Packaged Substations

Andres Illarramendi – Interface Manager
David Brannon – Electrical Systems Application Engineer
Dwaraka Padimiti – Field Applications Engineer
Packaged Substations

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
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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
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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

[Diagram of RACI Matrix]

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**Roles and Responsibilities**
Responsible, Accountable, Consulted, Informed

<table>
<thead>
<tr>
<th>Deliverable or Task</th>
<th>Status</th>
<th>Roles</th>
<th>Project Team</th>
<th>Other Resources</th>
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<tbody>
<tr>
<td>Phase 1</td>
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<td>Deliverable/Task 2</td>
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Legend:
- **R**: Responsible
- **A**: Accountable
- **C**: Consulted
- **I**: Informed

Assign to complete the task or deliverable.
Has final decision-making authority and accountability for completion. Only 1 per task.
An advisor, stakeholder, or subject matter expert who is consulted before a decision or action.
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

<table>
<thead>
<tr>
<th>Nominal Voltage to Ground</th>
<th>Minimum Clear Distance</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Condition 1</td>
</tr>
<tr>
<td>0–150</td>
<td>914 mm (3 ft)</td>
</tr>
<tr>
<td>151–600</td>
<td>914 mm (3 ft)</td>
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<tr>
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<td></td>
</tr>
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</table>

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

<table>
<thead>
<tr>
<th>Nominal Voltage to Ground</th>
<th>Minimum Clear Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Condition 1</td>
</tr>
<tr>
<td>601–2500 V</td>
<td>900 mm (3 ft)</td>
</tr>
<tr>
<td>2501–5000 V</td>
<td>1.2 m (4 ft)</td>
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<tr>
<td>5001–25000 V</td>
<td>1.2 m (5 ft)</td>
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<tr>
<td>25001 V–75 kV</td>
<td>1.8 m (6 ft)</td>
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<tr>
<td>Above 75 kV</td>
<td>2.5 m (8 ft)</td>
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</tbody>
</table>
Packaged Substations

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
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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
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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
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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
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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
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Major Electrical Equipment

**AC/DC UPS and Critical Systems**

- AC/DC UPS Systems
- Static Transfer Switches
- Automatic Transfer Switches
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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
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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 CO₂ 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
– 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

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**Layouts and Elevations**

**Not only floor space but sometimes wall space is prime**
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 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.

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>½ MONTHS</th>
<th>E-House concept</th>
<th>Traditional concept</th>
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<tr>
<td>Basic Design</td>
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<td>Detailed Engineering</td>
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<td>Installation</td>
<td>17 18 19 20 21 22</td>
<td>E-House concept</td>
<td>Traditional concept</td>
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<td>Pre-Commissioning</td>
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<td>Testing</td>
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<td>Shipment to site</td>
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<td>Site Testing &amp; Commissioning</td>
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<td>Final Acceptance</td>
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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…
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Q & A Session