SUBSTATIONS

SUBSTATION FUNDAMENTALS

PART 2 PLANNING

Module 1

Part 2 – Outline

Module 1

1. Introduction
2. System Requirements
3. Site Location and Selection
4. Type of Switchgear
5. Switching Configurations

Part 2 – Outline

Module 2

1. Specification and Evaluation
2. Innovation and Standardisation
3. Contracting Options

Introduction

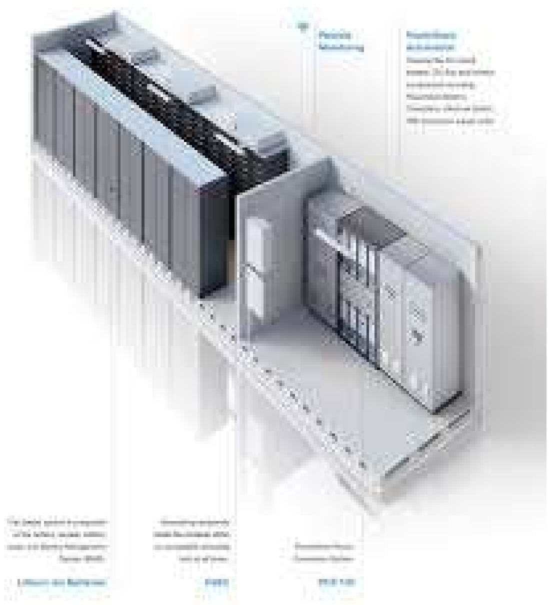
Network Planning - 1

- The process of planning for a new substation or expansion of an existing one is dependent upon the overall planning of the network.
- For Transmission networks the Utility will normally have a long term plan looking between five and ten years ahead .
- This plan will look at how they see the network developing over the next few years.
- In the past this was relatively simple based on new generation to be connected to the network and a forecast of new load based on information received from the distribution companies.

Introduction

Network Planning - 1

- However with the change in the structure of electricity networks with increasing connection of renewable generation, energy storage devices, electric cars etc., together with the TSO and Regulator’s requirements it is now causing Utilities to take a probabilistic approach rather than the traditional deterministic one.



Introduction

Network Planning - 2

Nevertheless the Transmission Utility or System Operator will carry out a number of system studies based on the most likely scenarios. These studies will include the following types of study

- DC Load flows to assess the real power flows (DC meaning looking at angle and MW only)
- AC load flows to assess real and reactive power flows and voltages. These would be carried out for system maximum and minimum load conditions, taking into account the required contingencies (N-1, N-2 etc), and are very important to assess the need for static or dynamic compensation plant which would need to be accommodated in the substations.
- Fault level studies for maximum and minimum conditions. These are necessary to define the equipment specification and possible need for special time constants on the circuit breakers and also protection performance.
- System stability studies which may define the required fault clearance times.
- Harmonic studies may be required to assess the need for filters.

Introduction

Network Planning - 3

- Based on the output of the system studies mentioned in the previous slide the Utility will determine the required system reinforcement needed.
- This may be a completely new substation, additional overhead lines and/or transformers to be connected into an existing substation or upgrades to increase the rating of transformers.
- Other possibilities are the need for series reactors to limit fault levels, phase shifting transformers to control real power flows, the addition of shunt capacitors or shunt reactors to control voltages at heavy or light load.

Introduction

Network Planning - 3

- In some cases more dynamic response may be necessary requiring Unified Power Flow Controllers(UPFC), Statcoms or Static Var Compensators (SVC).

Introduction

Network Planning - 4

- With regard to Distribution voltage level substations a similar process takes place.
- The Utilities will have a Long Term Development Plan.
- Distribution planning used to be dominated by new loads being connected to the network that had to be supplied.
- Nowadays, there are many other considerations to take into account with so much renewable generation (wind, solar etc,) being embedded within the distribution networks.
- The possibilities of issues such as reverse power flows, voltage issues on feeders, sudden cloud reducing overall input, technical issues such as the settings of multiple solar system inverters, safety issues for emergency services, maintenance issues have to be planned for within these new substations.
- There is now a much greater need for co-ordination in the planning between the Transmission and Distribution Network Operators.

Introduction

Types of Substation - 1

Traditionally the Transmission network performed three main functions:-

a) The transmission of electric power from generating stations (or other networks) to load centres.

b) The interconnection function, which improves security of supply and allows a reduction in generation costs.

c) The supply function which consists of supplying the electric power to sub transmission or distribution transformers and in some cases to customers directly connected to the transmission network.

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Introduction

Types of Substation - 2

These network functions were fulfilled through different types of substations as follows:-

a) Substations attached to Power Stations

b) Interconnection substations

c) Step Down (EHV/HV, EHV/MV, HV/MV) substations

A single substation may have performed more than one of these functions.

Introduction

Types of Substation - 3

With the increasing amount of renewable generation being used these days, a need has arisen for new types of transmission substation.

a) Substations for the connection of wind farms, both onshore and offshore, and large photovoltaic solar farms. These substations will normally involve the inclusion of static and dynamic compensation equipment and possibly harmonic filters

Introduction

Types of Substation - 3

b) HVDC Interconnection substations. These providing point to point links for bulk transmission of power from areas of high wind generation, usually in remote areas, to the large load centres.

Introduction

Types of Substation - 4

The increasing amount of distributed renewable generation (Distributed Energy Resources (DER)) has also given rise to new types of Distribution voltage level substations. The main changes are :-

a) New smaller wind farms are being built which are being connected into the distribution voltage network and these will often require compensation plant and harmonic filters.

b) The use of Photovoltaic (solar) cells has been strongly encouraged for consumers. Not only does this reduce the load requirements but it has the potential to turn a load centre into a small source of generation thus reversing the traditional load flow direction.

c) With the increasing trend towards electric vehicles the demand for an ever increasing requirement for charging points needs to be addressed.

d) This means that in many cases distribution voltage substations can no longer be considered as supply points for load but need to be designed to be able to deal with reverse flows. This will have an impact on the plant utilised and the protection requirements in these substations.

System Requirements

Main Plant Parameters - 1

The Utility's planning department will define the key parameters for the new substation or substation extension. System Planners seek to optimise these parameters which apply to the complete transmission system.

Examples of these parameters which will normally be common to the whole network are:-

- **Insulation impulse levels** – the lightning impulse withstand level and the switching impulse withstand level to be applied. The IEC standard offers a range of values for each normal operating voltage and the utility needs to clarify which values will be applicable to their network.
- **Fault current levels** – the short circuit current rating of the substation equipment (busbars, circuit breakers, current transformers etc.) insulators and support structures. These short circuit current ratings will define the applicable short circuit forces and are usually also linked to a time duration, typically one second for voltages in excess of 170kV and three seconds for lower voltages which define the thermal rating required.

System Requirements

Main Plant Parameters - 2

- **Fault clearance time with respect to system stability** – transient stability characterises the dynamic behaviour of a generator in the case of large oscillations following a major disturbance. In order to comply with the requirements of the network (system stability) or the specifications of particular utilities, specified fault clearance times must not be exceeded. Fault clearance time limits and the reclosing conditions may influence the choice of circuit breaker and other switchgear.
- **Current rating** – the maximum load current passing through the components in the substation (which is normally related to the maximum current capacity of the lines and underground cables)
- **Neutral point earthing** – the electrical networks may be effectively or solidly earthed (earth fault factor up to 1.4), non-effectively earthed for example resistance earthed or resonant earthed (earth fault factor 1.7) or isolated.

System Requirements

General Control Requirements

These are items such as the methodology of control which may be dependent on:-

- Whether disconnectors are operated manually or by motor
- Presence of earthing switches
- Degree of substation automation, sequence control
- Remote control from Grid Control Centre
- Regulations

The need for telecontrol and telecommunication links depends on the needs of the automation, remote control, data transmission and operation of the network. Substations are frequently also the nodal point of a data transmission network.

The requirement for load shedding, network sectioning, voltage regulation and load distribution regulation devices may be placed in substations.

System Requirements

General Protection Requirements

The substation has to be constructed so that all possible faults can be cleared:-

- Selectively, to minimise the impact to the system as a whole. For current/time graded protections the clearing times must be fully coordinated to achieve selectivity.
- Without exceeding the current rating of the lines and equipment
- Without causing danger to personnel and ensuring that the requirements of the safety codes are fulfilled
- Sufficiently quickly to ensure that the stability of the network is maintained
- In such a way that the load/generation balance is preserved

Requirements for main protections redundancy and provision of back up protection should be defined.

System Requirements

Other Requirements

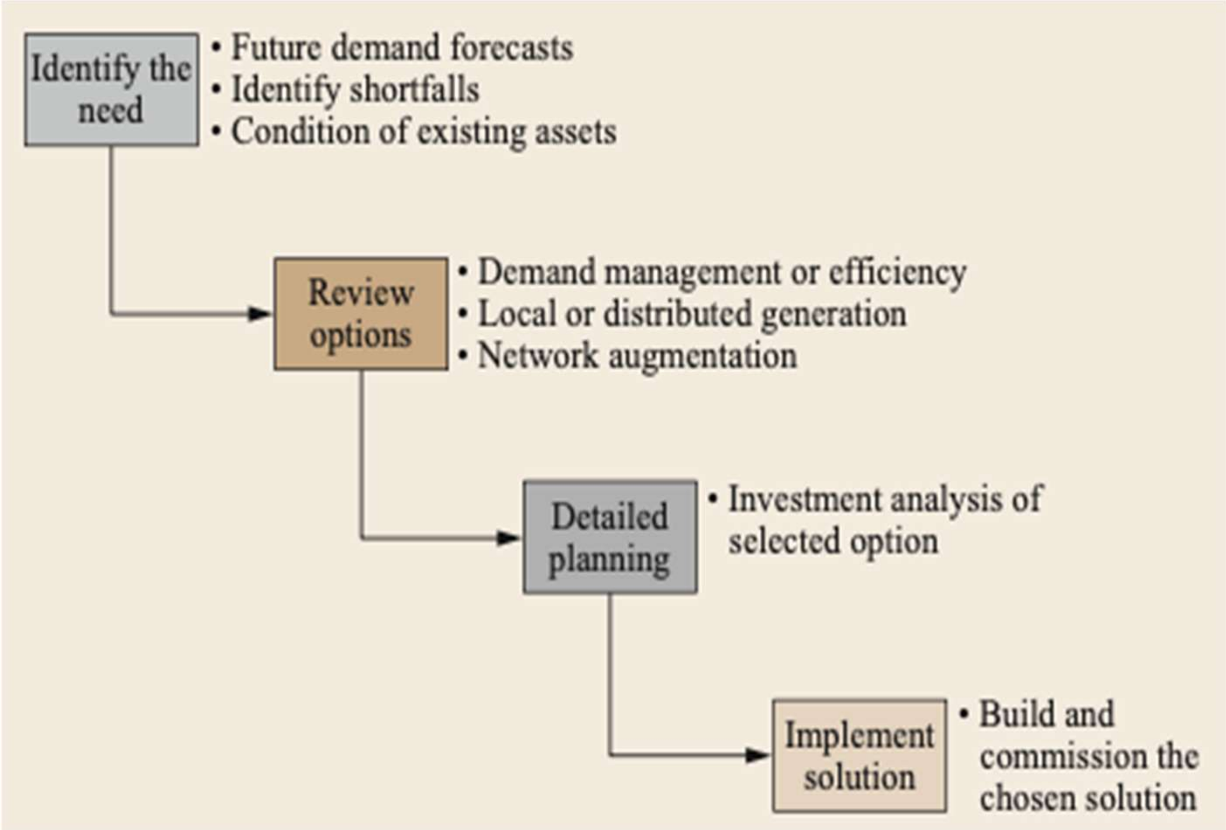
Other parameters relevant to specific substations but driven by system requirements are:-

- Required availability of the circuits and busbar schemes
- Extent of the substation – this will be dependent upon the area available for the substation, the number of outgoing feeders of different voltage levels, the number of main transformers, the busbar schemes and the possibility of extension as well as options for compensating equipment should be selected for the needs of the future. It should be noted that the lifetime of the substation may be between 30 – 50 years.
- Future extensions – it is very important to allow sufficient space for extension, and network planning is needed to estimate the necessary reserve space. In case of GIS, it is usual to reserve space for a number of spare bays and also to make allowance for the future extension of the control building.
- The outgoing line corridors should be planned in coordination with the substation and designed to minimise the number of crossings between different circuits.

Substation Selection

Selection Considerations

The decision to build a new substation or extend an existing one comes from the overall planning for reinforcing the network and is considered alongside other options. (See diagram for process)



Site Location and Selection

Site Selection Considerations

Having eliminated other options such as uprating existing circuits. The overall planning considerations should endeavour to:-

- Minimise the losses in power transmission and transformation
- Achieve the required reliability and busbar schemes
- Satisfy the required fault level and load flow requirements

As obtaining new line corridors is becoming increasingly difficult to achieve once it has been decided to build a new substation the availability of line corridors alone may be the determining factor for the location of the substation.

Site Location and Selection

Site Selection Considerations

Selection of substation site locations must be an acceptable balance of:

- Terrain
- Public concerns
- Aesthetics or visibility
- Environmental aspects
- Surrounding land use
- Number of properties involved
- Engineering

Site Location and Selection

Site Selection Considerations

The site location must also meet a number of other criteria such as:-

- Transmission line access
- Distribution line access
- Vehicle accessibility (Particularly for transporting large items of plant such as transformers)
- Constructability & maintainability
- Proximity of other utilities (pipe lines, etc.)

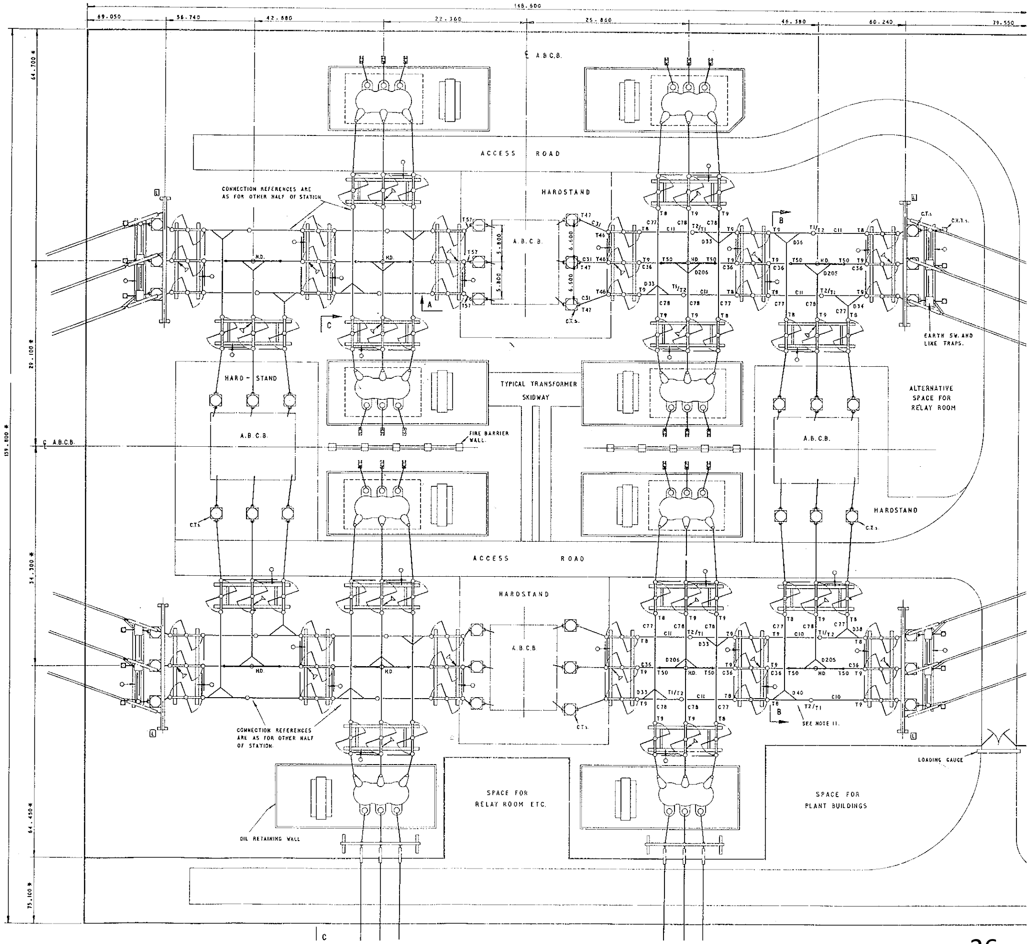
Site Location and Selection

Site Selection Considerations

The site location must be capable of accommodating all of the plant defined in the single line diagram.

Usually an initial layout drawing will have been produced taking account of the locations of the overhead line entries, road access etc.

However this layout may be modified if necessary to fit the space available on an otherwise favourable site.



Site Location and Selection

Site Acquisition and Permits

Once the preferred site location has been identified then the process of acquiring the site has to start which needs to cover the following

- Existing property parcel of the owner of the possible site
- Minimum property needed for substation
- Right-of-way needed for transmission lines
- Right-of-way needed for distribution lines
- Right-of-way needed for access road
- Any Special Requirements (oil containment, stormwater management)
- Include buffer space for screening, noise attenuation, O&M, etc.
- Include initial and future ultimate requirements

All requirements must be located and dimensioned for clarity.

Site Location and Selection

Site Acquisition and Permits

It is certain that some form of Planning Consent will be required associated with the new substation. There will normally be an overall planning consent but particular permits may well be required for

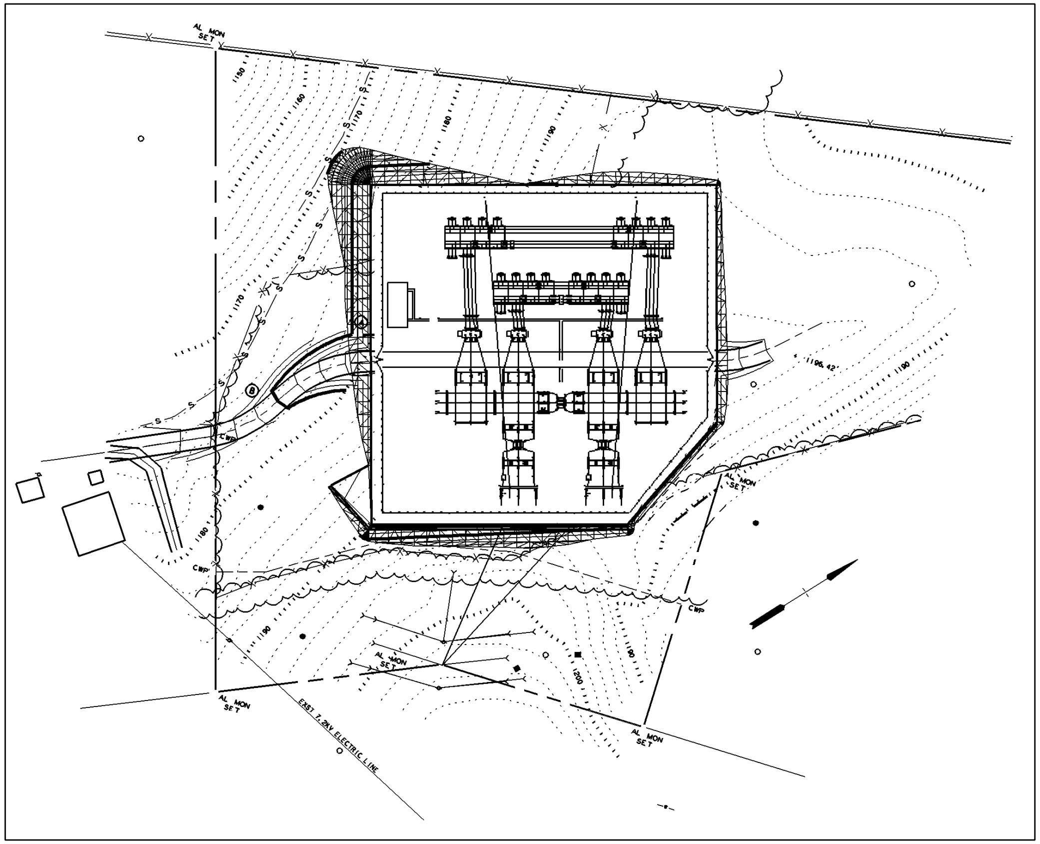
- Erosion control and sedimentation
- Excavation and blasting
- Road entrance permit to access main highway
- Storm water management plan
- Oil spill control and protection plan
- Wetland mitigation and re-forestation plans
- Building permit for control house
- Other: noise, light pollution, screening, landscaping

Site Location and Selection

Site Acquisition and Permits

The planning consent and permits for a Site are no longer reasonably automatic and a Site Plan is often required for the process.

- This is an overall drawing showing property, contours, grading, road and ultimate substation on the project site
- As aesthetic appearance and noise are becoming more important considerations then elevation views, sound levels, etc. are more frequently needed for approval
- The substation engineer is responsible to provide all that is required for this plan



First set of Questions

Type of Switchgear

Transmission Substations

Another important decision which has to be made at the planning/concept stage is which type of equipment will be used for the substation. Three types of equipment are available for selection by a transmission substation designer in order to implement the most appropriate solution for a particular substation i.e.

- Air-Insulated Switchgear (AIS)
- Gas-Insulated Switchgear (GIS)
- Mixed-Technology Switchgear (MTS)

Type of Switchgear

Transmission Substations – Air Insulated Switchgear (AIS)

Switchgear and other high-voltage equipment where the insulation to earth and between phase conductors is mainly provided by air at atmospheric pressure and where some live parts are not enclosed.

Advantages

- Equipment is usually the cheapest
- Relatively easy to extend and modify

Disadvantages

- Large space required because of clearances
- Affected by salt and industrial pollution
- Risk of electrocution from bare conductors
- Complex to asset replace – proximity, outages etc.
- Tends to be less pleasing aesthetically

Type of Switchgear

Transmission Substations – Gas Insulated Switchgear (GIS)

Metal-enclosed switchgear and other high-voltage equipment where the insulation is obtained, at least partly, by an insulating gas other than air at atmospheric pressure This gas is usually SF_6 or an SF_6 mixture with other gases although new gases are being developed.

Advantages

- Compact - good for areas with high land cost
- Easily housed indoors for better aesthetics and protected from pollution
- Good for asset replacement

Disadvantages

- Equipment is expensive
- Uses large volume of SF_6 (considered as a greenhouse gas)
- Difficult to extend or modify

Type of Switchgear

Transmission Substations – Mixed Technology Switchgear (MTS)

Equipment which has been developed from AIS or GIS into one of the following combinations:
AIS in compact and/or combined design
GIS in combined design
Hybrid-Insulated Switchgear where bays are made from a mix of AIS and GIS technology components.

Advantages

- Compact – combines multiple functions
- Useful for extending AIS substations where space is limited
- Good compromise between land and equipment cost.
- Modularity enables flexible extensions of AIS

Disadvantages

- More susceptible to pollution than GIS
- More expensive equipment than AIS

Type of Switchgear

Distribution Substations

There are four types of equipment available for selection by a substation designer in order to implement the most appropriate solution for a particular distribution substation i.e.

- Open Air Switchgear (AIS)
- Metal Enclosed Switchgear
- Metal-clad Switchgear
- Gas-Insulated Switchgear (GIS)

Type of Switchgear

Distribution Substations – Open Air Switchgear (AIS)

Open air substations contain separately mounted and interconnected switching equipment and components, like current transformers (CTs), voltage transformers (VTs), busbar support insulators, cable sealing ends, etc., where atmospheric air provides the main insulation path to earth.

Advantages

- Equipment is usually the cheapest
- Relatively easy to extend and modify

Disadvantages

- Large space required because of clearances
- Affected by salt and industrial pollution
- Not aesthetically pleasing

Type of Switchgear

Distribution Substations – Metal Enclosed Switchgear

With a metal enclosed arrangement all switching devices and associated components are enclosed in a metallic earthed structure on a per-bay basis and are cable connected. Can be located indoors or outdoors.

Advantages

- Relatively cheap
- Does not require large area

Disadvantages

- No segregation in panels so fault in one area can spread to other areas
- Not suitable if high reliability and availability are required.

Type of Switchgear

Distribution Substations – Metal-clad Switchgear

This is a derivative of the metal-enclosed switchgear where all major components per bay are physically segregated from one another by means of earthed metalwork such that a fault in any one compartment cannot readily spread to adjacent compartments. Can be located indoors or outdoors.

Advantages

- Suitable when high reliability and availability are required
- Good from safety point of view

Disadvantages

- Still relies on air as insulation
- Better mounted indoors to avoid corrosion

Type of Switchgear

Distribution Substations – Gas Insulated Switchgear(GIS)

This is a metal-clad switchgear with typically three gas filled compartments for busbar, circuit breaker and cable. The insulation was traditionally SF_6 but can now be compressed dry air.

Advantages

- High reliability and availability not affected by humidity
- Safest Design
- Low maintenance and operating costs

Disadvantages

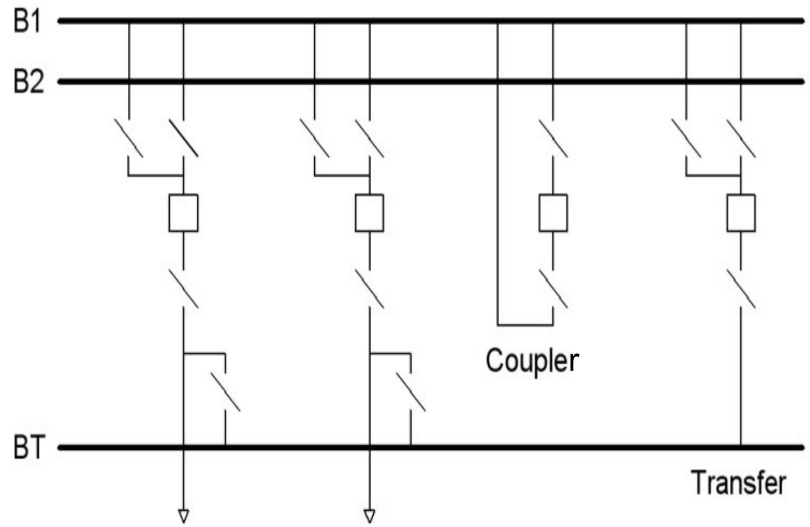
- Higher capital cost

Switching Configurations

Basic Principles

Introduction

- In the past, maintainability and accessibility of high voltage equipment was very important due to the requirements for frequent maintenance.
- These requirements meant that various configurations and arrangements of substations were developed to isolate the circuit breaker and current transformer in a bay for maintenance while ensuring availability of supply on adjacent equipment
- Disconnectors are required to deal with safety requirements and provide physical isolation during maintenance activities.



Switching Configurations

Basic Principles

Requirements

- The developments in the design of high voltage devices and new switchgear components using different design principles with higher reliability or integrated functions, mean that the reliable and efficient circuit arrangements of the past may not be necessary and result in onerous life-cycle-cost requirements for utilities. So the switching configurations nowadays need to consider the equipment, its functionality and the specific requirements of the substation.

- The substation has to fulfil a specific function in the network taking into consideration parameters defined by system studies and economic aspects. There are three main requirements which have to be analysed and evaluated during the selection process:
  - Service Security
  - Availability during maintenance
  - Operational Flexibility

Switching Configurations

Basic Principles

Requirements

Additionally the circuit arrangement can be influenced by:

- Extension of an existing substation
- Familiarity and good experience with particular equipment
- Long term procurement contracts
- Environmental protection issues such as sustainability, gas and oil leakage, material recycling, physical aesthetic, etc.
- Use of a particular technology due to environmental reasons e.g. proximity to salt water, lightning-prone area or space limitations, etc.

Switching Configurations

Basic Principles

Reliability

Reliability is an important consideration as it affects the availability of the substation components, circuit breakers, disconnectors, busbars, transformers etc.

The reliability is usually calculated using a computerised Failure Mode and Effect Analysis (FMEA) study taking account of failure rates (MTBF Mean time between failure) and average repair times.

The input data to this study must use the correct information relevant to the particular equipment taking account of any recent developments in the design of the equipment including any integrated functions and reliability improvements. Also changes in the maintenance strategies can influence the MTBF value and hence the reliability so the correct strategy should be considered.

Switching Configurations

Basic Principles

Service Security

The following slides show one way in which these factors can be assessed in order to try to achieve the optimal switching configuration for a substation.

- If we focus on the consequences to the network of the behaviour of the substation under contingency situations. If the configuration is able to support a contingency with no effect on the system, the substation will provide the highest level of service security for this situation.
- Service Security is the analysis of the substation's configuration in terms of availability of supply to the network after internal (busbar side of CB) and external faults (circuit side of CB), prior to any switching operations.
- Both circuit side and busbar side type primary faults are studied with and without breaker failure when a trip signal is sent to the appropriate circuit breaker(s).
- The scores in the following table are: 1 the worst, i.e. the highest impact; 6 best, i.e. the lowest impact.

Switching Configurations

Basic Principles

Service Security

Score	Possible consequences to the network because of a primary fault	Possible consequences to the network because of a primary fault when breaker fails to open
1	Possible loss of the whole substation	Loss of the whole substation
2	Loss of one or more feeders but not the whole substation	Loss of more than one feeder or the whole substation
3	Loss of one or more feeders but not the whole substation	Loss of more than one feeder but not the whole substation
4	Loss of one feeder	Loss of one feeder and always one feeder more but not the whole substation
5	Loss of none or one feeder	Loss of one feeder and possibly one feeder more but not the whole substation
6	Loss of none or one feeder	Loss of one feeder

Switching Configurations

Basic Principles

Maintenance Availability

- Availability during maintenance is a function of the substation configuration's ability to maintain feeders energized while maintaining disconnectors and circuit breakers.
- Switching risks and primary faults during maintenance operations have not been considered.
- Maintenance of circuit DS (circuit side of CB) always leads to an outage of the circuit. This is common for all circuit configurations and is therefore not mentioned in the following table. This element will impact on the ability to provide supply security for switching time.
- The scores listed in the following table have the following values, 1 - the worst consequences in the network: outage of whole substation and 7 - the least consequences in the network: no network element is disconnected and the network topology is not weakened.

Switching Configurations

Basic Principles

Maintenance Availability

Score	Maintenance of	Consequence
1	Any busbar disconnector	Outage of whole substation
2	Sectionalizer disconnector	Outage of whole substation
3	Any busbar or sectionalizer disconnector	Outage of half the substation
4	Any busbar disconnector	Outage of one busbar, remaining objects in service on the same busbar
5	Any busbar disconnector	Outage of one busbar, remaining objects in double busbar configuration
6	Any busbar disconnector	Remaining circuits in service
		Open ring
		Split-up of the substation
	Circuit breaker	Split-up of the substation and all circuits in service
7	Any busbar disconnector	Outage of one busbar, all objects in service on the same busbar
	Circuit breaker	All circuits remain in service

Switching Configurations

Basic Principles

Operational Flexibility

- Operational Flexibility is the analysis of the substation ability to reconfigure the feeders and split up the substation.
- Some switching configurations allow the substation to be split up into more than two parts. In the following table we consider flexibility only on the ability to split the substation in two separate electrical parts. This helps to manage fault levels and balance power flows to meet network security, stability and efficiency targets.
- In the following table the scores are defined as follows, 1 – it is not possible to split the substation into two separate electrical parts and 6 –it is possible to split the substation into two separate electrical parts and there is a high level of flexibility about how to do it.

Switching Configurations

Basic Principles

Operational Flexibility

Scores	Definition
1	Not possible to split
2	Non-energized split (disconnector only), no flexibility
3	Energized split (with circuit breaker), no flexibility
4	Energized split (with circuit breaker), low flexibility
5	Energized split (with circuit breaker), high flexibility, switching with disconnector
6	Energized split (with circuit breaker)
	High flexibility, switching with circuit breakers
	Highest flexibility, switching with disconnector

Switching Configurations

Basic Principles

Overall Assessment

- It is possible to make an overall assessment of the proposed configuration by combining the scores from Service Security, Maintenance availability and Operational flexibility.

- The relative weighting of each score will be different depending upon the function of the substation - Substations attached to Power Stations, Interconnection substations, Step Down (EHV/HV, EHV/MV, HV/MV) substations

The table below shows an example of the Weighting factors for a substation directly connected to a Power Station

Power station	Service security	Availability during maintenance	Operational flexibility	Sum
Weight factor	90%	5%	5%	100%

More detailed information on this aspect is available in the CIGRE Green Book for Substations Sections 4.4 to 4.6

Second set of Questions

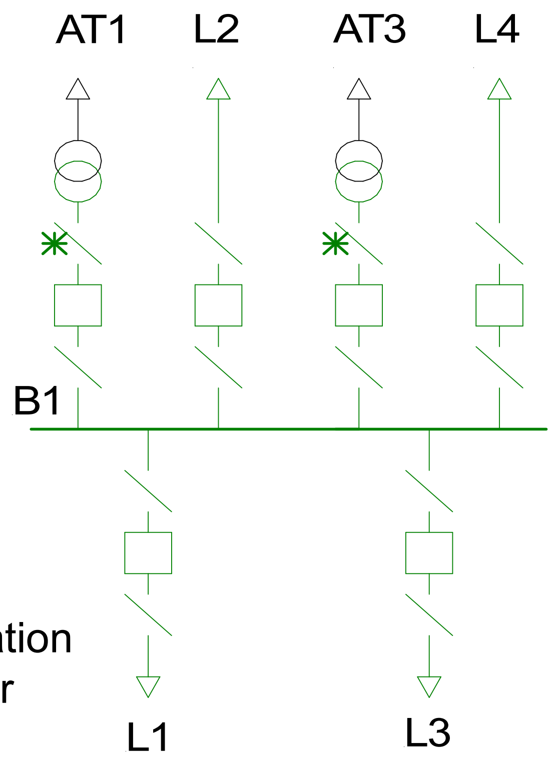
Switching Configurations

Examples of Different Switching Configurations

Single Busbar

A substation in which the lines and transformers are connected to one busbar only

Advantages
- Cheap
- Simple
- Easy to operate



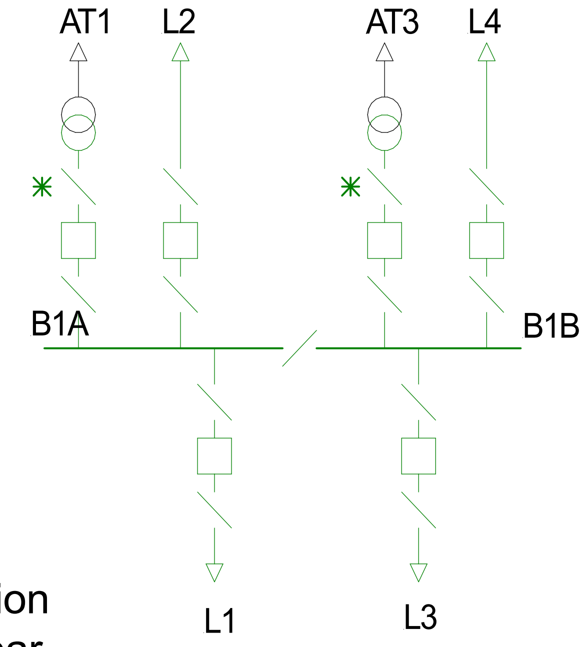
Disadvantages
- Virtually no flexibility for load flow control or short circuit level reduction
- A fault on busbar, any busbar disconnector or any CB loses whole substation
- Maintenance of any busbar disconnector requires shutdown of the busbar

Switching Configurations

Examples of Different Switching Configurations

Sectionalisable Single Busbar

A busbar including disconnector(s) in series intended to connect or disconnect two sections of that busbar, off load. Using a section CB allows sectionalizing on load and under fault conditions.



Advantages

- Relatively Cheap, simple and easy to operate
- Gives limited flexibility for load flow control and short circuit level reduction
- If a section CB is used only half the substation is lost for a busbar fault

Disadvantages

- Only limited flexibility for load flow control or short circuit level reduction
- A fault on busbar, any busbar disconnector or any CB loses half of the substation
- Maintenance of any busbar disconnector requires shutdown of half of the busbar and maintenance of section disconnector requires shutdown of whole substation.

Switching Configurations

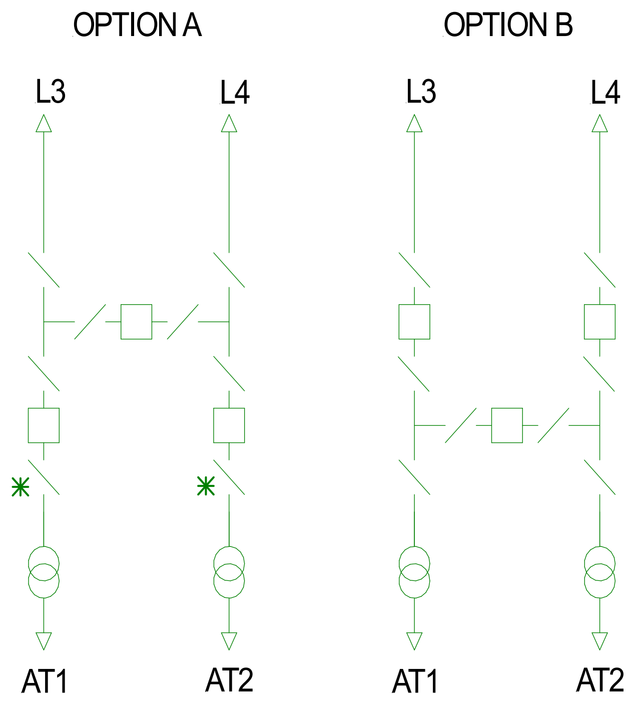
Examples of Different Switching Configurations

H3 Configurations

H-configurations are single busbar arrangements with specific arrangement (H-shape) H3 employs three circuit breakers. Note a H1 is possible but not covered here.

Advantages
- Useful for connection of factory or wind farm
- Option A fault on transformer does not lose through line.
- Option B fault on either line does not lose any transformers.

Disadvantages
- Option A - fault on either line loses the through connection and one transformer.
- A fault on section CB loses the whole substation
- Maintenance of busbar side disconnectors require shutdown of half of the substation

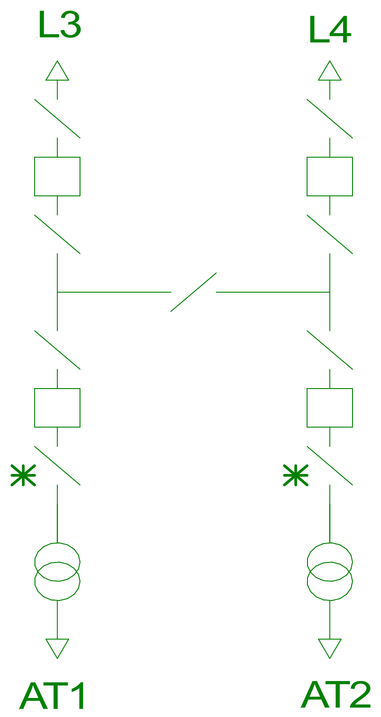


Switching Configurations

Examples of Different Switching Configurations

H4 Configuration

H-configurations are single busbar arrangements with specific arrangement (H-shape) H4 employs four circuit breakers.



Advantages

- Useful for connection of factory or wind farm
- Fault on either transformer does not lose through line.
- Fault on either line does not lose any transformers.

Disadvantages

- A fault on section disconnector loses the whole substation
- Maintenance of busbar side disconnectors require shutdown of half of the substation
- Maintenance on section disconnector requires shutdown of whole substation

Switching Configurations

Examples of Different Switching Configurations

H5 Configuration

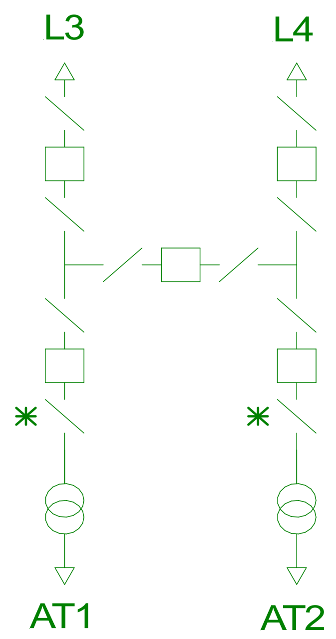
H-configurations are single busbar arrangements with specific arrangement (H-shape) H5 employs five circuit breakers.

Advantages

- Fault on either transformer does not lose through line.
- Fault on either line does not lose any transformers.
- Fault on corner busbars only loses half of the substation

Disadvantages

- A fault on section CB loses the whole substation
- Maintenance of busbar side disconnectors require shutdown of half of the substation

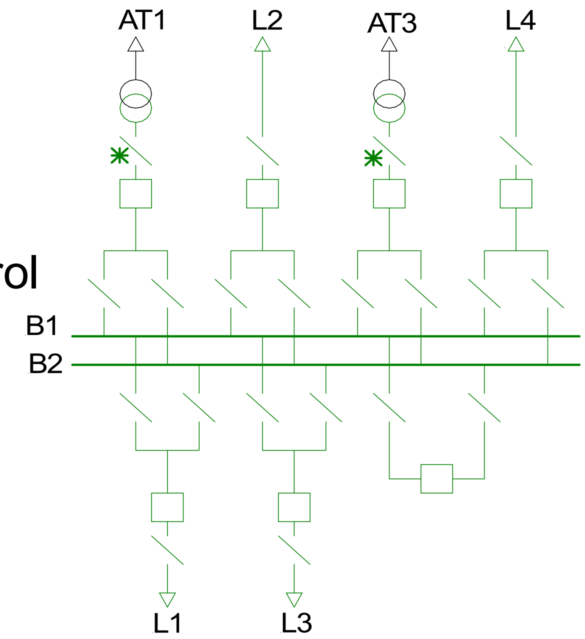


Switching Configurations

Examples of Different Switching Configurations

Double Busbar

A substation in which the lines and transformers are connected to two busbars



Advantages

- Flexibility of running arrangements for load flow and short circuit control
- Circuits can be transferred from one busbar to the other on load
- Any section of busbar can be maintained without loss of any circuits

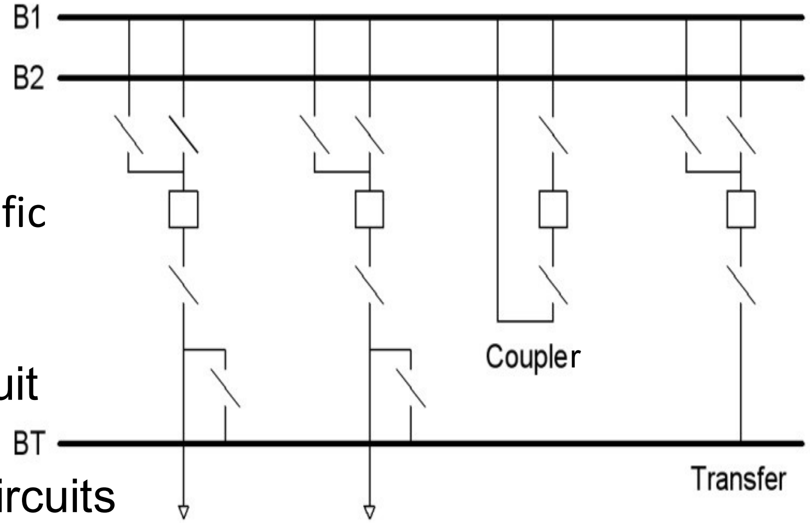
Disadvantages

- Maintenance of a circuit breaker loses that circuit
- A fault on a busbar will lose some circuits until the substation can be reconfigured
- A fault on the bus coupler CB (or section CB if fitted) will lose two sections of busbar,

Switching Configurations

Examples of Different Switching Configurations

Double Busbar with Transfer Bus



A substation in which the lines and transformers are connected to two busbars with a back-up busbar to which any circuit can be connected independently of its bay equipment (circuit-breaker, instrument transformer), the control of this circuit being ensured by another specific bay, available for any circuit.

Advantages

- Flexibility of running arrangements for load flow and short circuit control
- Any section of busbar can be maintained without loss of any circuits
- CBs can be maintained without loss of the circuit using transfer bus

Disadvantages

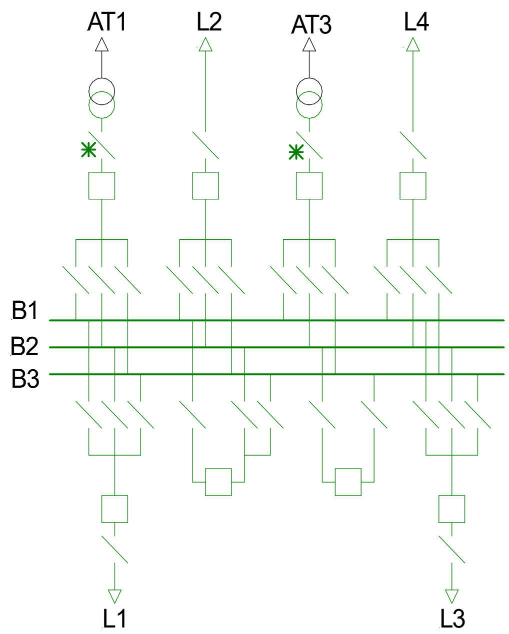
- A fault on a busbar will lose some circuits until the substation can be reconfigured
- A fault on the bus coupler CB (or section CB if fitted) will lose two sections of busbar.

Switching Configurations

Examples of Different Switching Configurations

Triple Bus

A substation in which the lines and transformers are connected via three busbars by means of selectors



Advantages

- Improved flexibility of running arrangements for load flow and short circuit control
- Circuits can be transferred from one busbar to the other on load
- Any section of busbar can be maintained without loss of any circuits

Disadvantages

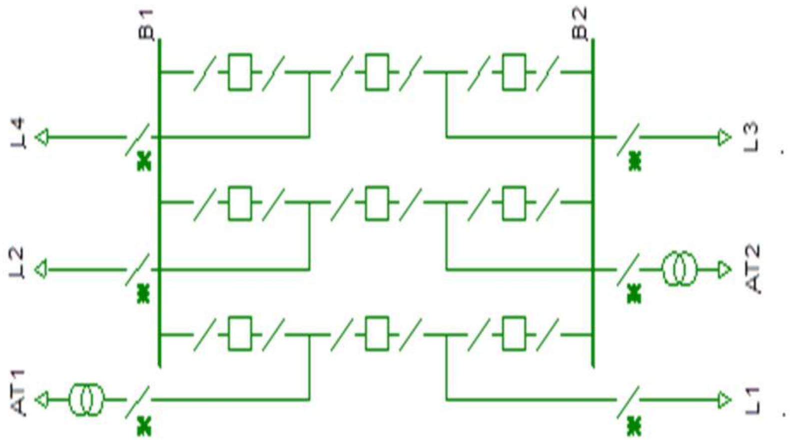
- Maintenance of a circuit breaker loses that circuit
- A fault on a busbar will lose some circuits until the substation can be reconfigured
- A fault on the bus coupler CB (or section CB if fitted) will lose two sections of busbar,

Switching Configurations

Examples of Different Switching Configurations

One and a Half Circuit Breaker

A double busbar substation where, for two circuits, three circuit-breakers are connected in series between the two busbars, the circuits being connected on each side of the central circuit-breaker. The connection between busbars is called a diameter.



Advantages

- Busbar Fault does not lose any circuits during the fault.
- Provides bus coupling at every diameter.
- Maintenance of any CB or the main busbars does not require any circuit outage

Disadvantages

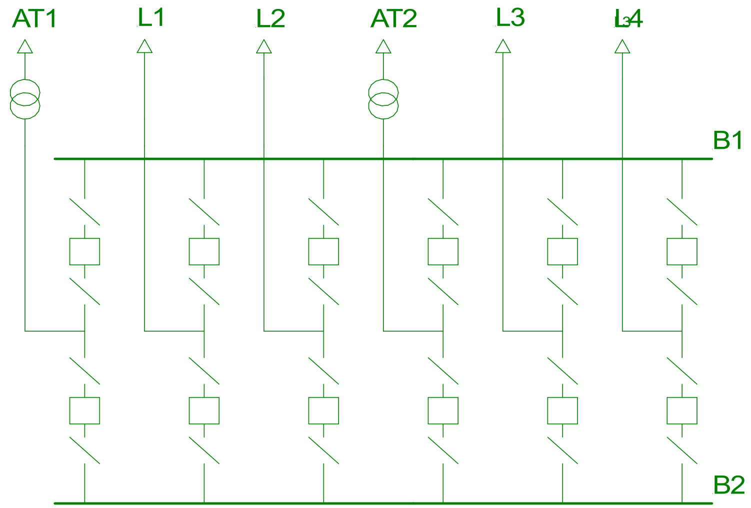
- Expensive – each circuit requires one and a half circuit breakers
- Not suitable for sectionalising for fault level control.
- Requires more circuit breakers to open to clear faults.

Switching Configurations

Examples of Different Switching Configurations

Double Bus Double Circuit Breaker

A double busbar substation in which the selectors are circuit-breakers.



Advantages

- Busbar Fault does not lose any circuits during the fault.
- Provides bus coupling at every bay..
- Maintenance of any CB or the main busbars does not require any circuit outages.

Disadvantages

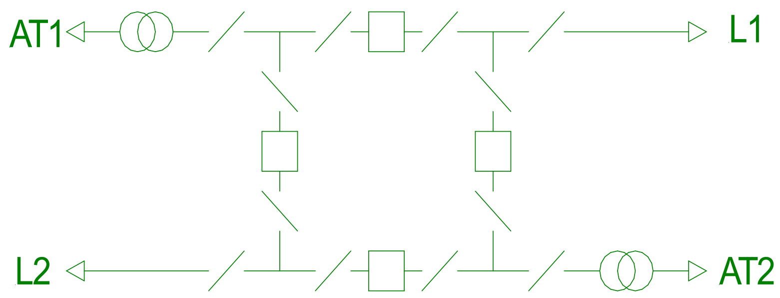
- Expensive – each circuit requires two circuit breakers
- Requires more circuit breakers to open to clear faults.

Switching Configurations

Examples of Different Switching Configurations

Ring Bus or Mesh

A Ring bus or mesh substation is a single busbar substation in which the busbar is formed as a closed loop



Advantages

- Circuit breakers can be maintained without loss of any circuits
- After clearance of circuit faults the CBs can be closed to complete the ring
- Fault on a circuit only loses that circuit.

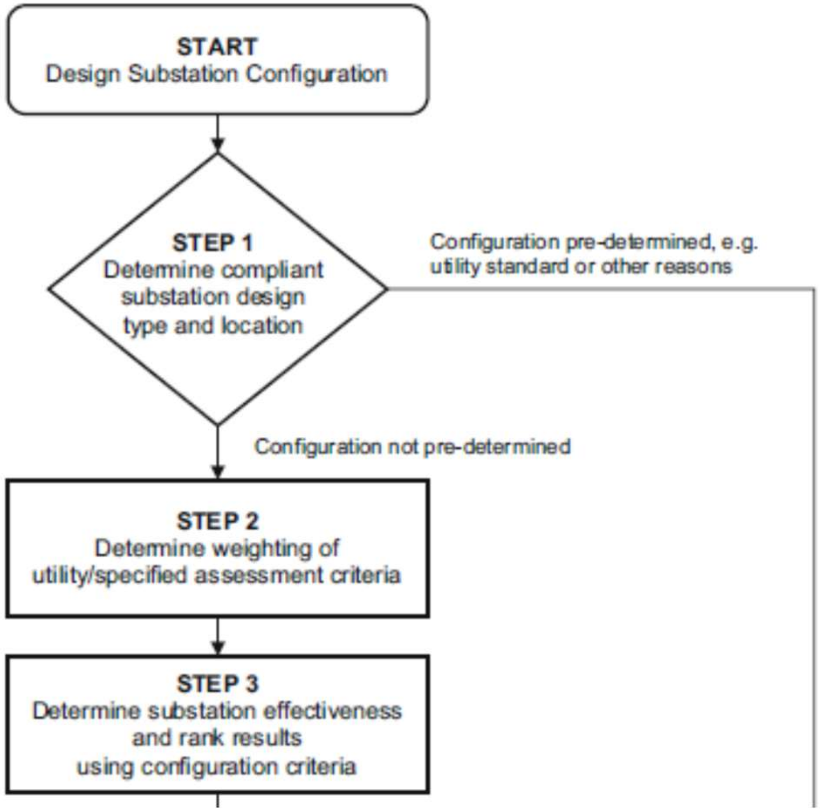
Disadvantages

- Cannot be sectionalised for short circuit limiting
- May require complex protection, inter-tripping and auto-reclose schemes.
- Not easy to extend

Switching Configurations

Selection Process

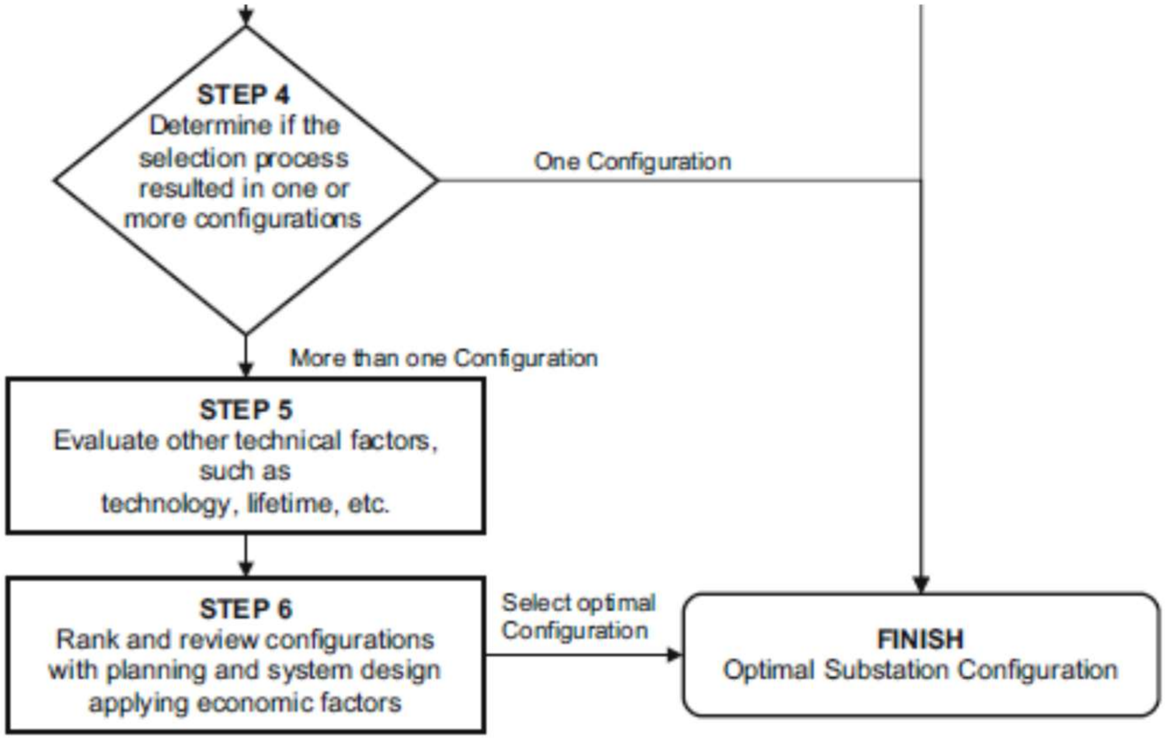
Selection Process Flowchart



Switching Configurations

Selection Process

Selection Process Flowchart



Final Questions

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For power system expertise