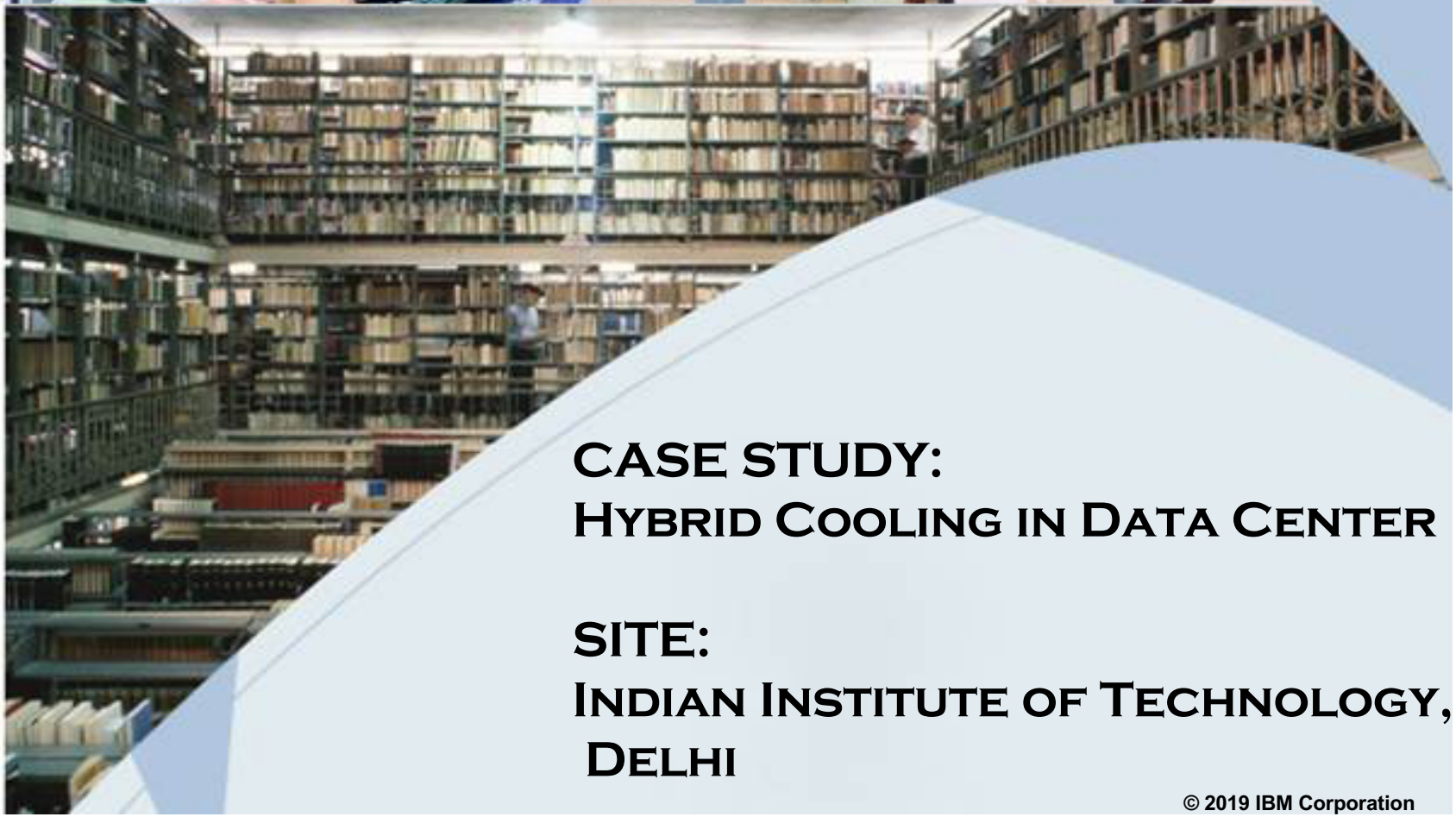


CASE STUDY:
Hybrid Cooling in Data Center

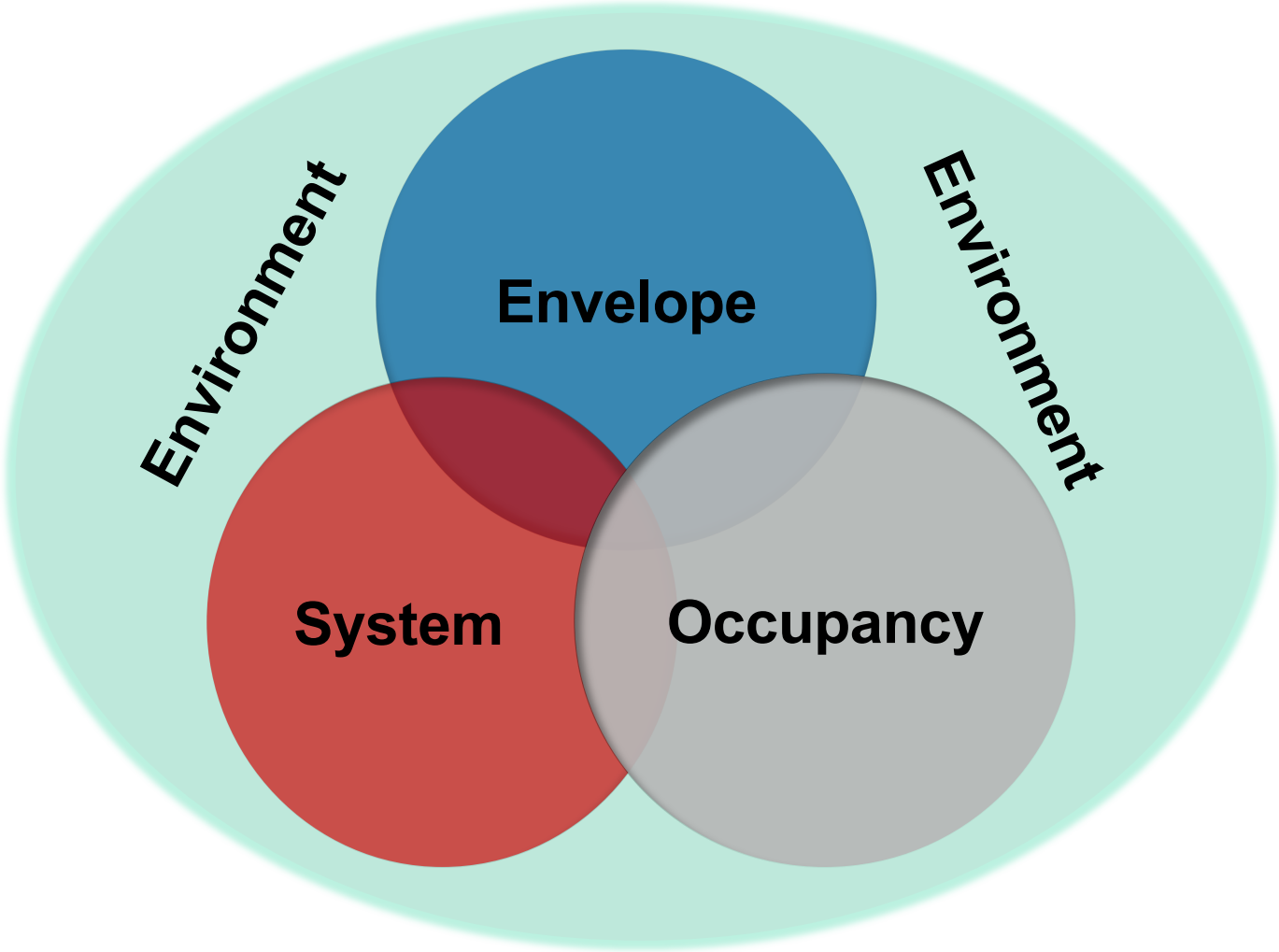
SITE:
Indian Institute of Technology, Delhi

Agenda

- ***Business Requirement***
- ***Design overview: Efficiency and Automation***
- ***Optimization***
- ***Results***

BUILDING PHYSICS

DATA CENTER BUILDING



OPERATING HOURS AND DBT

DBT verse Operating Hours									
BIN	Ahmedabad	Delhi	Bangalore	Chennai	Calcutta	Nagpur	Goa	Triv	Mumbai
10	13	443	0	0	0	10	0	0	0
12.8	61	541	0	0	65	84	0	0	1
15.6	301	606	135	0	272	263	0	0	5
18.3	591	625	549	0	523	575	3	0	136
21.1	626	738	2052	186	646	704	201	3	571
23.9	653	754	2271	775	830	1025	865	549	850
26.7	1395	980	1819	1979	1565	1979	2796	3647	1911
29.4	1848	1365	1090	2760	2614	1520	3057	2784	3047
32.2	1530	1200	575	1892	1352	1110	1552	1585	1809
35.0	913	823	253	877	709	567	283	191	421
37.8	486	410	16	245	170	393	3	1	9
40.6	243	211	0	41	14	295	0	0	0
43.3	97	63	0	5	0	190	0	0	0
46.1	3	1	0	0	0	45	0	0	0

Indian Institute of technology (IIT) Delhi Requirements

Business Requirement

IIT Delhi wanted to setup a 1Peta Flop High Performance Computing DC and DRC in its campus. The purpose was to undertake research work for new product development for Indian industries, weather modeling, cloud computing etc

- **DC and DRC to be built as a retrofit case in limited space in two building of around 4000 Sq ft with White space of 1200 sq ft**
  - ***Maximum white Floor space efficiency***
  - ***Minimum floor space for indoor and outdoor non-IT equipment***

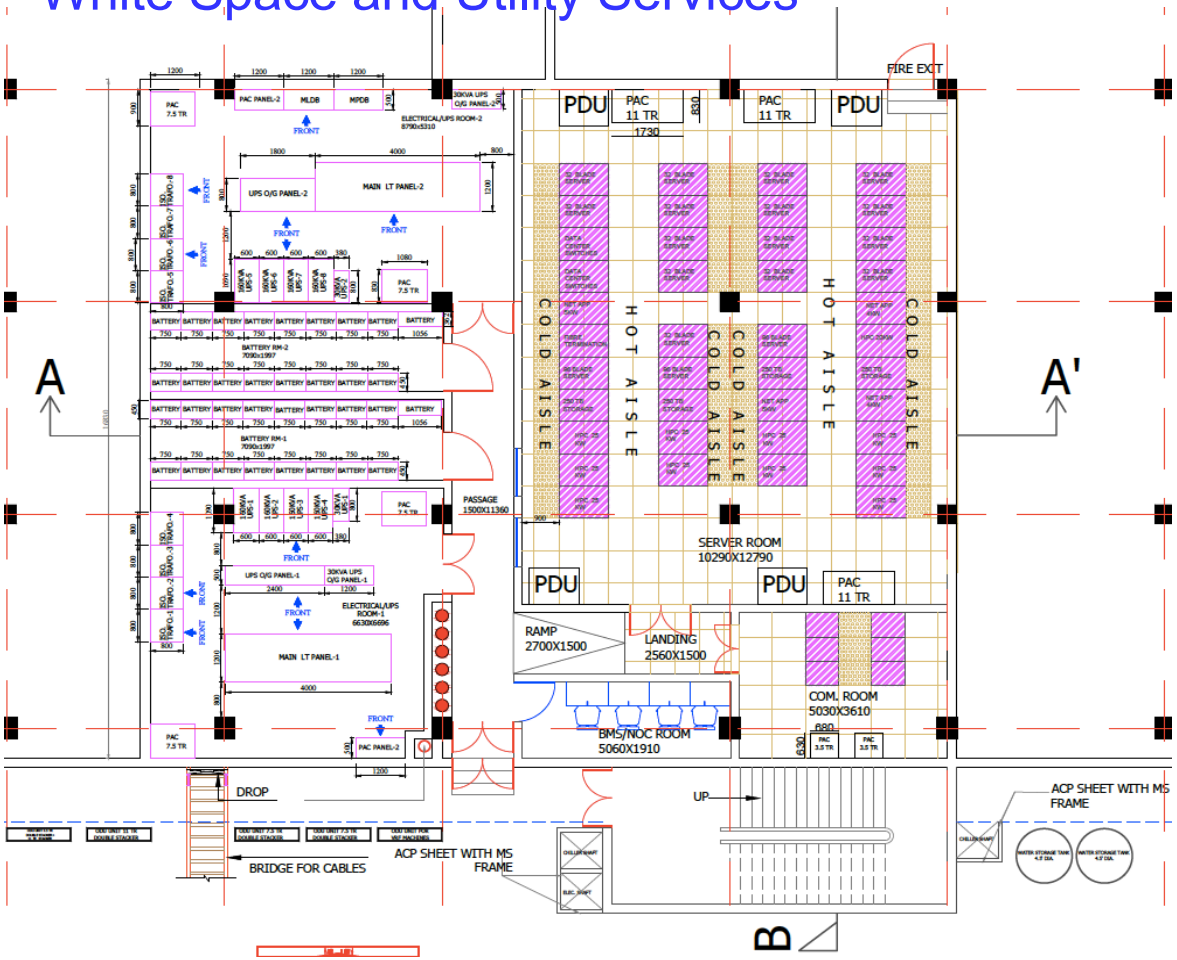
- **Best possible energy efficiency** (lowest PUE) possible in Delhi ensuring lowest carbon footprint . PUE less than 1.4 in DC and DRC to be less than 1.5 for 100% IT Load as per Advanced Green Grid (From servers)

- **Automated Data centre** operations and Real time energy consumption measurements as per ASHRAE TGG

- Rack density 25KW in DC (40 racks in DC) for HPC servers and 8KW in DRC (11 racks in DRC)
- Tier Compliance: **Uptime Institute Tier III (w/o certification)**
- All HVAC equipment to be selected based **on ASHRAE, n=20 years (max) condition** as per Uptime requirement.
- Cooling Compliances: ASHRAE TC 9.9-2011 or latest
- Fire and Security compliances: NFPA 2010 or Latest
- Data Centre Maturity Model compliance: Green Grid 2011
- DCIM software and BMS integration
- Provision for seamless integration to future load expansion of additional 50% IT Load.
- SLA: 24 x 7 x 365 support and conforming to **uptime of 99.982%** on monthly basis for a period of 5 Years

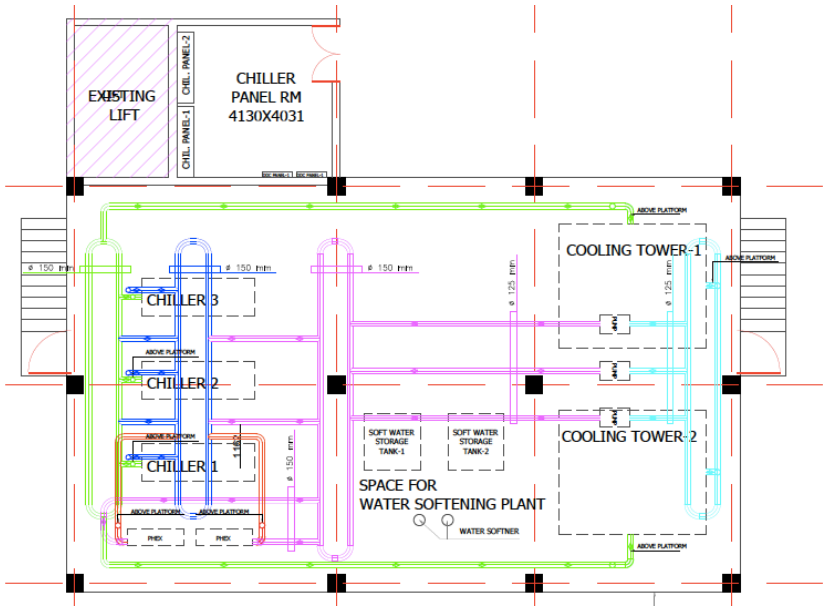
SITE PLAN

White Space and Utility Services



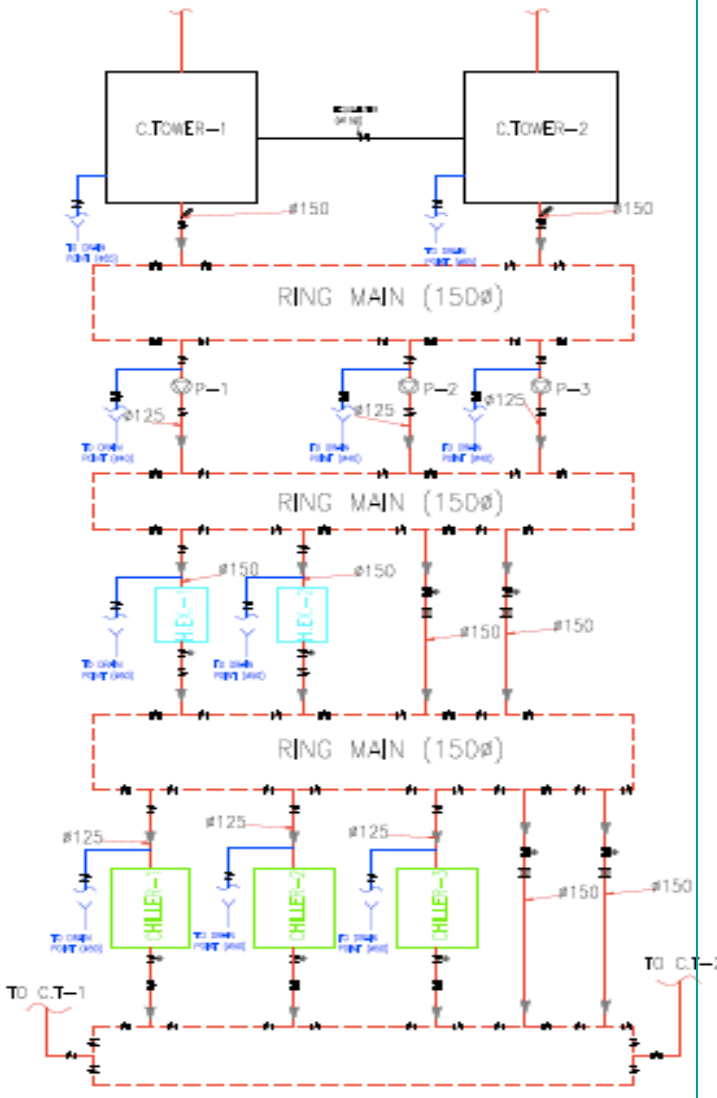
Ground Floor

Chiller Plant room and CT

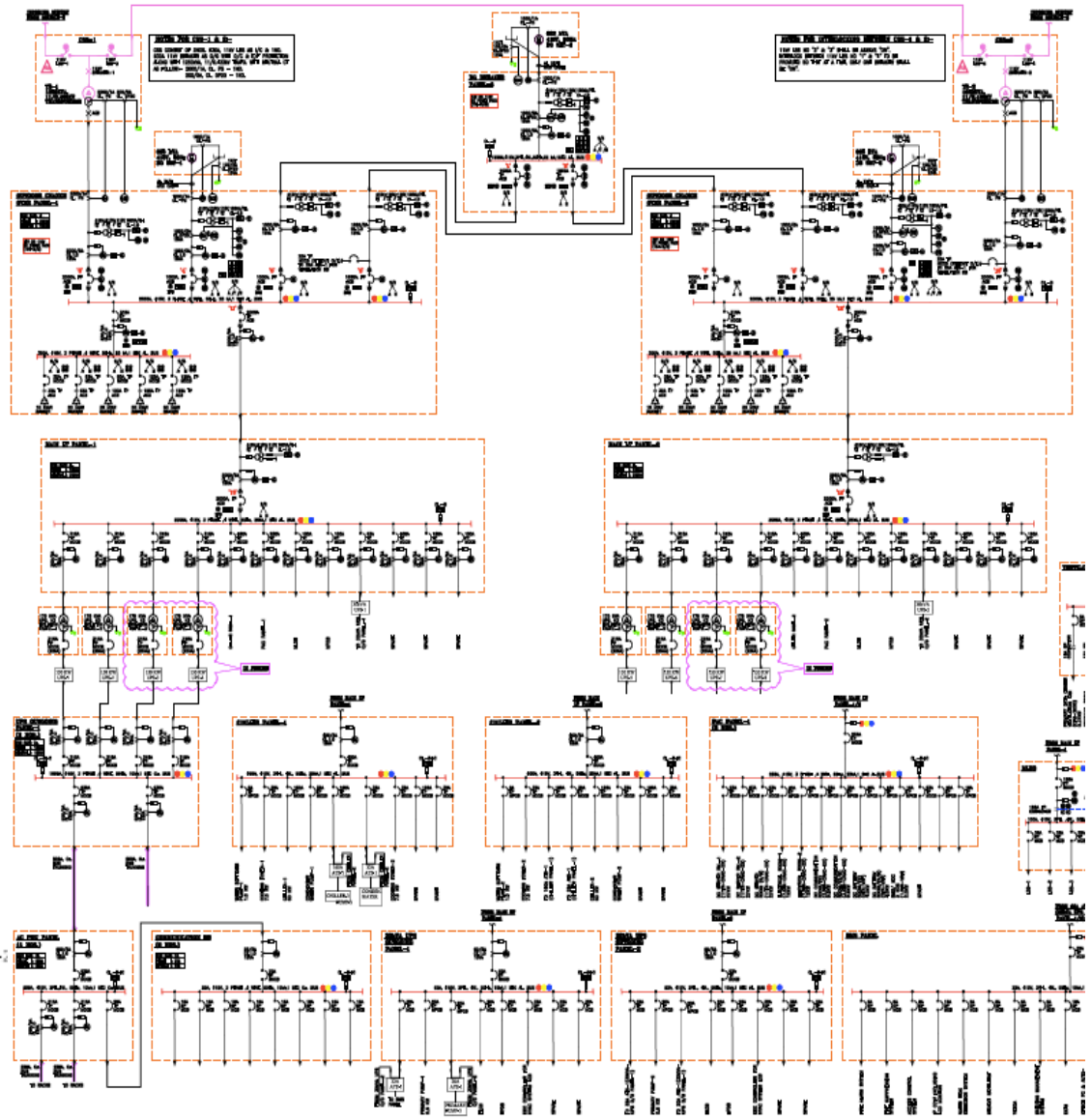


Terrace

SYSTEM DESIGN



HVAC



Electrical

Design considerations for energy efficiency, PUE/DCiE, innovative approaches for low carbon footprint

PERFORMANCE								
Requirement	Rating	Load						Remarks
	Specify Rating	25%	30%	40%	50%	75%	100%	
Modular UPS (DC) 150 KW x 2x2	150 KW	96.70%	96.70%	96.70%	96.70%	96.70%	96.30%	Efficency will remain same using VMMS feature
Modular UPS (DRC) 80 KW x2	80 KW	96.70%	96.70%	96.70%	96.70%	96.70%	96.30%	Efficency will remain same using VMMS feature
30 KVA UPS (DC) x 2	30 KVA	98%	98%	98%	98%	98%	98%	ECO MODE
5 KVA UPS (DRC) x 2	5 KVA	87%	87%	90%	90%	91.30%	92.50%	ON-LINE

- Highly efficient UPS system in N+N configuration
- Uninterrupted power management technology
- PDU Losses restricted to 1.5%
- Distribution Transformer losses restricted to 1.2%
- Lighting sensors and LED Lights for emergency lighting system
- Dynamic PUE monitoring tools (DCiM)

- Water cooled Chillers with highest possible chilled water temperature **(19˚C/26 ˚C)** for higher energy efficiency and max free-cooling, Low approach cooling tower.
- **IBM Patented Design: Water side Economizers** (Plate type heat exchangers and Cooling Towers) for Free /Pre-cooling
- **Primary Variable premium** efficiency pumping systems
- **Chiller water ΔT is 7°C, e**nsuring lesser flow rates and pumping energy
- **Chiller plant Manager** for automated Chiller operations
- **Thermal storage tanks** (2*5 min) to avoid Thermal Run away.
- **RDHX units for Very High Density Racks without CDU (**for 10KW to 25KW racks). Nil Energy consumption
- **Inverter Scroll PAC** cooling in DC for no RDHx racks less than between 4-7 KW and Primary cooling in DRC. **Lowest iKW/TR**
- **VRV systems for comfort cooling for support areas like BMS, NOC.(Low ikw/Tr)**
- **Concurrent maintainability Topology** for all HVAC equipment including valves as per Uptime standards for concurrent maintainability
- **Air side Free Cooling** for Utility Rooms
- All HVAC equipment to be selected based on **ASHRAE, n=20 years (max)** condition as per Uptime requirement.

KEY ASPECTS OF MECHANICAL SYSTEM

Total free cooling hours based on 26/19 ˚C chilled water temperature is 455328.52 TR HR which amounts to 36 % of total cooling requirement

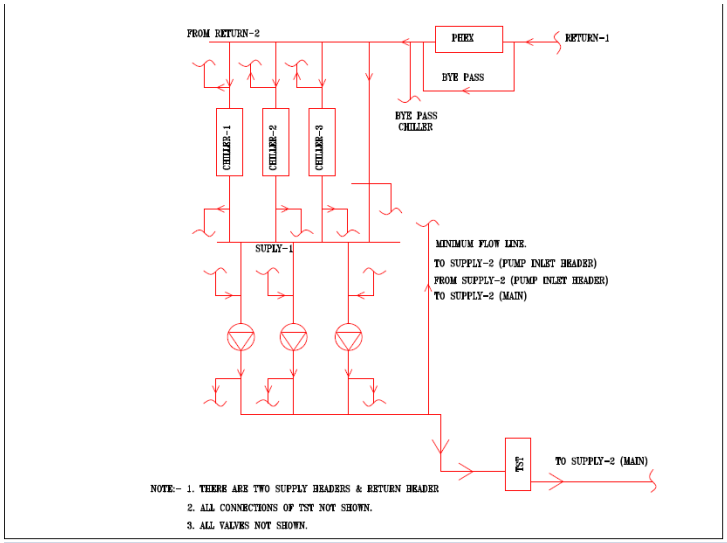


Fig 1

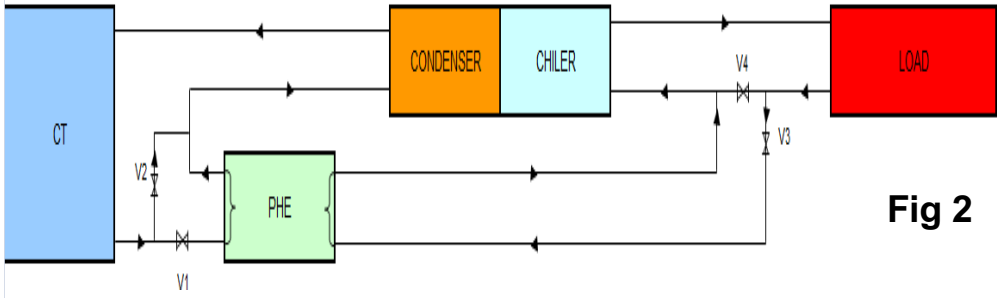


Fig 2

Case No.	Discription	Motorized Valve Status			
		V1	V2	V3	V4
Case No 1	Only Mechanical Cooling	Close	Open	Close	Open
Case No 2	Only Free Cooling	Open	Close	Open	Close
Case No 3	Mechanical and Free cooling	Open	Close	Open	Close

Variable speed pump for both CHW and CDW/Cooling Tower Pump

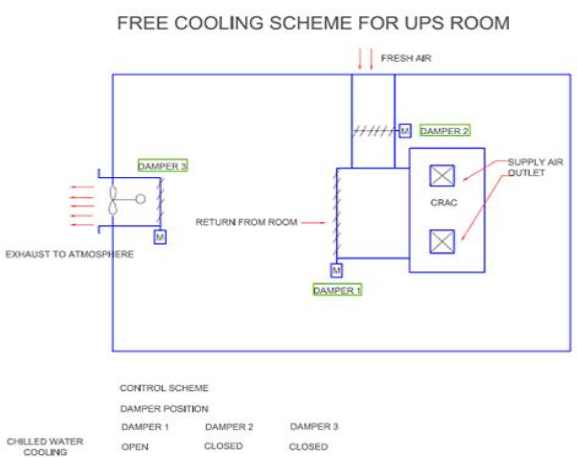
Free cooling TRH at 100% Load		
CITY		
UNITS FOR CALIBRATION		
Total Tonnage	144.24	TR
Chilled Water Inlet Temp	19	Deg C
Chilled Water Outlet Temp	26	Deg C
Chilled water Flow(USGPM)	62.31168	CMH
Tot Hrs of Mech.Cooling only	3968	Hours
Tot Hrs of Free Cooling only	1173	Hours
Tot Hrs of Mech+FC	3619	Hours
Total FC TR	**455,328.52**	TRH
Total Cooling Req in 1 yr	**1,263,542.40**	TRH
Total Equivalent .Hrs of FC	3156.742374	Hrs
% of Total Free Cooling/yr	36%	

Full Free Cooling: **1173 hours** , Free cooling will happen through cooling towers through plate heat exchanger.

Partial Free Cooling: **3619 hours** , cooling requirement reduces proportionately. Thereby further increase in energy efficiency.

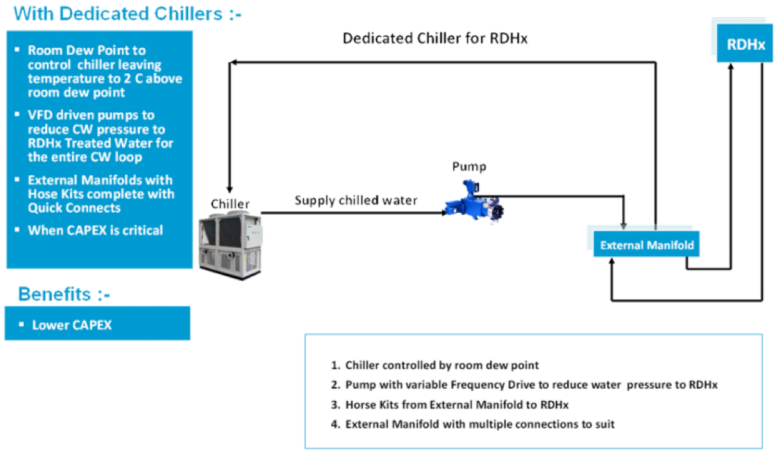
Air Side Free Cooling For Ups/Electrical Room

- In the UPS room and Electrical room: **Air side free cooling** with the ambient temperature outside is 20 ˚C or less.
- The Free cooling fans will get activated by Enthalpy sensors (Temperature and Humidity). In this mode, Free cooling supply and exhaust units start operation..
- In Delhi/NCR the Free cooling hours **(temp less than 20 ˚C are estimated** as **2400** hours every year
- TR reduced from CRAC: **12 TR (28000 TRH)**



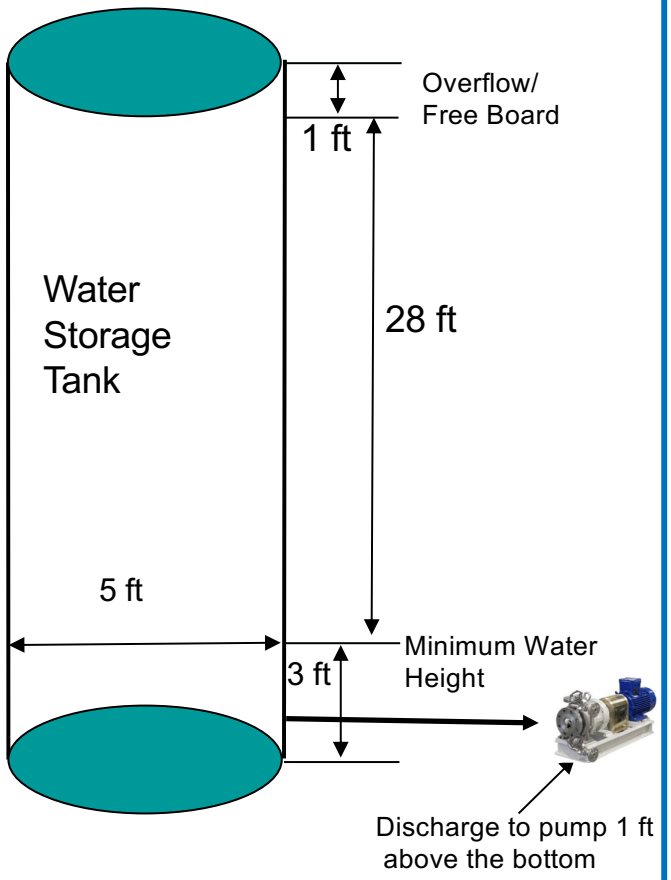
Rear Door Heat Exchanger (High Density Cooling)

- RDHx without CDU arrangement –
  - Since the CW temperature is quite high (19 ˚C and return 26 ˚C), CDU can be directly coupled to the chiller
  - This gives further energy savings due to elimination of CDU and its pumps
- To have humidity control and also Server room space load cooling, CRAC units @10TR has been proposed in Very High Density Server room



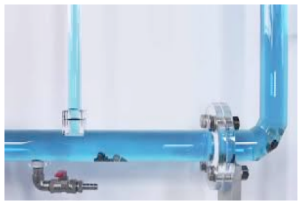
Thermal Storage and runaway Calculation

Two tanks each sizing 15550 liters along with water piping will hold the water totaling 63100 liters of water for taking care of **10 minutes of thermal runaway ***



4108
Gallon=7.47*28*2.5*2.5*22/7
4108 Gallon=15550 litter

Thermal Storage Tanks



water Quantity in chilled water pipe Line				
Diameter (mm)	Water , (lb/feet)	Water, (Kg,/Mt)	Length R M	Water quantity, liter
100	5.45	8.13	320	2602
125	8.51	12.69	160	2030
150	12.26	18.28		
175	16.68	24.87		
200	21.79	32.49	150	4873.5
225	27.58	41.12		
250	34.05	50.77	300	15231
300	49.03	73.1	100	7310
Total Water Quantity				32047

Thermal Storage in water pipes

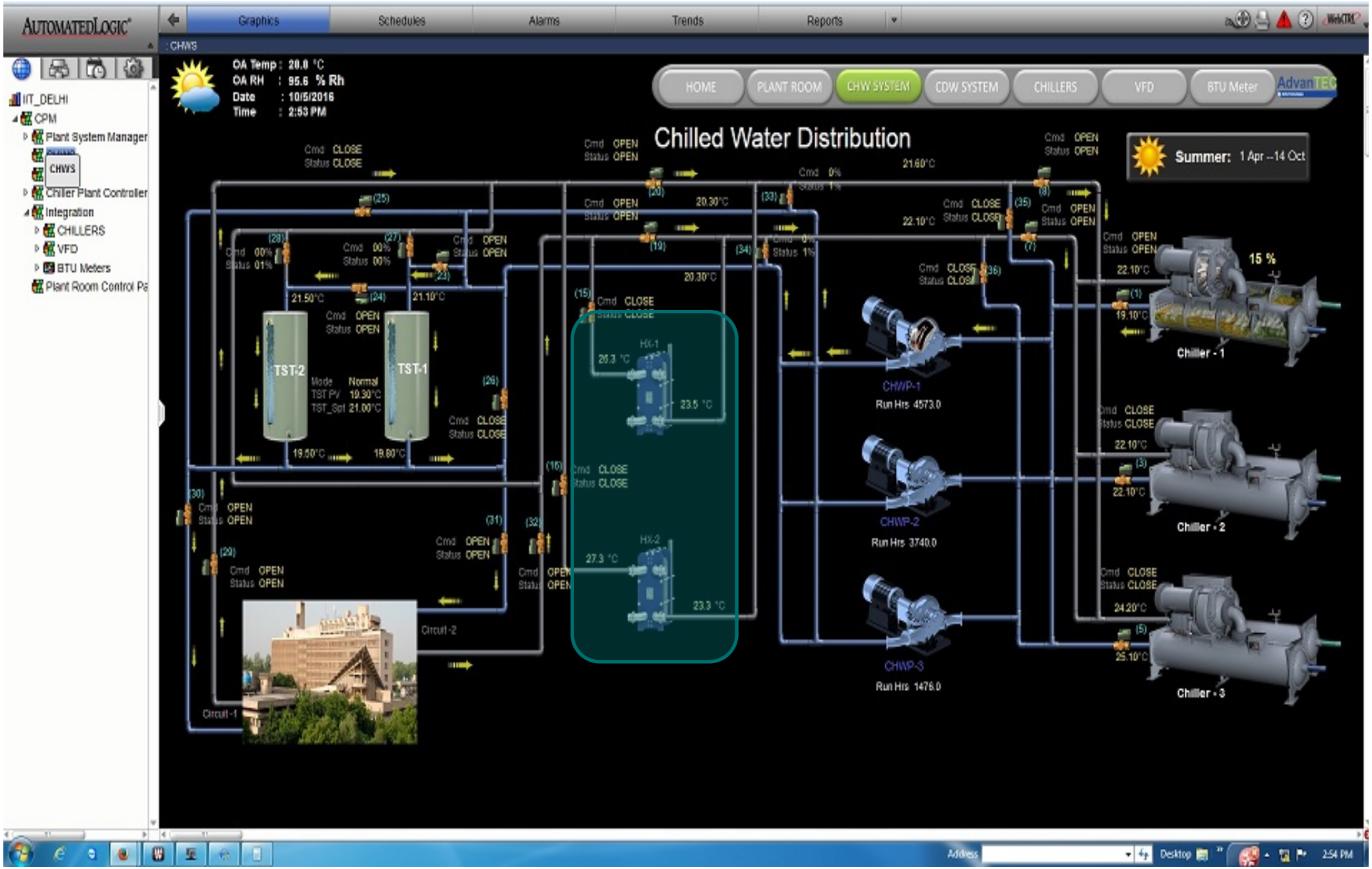
** Calculation are not for IIT project*

DC Automation

Instrumentation Landscape: ASHRAE TGG 2009

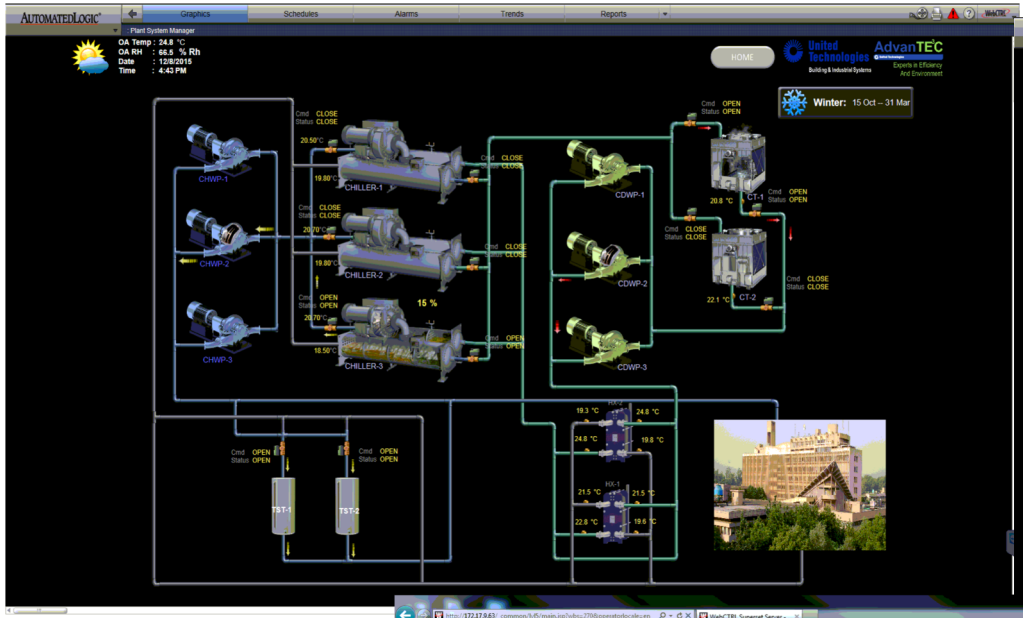
SL. NO.	DESCRIPTION	Data center QTY.	DR Center QTY.	Accuracy	Remarks DC	Remarks DRC
1	Immersion type water temperature sensor	21		(+/-0.25%) accuracy	2 for Thermal storage tank, Chilled water supply and return 2 each, 2 for condensor return temperature., 3 for cooling tower header, 10 for Heat exchanger,	Not Applicable
2	Level sensor for thermal storage	2		(+/-5%) accuracy	For all thermal Storage tank	Not Applicable
3	BTU Meter	2		(+/-2%) accuracy	for each Header of cooling pipes	Not Applicable
4	Air Flow velocity Meter	40	12	(+/-0.5%) accuracy	In each rack there shall be 300 mm x 300 mm x 85 mm flow straightner, which would be installed in front of rack with 2 numbers rapid averagee tube.	In each rack there shall be 300 mm x 300 mm x 85 mm flow straightner, which would be installed in front of rack with 2 numbers rapid averagee tube.
5	Flow meter (DG)	3		(+/-3%) accuracy	For 3 DG Set main fule line from tank to DG	Not Applicable
6	DPDT relay for fire dampers	14	6		for fire dampers	for fire dampers
7	Flame proof level switch	6		(+/-5%) accuracy	for DG Set Day tanks, total number of day tanks is 6, 2 each	Not Applicable
8	Room temperature/Humidity sensor probe	76	20	(+/-1%) accuracy	38 racks 2 probe each in DC, each temp/humidity assemble has 10 Probes	10 racks 2 probe each in DRC
9	Environmental Monitoring Unit	15	6	(+/-1%) accuracy	Each EMU can take upto 10 probes of adjacent racks ie 5 racks in a row, each rack with 2 probes, In DC 8 EMU for 38 Racks (10 racks in row 1 and 4 and 9 racks in middle rows) and 2 additional EMU (inbuilt sensors) for another 2 racks of 11 rack row, One EMU each in Elecctrical rooms, battery rooms, NOC/BMS room and coomunication room. collectively in Server room 10 no.s and 5 more for each room	each row one EMU and one additional for 6th rack (there are 2 rows hence 4 no.s), one in UPS room and one in electrical room
10	CO2 Sensor	8	4	(+/-1%) accuracy	for Human area and Electrcial room	for Human area and Electrcial room
11	H2 Sensor	2	2	(+/-1%) accuracy	for battery rooms	for battery rooms
12	pH meter	1		(+/-1%) accuracy	For Water Treatment plant	Not Applicable
13	TDS meter	1		(+/-2%) accuracy	For Water Treatment plant	Not Applicable
14	Outside temperaure sensor	2	1	(+/-1%) accuracy	At terrace for ambient and one for Air side free cooling in utility room	Outside premises of DR
15	Outside RH Sensor	2	1	(+/-1%) accuracy	At terrace for ambient and one for Air side free cooling in utility room	Outside premises of DR
16	Differntial Pressure Sensor	5		(+-2%) accuracy	for chilled water pipeline 2 no.s, primary pump 3 no.s,	Not Applicable
17	Water Level Switch	6		(+-5%) accuracy	For cooling tower sump, high low indication, there are 3 CT	Not Applicable
18	EA Meter/ Multi Function Meter	53	26	(+-1%) accuracy	For All MFM/EA Meters, inline to RFP requirement to provide MFM/EAM for and above 400 Amps Switchgear	For All MFM/EA Meters, inline to RFP requirement to provide MFM/EAM for and above 400 Amps Switchgear

CHWS CIRCUIT on CPM

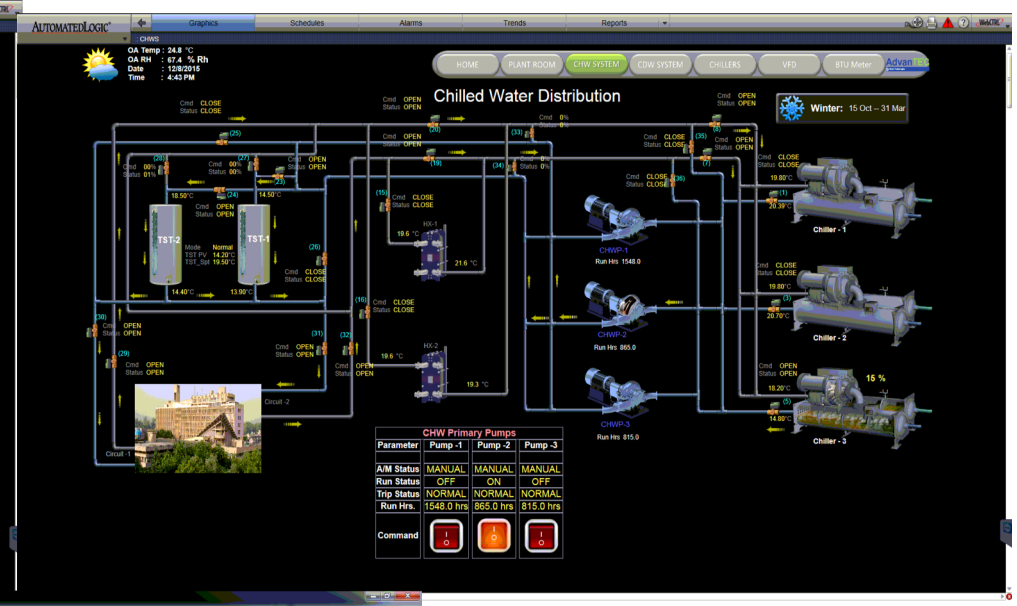


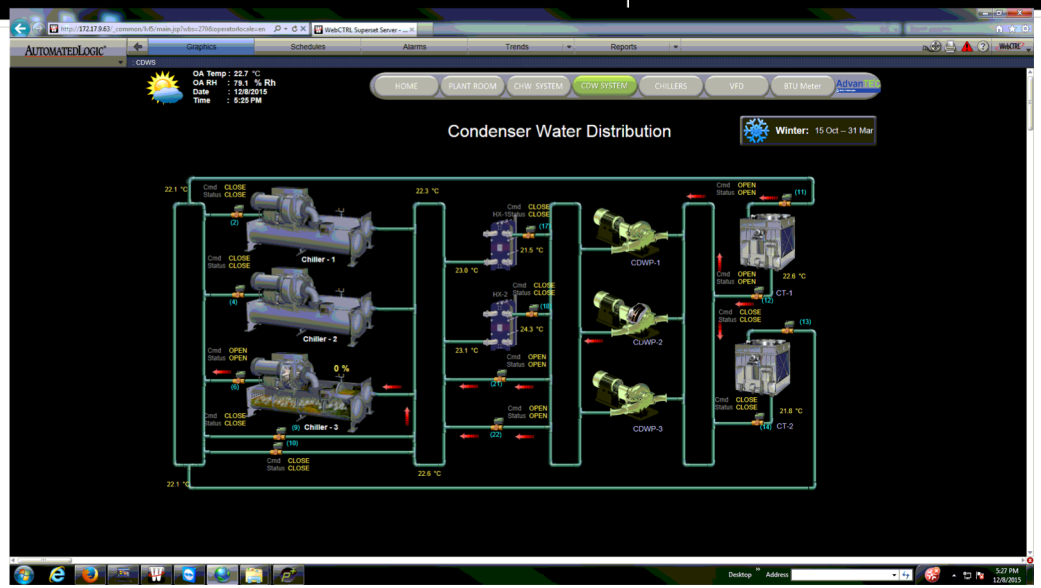
PLANT LEVEL SYSTEM OPERATION

Chiller Plant



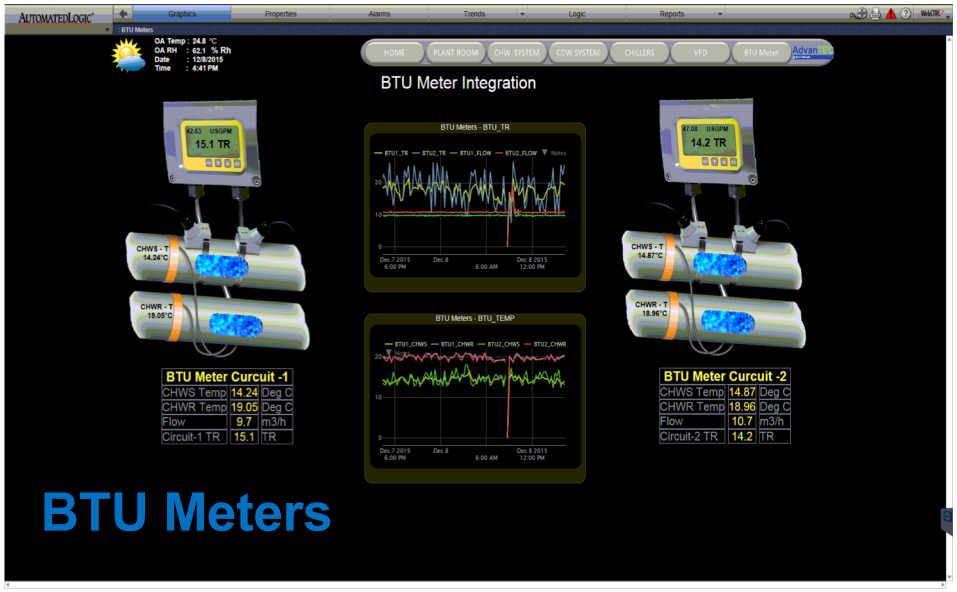
Chilled water distribution

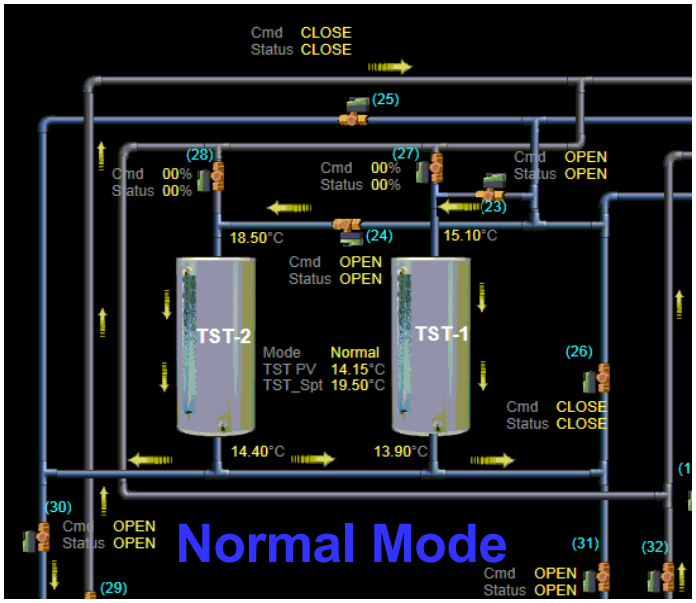


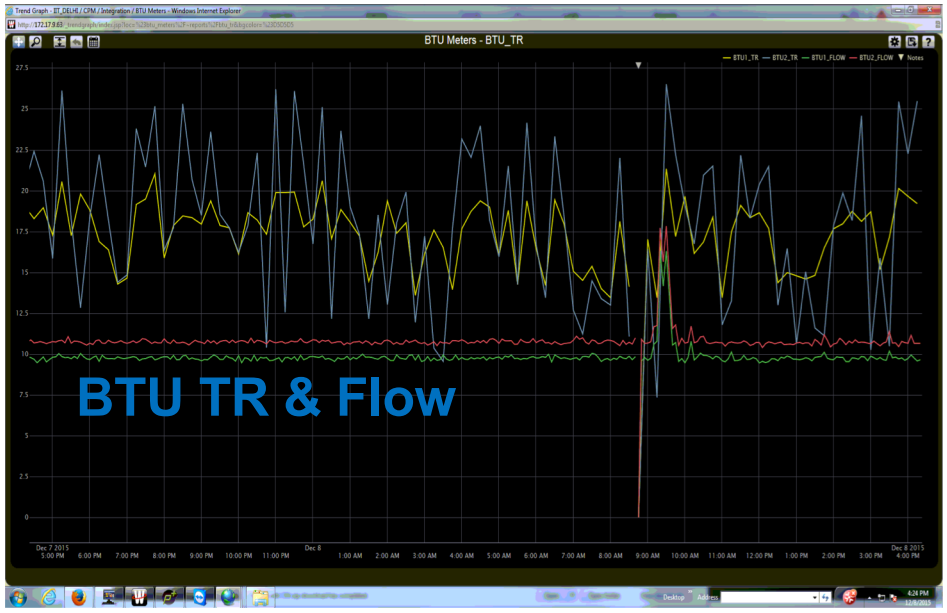


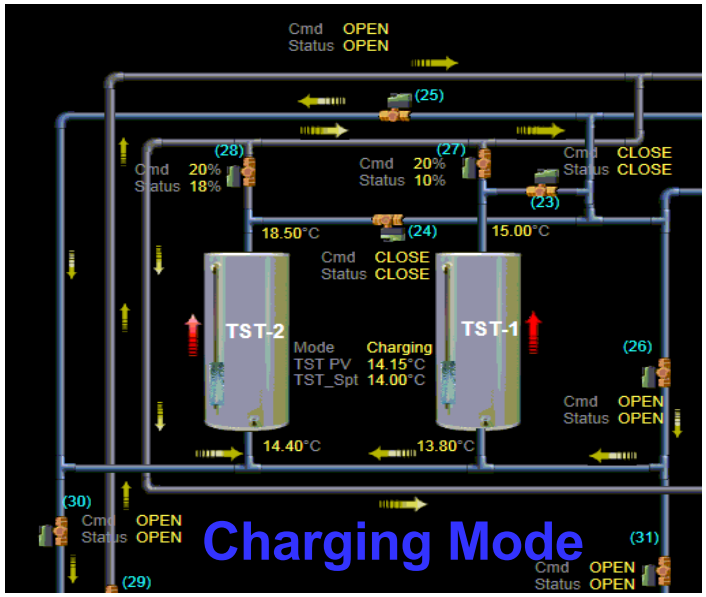
Cooling water distribution

THERMAL STORAGE TANK

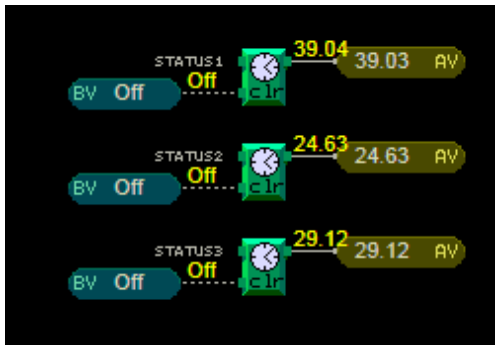








EQUIPMENT RUNTIME

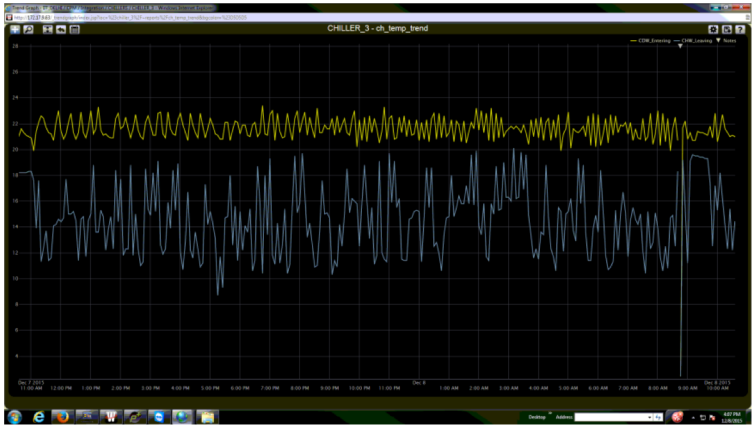


1
2
3

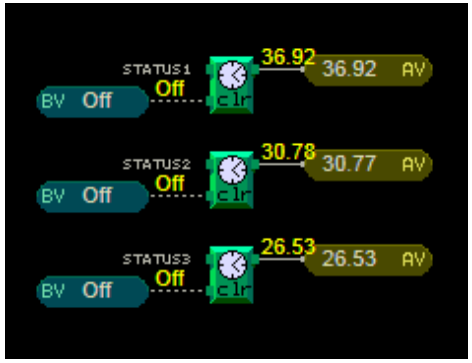
Chillers Enable runtime

1
2

CT Runtime

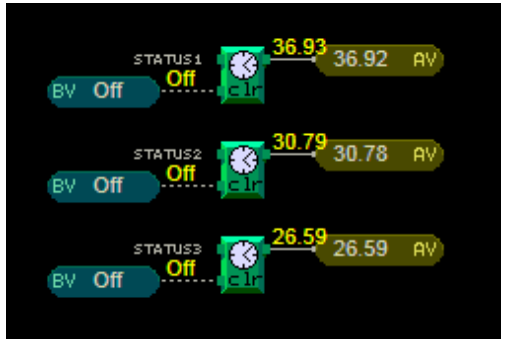


Chiller CDW-in & CHW-out



1
2
3

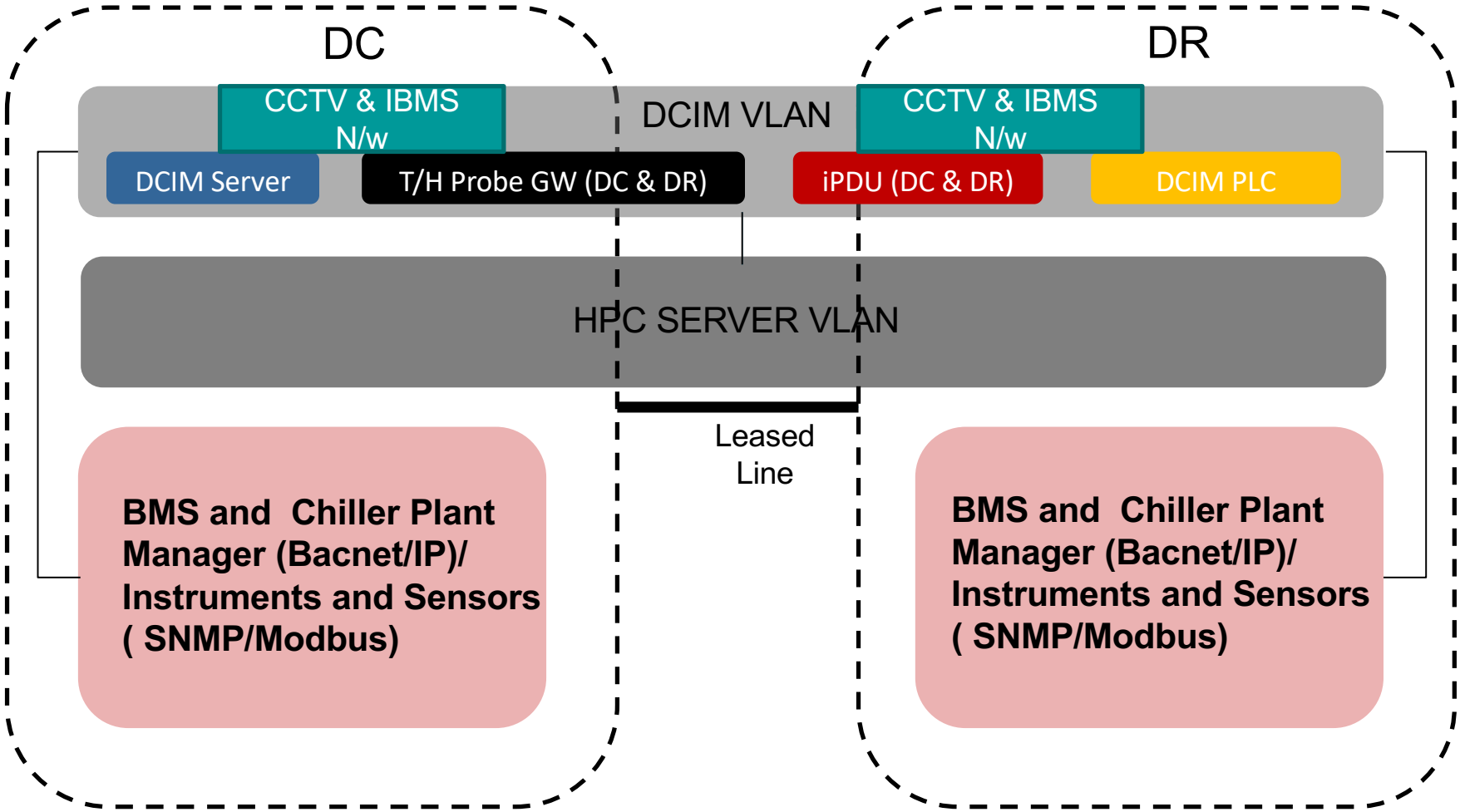
CDWP Runtime



1
2
3

CHWP Runtime

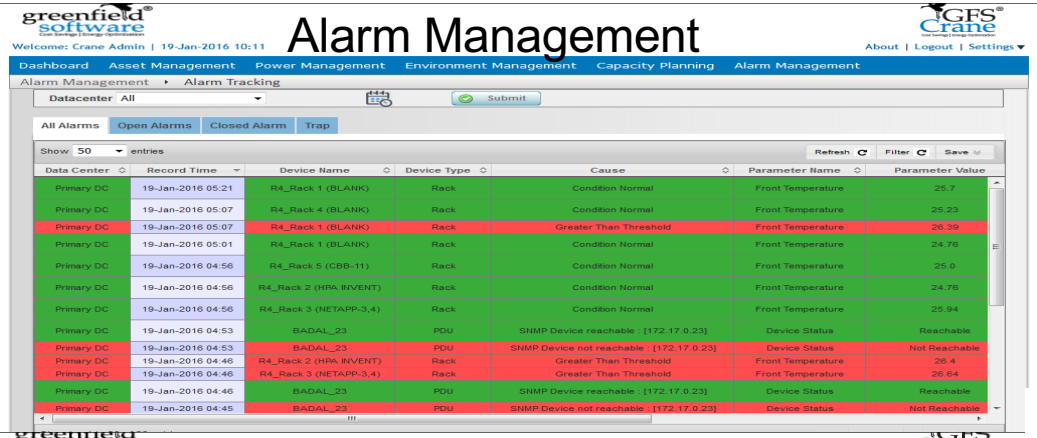
DCIM Network Architecture – Inter-VLAN Connectivity

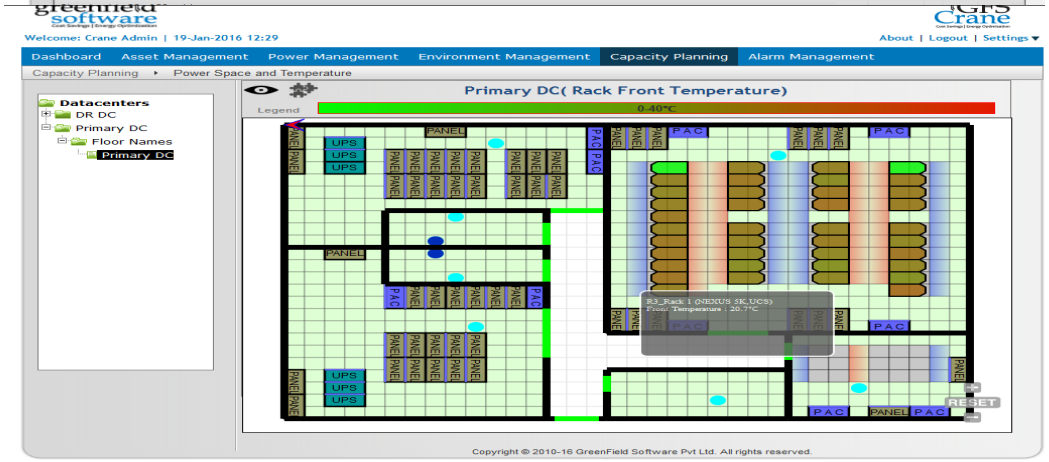


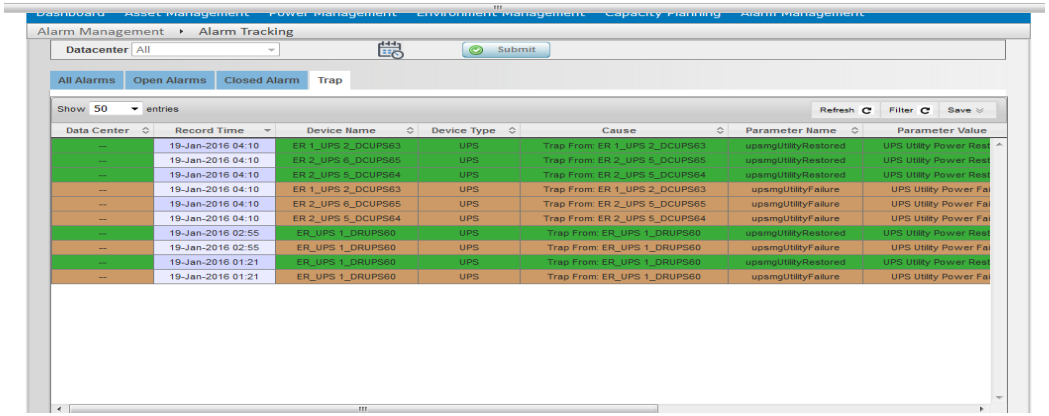
800+ sensors/instrumentation to control all mechanical and electrical system

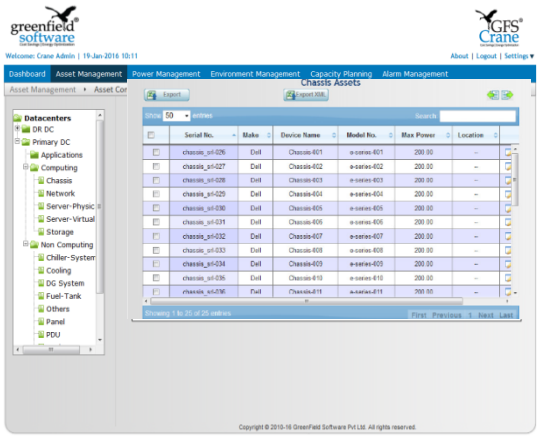
DCIM ASSET MANAGEMENT

Alarm Management

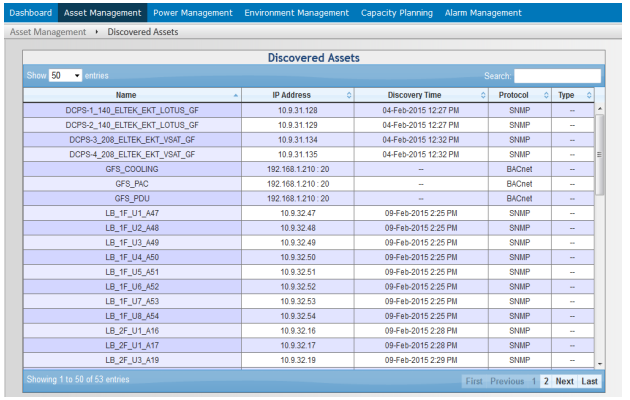








Single console to manage IT & facility assets



Auto discovery of Assets

DC OPTIMIZATION STEPS

- **Air side Balancing**
  - Elimination of mixing of Air within the racks
  - Elimination of air mixing inside the racks
  - Elimination of Supply of high Temp Alerts > 26 ˚ C
  - Air side Free cooling in Utility rooms (<= 23 ˚ C/Rh <= 75%) for Utility Area
- **Water side Balancing**
  - Water side Balancing in server room (RDHX) and Chiller side (variable Primary does not work efficiently)
  - Water side economizers re-commissioning.
- **Automation Related**
  - Optimized logic to have automated Free/Pre cooling operations in Chiller Plant Manger.
  - DCIM related points like: L3 PUE (KWH) at Server level, DC-DRC failover, Alert threshold configurations, Automated availability reports, real time losses in electrical/mechanical subsystem.
- **Electrical optimization**
  - Make Control/instrumentation circuits robust (dual UPS power, STS switches, dual PDU controllers, DCIM/BMS in DC-DRC failover mode etc.)
  - Thermal mapping on electrical breaker.
  - Dual PLCs for breaker Panel operations

RESULTS

- *Fully operational automated DC and DRC.*
- *Nil high temperature Alerts*

Designed PUE (Annual Average)

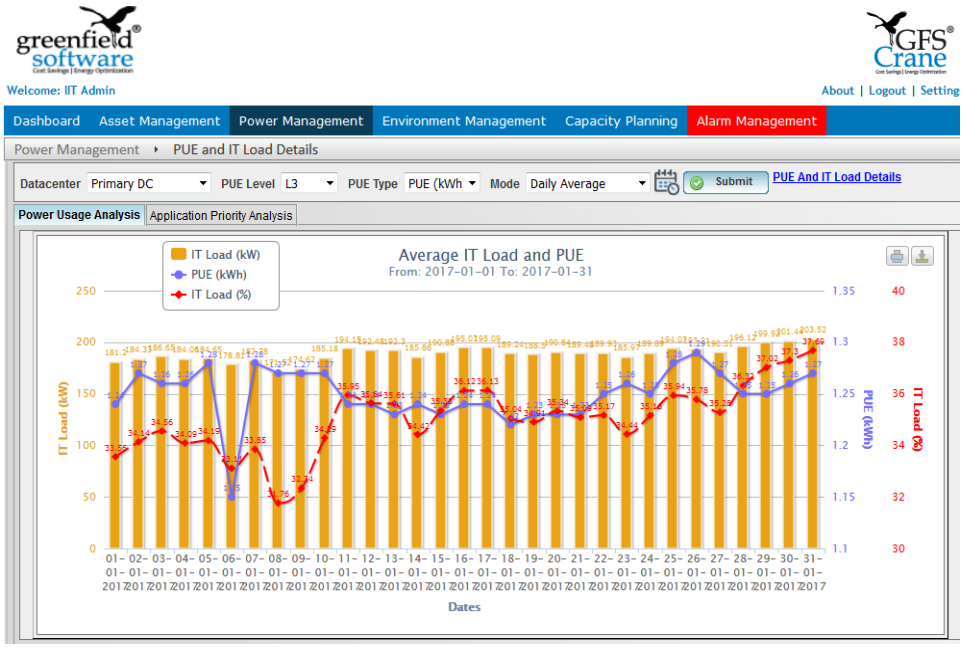
Operating Energy and water requirements	Annual Avg. PUE
Design PUE and annualized average PUE based on hourly analysis for **100% load**	1.28
Design PUE and annualized average PUE based on hourly analysis for **75% load**	1.30
Design PUE and annualized average PUE based on hourly analysis for 50% load **(50% Load:**	1.34
Design PUE and annualized average PUE based on hourly analysis load **(40% Load)**	1.37

Designed Monthly PUE@40% Load

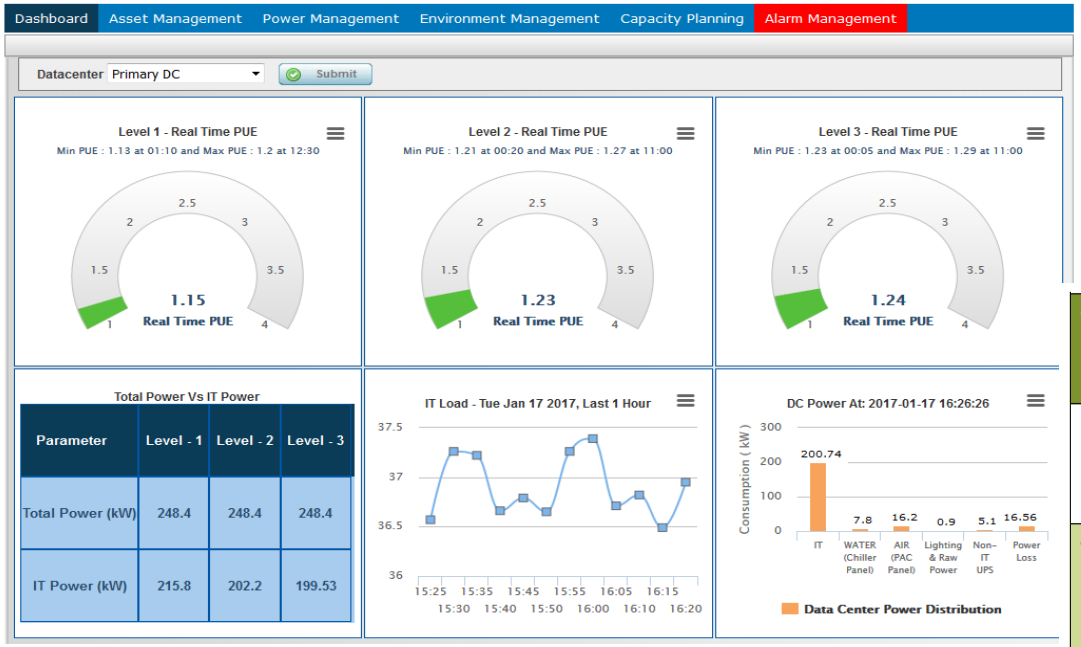
AT 40% IT LOAD											
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1.27	1.29	1.32	1.35	1.36	1.41	1.41	1.41	1.39	1.36	1.3	1.27

Actual PUE Results Better than designed

1.26 at 37.7% IT Load (16-31Dec)
1.25 at 35 % IT Load (Jan)
1.29 at 36.4% IT Load (Feb)
1.32 at 37% IT Load (Mar)
1.35 at 36% IT Load (April)



DCIM PUE AND LOSS DASHBOARD



Where do I measure? How often do I measure?		Level 1 (L1) Basic	Level 2 (L2) Intermediate	Level 3 (L3) Advanced
IT Equipment Energy	Required	UPS outputs	PDU outputs	IT equipment input
Total Facility Energy	Required	Utility inputs	Utility inputs	Utility inputs
	Additional recommended measurements*		**UPS inputs/outputs** **Mechanical inputs**	**PDU outputs** **UPS inputs/outputs** **Mechanical inputs**
Measurement Intervals	Required	Monthly	Daily	15 minutes
	Additional recommended measurements*	**Weekly**	**Hourly**	**15 minutes or less**

THANK YOU