Compact Substation Design

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Agenda

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1. TGOOD Electric
Key Facts

Sino German Joint Venture

Leading manufacturer of prefabricated substations in China

$1.7 Billion USD Market

Vertically integrated production of E-Houses and switchgear

Global Headquarter in city of Qingdao, China

Africa Headquarter in Johannesburg
Manufacturing Excellence

5000+ E-Houses & Substations produced annually

3000+ employees

ISO 9001:2008; ISO14001; ISO 18001 certified facilities

5.4 million ft$^2$ production facilities
2. Compact Substations
Right now about 40 percent of African people live in urban environments,

But by 2030, the number will exceed 50 percent - some cities to swell by up to 85% of current size.

Extremely high urban growth rate in Sub-Saharan Africa of 3.6 percent, double the world average.

Availability of land in urban areas is a rising concern.

The increasing cost of land

Demand for compact power systems are the primary drivers bolstering the market for gas insulated substations.

GIS and HGIS substations can be installed in approximately 20% of space vs. that needed by conventional substations.
10 Biggest Cities:

1. Dar es Salaam (Tanzania),
2. Luanda (Angola),
3. Khartoum (Sudan),
4. Abidjan (Côte d'Ivoire),
5. Nairobi (Kenya),
6. Kano (Nigeria),
7. Ibadan (Nigeria),
8. Dakar (Senegal),
9. Ougadougou (Burkina Faso), and
10. Addis Ababa (Ethiopia)

- Population of these cities is projected to almost double by 2030.
- UN projections indicate by 2030, Dar es Salaam and Luanda - could have bigger populations than London has now.
Substation overview

- Substation - A set of equipment reducing the high voltage electrical power transmission to that suitable for supply to consumers.
- Components: HV switchgear, power transformer, MV switchgear.
- Transmission voltages: ≥66kV
- Distribution voltages: ≤33kV
Compact Substation: Definition

- Majority of equipment is pre-assembled and pre-tested equipment and typically housed in E-House
- Footprint significantly smaller than traditional substation with components more closely spaced
- GIS or Hybrid GIS on high voltage line side
- Less civil works required than traditional substation
- Substation modules may be moved if relocation is required
- Minimal work required on site; site commissioning complete in <2 months
Basic Components: GIS Substation

- Underground Cable Entry
- HV GIS
- MV Switchgear Feeders
- Power Transformers
Basic Components: Hybrid Compact Substation

- Incoming Overhead Line
- HV HGIS
- Power Transformers
- Air Disconnect Switch
- MV Switchgear Feeders
Traditional E-Houses

- Large “traditional” E-Houses
- Maximum dimensions per module: 17m long x 3.6m wide x 4.5m high
- Ideal for housing large switchgear, VFDs, HV GIS, etc.
- Heavy duty 14 gauge steel sandwich panels with injected foam insulation – tested and proven in harsh artic environments
Modular T-House

Including all switchgear (5~38kV) and electrical components

Significantly reduced overall shipping costs

Insulated E-House design offers exceptional all-climate performance

Conforms to CSC, ABS and ISO marine shipping criteria with all switchgear installed
Mobile E-House Options

Local Transport approved trailers

Heavy duty draggable skid-mount base available

Design accommodates large transformers (up to 70 MVA on separate skid/trailer) and other heavy equipment including gensets

Overhead line bushings for fast connection and quick connect high voltage couplers available
B. Major Advantages of Compact Substations
Extremely Compact Layouts

15kV Prefabricated Cabin

145kV Prefabricated Cabin

15kV Prefabricated Cabin

Fire Exit

Transformer Prefabricated Cabin

Transformer Prefabricated Cabin

Fire Exit
GIS Substation – Typical Timeline

Full substation engineering performed in-house

Configurable modules vastly reduce design and manufacturing times

Vertically integrated manufacturing allows for rapid customization

Rigorous factory testing reduces commissioning times to one month or less
Enclosed Equipment for Harsh/Polluted Environments

- In traditional substations, muck can build up, reducing safe operating clearances around equipment
- In arctic environments, snow and ice buildup can effect exposed electrical components
- Sand and dust in desert environments reduces operational lifespan of equipment

➤ Solution: E-House enclosures for electrical components
Safe and Vandal Resistant Design (GIS cable entry)

- Unlike traditional substations, compact substations are safe to touch, reducing risk to personnel and public.
- Painted to beautify urban settings.
- Structure is resistant to vandalism and may be equipped with security cameras and alarms in urban settings.
GIS Advantage Over AIS

- SF6 has excellent Dielectric properties
- SF6 gas provides 2.5 times better insulation compared to air and allows for more compact design
- Rapid quenching of arc energy for cooling
- High-grade switchgear remains hermetically sealed for its whole service life.
- No reduction in the current carrying capacity due to oxidation. No reduction in insulation capacity due to external factors.
- Very high operational reliability. Longer service life.
- Significantly less maintenance than AIS
- Environmental conditions within range (humidity, altitude, dust, contamination etc.) do not impact operation or reliability
2. Design Considerations
A. Standards
Standards that Apply

The IEEE (IEEE Std. C37. 122-1993; IEEE Std C37. 122.1-1993) and the IEC (IEC, 1990) have standards covering all aspects of the design, testing, and use of GIS. For the new user, there is a CIGRE application guide (Katchinski et al., 1998). IEEE has a guide for specifications for GIS (IEEE Std. C37.123-1996).

Canadian National Building Code 3.1.9. Firestop
ASCE (American Society of Civil Engineers) Substation Structure Design Guide (IEC)
IEEE Std 1427-2006
IEEE Guide for Recommended Electrical Clearances and Insulation Levels in Air Insulated Electrical Power Substations
Additional Standards

IEEE Std 80-2000 - SUBSTATION GROUNDING
IEEE 980-1994 - Oil Containment in Substations
IEEE Guide for Substation Commissioning and Turnover Planning

- IEC 62271-1 Common specifications for SF₆-insulated and air-insulated high-voltage switchgear and controlgear
- IEC 62271-200 Standard of medium-voltage SF₆-GIS
- IEC 62271-203 High-voltage switchgear and controlgear >52 kV
  - Revision published in 9/2011
- IEC 62271-303¹ Use and handling of SF₆
- IEC 60376² Specification for new SF₆-gas
- IEC 60480² Checking and treatment of sulfur hexafluoride (SF₆) taken from electric equipment
- IEEE C37.122 Gas Insulated Substations
- IEEE C37.122 IEEE Guide for Sulphur Hexafluoride
- ASTM D2472-00 SF₆-gas

¹ Revision in progress: IEC 62271-4
² Maintenance of the standard scheduled until 2014.

Target: 1 standard only, SF₆-Gas mixtures to be included, recommendation on monitoring.
Grounding

  - Safety Risks
  - Humans as Electrical Components
  - Soil Modeling
  - Fault Currents and Voltage Rise
  - Demands Use of Analytical Software

- NESC
  - Points of Connection
  - Messengers & Guys, Fences
  - Grounding Conductors, Ampacity, Strength, Connections
  - Grounding Electrodes
  - Ground Resistance Requirements
A. Kumtor Substation Replacement
Reference Project: Kumtor Substation

- 110kV-6.3kV 2 x15MVA Mining substation replacement
- 110kV roof-mounted Hybrid Gas Insulated Switchgear (HGIS)
- 16 6.3kV feeder cells supply power to mine
- Second-highest gold mining operation the world at 4000m elevation

Centerra Gold is a Canadian gold mining and exploration company with operations in Canada and Asia and annual gold production of 1.5 million ounces.
Compact GIS Substation

- Reduces construction times to between 3 and 6 months
- Uses only 20% of the space required by traditional air-insulated substation
- Safe to touch and resistant to vandalism
- Modular design facilitates rapid transport
- SF6 circuit breaker IEC and ANSI tested
Thank You