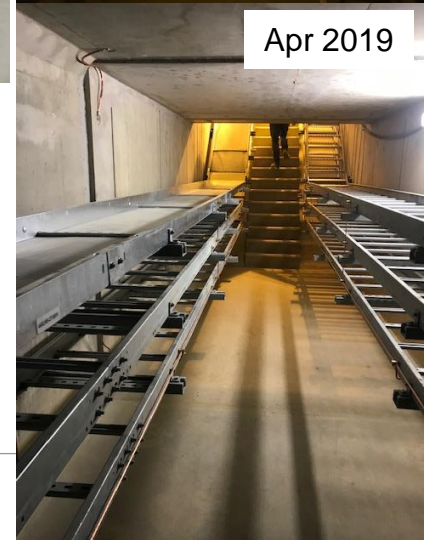
Nov 2018

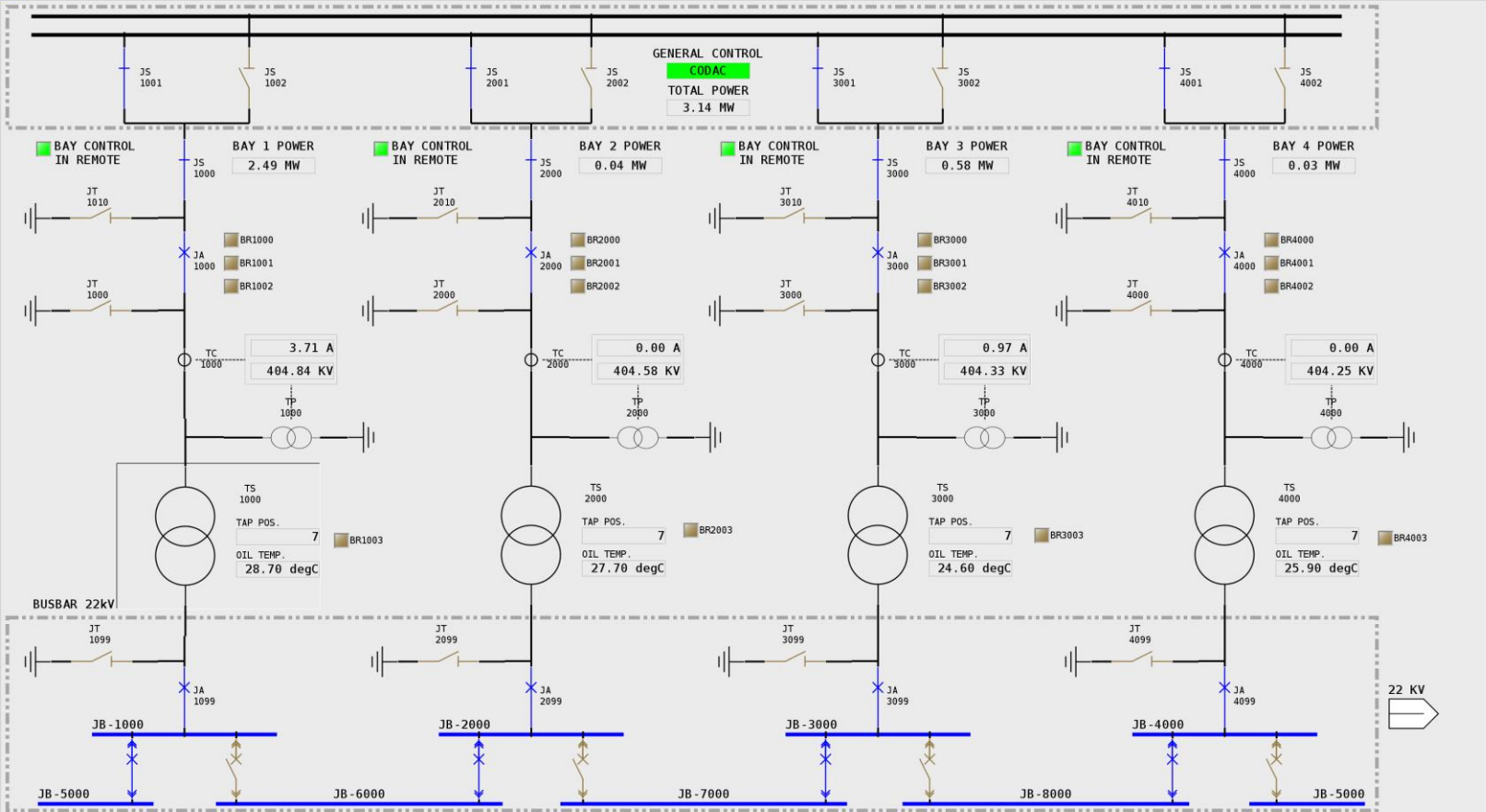


EPICS

R,

Electrical – First plant system





ALARMS

Current Alarms (0 of 0 alSelect xl)

Acknowledged Alarms (0 of 35 alarms)

At	Description	Alarm Ts
<input checked="" type="checkbox"/>	EB7100 Battery Fuse	16:32:46
<input checked="" type="checkbox"/>	EU7100 UPS Common Fa	15:43:58
<input checked="" type="checkbox"/>	SYS HVAC system Anom	07:55:48
<input checked="" type="checkbox"/>	BR0001 IED Relay Fai	15:02:06
<input checked="" type="checkbox"/>	48DC Busbar 2 High V	15:02:06
<input checked="" type="checkbox"/>	48DC Busbar 2 Low V	15:02:06
<input checked="" type="checkbox"/>	48DC Busbar 1 High V	15:02:06
<input checked="" type="checkbox"/>	48DC Busbar 1 Low V	15:02:06

43AC00-TS1000

STATUS TRENDS A1 A2 TAP

28.70 degC	OIL TEMP. MAIN TANK
27.30 degC	22 kV WINDING TEMP
23.70 degC	400 kV WINDING TEMP

FAULT STATUS

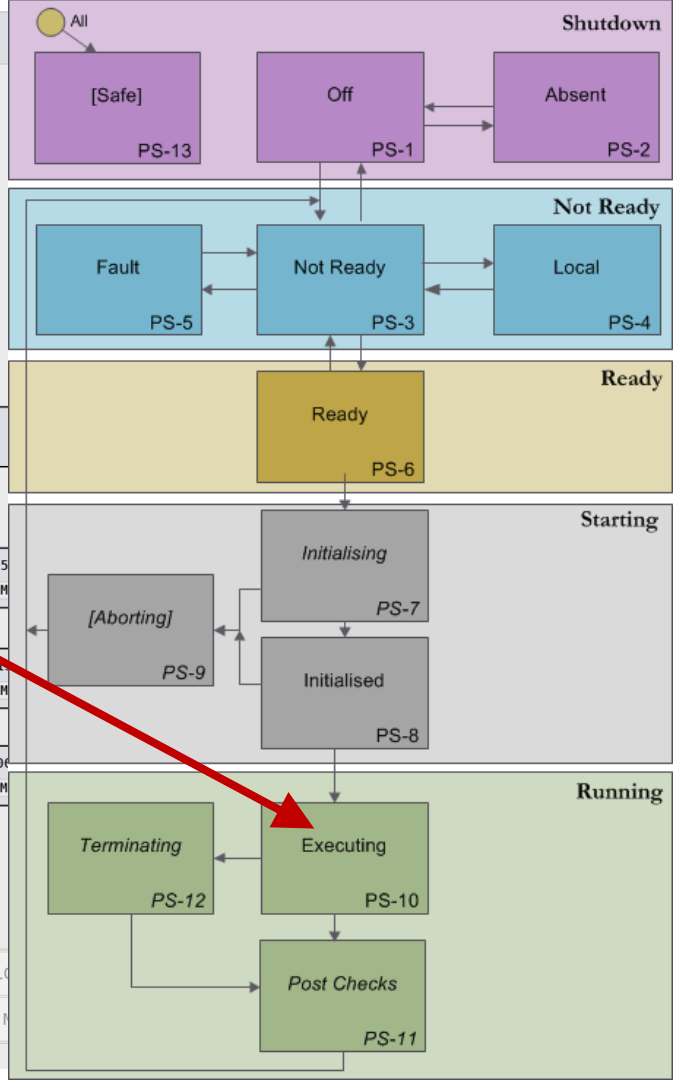
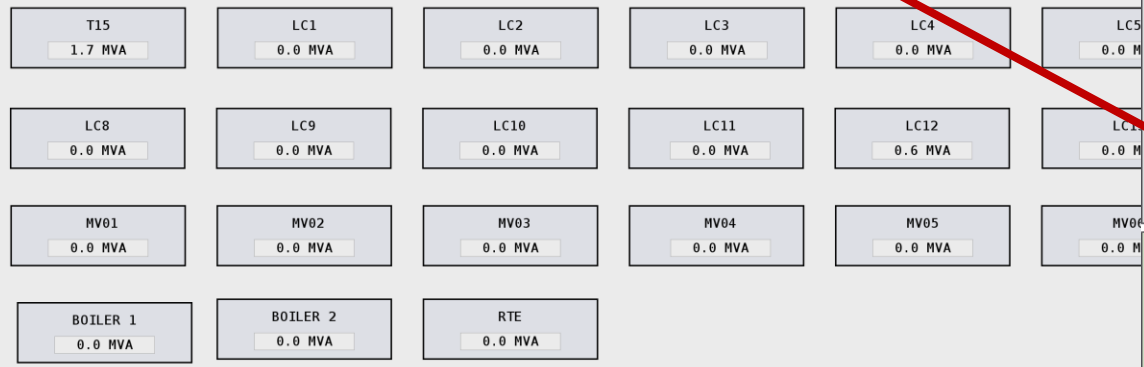
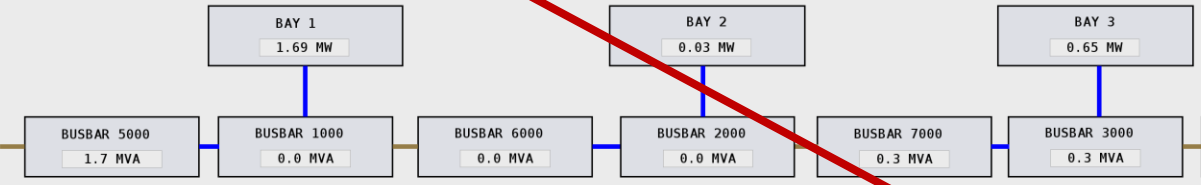
- FAN GROUP 1 RUNNING
- FAN GROUP 2 RUNNING
- POWER SWITCH ON NORMAL PS
- HEALTHY IED CONNECTION

MODE

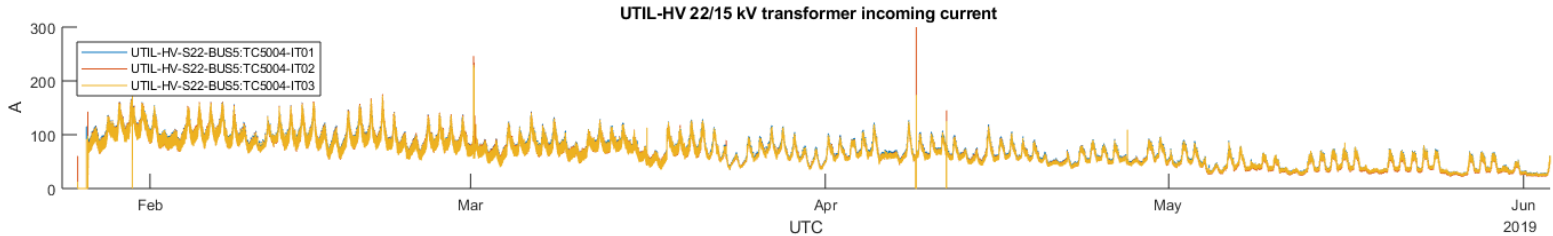
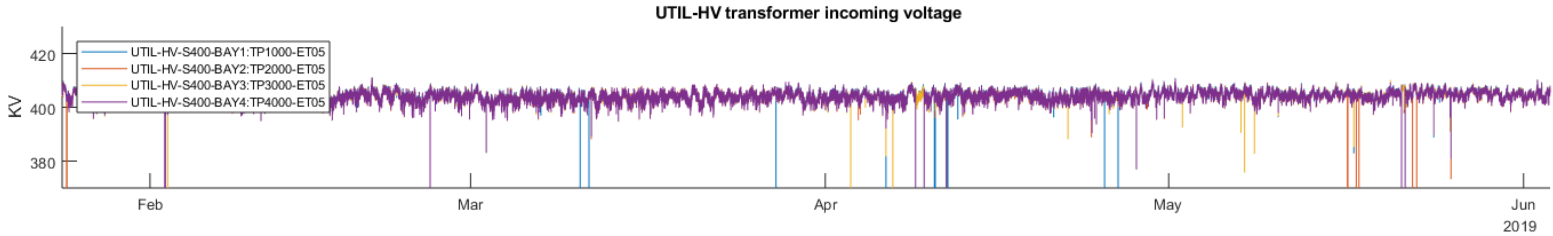
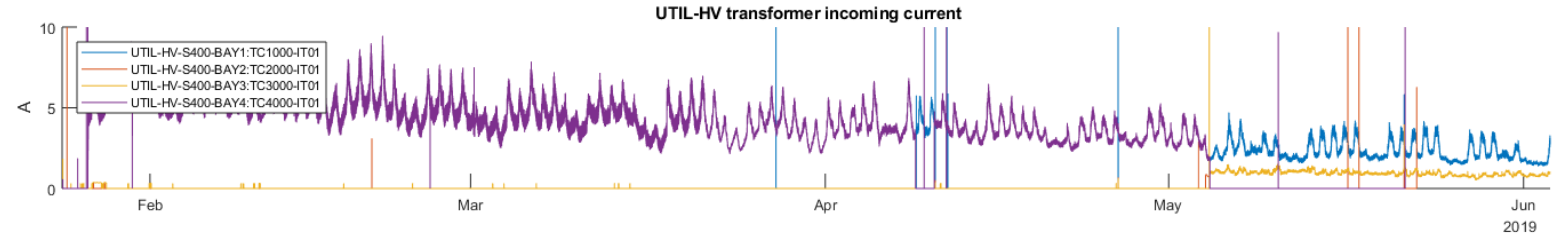
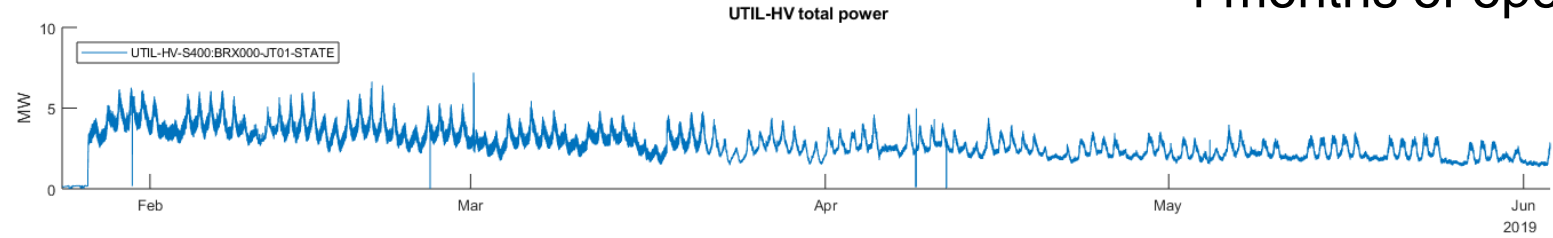
- FAN GROUP 1 MANUAL
- FAN GROUP 1 AUTO
- FAN GROUP 2 MANUAL
- FAN GROUP 2 AUTO

COS OPERATION STATE
Executing

TOTAL POWER
 2.38 MW



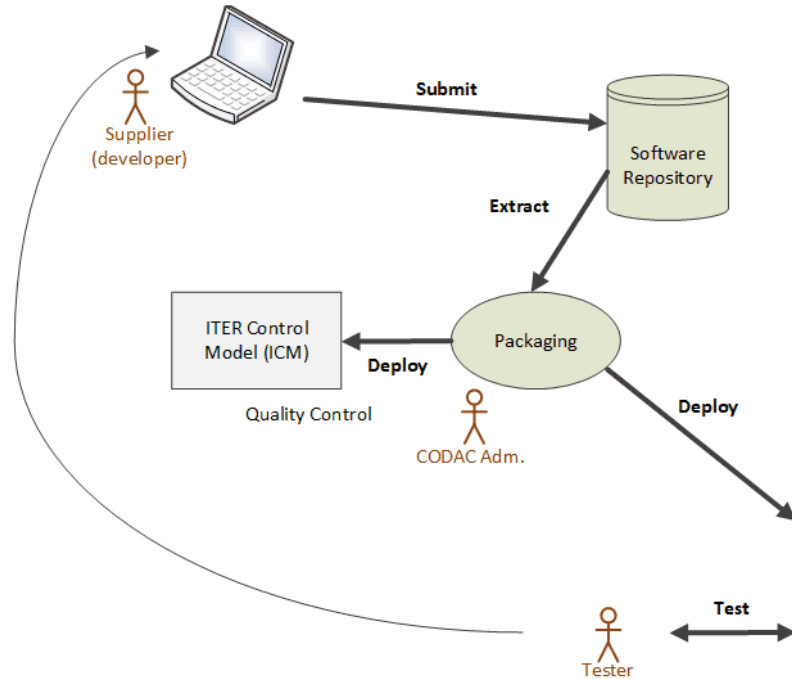
4 months of operation



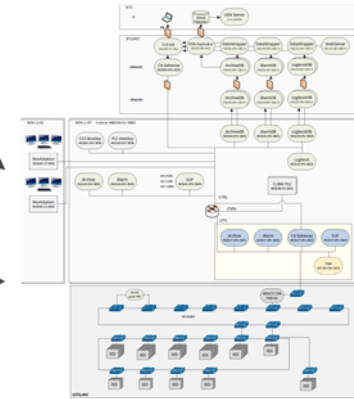
Software Configuration Control (Work flow)



Wed May 29, 2019

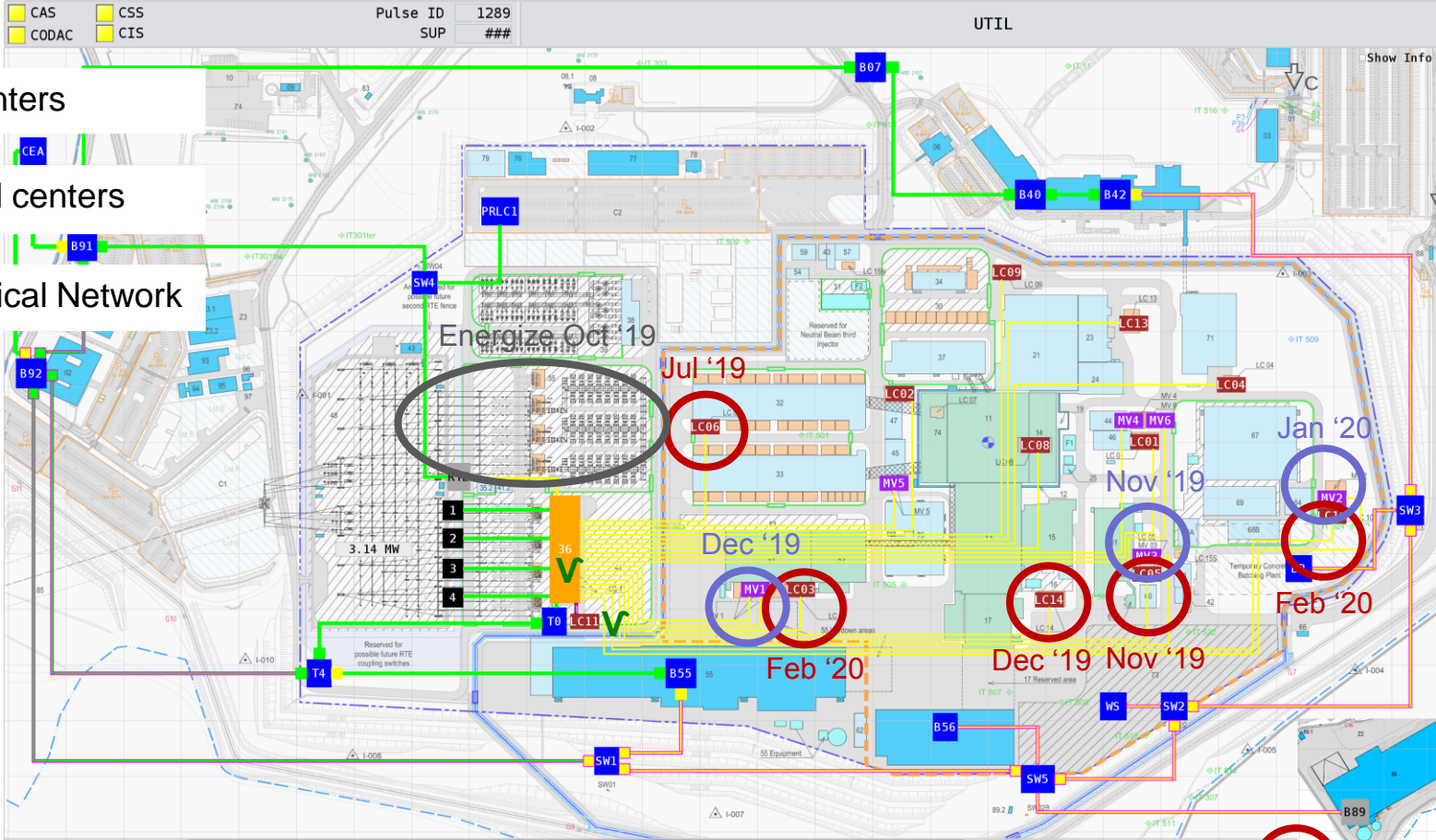


<input type="checkbox"/>	m-UTIL-HV-S22/	94163	1h 06m	martr	Log	RSS
<input type="checkbox"/>	m-UTIL-HV-S400/	94168	50m	martr	Log	RSS
<input type="checkbox"/>	branches/	94077	2d 21h	bauvirb	Log	RSS
<input type="checkbox"/>	tags/	93986	7d 02h	martr	Log	RSS
<input type="checkbox"/>	20180319-GTD-DELIVERY/	84955	227d 00h	stepand	Log	RSS
<input type="checkbox"/>	20180710-GTD-DELIVERY/	90832	115d 04h	simelia	Log	RSS
<input type="checkbox"/>	20180719-GTD-DELIVERY/	91226	102d 03h	fujitaj	Log	RSS
<input type="checkbox"/>	20180724-GTD-DELIVERY/	91271	101d 06h	martr	Log	RSS
<input type="checkbox"/>	20180801-GTD-DELIVERY/	91477	93d 03h	martr	Log	RSS
<input type="checkbox"/>	20180802-GTD-DELIVERY/	91532	92d 05h	martr	Log	RSS
<input type="checkbox"/>	20180807-GTD-DELIVERY/	91670	86d 06h	fujitaj	Log	RSS
<input type="checkbox"/>	20180810-GTD-DELIVERY/	91718	84d 04h	martr	Log	RSS
<input type="checkbox"/>	20180827-GTD-DELIVERY/	92121	66d 21h	martr	Log	RSS
<input type="checkbox"/>	20180904-GTD-DELIVERY/	92498	58d 20h	martr	Log	RSS
<input type="checkbox"/>	20180912-GTD-DELIVERY/	92762	50d 20h	martr	Log	RSS
<input type="checkbox"/>	20180913-GTD-DELIVERY/	92790	50d 02h	martr	Log	RSS
<input type="checkbox"/>	20180914-GTD-DELIVERY/	92834	49d 02h	martr	Log	RSS
<input type="checkbox"/>	20180925-GTD-DELIVERY/	93222	35d 07h	fujitaj	Log	RSS
<input type="checkbox"/>	20181004-GTD-DELIVERY/	93385	29d 03h	martr	Log	RSS
<input type="checkbox"/>	20181026-GTD-DELIVERY/	93986	7d 02h	martr	Log	RSS



More details Thursday (Bustos)

Coming up for Electrical...



Low voltage load centers

Medium voltage load centers

Pulsed Power Electrical Network

Energize Oct 19

Jul '19

Dec '19

Feb '20

Nov 19

Dec '19

Nov '19

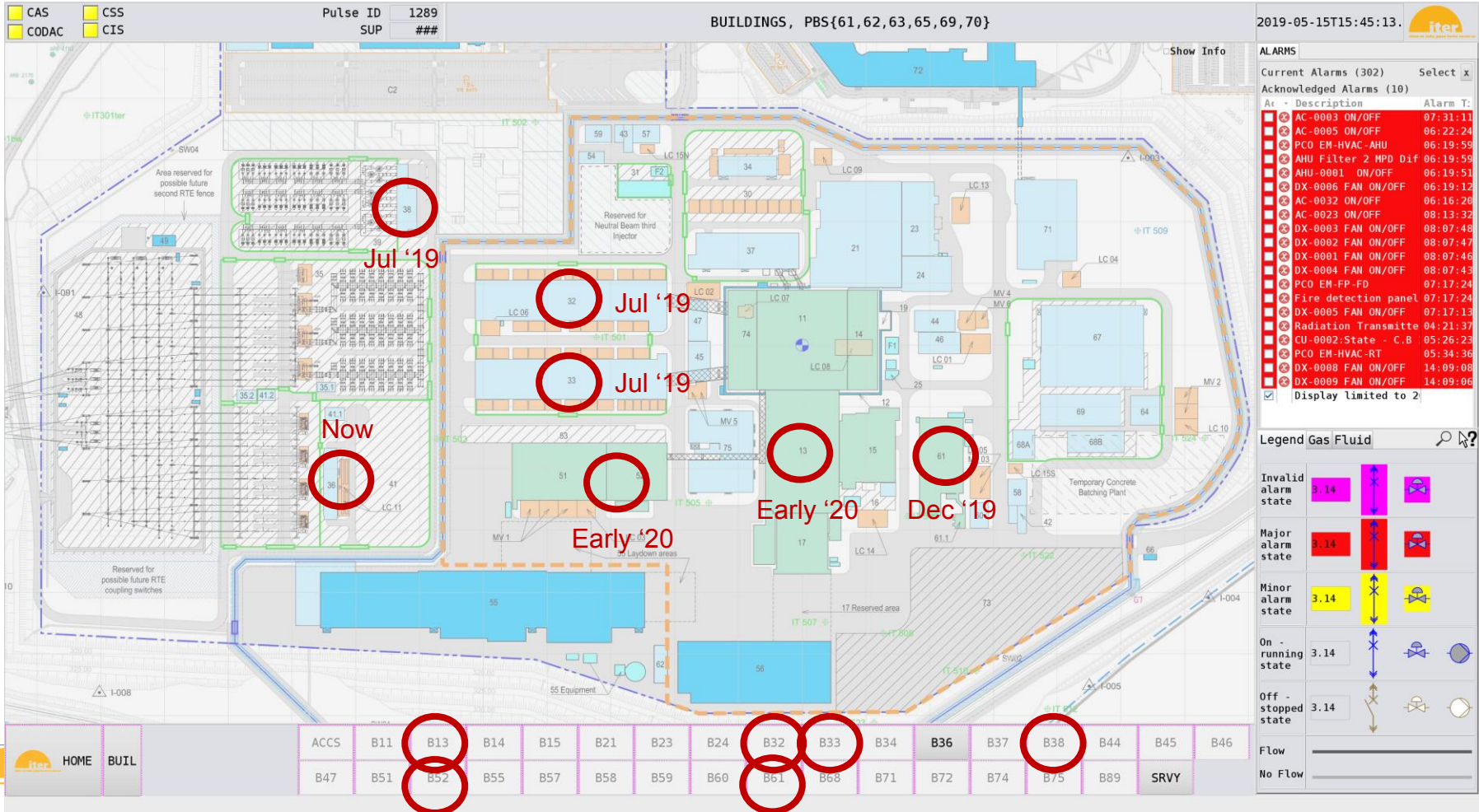
Jan '20

Feb '20

Building Services

- HVAC, electricity, lighting, compressed air, demineralized water, fire monitoring..., but also some instrumented occupational safety functions ...
- Delivered as part of buildings by Europe

Coming up for Building Services...



ALARMS		
Current Alarms (302) Select x		
Acknowledged Alarms (10)		
Ac	Description	Alarm T:
AC-0003	ON/OFF	07:31:11
AC-0005	ON/OFF	06:22:24
PCO EM-HVAC-AHU		06:19:59
AHU-Filter 2 MPD Dif		06:19:59
AHU-0001	ON/OFF	06:19:51
DX-0006	FAN ON/OFF	06:19:12
AC-0032	ON/OFF	06:16:20
AC-0023	ON/OFF	08:13:32
DX-0003	FAN ON/OFF	08:07:48
DX-0002	FAN ON/OFF	08:07:47
DX-0001	FAN ON/OFF	08:07:46
DX-0004	FAN ON/OFF	08:07:43
PCO EM-FP-FD		07:17:24
Fire detection panel		07:17:24
DX-0005	FAN ON/OFF	07:17:13
Radiation Transmitter		04:21:37
CU-0002:State - C.B		05:26:23
PCO EM-HVAC-RT		05:34:36
DX-0008	FAN ON/OFF	14:09:08
DX-0009	FAN ON/OFF	14:09:06

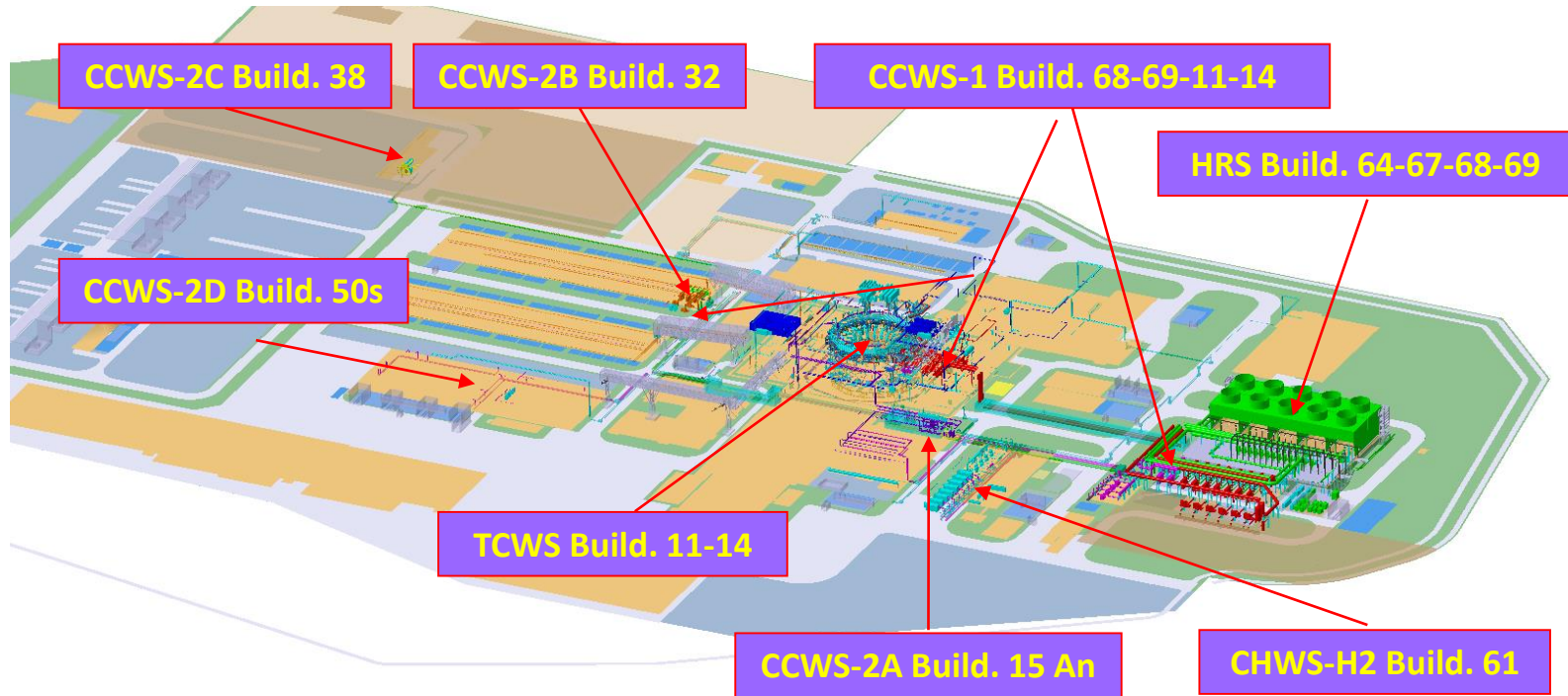
Display limited to 2

Legend Gas Fluid

Invalid alarm state	3.14	
Major alarm state	3.14	
Minor alarm state	3.14	
On - running state	3.14	
Off - stopped state	3.14	
Flow		
No Flow		

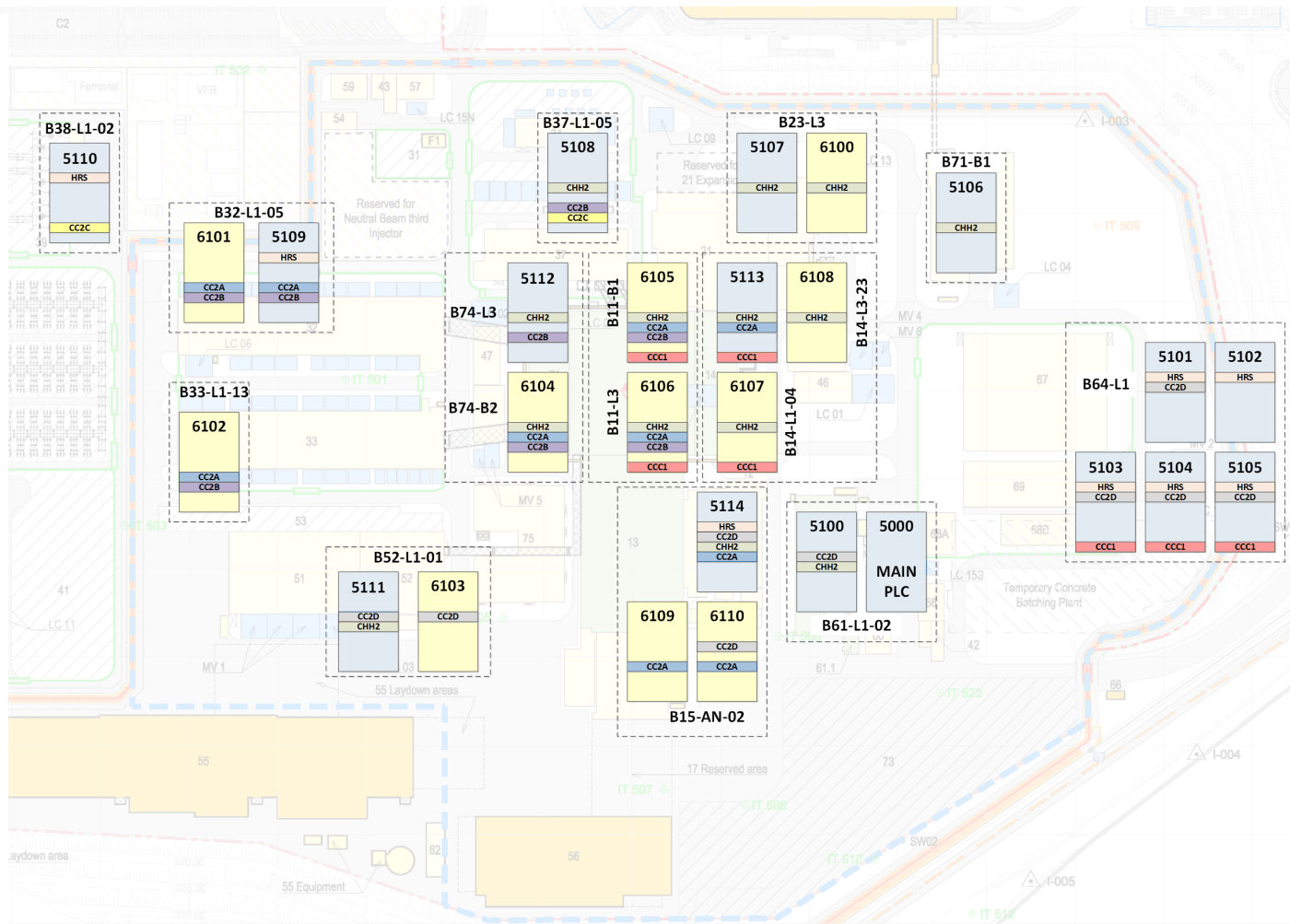
Secondary Cooling Water

- High level design as of 2017
- Multiple component cooling water loops, chilled water loops and heat rejection

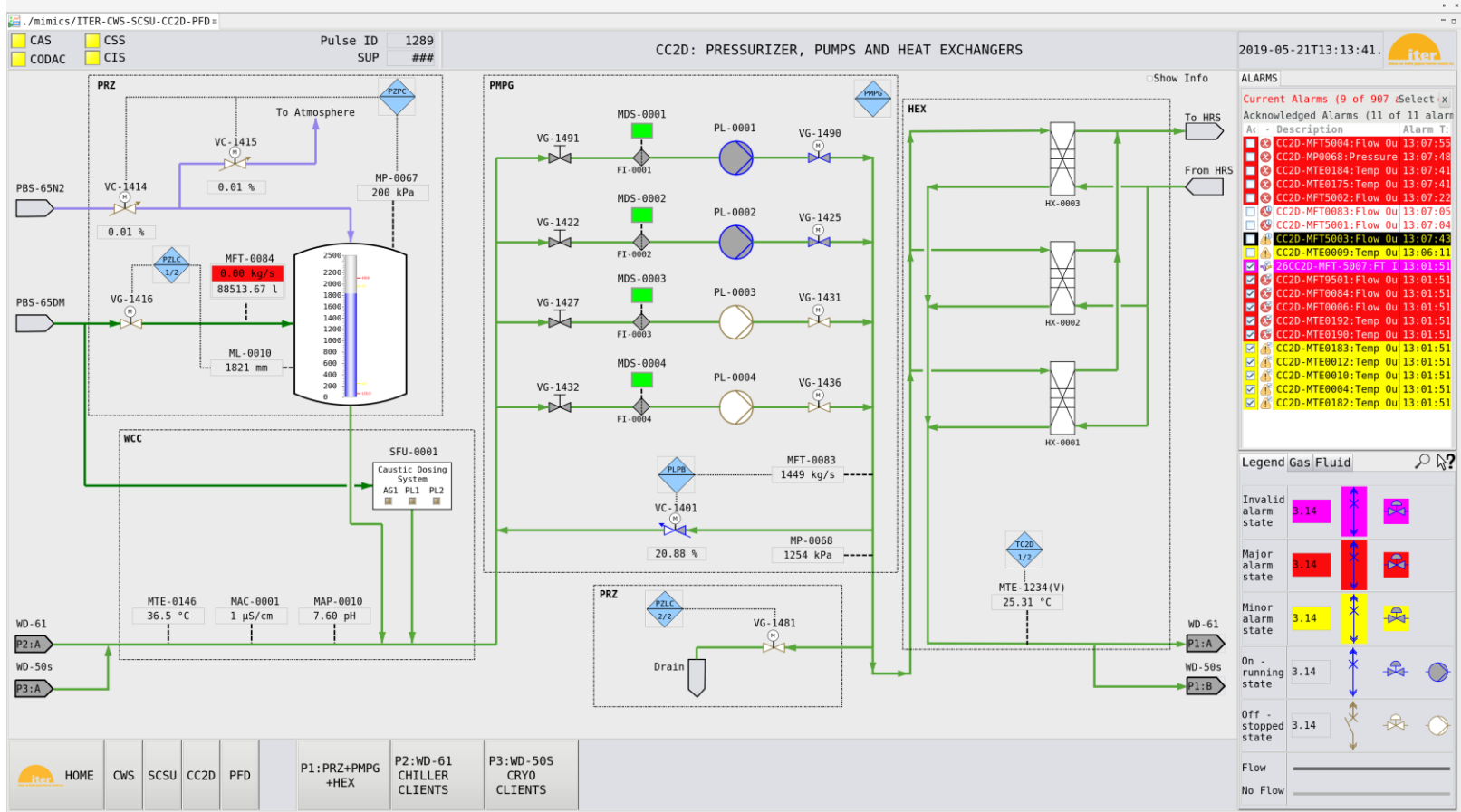


Secondary Cooling Water

- 16 blue cubicles delivered by India
- 11 yellow cubicles in IO scope to interface clients
- Most cubicles interface to multiple loops
- Software for HRS, CC2D and CHH2 developed and under test
- Single PLC controlling everything
- Commissioning loop X when loop Y operating ???




Secondary Cooling Water

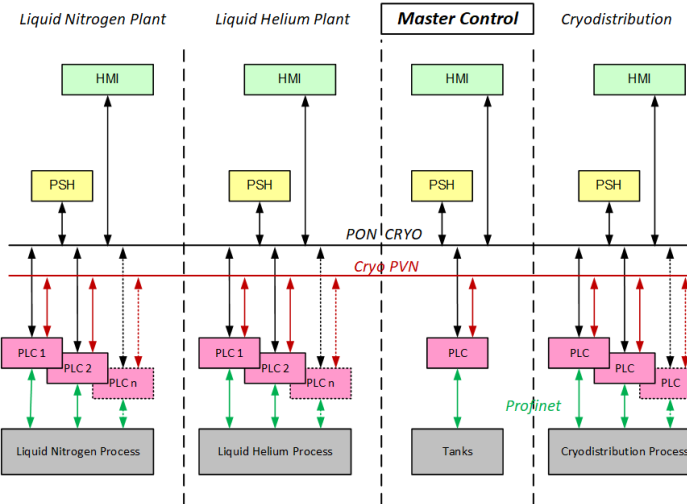
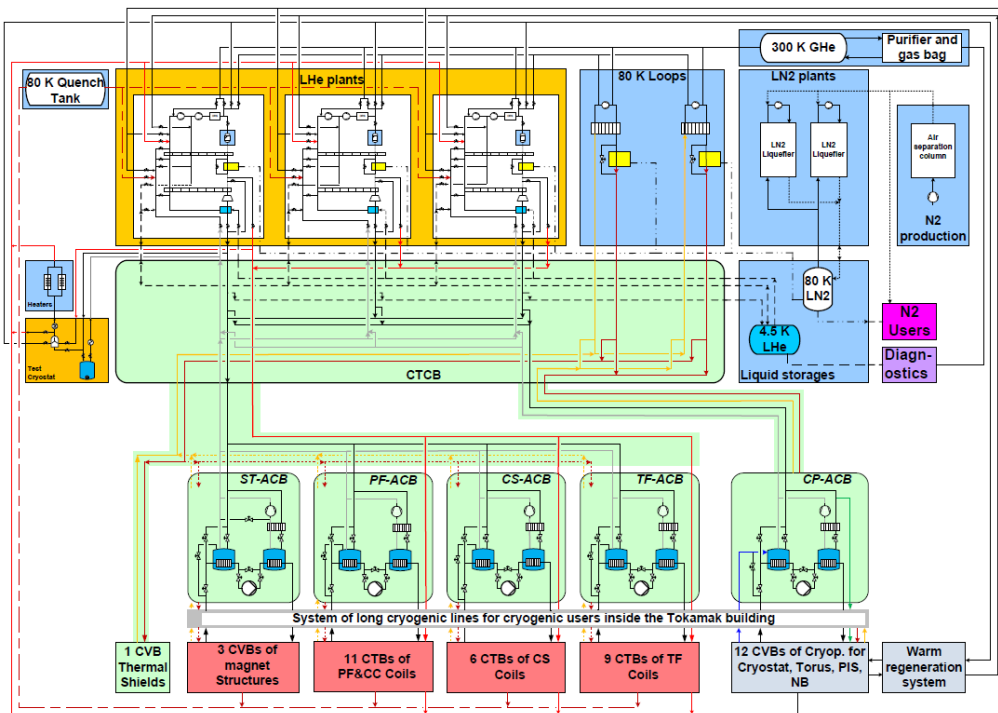


Coming up for Secondary Cooling Water...

- Lab tests of “early operation” for cryoplant (now)
- Install B61 TCR and establish external connectivity (late 2019)
- Start of commissioning for “early operation” in B61 (late 2019)
- Plan for version 2 to separate cooling loops (multiple PLC’s, rewiring,...)

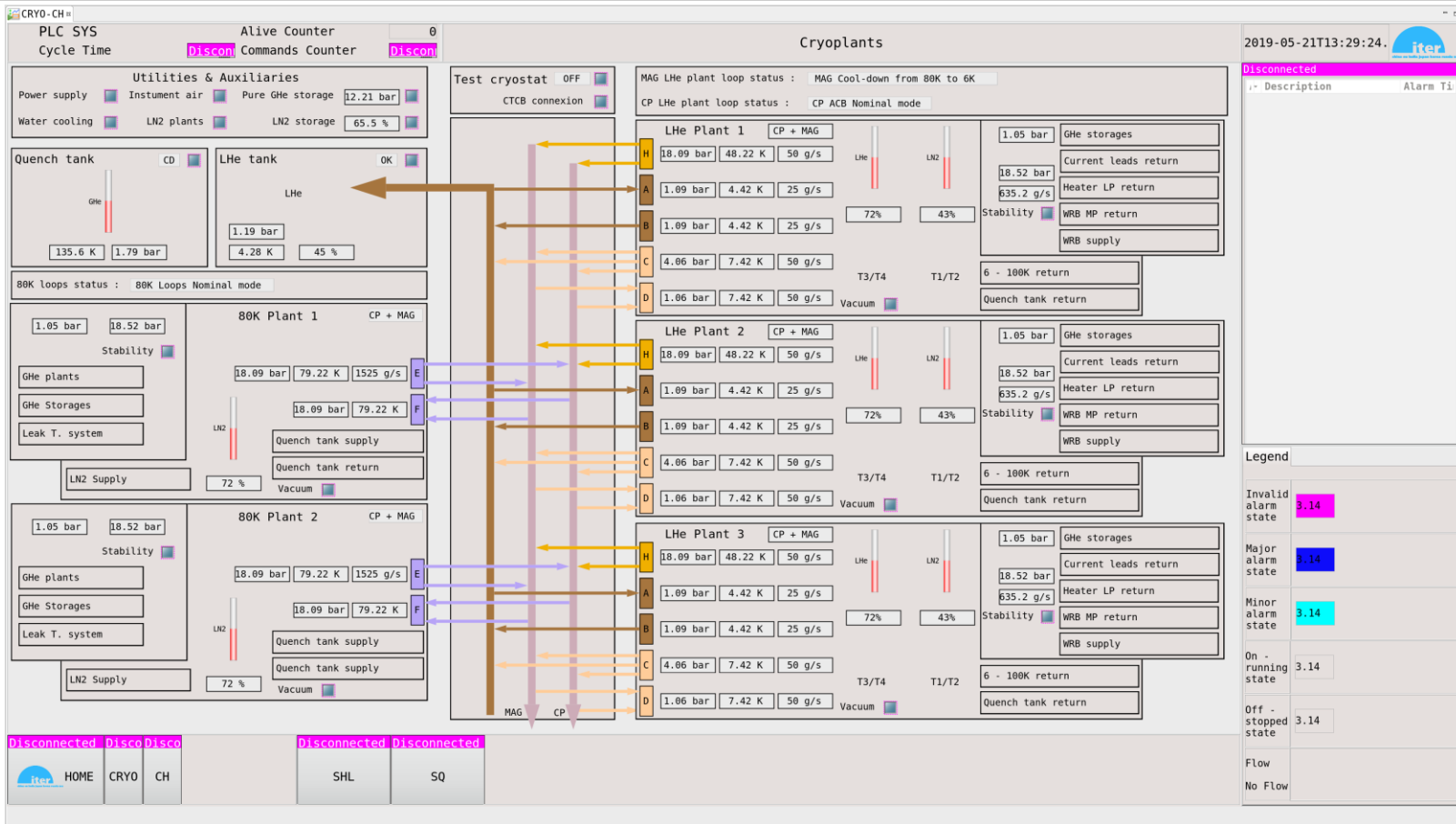
 HOME	BUIL	CRST	CRYO	CTRL	CWS	D1	D2	EC	FUEL	IC
	MAG	NB	PFCS	RAD	RH	SAFE	TRIT	UTIL	VAC	VV

Cryogenics




- Good mapping between suppliers (Europe, India, IO) and systems
- Common library
- LN2 plant control FAT two years ago
- Strong control group, but main developer just left

Cryogenics

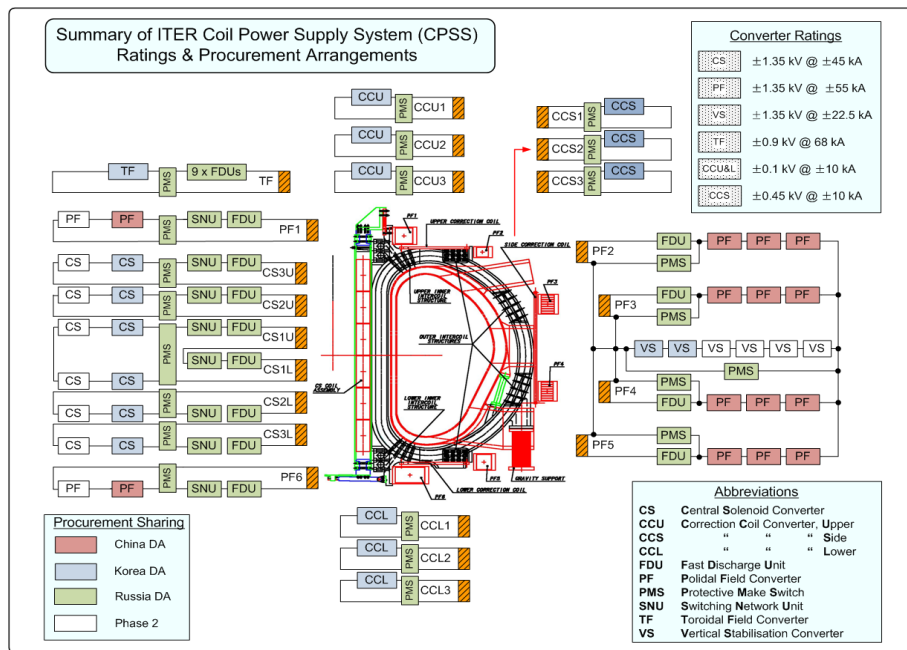


Coming up for Cryogenics...

- Install B52 internal network, TCR and establish external connectivity (early 2020)
- Start of commissioning in B52 (2020)

 HOME	BUIL	CRST	CRYO	CTRL	CWS	D1	D2	EC	FUEL	IC
	MAG	NB	PFCS	RAD	RH	SAFE	TRIT	UTIL	VAC	VV

Coil Power Supplies and Reactive Power Compensation (RPC)



- Installations of transformers and converters started (18 months)
- Many control FAT's done, some more to come
- High Performance Networks (SDN, DAN)
- Active control group

Coil Power Supplies

CAS CSS
CODAC CIS

Pulse ID 1289
SUP ###

COS OPSTATE	Executing	P50S OPSTATE	Executing
COS OPREQ	Execute	P50S OPREQ	GoToExecutingLine
MAG COS OPSTATE	Executing	CV0S OPSTATE	Running
MAG COS OPREQ	Execute	CV0S OPREQ	GoToRUN

MAG-PFCS-VS

2017/11/12 23:31:58

CONVERTER STATUS

Converter Cause

Converter Status #1

Converter Status #2

Converter Status #3

Converter Status #4

Bypass / Bridge Status

DC Reactor Status

Error Code Help

Reference

Current Reference

Voltage Reference

Show Info

Plant Interlock Controller

VS1-1 Convert Fault Power Permit

Non Critical Interlock Data

Main Power	NONE	OCTC2 TAP	NONE
Failure	NONE	Position - HIGH	NONE
B-H RELAY TRIP	NONE	OCTC2 TAP	NONE
DEVICE 1TRIP	NONE	TAP Changer in	NONE
DEVICE 2TRIP	NONE	OCTC2 Operation	NONE
DTI Temp. TRIP	NONE	Back-up Power	NONE
WTI TRIP(2V1)	NONE	Failure	NONE
WTI TRIP(2V2)	NONE	Fan Overload	NONE
400V Under	NONE	Failure	NONE
Voltage Failure	NONE	AC CP Failure	NONE
230V Under	NONE	LCP H&L Failure	NONE
Voltage Failure	NONE	LCP DOOR OPEN	NONE
Source Out	NONE	B-H RELAY ALARM	NONE
Signal of OCTC1	NONE	OIL Lv Low Alarm	NONE
Source Out	NONE	OIL Lv High Alarm	NONE
Signal of OCTC2	NONE	DTI Temp. Alarm	NONE
MDU Local/Remote	NONE	WTI(2V1) Alarm	NONE
Signal of OCTC1	NONE	WTI(2V2) Alarm	NONE
OCTC1 TAP	NONE	Position - LOW	NONE
OCTC1 TAP	NONE	Position - HIGH	NONE
OCTC1 TAP	NONE	Position sync	NONE
OCTC1 TAP	NONE	Pump Motor	NONE
OCTC1 TAP	NONE	Overload Alarm	NONE
OCTC1 TAP	NONE	Cooler power Auto	NONE
MDU Local/Remote	NONE	Transfer	NONE
Signal of OCTC2	NONE	Fan Overload	NONE
OCTC2 TAP	NONE	Failure	NONE
Position - LOW			

VS1-1 VS2-1

Description **Alarm Tr**


Status Trends Controls PCS Sca

HOME
MAG
PFCS
VS

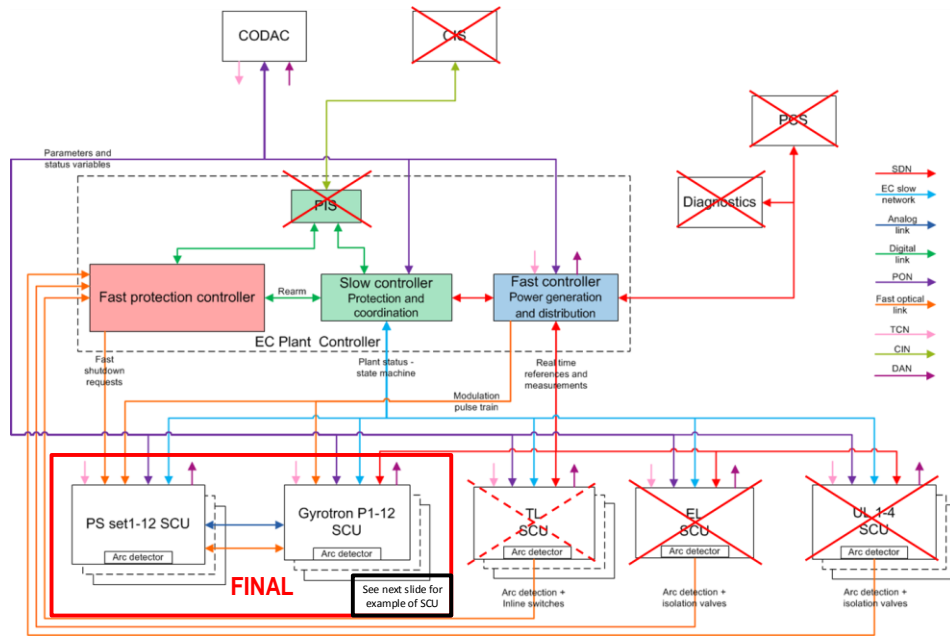
dummy

Coming up for Coil Power Supplies and Reactive Power Comp...

- Install B30's network, TCR's and establish external connectivity (now). To first service B32, B33, B38 BMS and later RPC and CPSS
- Mechanical installations until end of 2020
- Lab tests in 2020
- Start commissioning Reactive Power Compensation in 2020 and Coil Power Supplies in 2021

 HOME	BUIL	CRST	CRYO	CTRL	CWS	D1	D2	EC	FUEL	IC
	MAG	NB	PFCS	RAD	RH	SAFE	TRIT	UTIL	VAC	VV

Electron Cyclotron Heating and Current Drive



- Many different suppliers with Europe responsible control system integration
- Falcon gyrotron test facility in Lausanne in operation since two years
- High Performance Networks

Electron Cyclotron Heating and Current Drive

TEST-AUX-TDK-Lambda 83

CAS CSS
CODAC CIS

Pulse ID 1289
SUP ###

TEST-AUX-TDK

2019/05/21 16:48:17.801

Collector DC Coil PS

Status
Measured Voltage 0.00 V V/I Mode
Measured Current 0.00 A Current MW 0.00 A

Alarms
Alarm Program error
Overvoltage Wrong command
Overtemperature Buffer overflow
AC fault Wrong voltage
Foldback Wrong current

Commands
Armed Arm Release Cancel

Foldback Protection
Armed

Local / Remote
Local Remote

Output
PS On Start Stop
Output On On Off

Configurations
Readback Active New
SP Current 10.00 A 0.00 A 10 Apply
SP Voltage 24.98 V 0.00 V 24.99 Apply
OverVoltage Limit 29.00 V 0.00 V 29.9 Apply
UnderVoltage Limit 0.00 V 0.00 V 0 Apply

Communication Diagnostics
Initializing Starting/Stopping Serial wrong command Reset Com Fault
Monitoring Configuring Serial communication fault

ManualRequest **Go To Ready** **Load**
ManualRelease **Go To Idle** **Reset**
RELEASED ALARM To MAIN OPI

Gun Coil PS

Status
Measured Voltage 0.00 V V/I Mode
Measured Current 0.00 A Current MW 0.00 A

Alarms
Alarm Program error
Overvoltage Wrong command
Overtemperature Buffer overflow
AC fault Wrong voltage
Foldback Wrong current

Commands
Armed Arm Release Cancel

Foldback Protection
Armed

Local / Remote
Local Remote

Output
PS On Start Stop
Output On On Off

Configurations
Readback Active New
SP Current 0.20 A 0.00 A 0.2 Apply
SP Voltage 14.97 V 0.00 V 14.98 Apply
OverVoltage Limit 16.00 V 0.00 V 16 Apply
UnderVoltage Limit 0.00 V 0.00 V 0 Apply

Communication Diagnostics
Initializing Starting/Stopping Serial wrong command Reset Com Fault
Monitoring Configuring Serial communication fault


ManualRequest **Go To Ready** **Load**
ManualRelease **Go To Idle** **Reset**
RELEASED ALARM To MAIN OPI

Legend
Invalid alarm state 3.14
Major alarm state 3.14
Minor alarm state 3.14
On - running state 3.14
Off - stopped state 3.14
Flow No Flow

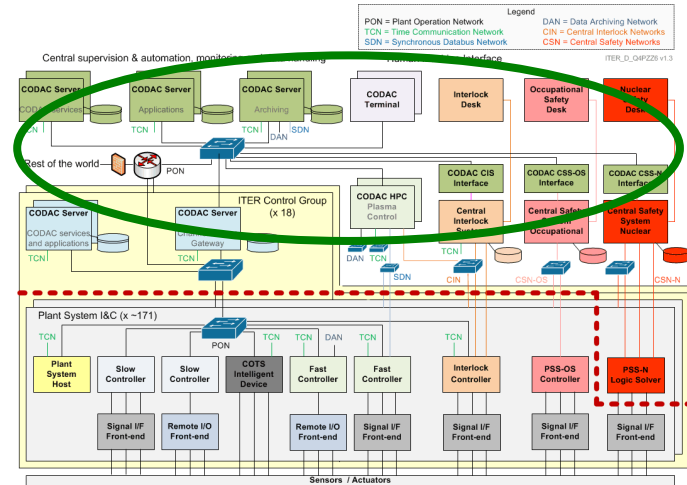
HOME TEST AUX

Coming up for Electron Cyclotron Heating and Current Drive...

- Install B13/B15 network, TCR's and establish external connectivity 2020.
- Waiting for B15 Ready For Equipment to start mechanical installations
- Continue tests at Falcon (Europe)
- Lab tests in 2020
- Start commissioning Electron Cyclotron Heating in 2021

 HOME	BUIL	CRST	CRYO	CTRL	CWS	D1	D2	EC	FUEL	IC
	MAG	NB	PFCS	RAD	RH	SAFE	TRIT	UTIL	VAC	VV

- And then we move into the Tokamak Complex



- And build functionality on top

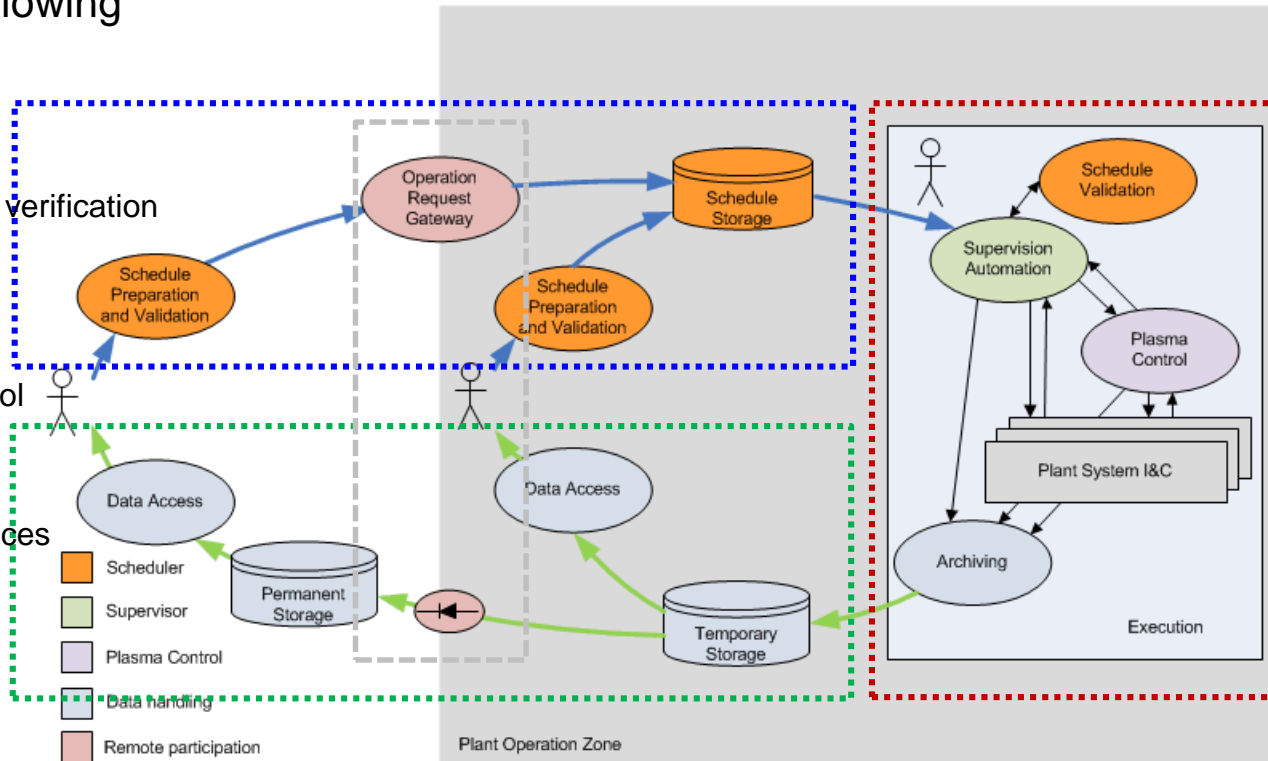
	BUIL	CRST	CRYO	CTRL	CWS	D1	D2	EC	FUEL	IC
	MAG	NB	PFCs	RAD	RH	SAFE	TRIT	UTIL	VAC	VV

CODAC Operation Applications

The software suite for supporting plant system commissioning, tokamak operation and plasma experiments by delivering the following functions:

Exploring EPICS 7 for “Execution” (Bauvir, Neto this afternoon)

- Preparation
 - Pulse configuration, validation & verification
- Execution
 - Supervision & Automation
 - Plasma real-time feedback control
- Analysis
 - Data archiving, access and services
- Remote participation



Conclusions

- ITER Control System is in operation
- Over the coming years more and more systems will be commissioned and put into operation
- Serious work started using EPICS 7
- Many control system job opportunities coming up <https://www.iter.org/jobs>