IEEE HOUSTON CED SEMINAR (OCTOBER 22, 2019)

Packaged Substations

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David Brannon – Electrical Systems Application Engineer

Dwaraka Padimiti – Field Applications Engineer

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Agenda

- Safety Moment
- Overview
- Project Execution (Dave Brannon
- Electrical Equipment (Dwaraka Padimiti)
- E-House (Andres Illarramendi)
- Q&A

Safety Moment

Distracted Driving

- Distractions behind the wheel are a lot more common than you think.
- In fact, 8-in-10 people engage in smartphone activities while driving.
- The latest news, social media uploads, and emails are all just a click or swipe away.
- But when you're behind the wheel, they can put you and everyone else in your path in danger.
- Distracted Driving is Never OK.
- #ItCanWait

Packaged Substations

Definition

Scope Definition

- Prefabricated modular assembly comprised of electrical distribution equipment suited for a specified power distribution application.
- Common applications
  - Electrical Houses (E-Houses, PDCs, PCRs etc..)
  - Mobile Substations
  - Distribution Skids

- Key Advantages
  - Single Source Responsibility, Coordination and Accountability
  - Reduced Installation
  - Cost & Application Flexibility

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Project Execution

Scope Understanding

- Material Scope of Supply
- Engineering Services Scope of Supply
- Schedule / Key Commercial Milestones
- Understanding of Project Specifications
- **Unknown Concessions from Sales/Procurement teams
- Documentation Deliverables
- Project Team

Procurement Bid Package

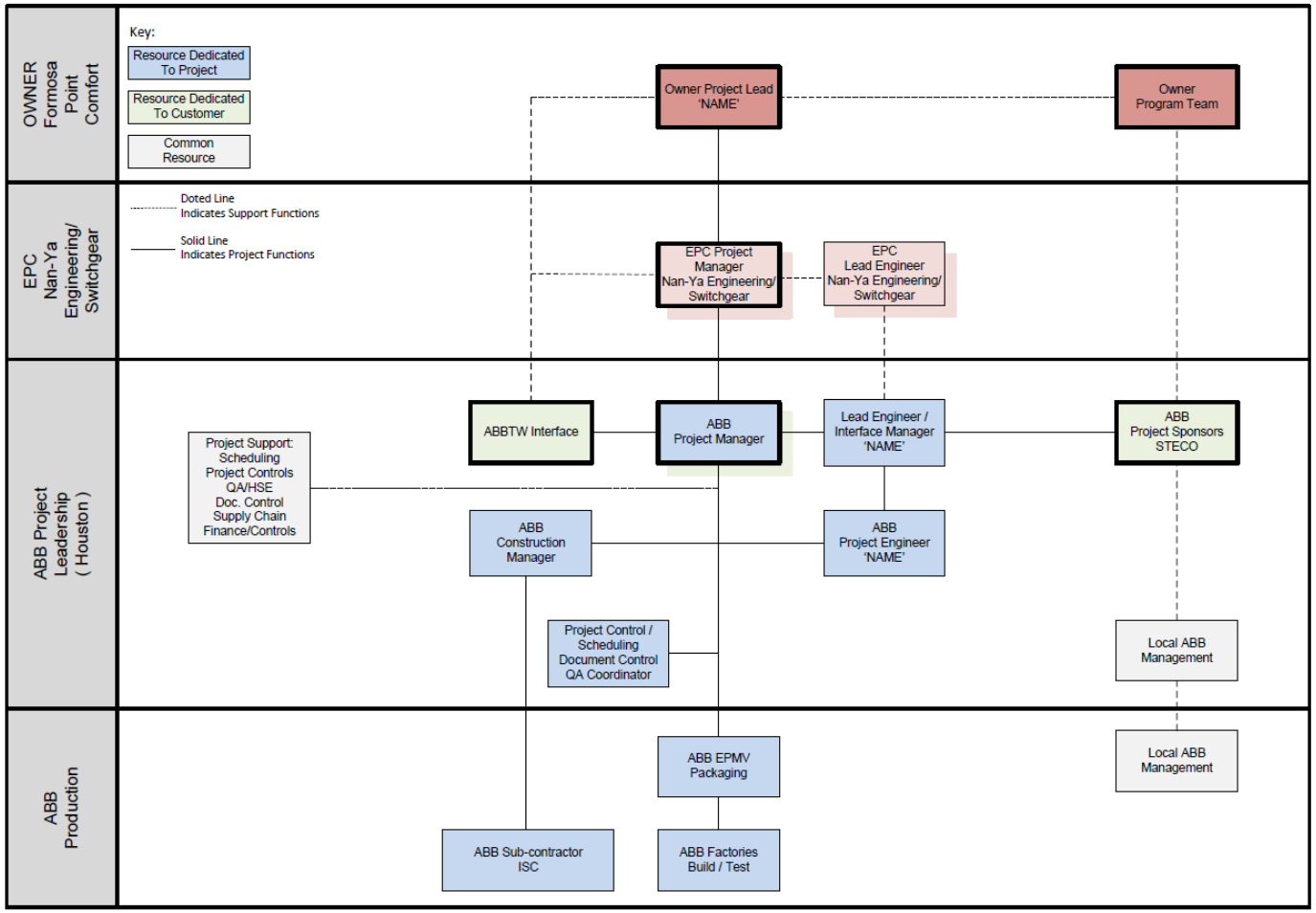
Final Product

Packaged Substations

Project Execution - Project Team & RACI Matrix

Project Team

- Customer/End User Project Team
  - Owner's Engineer / EPC
- Packaged Substation Supplier
  - Project Manager / Project Controls
  - Design Engineering Team
  - Manufacturing / Production Team
  - Electrical Installation Team
  - Procurement & Logistics
  - Quality Control
  - Leadership / Executive Sponsor



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Project Execution - Project Team & RACI Matrix

RACI Matrix

- Provide visibility to critical task
- Create collaboration among the entire project team
- Assign ownership

RACI Matrix

[Project Title]

Roles and Responsibilities

Responsible, Accountable, Consulted, Informed

ROLES		Sponsor	Name or Role	Name or Role	Name or Role	Name or Role	Project Manager	Technical Lead	Name or Role	Name or Role	Name or Role	Consultant	Name or Role	Name or Role	Name or Role	Name or Role
Deliverable or Task	**Status**	**Sponsor / Leadership**					**Project Team**					**Other Resources**				
Phase 1																
Deliverable/Task 1		A	R				I									
Deliverable/Task 2		A		R			I									
Phase 2																
Deliverable/Task 1		C	I				A	R								
Deliverable/Task 2			I				A		R							
Phase 3																
Deliverable/Task 1			I				A	I		R		C				
Deliverable/Task 2			I				A	I	R			C				
Phase 4																
Deliverable/Task 1				I			A	R					C			
Deliverable/Task 2				I			A		R							
Insert new rows above this one																

R	Responsible	Assigned to complete the task or deliverable.
A	Accountable	Has final decision-making authority and accountability for completion. Only 1 per task.
C	Consulted	An adviser, stakeholder, or subject matter expert who is consulted before a decision or action.
I	Informed	Must be informed after a decision or action.

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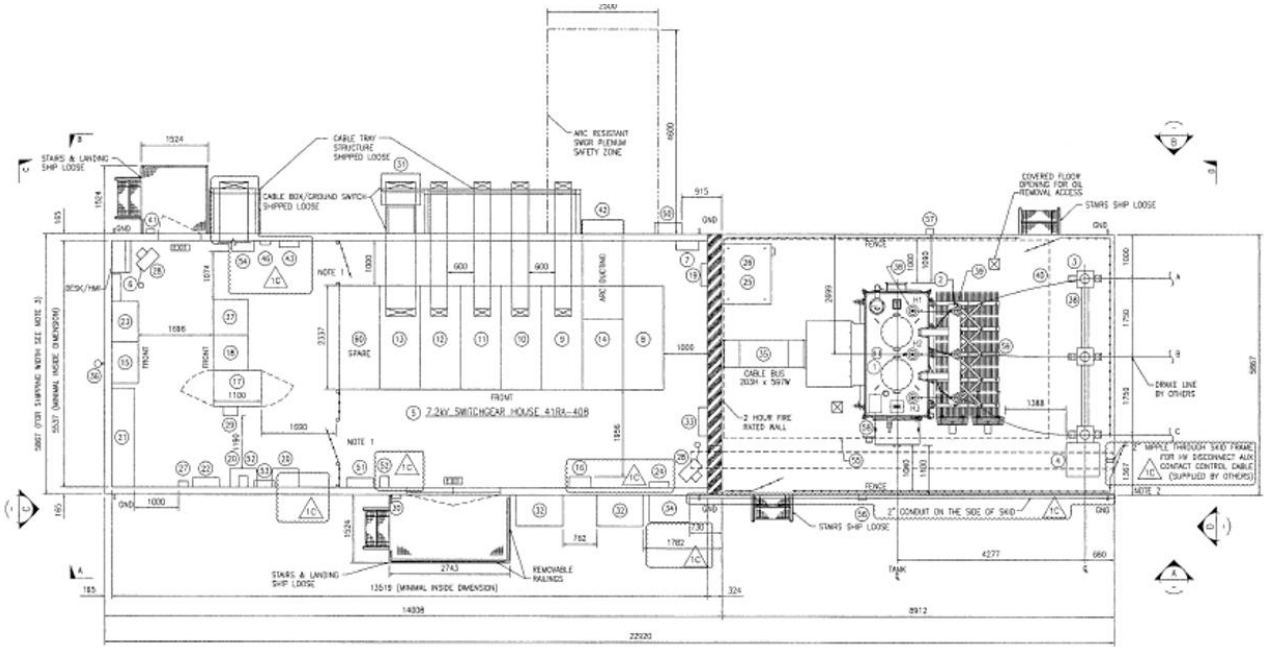
Project Execution - Project Team & RACI Matrix

Design & Application Engineering Team

- Qualified Multi-Discipline Engineering Team
  - Architectural / Civil / Structural
  - Electrical (Power, Communication, etc)
  - Mechanical (HVAC, Fire Protection, etc)
  - System Specialist (as required)
  - Testing and Commissioning Engineers



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Project Execution - Project Team & RACI Matrix

Manufacturing and Production Team

- Qualified Multi-Discipline Construction Team
  - Welding & Steel Fabrication
  - QA Inspectors
- Electrical Construction
  - High & Low Voltage Wiring Installation & Testing
  - Bus Duct
  - Cable Tray & Conduit Installation
  - MV & LV MCC's/Switchgear Installation
  - Transformers
  - Power & Lighting Panels
  - Grounding
  - Lighting
  - Lighting Protection
  - Telecom Systems (structured cabling, PAGA, CCTV etc)

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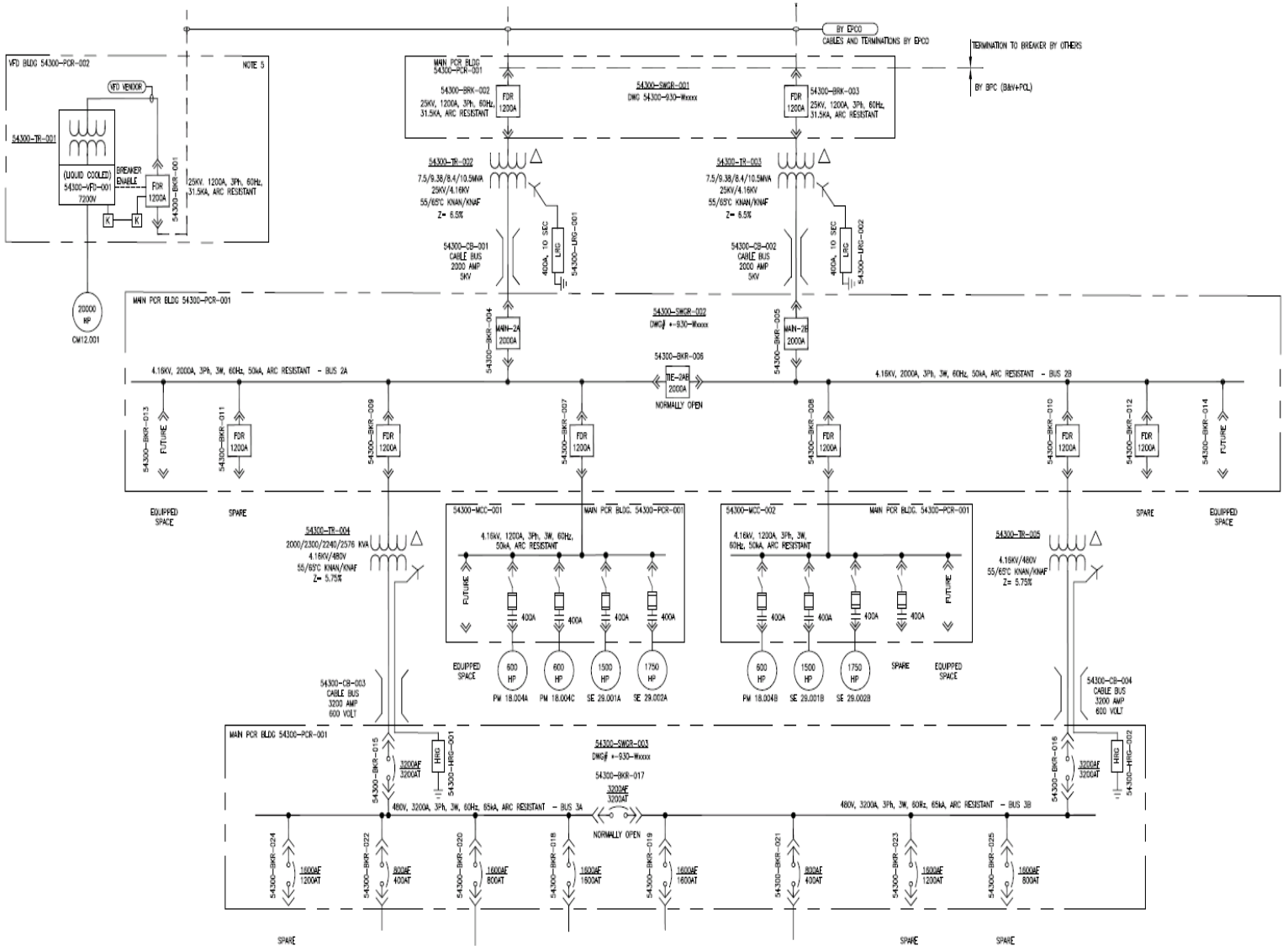
Project Execution - Front End Design

Front End Design – Power Dist. System

- Power Distribution Design
  - Power Systems Studies
  - Protection and Control Design
  - Single-line development
  - Substation Automation Design
  - Substation Control Power System Design
  - Load List Completion (MCC)
  - Finalize equipment specification



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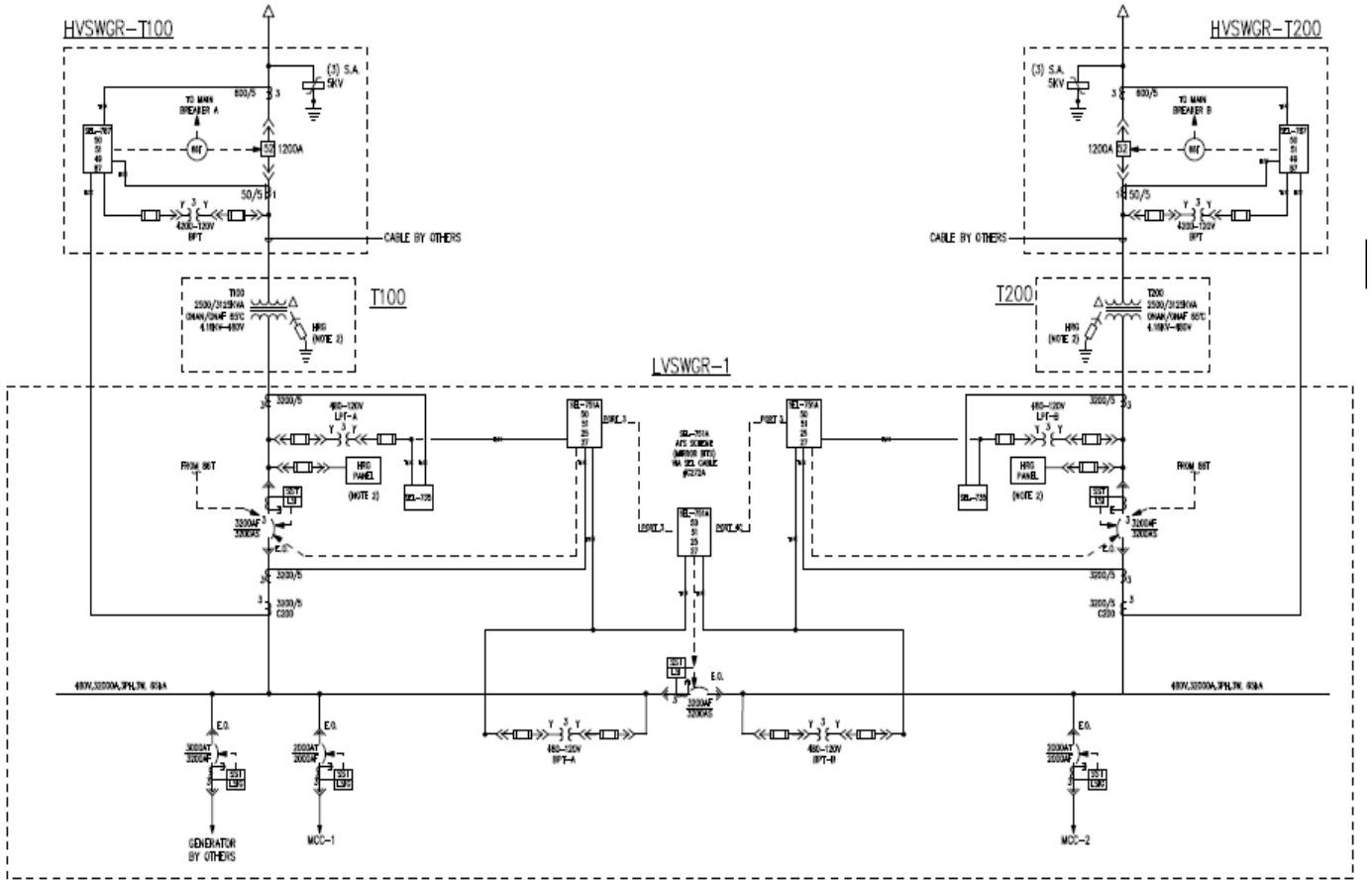
Project Execution – Detailed Design Approved Project One-line diagram



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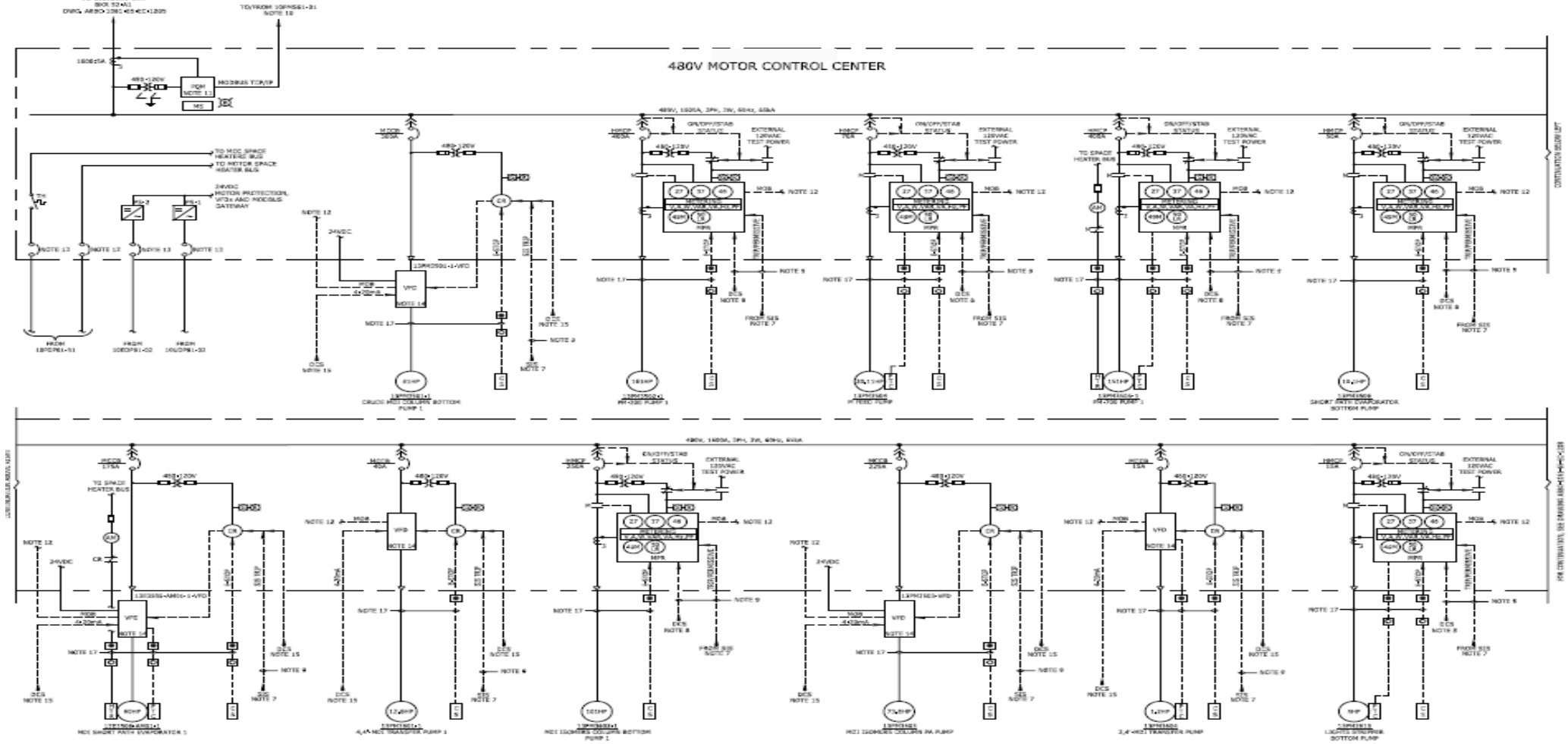
Project Execution – Detailed Design Approved Project One-line diagram



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Project Execution – Procurement & Logistics

Procurement – Major Equipment

- Procurement of Long Lead Electrical Equipment
  - Switchgear
  - MCCs
  - MV VFDs
  - Transformers
- Approval drawings required for building coordination.
- Take Measures to ensure successful FAT at native factories prior to shipment.

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Project Execution – Customer FIE

Customer “Free Issued Equipment”

- DCS Equipment
  - Automation Control Cabinet
  - Control Room Furniture
  - AC UPS Systems
- Approval drawings required for building coordination.
- Ensure proper ownership between Customer and Substation Supplier
- Take Measures to ensure successful FAT at native factories prior to shipment.
- Ensure all installation details are provided

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Project Execution - Procurement

Procurement – Major Equipment

- HVAC Systems
  - Wall Mounted Units
  - Pad Mounted Units
  - Hazardous Area Classification
  - Pressurization Systems
  - Interior Duct Work
  - HVAC Controls
  - Pre-Commissioning / Breakdown & Crating

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Project Execution – Detailed Design Elect Room Layout

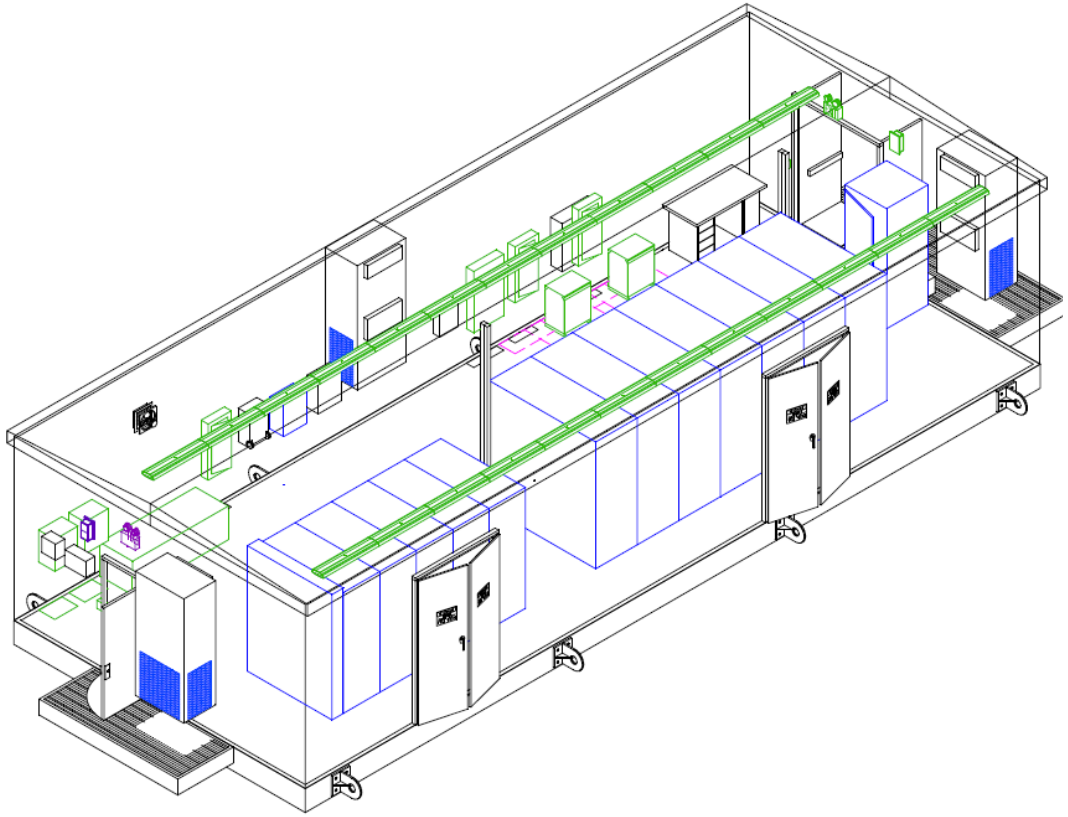
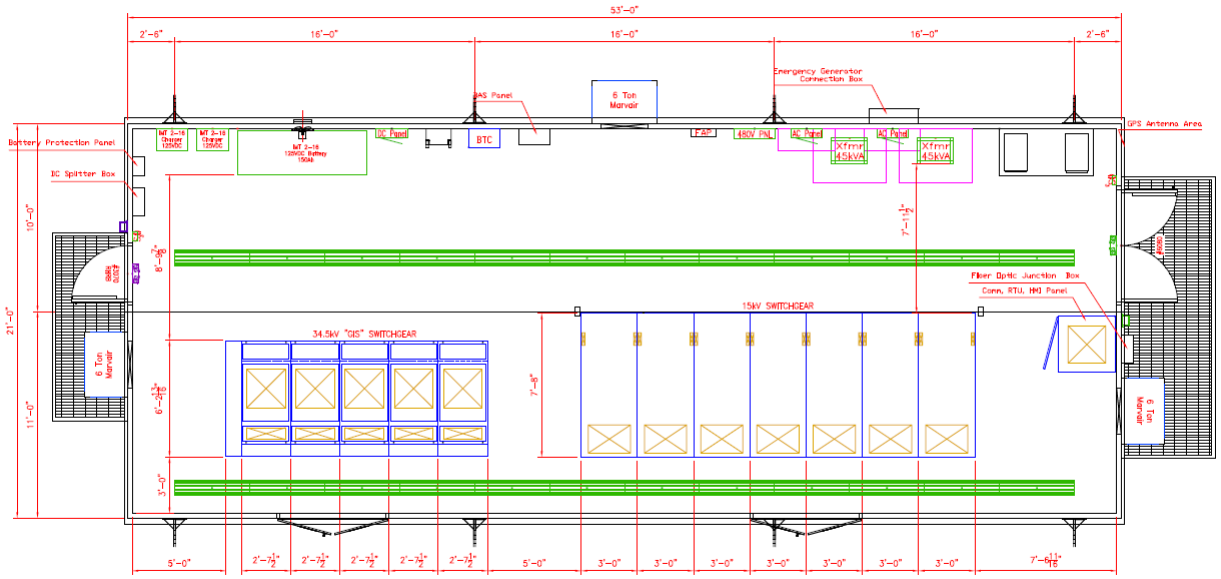


Table 110.26(A)(1) Working Spaces

Nominal Voltage to Ground	Minimum Clear Distance		
	Condition 1	Condition 2	Condition 3
0–150	914 mm (3 ft)	914 mm (3 ft)	914 mm (3 ft)
151–600	914 mm (3 ft)	1.07 m (3 ft 6 in.)	1.22 m (4 ft)

Table 110.34(A) Minimum Depth of Clear Working Space at Electrical Equipment

Nominal Voltage to Ground	Minimum Clear Distance		
	Condition 1	Condition 2	Condition 3
601–2500 V	900 mm (3 ft)	1.2 m (4 ft)	1.5 m (5 ft)
2501–9000 V	1.2 m (4 ft)	1.5 m (5 ft)	1.8 m (6 ft)
9001–25,000 V	1.5 m (5 ft)	1.8 m (6 ft)	2.8 m (9 ft)
25,001 V–75 kV	1.8 m (6 ft)	2.5 m (8 ft)	3.0 m (10 ft)
Above 75 kV	2.5 m (8 ft)	3.0 m (10 ft)	3.7 m (12 ft)



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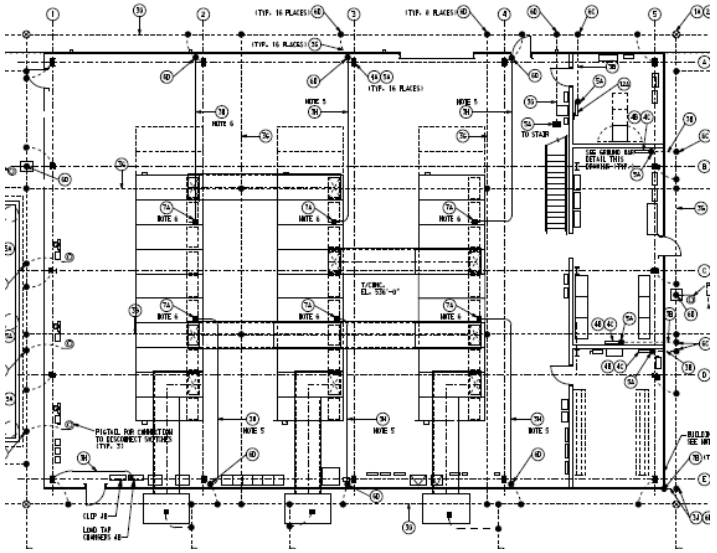
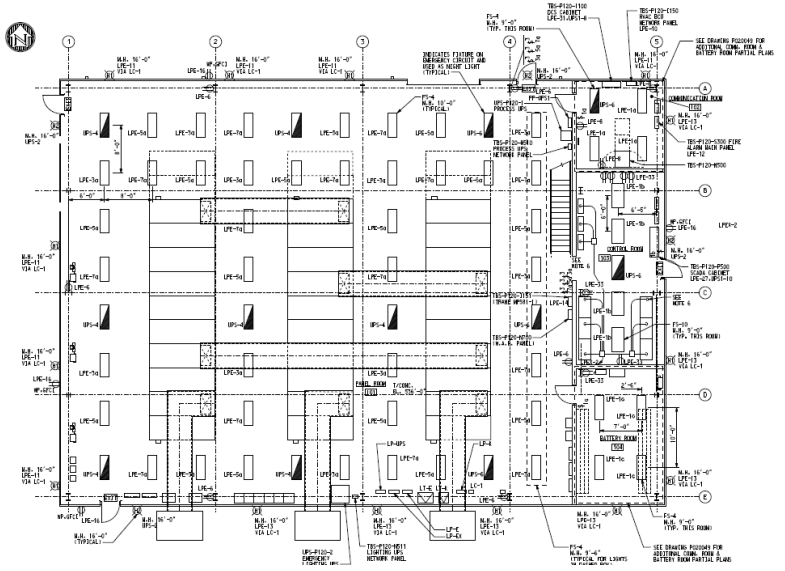
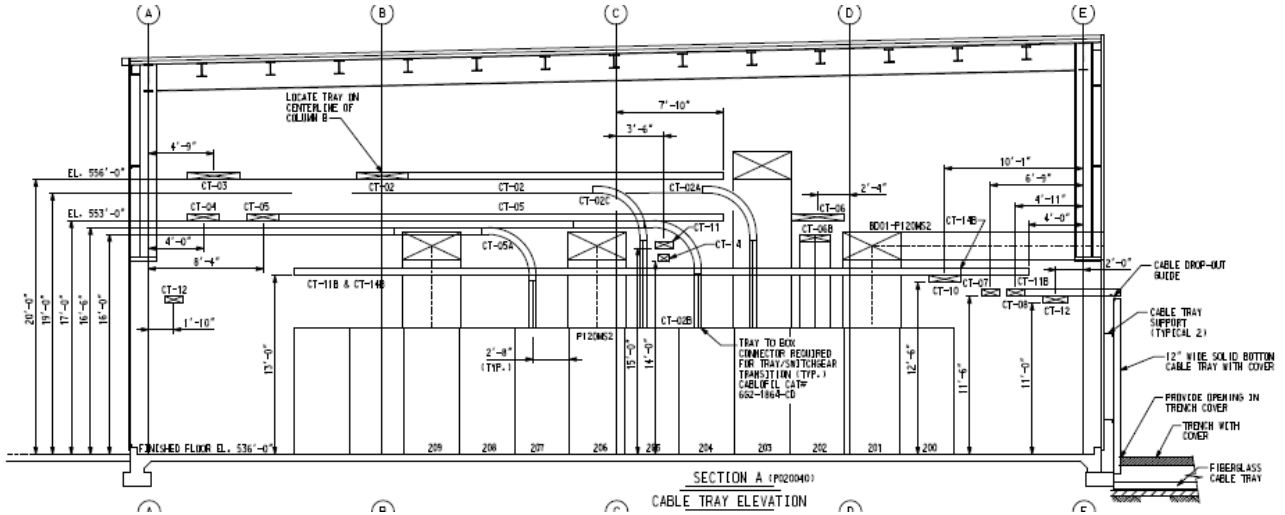
Project Execution – Detailed Design

Electrical Room Design

- Electrical Systems Design and Inter discipline coordination
- Lighting & Convenience Power Design
- Grounding & Lightening Protection Design
- Cable Tray & Raceway Design
- HVAC Design
- Fire Protection Design
- Communications Design







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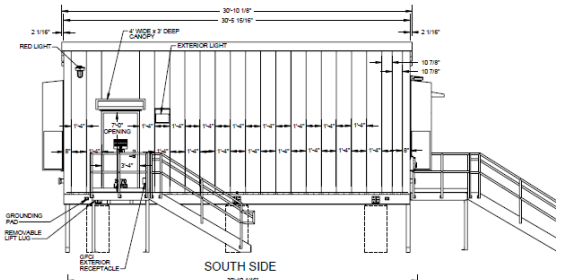
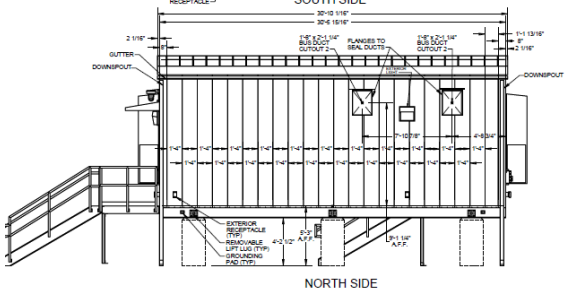
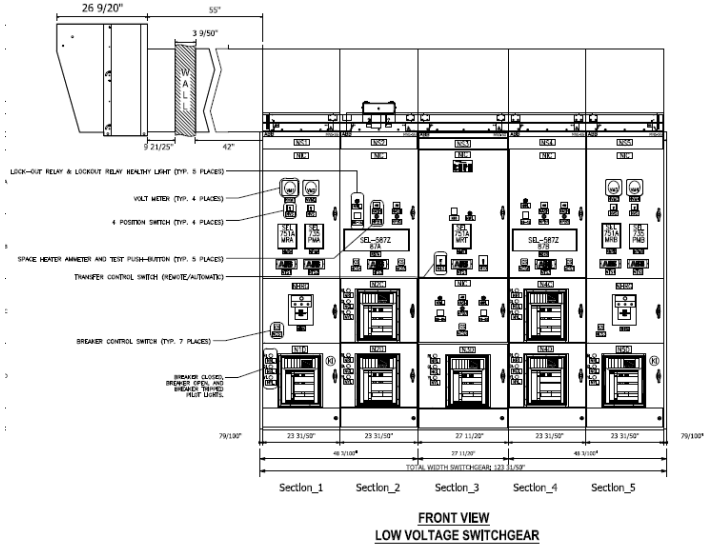
Project Execution – Detailed Design

Submittal / Shop drawing Review

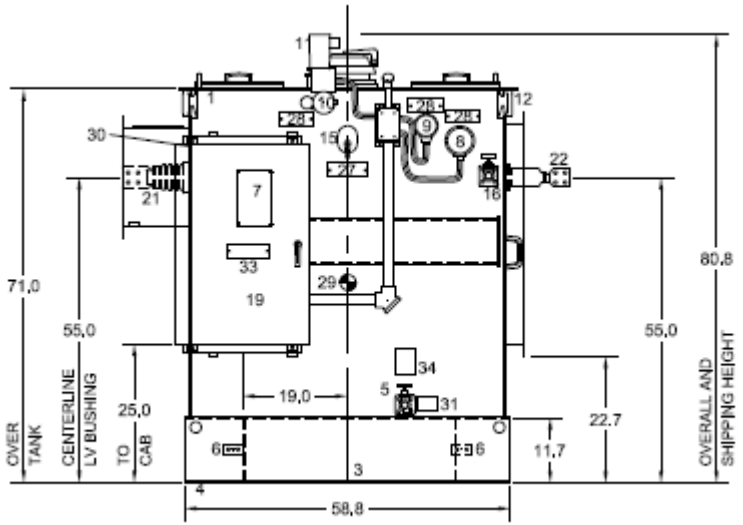
- MV / LV Switchgear
- MV / LV MCCs
- 125VDC System
- Transformers
- Bus Duct
- Customer FIE (DCS/PMS/SCADA etc..)
- Electrical Building
  - Utilities (Lighting, Power, Grounding)
  - HVAC
  - Fire Alarm
  - Telecoms
  - Electrical Integration

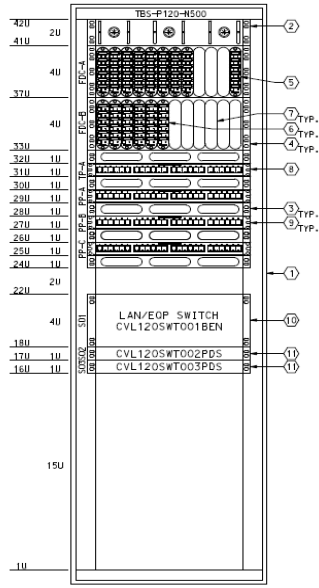






FRONT VIEW
LOW VOLTAGE SWITCHGEAR





CABINET "A"

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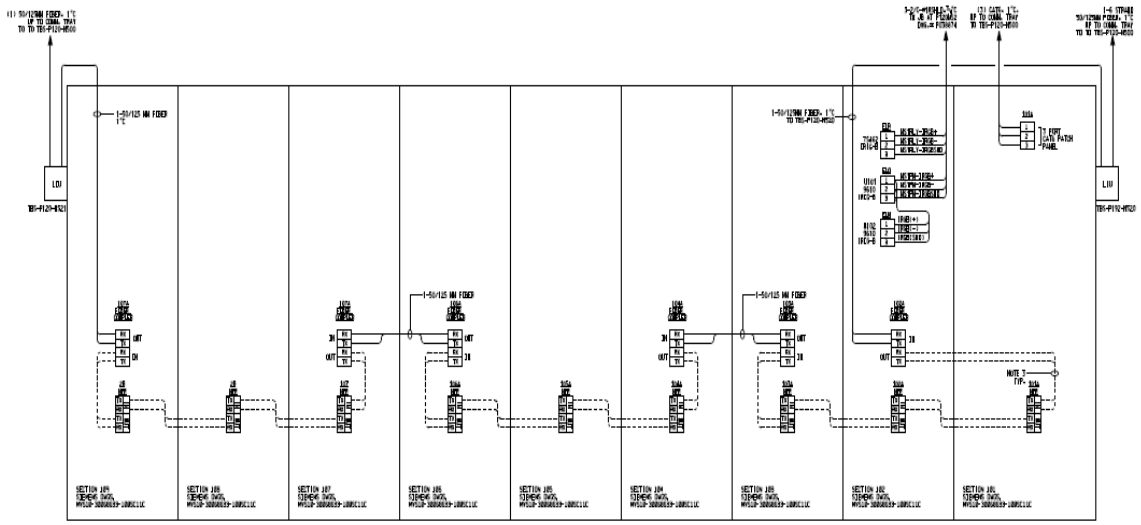
Project Execution – Detailed Design

Electrical Integration

- Detailed Instruction to support complete system installation & functionality
  - Interconnection Cable Schedules
  - Supporting Interconnection diagrams
  - Installation Details



ABB

INTERCONNECTION CABLE SCHEDULE (POWER CABLES)

Project: Building — Stowe Engineering: Boiler E-House — Rev. 0

Item No.	CABLE DESCRIPTION	CONDUCTOR SIZE	CABLE SIZE	CIRCUIT VOLTAGE	LOAD (KVA, KW, KVAR, HP)	FROM	TO	TBD BY SUPPLIER: ESTIMATED LENGTH INCLUDED IN PROPOSAL	REMARKS
						STRUCTURE #	STRUCTURE #	LF	
1	600V TC - (POWER) Copper, XHHW-2 Insulation	#/2/0 AWG	3-C #2/0 w/ #6 GND	480VAC	175A	MCC-3	75KVA Utility XFMR 1 (By POC Supplier)		480V Feeder to POC Utility XFMR-1
2	600V TC - (POWER) Copper, XHHW-2 Insulation	#4/0 AWG	3-C #4/0 w/ #4 GND	208VAC	225A	45KVA Utility XFMR 1 (By POC Supplier)	208/120 Utility Panel 1 (By POC Supplier)		Feeder to Building Utility 208Y/120V Panel 1
3	600V TC - (POWER) Copper, XHHW-2 Insulation	#8 AWG	3-C #8 w/ #10 GND	480VAC	35A	MCC-3	15KVA Utility XFMR 2 (By POC Supplier)		480V Feeder to POC Utility XFMR-2
4	600V TC - (POWER) Copper, XHHW-2 Insulation	#4 AWG	3-C #4w/ #10 GND	208VAC	50A	15KVA Utility XFMR 2 (By POC Supplier)	208/120 Utility Panel 2 (By POC Supplier)		Feeder to Building Utility 208Y/120V Panel 2
5	600V TC - (POWER) Copper, XHHW-2 Insulation	#4 AWG	2-C #4w/ #10 GND	208VAC	60A	208/120 Utility Panel 1 (By POC Supplier)	125VDC System		Feeder to 125VDC System (Base)
6	600V TC - (POWER) Copper, XHHW-2 Insulation	#4 AWG	2-C #4w/ #10 GND	208VAC	60A	208/120 Utility Panel 1 (By POC Supplier)	125VDC System		Feeder to 125VDC System (Charger #2)
7	600V TC - (POWER) Copper, XHHW-2 Insulation	#8AWG	2-C #8AWG w/ #10 GND	125VDC	40A	125VDC System (Base)	13.8kV SWGR Bus A		125VDC SWGR Control Power Bus A Ckt 1
8	600V TC - (POWER) Copper, XHHW-2 Insulation	#8AWG	2-C #8AWG w/ #10 GND	125VDC	40A	125VDC System (Base)	13.8kV SWGR Bus B		125VDC SWGR Control Power Bus A Ckt 2
9	600V TC - (POWER) Copper, XHHW-2 Insulation	#8AWG	2-C #8AWG w/ #10 GND	125VDC	40A	125VDC System (Base)	4.16kV SWGR Bus A		125VDC SWGR Control Power Bus A Ckt 1
10	600V TC - (POWER) Copper, XHHW-2 Insulation	#8AWG	2-C #8AWG w/ #10 GND	125VDC	40A	125VDC System (Base)	4.16kV SWGR Bus B		125VDC SWGR Control Power Bus A Ckt 2
11	600V TC - (POWER) Copper, XHHW-2 Insulation	#8AWG	2-C #12AWG w/ #12 GND	125VDC	20A	125VDC System (Base)	480V SWGR/MCC		125VDC SWGR Control Power
12	600V TC - (POWER) Copper, XHHW-2 Insulation	#6AWG	2-C #6AWG w/ #10 GND	120VAC	50A	208/120 Utility Panel 1 (By POC Supplier)	13.8kV SWGR Bus A		120VAC SWGR Heater Ckt 1
13	600V TC - (POWER) Copper, XHHW-2 Insulation	#6AWG	2-C #6AWG w/ #10 GND	120VAC	50A	208/120 Utility Panel 1 (By POC Supplier)	13.8kV SWGR Bus B		120VAC SWGR Heater Ckt 2

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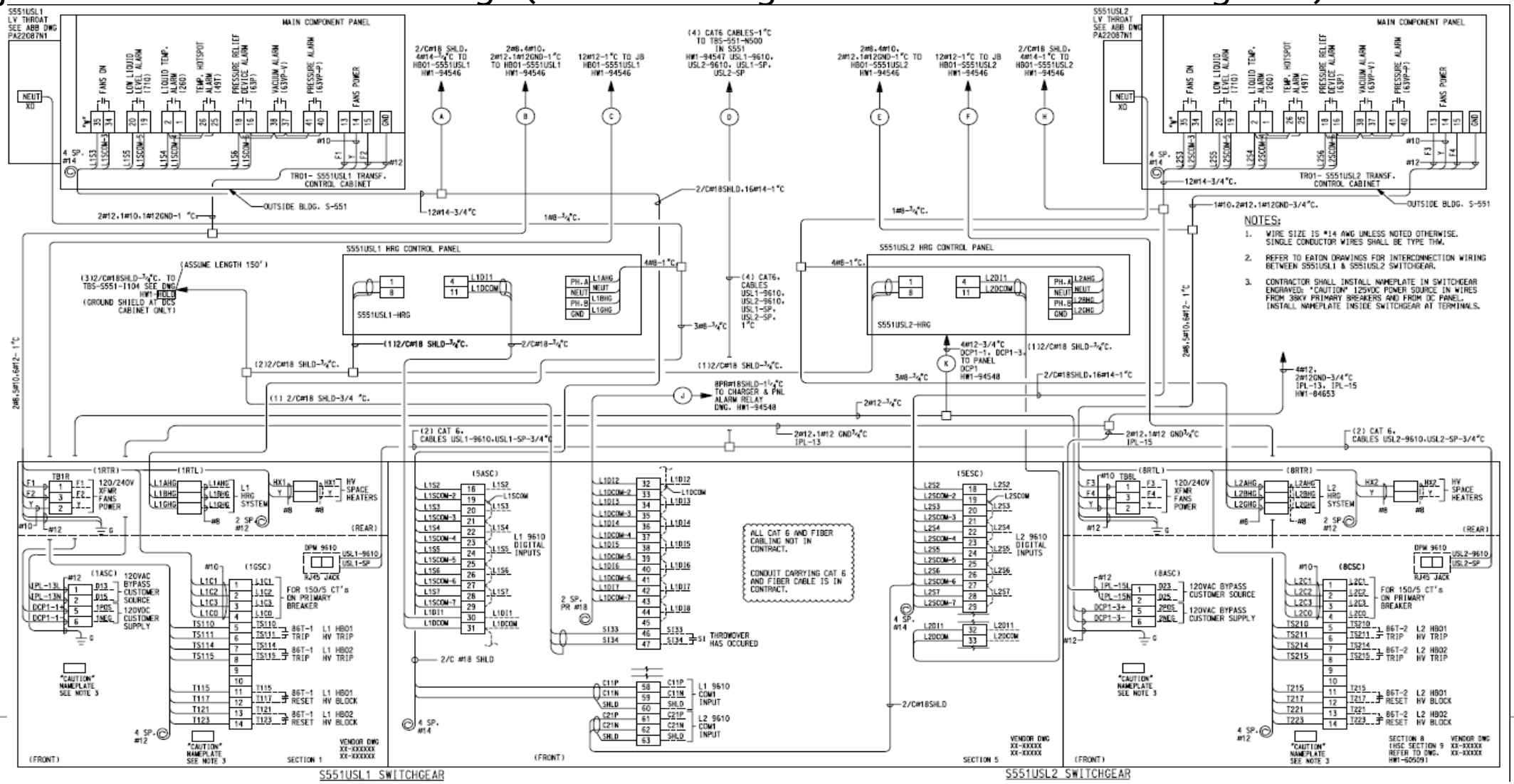
Project Execution – Detailed Design (Electrical Integration: Interconnection Diagrams)



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Project Execution – Detailed Design

Multi-Discipline / External Project Team Coordination

- Example: Bus Duct
  - Transformer – Vendor A
  - Building – Vendor B
  - Bus Duct – Vendor B
  - Civil Design - Customer

- Example: Stairs and Platforms
  - Elevation coordination

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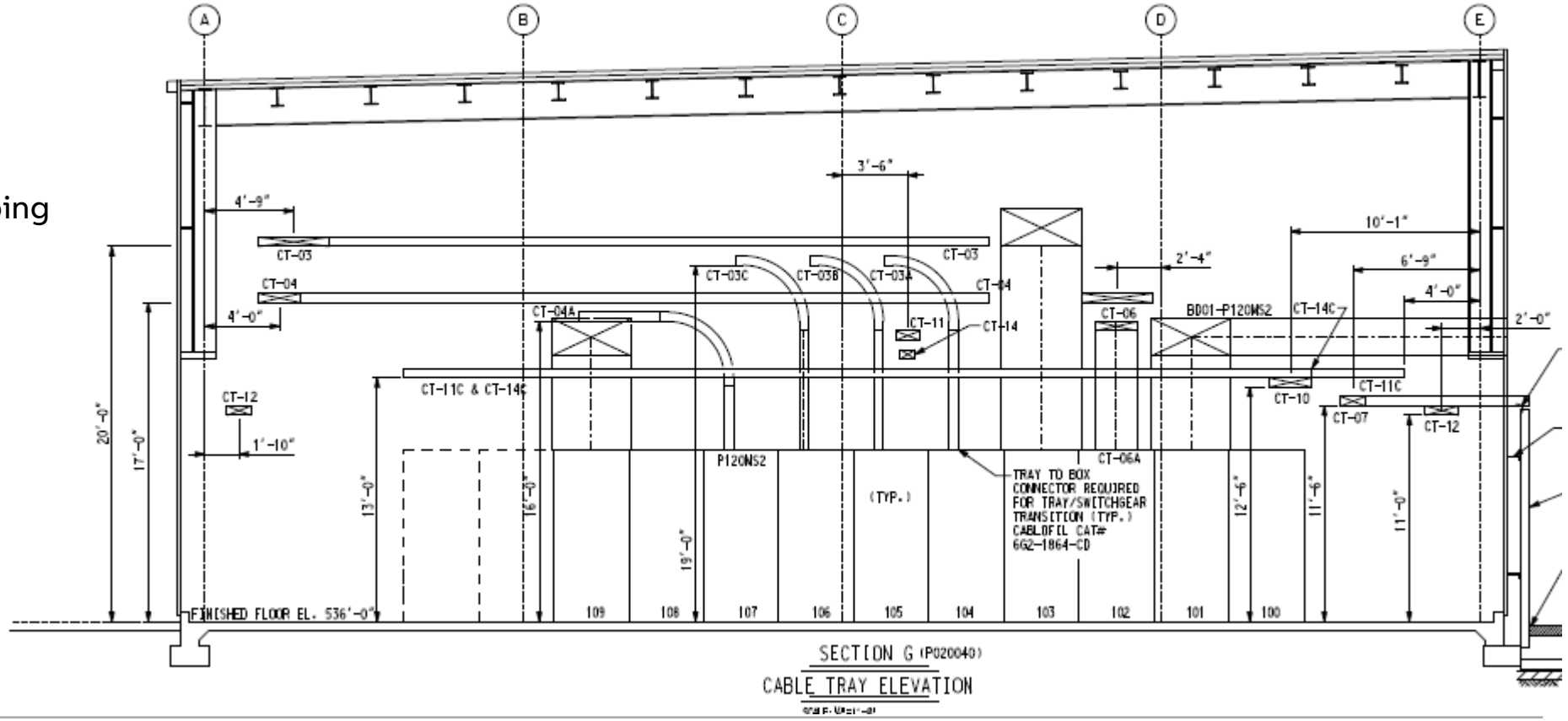
Project Execution – Detailed Design

Multi-Discipline / External Project Team Coordination

– Example: Internal Ceiling Height
  - Lighting
  - Arc Plenum
  - HVAC Duct (as applicable)
  - Cable Tray
  - Fire Suppression System Piping



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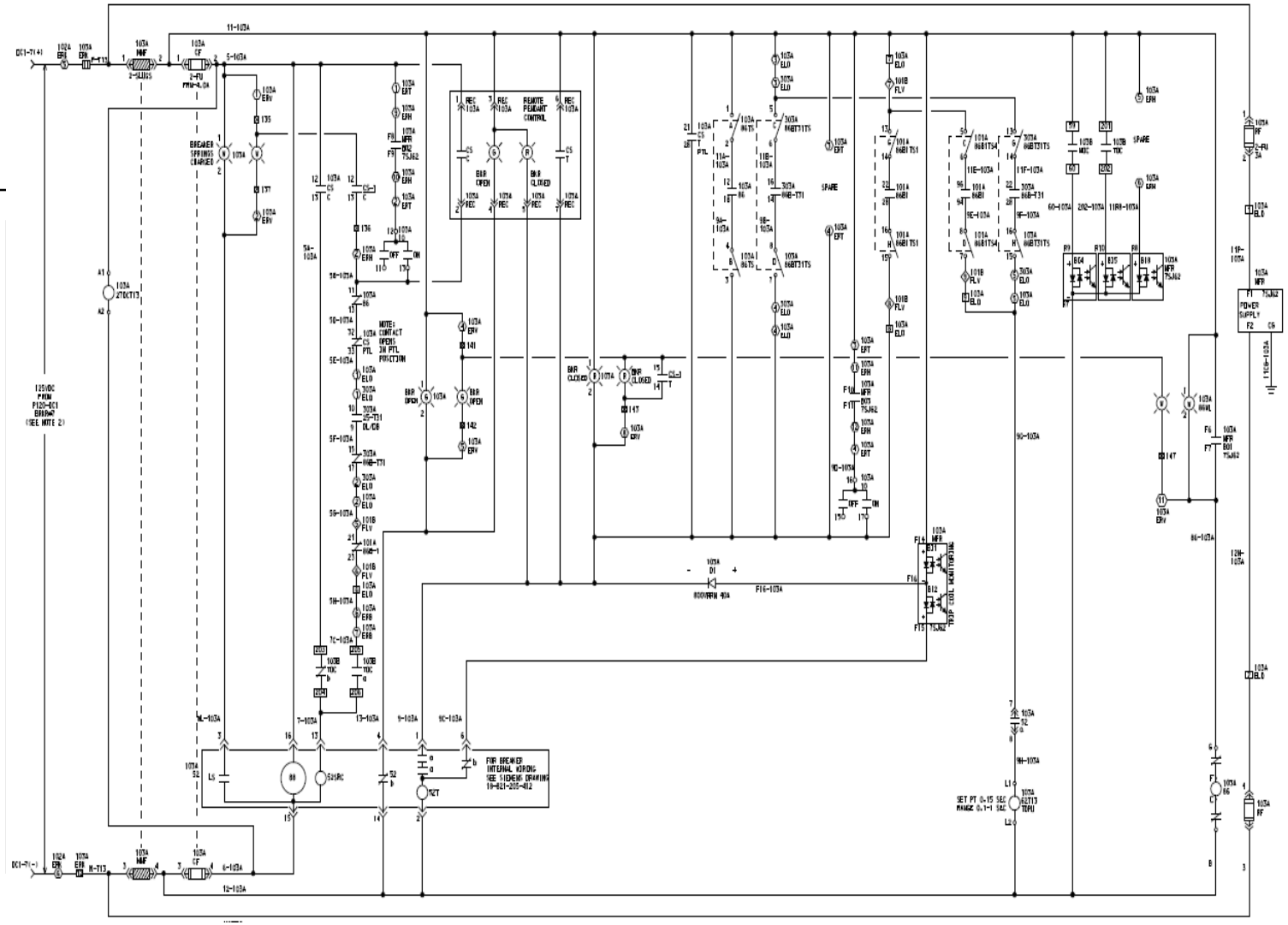
Project Execution – Detailed Design

Documentation

- Record Drawings “As-Built”
- Project Specific “As Commissioned”
- Modify Existing or create new documentation to reflect multi-system integration
  - Substation Automation / PMS Control
  - DCS Monitoring / Control
  - External Alarm Annunciation
  - Communications
  - Time Synchronization
  - Control Schemes via Relay Logic (ATS)
- Test Reports
- Handover/ Release/Transfer Forms



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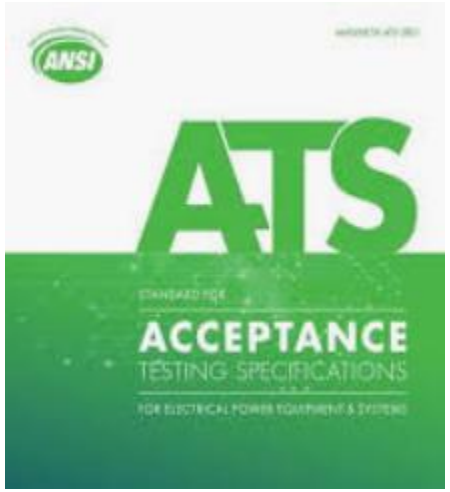
Project Execution – Testing, Commissioning, Support

- Customer Approved Inspection & Testing Plans
  - Native Supplier FAT
  - Integrated FAT (iFAT)
- Onsite services including installation, start up, and commissioning service, support, and supervision
- Complete product and system training programs
- Classroom training
- Spare parts programs to reduce inventory costs



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Major Electrical Equipment

Outdoor Equipment

- **Outdoor Breakers**
  - HV Dead tank breakers
  - Hybrid circuit breakers (SF6 interrupting medium)

- **Transformers**
  - Power Transformers
  - Distribution Class transformers
  - Mineral oil / natural Esther oil

Distribution

Power

Pad-mount

Specials

High voltage dead tank or hybrid circuit breaker

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Major Electrical Equipment

MV Equipment

– **Metal Clad switchgear/MCC**
  - Arc-resistant switchgear/MCC
  - Non-arc resistant switchgear

– **Metal-enclosed equipment**
  - Metal-enclosed Load interrupter switch
  - Metal enclosed MV MCC

– **MV Variable Frequency Drives**
  - Air cooled VFD
  - Water Cooled VFD

MV VFD Drives

Arc-res

Arc-res MCC

Adva nce®

Relia Gear®

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Major Electrical Equipment

LV Equipment

– **Low Voltage switchgear/MCC**

- Arc-resistant switchgear
- Arc-resistant Motor control
- Non-arc resistant switchgear
- Non-arc-resistant Motor control

Non-arc resistant LV motor control

Non-arc resistant switchgear

Arc-res LV Switchgear

Arc-res Motor Control

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Major Electrical Equipment

AC/DC UPS and Critical Systems

- AC/DC UPS Systems
- Static Transfer Switches
- Automatic Transfer Switches

Digital Static Transfer

Automatic Static
Transfer Switches

AC/DC UPS
Systems

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Major Electrical Equipment

LV Equipment

– **Low Voltage Panels / Transformers**

- Single/Three phase dry Type Transformers
- Low Voltage Switchboards
- Low Voltage Bus way / bus duct
- Power Panels / Lighting Panels
- Low Voltage Drives (rack mounted)
- Safety Switches

Enclosed Heavy Duty Safety Switches

Low Voltage Drives

Low Voltage Panelboards

Low Voltage Switchboard

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Major Electrical Equipment

Substation Control Power Systems

- **125VDC Systems (Conventional)**
  - Battery Chargers
  - Battery Rack, Spill Containment Pillows
  - DC Disconnect Switches & Panelboard
  - Increased footprint
- **125DC systems (Factory Packaged)**
  - Includes charger, battery, DC distribution
  - Ships fully assembled – cuts on-site labor time, cost and risk
  - Fully enclosed system – offers a safer working environment

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Major Electrical Equipment

IED Selection

- **Device Types**
  - Protection Relays
  - Power Meters
  - Annunciators
- **Functionality**
  - Protection
  - Metering
  - Control
  - Communication (MB, IEC61850,)
  - Time Synchronization

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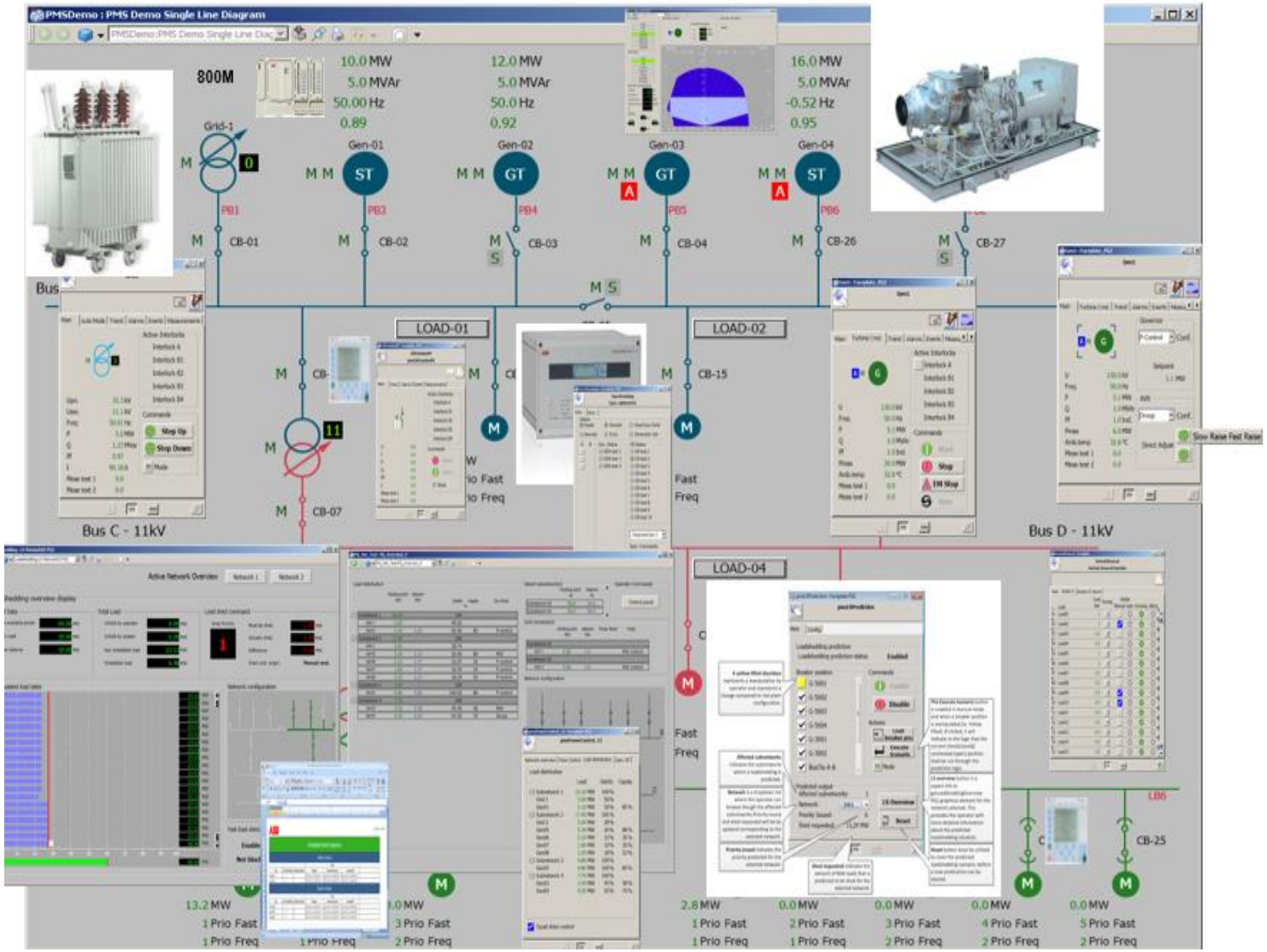
Major Electrical Equipment

Power Management Systems

- **Software**
  - Electrical Monitoring and Control
  - Load Shedding
  - Alarming / Annunciation
- **Hardware**
  - IT/ Networking (Servers, PCs, Switches)
  - HMI’s



Key functional considerations

Structure / Architecture	— Fully welded structural steel design — Inter-locking wall design, ceiling/roof panels by bolting — Color bond steel sheet wall design, ceiling & roofing by bolting — Fire rated walls, roof & floor — Blast resist design for building walls or roof — Split building design — Special environmental site conditions
HVAC	— Sized based on a variety of factors like ambient max. & min. temperature, equipment heat dissipation, thermal insulation capacity of wall & roof, desired operating temperature, zone classification, application specific e.g. purging system etc
Ventilation	— Normally provided for Battery room with a direct exhaust system to outdoor environment, so as to remove hazardous and explosive gases
Fire detection system	— Designed based on customer specification to provide early detection and integrated into plant's main fire detection system
Fire suppression system	— Form part of E-house utilities in various type such as Fire Suppression System — Includes portable CO_2 Fire Extinguishers at every entrance of the E-house

Key functional considerations

PA/GA system	— Wall mounted telephone handset and speakers, integrated with the Plant Communication System — Satellite link or Microwave link for telecommunication in remote/offshore installations
Lighting system	Internal & External Lighting that includes — Lux level calculations — Lighting layout design — Compliance to local / standards stipulated by international certifying agency — Compliance to zone classification etc.
Electrification & Instrumentation	Equipment engineering on — Layout arrangement / design — Heat dissipation (affects HVAC) — etc Interface engineering that has impact on — Installation — Schedule — Cable design and layout / routing
Shipping	— Type of E-house, loose items, openings, etc has to be taken into consideration and proper support / seals to be provided prior to shipment

Different types of E-Houses

Construction types

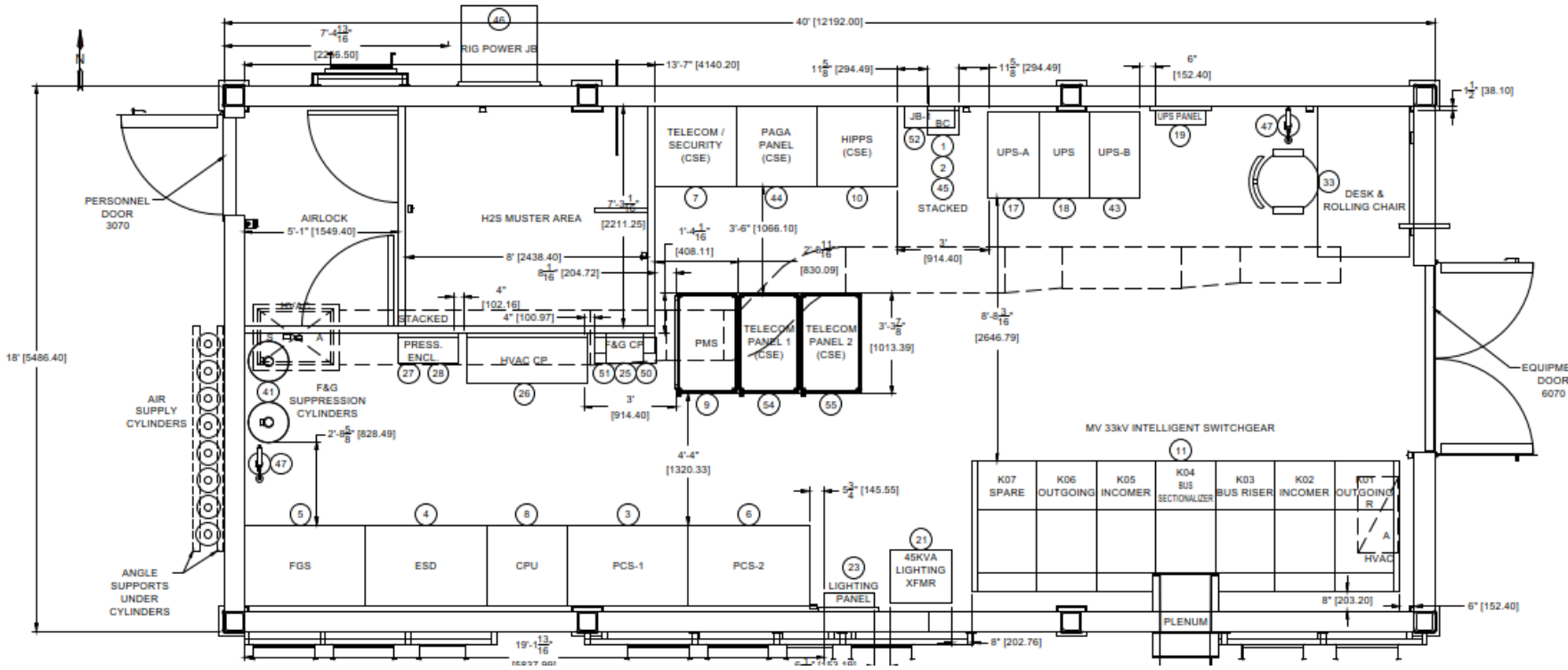
Structural Construction Types

- Fully welded structural steel design (Crimp Wall Design)
- Interlocking wall design, ceiling/roof panels by bolting
- Color bond steel sheet wall design, ceiling & roofing by bolting
- Hazardous Area Zone installation
- Blast resistant design for building walls or roof
- Fire rated walls, roof & floor
- Split building design
- Special environmental site conditions

Layouts and Elevations

Not only floor space but sometimes wall space is prime

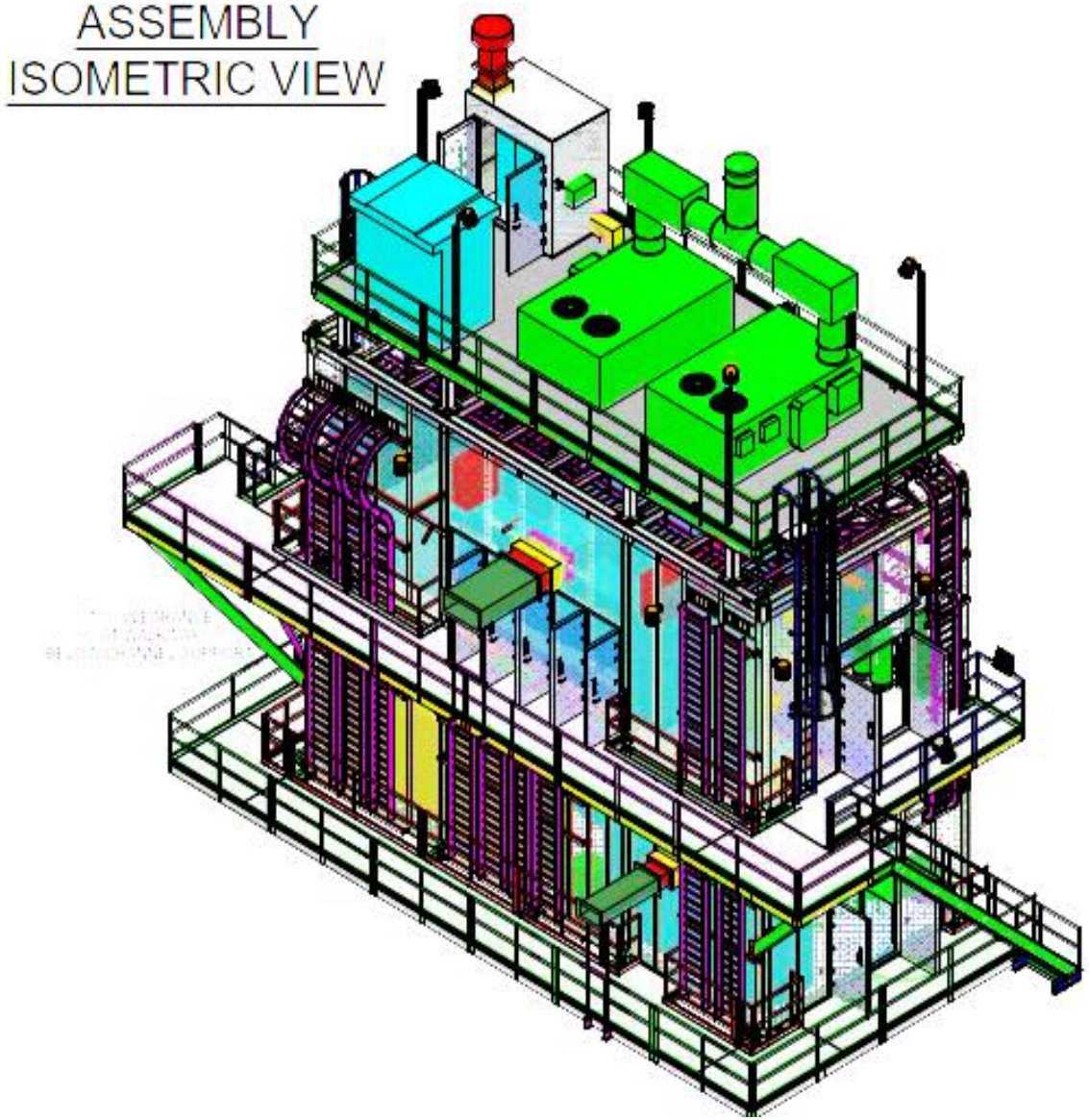
- Wall and floor penetrations needs to be identified in very early stages for structural purposes
- Always look for the miscellaneous devices to be installed in walls (light switches, receptacles, JB's, horns, strobes, gas detectors, etc…)
- Some wall mounted equipment and devices needs clearances also



3D Modeling

Devil is in the details…!!

- Look for clashes (equipment, cable trays, lights, HVAC ducting, suppression systems piping, etc…)
- All components are being accounted for wall and floor space (cabinets, transformers, conduit, junction boxes, panels, cable trays, etc…)
- Do not cut short in space in order to meet building and electrical codes and regulations
- Be aware of different room classifications when needed (battery room, electrical room, personnel room)



Onshore vs Offshore

Codes and Regulations

Be aware of which codes and regulations have to be met before you start your building design. These changes can be very costly when are not identified in the early stages of the project. Also, can throw away your schedule completely.

Some of the costly items for this category of onshore/offshore applications are but not limited to:

- Materials used (galvanized vs stainless steel vs aluminum)
- Area Classification (C1D2, C1D1, HVAC and Building Pressure)
- Suppression System (Inergen, FM200, NFPA92)
- Blast proof (doors, windows, walls, level of damage)
- Redundancy systems (HVAC, UPS, F&G)
- Fire rating (walls, floor/belly pan, penetrations, chartek, H-60)

Standards

SOLAS – Safety of Life At Sea

- Bulkheads and penetrations
- Fire rating and fire dampers
- Room classifications

ANSI/NEC

- Equipment clearances per code
- Equipment and fixtures used

IEC

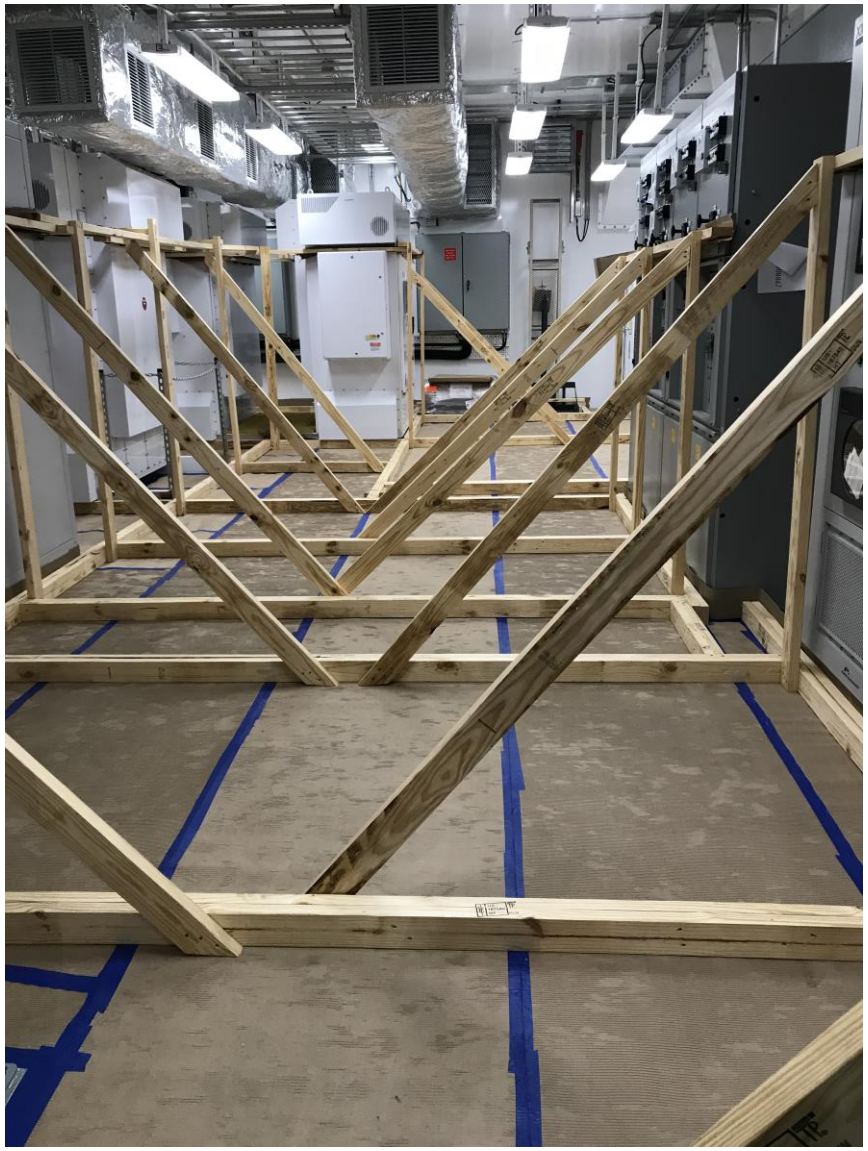
- Different from ANSI/NEC (wiring colors, grounding)
- Fixtures rating (cable glands)

Explosion Proof

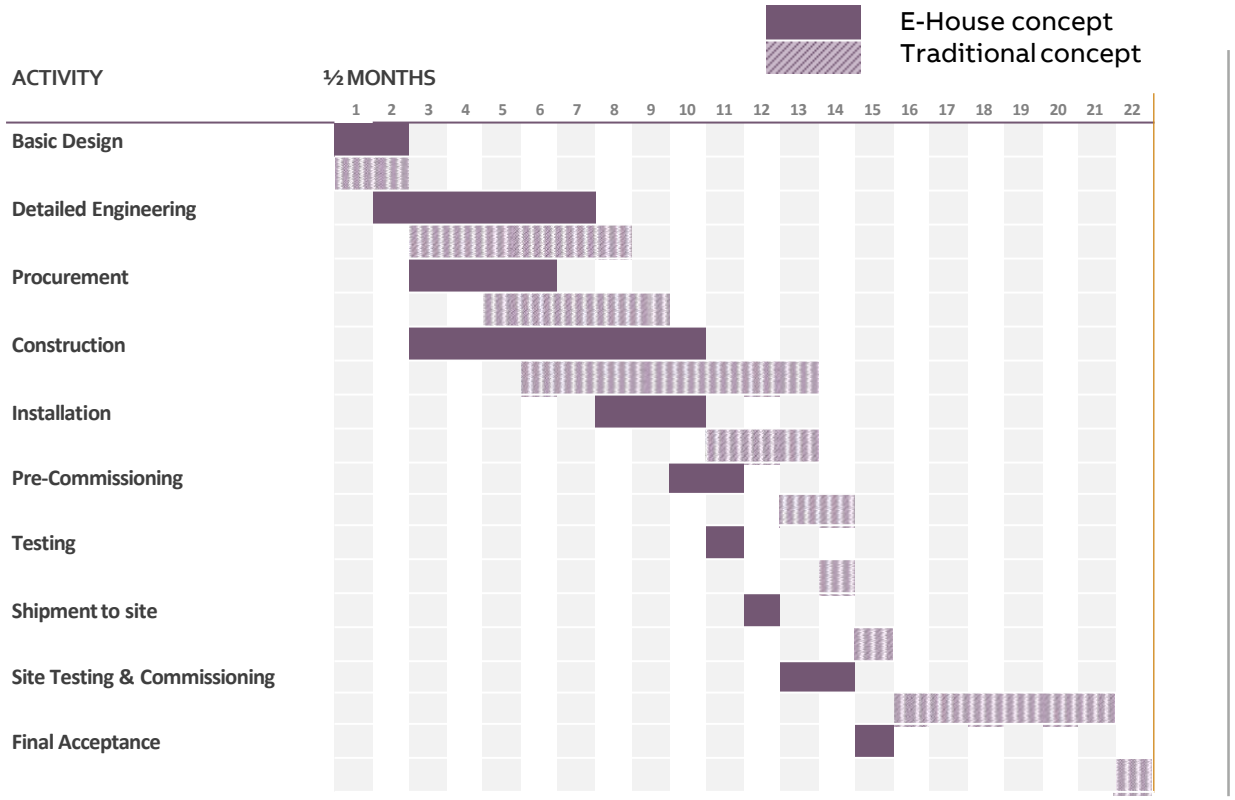
- Internal and External fixtures
- HVAC and Pressurization (Z-purge, black start)

Blocking and bracing

- Make sure electrical equipment has desiccant bags inside to dry out moisture
- Use proper wood type depending of the final destination
- Protect equipment with foam/cardboard to prevent scratches
- Customer/end user should be aware of preservation requirements when is received on site



Schedule efficiency via integrated approach



Changing the traditional procurement approach yields meaningful schedule gains

Site and Transportation Requirements

Many times missed when building is ready to ship or even in transit

- Safety (training, insurance, site access)
- Responsibility Table
- Power (permanent and temporary, volts, amps, location)
- Re-assembly when needed
- Loading and unloading (crane, SPMT, forklift)
- Preservation during transportation and at site
- Transportation (truck/barge, route, escort, power lines)
- Lightning protection
- Laydown area for material
- Others: Generator, HVAC, Fuel, Tools, etc…

Q & A Session