1. **OVERVIEW**

Electrical Substations play a disproportionately large role in the overall power system reliability. Designers must balance technical performance with cost, whilst still considering maintainability and availability to keep the overall lifecycle cost low. The design complexity is compounded by a multiplicity of switching configurations, and evolving switchgear technologies. The workshop not only provides theory and examples but also practical insights from projects and technology management. The material aims to demystify some of the confusion and contradictions by explaining why certain selections are made and the criteria they depend upon.

2. **CONTENTS**

The course will cover the following contents:

A. Substation Electrical Configurations and Reliability
   1. Substation Design Criteria
   2. Different substation types: Transformation vs. Switching, Transmission vs. Distribution vs. Collector substation
   3. Substation definitions according to Cigré: Components, Bays, Switchgear, Substation
   4. Substation Components and Arrangements
   5. Sub-transmission (132kV) substation example: Line Bay, Transformer Bay
   6. Substation availability and reliability
   7. Line bay topology for various levels of reliability
   8. Maintenance requirements: Redundancy, Access, Disconnection and Earthing
   9. Importance of Disconnectors
   10. Maintenance requirements for different types of switchgear
   11. Improving substation performance and reducing maintenance
   12. Manual disconnection devices
   13. Maintenance access
   14. Basic substation electrical configurations e.g. Double vs. Single busbar
   15. Sectionalised single busbar
   16. AIS Bus section arrangement facilitating maintenance
   17. Main and transfer busbar with bus-coupler
   18. Ring or meshed busbar
   19. Circuit-breaker-and-a-half
   20. Double breaker
   21. Relative cost and performance comparison
   22. Standby and Mobile transformers for reliability and availability
   23. MV switchgear layouts
   24. Double vs. Single busbar

B. Substation clearances and spacings for AIS
   1. Basic electrical clearances definition: Earth, Phase and Isolation (Disconnection)
   2. Derivation of the clearances
   3. Earthing philosophy and Temporary Overvoltage (TOV) effect on clearances
   4. AIS vs. GIS clearances
   5. Working or section clearances for maintenance
   6. Derivation of vertical and horizontal safety clearances
   7. Safety barrier
   8. Earthing switches vs. portable conductors
   9. Standardized electrical and safety clearances
   10. Derivation of design spacings
   11. Standardised design dimensions
   12. Substation vertical profile (height)
   13. Tension busbar conductor spacing
   14. Rigid busbar spacing
   15. Disconnector influence on transverse bay and bus dimensions
   16. Standard bay spacings
   17. Access for maintenance vehicles
   18. Longitudinal spacing between equipment
   19. Height of equipment connections

C. Insulation coordination
   1. Definition and basic principles of coordination
   2. Standards and Practical approach
   3. Overvoltage stresses
   4. Transient overvoltages and wave-shape and tolerances for testing: Lightning, Switching
   5. Origin of switching impulses
   6. Temporary overvoltages, origins and effects
   7. Statistical nature of overvoltages and insulation withstand
   8. Insulation level vs. surge protection margin
   9. USO (CFO) vs. Insulation level (U90)
   10. Insulation media classes and withstand characteristics
   11. Large vs. small air gaps
   12. Voltage classes MV, HV, EHV
   13. CFO vs. air gap for Lightning and switching
   14. Length of insulator and air gap clearances for overhead lines
   15. Effect of relative air density (RAD) on withstand
   16. Altitude and de-rating of insulation
   17. Standards and correction for altitude

D. Overvoltage (Surge) Protection
   1. Various protective devices and their protective characteristics (e.g. Spark gaps, gapped and gapless arresters)
   2. Spark gaps or arcing horns
   3. Spark gaps applications, coordination of spark gaps in system
   4. Spark gaps risks and disadvantages
   5. Use on line and modification for HV and EHV applications
   6. Adjustable gaps
   7. Protection of insulators
   8. Reduction in CFO and performance of Overhead lines with spark gaps
   9. Modern gapless surge arresters
   10. Construction and Voltage-current characteristic
   11. Electrical selection of arresters
   12. Protective margin
   13. Residual voltage
   14. Maximum continuous operating voltage (MCOV)
   15. Rated voltage
   16. Energy capability and line discharge class
   17. Temporary Overvoltage (TOV) capability and MCOV
   18. Arrester protective distance
   19. Environmental and mechanical selection
   20. Housing material and pollution performance
   21. Explosion risk and reinforcement of arresters
   22. Use of arresters for support
   23. Assembly of arresters and grading rings
   24. Substation arrester applications and installations

E. Electrical Ratings and Insulation Levels
   1. Definition of IEC voltage classes
   2. Standard IEC voltages
   3. Rated voltage: Nominal and maximum system voltages
   4. Rated frequency
   5. Rated continuous current
   6. Rated short-time current withstand
   7. Rated peak current withstand
   8. Arcing distance in AIS
   9. Lightning impulse withstand
   10. Switching impulse withstand
   11. Power frequency withstand
   12. Standardised insulation levels

F. Pollution Performance and Insulation Materials
   1. Insulation creepage distances
   2. IEC standard pollution severity classes
   3. Specifying creepages: Specific and Universal creepage
   4. Rationalisation of creepages based on environment and cost
5. Measuring creepage
6. Insulation materials and pollution performance
7. Properties of common insulation materials
   a. Toughened glass
   b. Porcelain
   c. Composite polymeric
8. Hydrophobicity and effect on leakage current
9. Vandalism
10. Insulator cleaning
11. Coatings and shed extenders

G. Substation Busbar Design and Post Insulators
1. Considerations for bus design: Steady state, corona, short circuit
2. Tension (flexible) busbars: Features, advantages and disadvantages
   a. Maintaining clearances
   b. Substation profile etc.
   c. Rigid busbar: Features, advantages and disadvantages
      a. Flexible and rigid connections to bay equipment
      b. Various indoor and outdoor examples
4. Tubular bus profiles and dimensions
5. Mechanical rigidity and deflection
6. Support of busbars on post insulators and disconnectors
7. Post insulator cantilever loads e.g. Short circuit forces and wind
8. Catering for thermal expansion
9. Aeolian vibration: Implications and mitigation

H. Flexible Conductors and Connectors
1. Flexible conductor: Properties, materials, types
2. Insulated conductors and connectors for vermin fault mitigation
3. Other mitigations for faults due to animals
4. Connectors: Properties, materials etc.
5. Connector types: Compression vs. bolted
6. Galvanic corrosion and joint compound
7. Development of hot connections
8. Bay stringing to cater for expansion

I. Power Transformers
1. Standards, definition and function
2. Transformer design challenges
3. The ideal transformer and ampere turns balance
4. Leakage flux and its implications (losses etc.)
5. Transformer types for power transmission and distribution
6. Double wound transformers
7. Auto-transformers
8. Core type transformers
9. 5 limb transformer
10. Shell type transformer advantages
11. Main components and function e.g. core, windings, paper, oil
12. Insulation types and materials
13. Insulation levels
14. Graded insulation
15. Temperature rise
16. Cellulose insulation and aging (degree of polymerisation DP)
17. Transformer conservator
18. Oil breakers and desicants
19. Online monitoring and dissolved gas analysis
20. Dry type transformers: Applications, advantages, cost
21. Gas insulated transformers
22. Impedance and fault current
23. Vector groups
24. Parallel operation of transformers
25. Cooling methods and ratings
26. Losses and life-cycle cost evaluation
27. Load and No-load losses
28. Hysteresis losses, noise and core materials
29. Core construction (laminations and step lapping)
30. Continuously transposed conductor

J. Circuit Breakers
1. Standards, definition and function
2. Design challenges and evolving technology
3. Basic types: Live vs. dead tank
4. Dead tank features and advantages
5. Implications of cold operating temperatures: dielectric gas proportions
6. Single and three pole operation
7. Point on wave or controlled switching
8. Interrupting medium
9. Advantages of SF6
10. Advantages of vacuum interrupters
11. Contacts: Main and sacrificial contacts
12. Breaking chambers
13. Interrupter ratings and operating times
14. Grading capacitors and insertion resistors
15. Operating mechanisms
16. Disconnecting circuit breaker (DCB)
17. Specifying breakers
18. Ratings for 132kV
K. Disconnectors (Isolators) and Earth Switches
1. Standards and disconnecter function
2. Disconnecter types, features and advantages
   a. Side break
   b. Centre break
   c. Centre rotate
   d. Vertical break
   e. Knee type
3. Pantograph
4. Substation layout and disconnectors
5. User specifiable dimensions
6. Switching capabilities of isolators
7. Load contacts
8. Sacrificial / commutating contacts
9. Ganged and single pole operation
10. Manual and Motorised operation
11. Motor drives
12. Auxiliary contacts
13. Earthing switches
14. Integral earthing switches on disconnectors
15. Philosophy of Portable earth conductors vs. switches
16. Induction and trapped charge at Extra High Voltage levels
17. Maintenance
18. Specification for disconnectors
L. Metalclad switchgear for MV distribution
1. Standards
2. General features
3. Safety – Internal arc rating and detection
4. Comparison between SF6 vs. vacuum for MV application
5. AIS features and disadvantages (safety, environmental etc.)
6. Fixed pattern (GIS) advantages
   a. Lifecycle cost
   b. Performance
   c. Safety
7. Emergency and mobile switchgear
M. Gas Insulated Switchgear
1. Definition and Major Components
2. GIS Construction
3. Network Integration and Connections e.g. Cables, AIS
4. Complete GIS Substations
5. Outdoor applications
6. Mobile GIS substations
N. Mixed Technology Switchgear
1. Different types of compact and combined switchgear
2. Compact AIS Modules
3. Development and Philosophy of Hybrid (Mixed Technology) Switchgear
4. Specifications and Equipment Rating Plates
5. Bay configurations
6. Functional components
7. Space savings with Hybrid switchgear
8. Further Hybrid examples
9. Maintenance philosophy
10. Comparison between technologies: Advantages and Disadvantages
11. Life-cycle costing comparison of the various technologies
THE SOUTH AFRICAN INSTITUTE OF ELECTRICAL ENGINEERS

TARGET AUDIENCE
- Engineers and Technicians in Plant, Project and Design, Power systems, Instrumentation & Control, Maintenance and Consulting
- Engineering Managers
- Safety Professionals
- Field & Service Technicians and Electricians

COST: Non-Member R10,850, SAIEE Member R8,500 (incl. teas, lunches and course material)
*Note: If proof of payment is received before commencement of the course, the following rates will apply:
Non-member R9,750 ; SAIEE member R7,600.

COURSE DATE:
28-30 March 2017 :
The Apollo Hotel, JOHANNESBURG
Registration: 08:00 – 08:30
Workshop: 08:30 - 16:30 (est.)

PRESENTER
Gavin Strelec is a registered Professional Engineer since 2003, with 18 years of related experience in the Electricity Utility Industry with Eskom in South Africa. He has gained considerable experience in Substation Design as a Project Engineer, and subsequently design standards and equipment specifications as a Substation Technology Specialist concentrating on medium and high voltage switchgear up to 132kV. For several years he was acting as Eskom national specialist for several substation equipment commodities, eventually appointed as a Chief Engineer in Distribution Technology. He presently holds the position of Chief Engineer in Eskom’s Research Department. He has recently obtained his MSc with distinction in Lightning Performance of HVDC Transmission lines.

He has been performing training seminars since August 2008 mainly on Substation Design but also Earthing and Overhead Line Design. He has presented in excess of 40 courses in various parts of South Africa, as well as the Democratic Republic of Congo, Ghana, Kenya and Uganda. His courses are always well received achieving high ratings from participating delegates. He uses many photographs and diagrams to communicate the principles and his presentation style is dynamic and engaging.

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