Substation Switching Schemes

Switching Scheme Of Substation

This technical article is intended to provide description and comparison of single line options for a DESN substation. The goal is to provide an analytical comparison for all options so that one can select the optimum solution considering cost, reliability, maintainability, ease of operation.

This article describes alternative solutions to the deficiencies at the station.

Description Of Options Studied

Switching Scheme Of Substation

Switching scheme of substation determines the electrical and physical arrangement of the switching equipment. Different switching schemes can be selected as emphasis is shifted between the factors of security, economy, extendibility, maintainability, operational flexibility, protection arrangement, short circuit limitations, land area, safety and simplicity dictated by function and importance of the substation.

Security of supply

Security of supply or substation service continuity is the main factor in selecting the switching scheme.
Complete security of supply may be achieved by duplicating all circuits and substation equipment such that following a fault or during **maintenance** connections remain available. This would be extremely costly. Switching schemes discussed in this report are mainly based on a compromise between complete security of supply and capital investment.
Considering that line or transformer faults destroy service continuity on the affected circuits, substation service continuity could be categorized into four categories, as described below.

Switching schemes will be categorized in accordance with this categorization.

Category 1 – No outage necessary within the substation for either maintenance or fault; e.g. the 1 ½ breaker scheme under maintenance conditions in the circuit breaker area.
Category 2 – Short outage necessary to transfer the load to an alternative circuit for maintenance or fault conditions; e.g. the double busbar scheme with bypass disconnect switch and bus-coupler switch under fault or maintenance conditions in the circuit breaker or busbar area.
Category 3 – Loss of a circuit or section; for example the single busbar with bus section circuit breaker scheme for a fault in the circuit breaker or busbar area. The single feed scheme also comes under category 3 service continuity and for this arrangement the addition of incoming circuit breakers, busbar and transformer circuit breakers does not improve the classification.
Category 4 – Loss of substation; for example the single busbar scheme without **bus sectionalization** for a fault in the busbar area.

Extendibility

The design should allow for future extendibility. Adding bays of switchgear to a substation is normally possible and care must be taken to minimize the outages and outage durations for construction and commissioning. Where future extension is likely to involve major changes (such as from a **single to double busbar** arrangement) then it is best to install the final arrangement at the outset because of the disruption involved.

When minor changes such as the addition of overhead line or cable feeder bays are required then busbar disconnect switches may be installed at the outset thereby minimizing outage disruption.

Maintainability

The switching scheme must take into account the electricity supply company system planning and operations procedures together with knowledge of reliability and maintenance requirements for the proposed substation equipment. The need for circuit breaker disconnect switch bypass facilities may therefore be obviated by an understanding of the relative short maintenance periods for modern switchgear.

Operational flexibility

The switching scheme must permit the required power flow control of individual circuits and groups of circuits. In a two transformer substation operation of either or both transformers on one infeed together with the facility to take out of service and restore to service either transformer without loss of supply would be a normal design consideration. In general a multiple busbar arrangement will provide greater flexibility than a ring busbar.

Protection arrangements

The switching scheme must allow for the protection of each system element by provision of suitable CT locations to ensure overlapping of protection zones. The number of circuit breakers that require to be tripped following a fault, the auto-reclose arrangements, the type of protection and extent and type of mechanical or electrical interlocking must be considered.

For example a 1½ breaker substation layout produces a good utilization of switchgear per circuit but also involves complex protection and interlocking design which all needs to be engineered and thus increases the capital cost.

Short circuit limitations

In order to keep fault levels down parallel connections (transformers or power sources feeding the substation) should be avoided. Multi-busbar arrangements with sectioning facilities allow the system to be split or connected through a fault limiting reactor. It is also possible to split a system using circuit breakers in a mesh or ring type substation layout although this requires careful planning and operational procedures.

Cost

A satisfactory cost comparison between different substation switching scheme is extremely difficult because of the differences in performance and maintainability. It is preferable to base a decision for a particular scheme on technical grounds and then to determine the most economical means of achieving these technical requirements.

The options studied are described in this section.

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Alternative Switching Schemes

1. Single Bus Scheme

The single **busbar arrangement** is simple to operate, places minimum reliance on signalling for satisfactory operation of protection and facilitates the economical addition of future feeder bays. ***Figure 1*** illustrates a single busbar scheme with fourteen feeder circuits and one bus section circuit breaker.

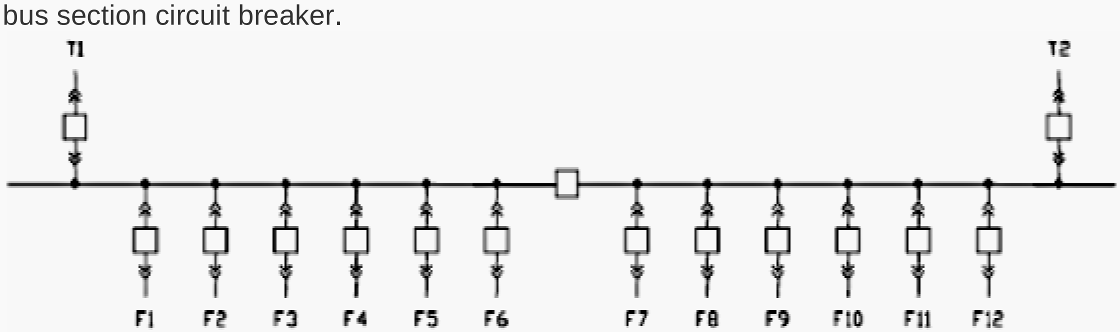

Figure 1: Single Bus scheme with Bus Section Breaker

Characteristics:

1. Each circuit is protected by its own circuit breaker and hence a fault on a feeder/transformer does not necessarily result in loss of supply to other feeders.
2. A fault on a feeder or transformer circuit breaker causes loss of the transformer and feeders circuits. They may be restored after isolating the faulty circuit breaker.
3. A fault on a bus section circuit breaker causes complete shutdown of the substation. All circuits may be restored after isolating the faulty circuit breaker and the substation will be 'split' under these conditions.
4. A busbar fault causes loss of one transformer and all feeders on that bus section. Maintenance of one busbar section will cause the temporary outage of all circuits. Can be used only where loads can be interrupted.
5. Bus cannot be extended without de-energizing of half of the substation
6. Difficult to do any maintenance, maintenance of a feeder or transformer circuit breaker involves loss of that circuit.
7. Lowest cost
8. The introduction of bypass isolators between the busbar and circuit isolator (***Figure 2***) allows circuit breaker maintenance facilities without loss of the circuit. Under these conditions full circuit protection is not available.
9. Bypass facilities may also be obtained by using a disconnect switch on the out-going ways between two adjacent switchgear bays (***Figure 3***). The circuits are paralleled onto one circuit breaker during maintenance of the other. It is possible to maintain protection (although some adjustment to settings may be necessary) during maintenance but if a fault occurs then both circuits are lost. With the high reliability and short maintenance times involved with modern circuit breakers such bypasses are not nowadays so common.

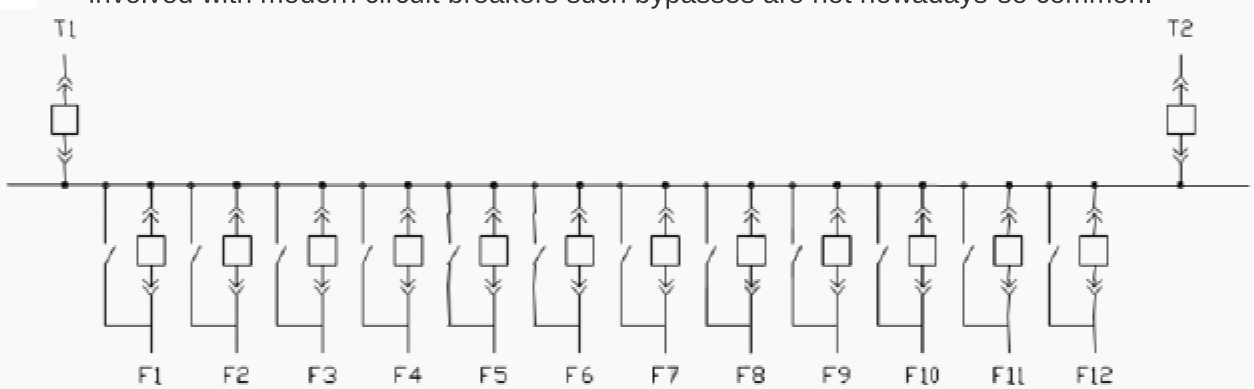

Figure 2: Single Bus scheme with Bypass Isolator

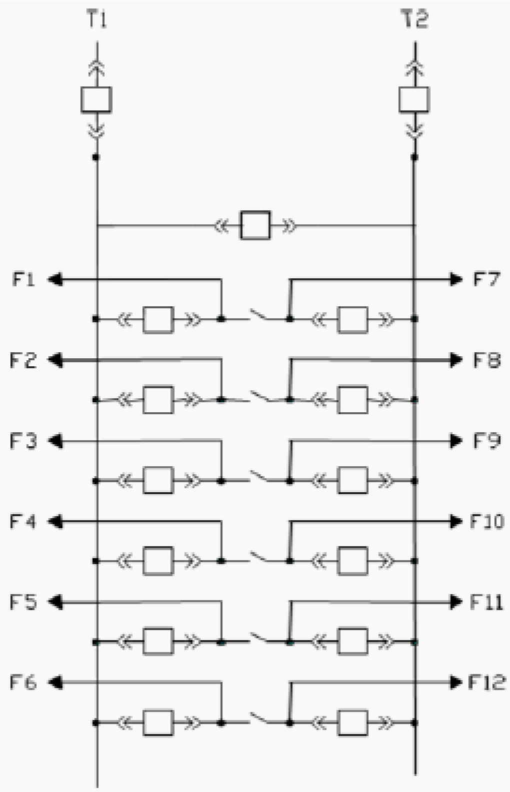

Figure 3: Single Bus scheme with Bypass Switch between Two adjacent Bays

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2. Mesh Scheme

Each section of the mesh scheme, as shown in ***Figure 4***, is included in a line or transformer protection zone so no specific separate busbar protection is required. Operation of two circuit breakers is required to connect or disconnect a circuit and disconnection involves opening the mesh.

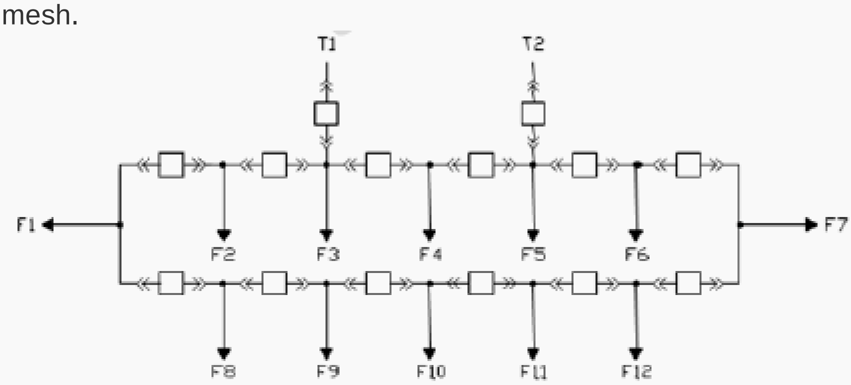

Figure 4: Mesh Scheme

Line or transformer circuit disconnect switches may then be used to isolate the particular circuit and the mesh reclosed:

1. **Circuit breakers** may be maintained without loss of supply or protection and no additional bypass facilities are required. The particular circuit may be fed from an alternative route around the mesh.
2. If a fault occurs during a breaker maintenance period, the mesh can be separated into two sections
3. Busbar faults will only cause the loss of one circuit.
4. Circuit breaker faults will involve the loss of a maximum of two circuits. Breaker failure during a fault on one of the circuits causes loss of one additional circuit owing to operation of breaker-failure relaying
5. Maximum security is obtained with equal numbers of alternatively arranged infeeds and load circuits.
6. Flexible operation for breaker maintenance. Any breaker can be removed for maintenance without interrupting load.
7. Does not use main bus.
8. Each circuit is fed by two breakers however the ratio of circuit breakers to circuits is 1/1.
9. Automatic reclosing and protective relaying circuitry rather complex
10. If a single set of relays is used, the circuit must be taken out of service to maintain the relays. (Common on all schemes)
11. Requires potential devices on all circuits since there is no definite potential reference point These devices may be required in all cases for synchronizing, live line, or voltage indication.
12. Low initial and ultimate cost.

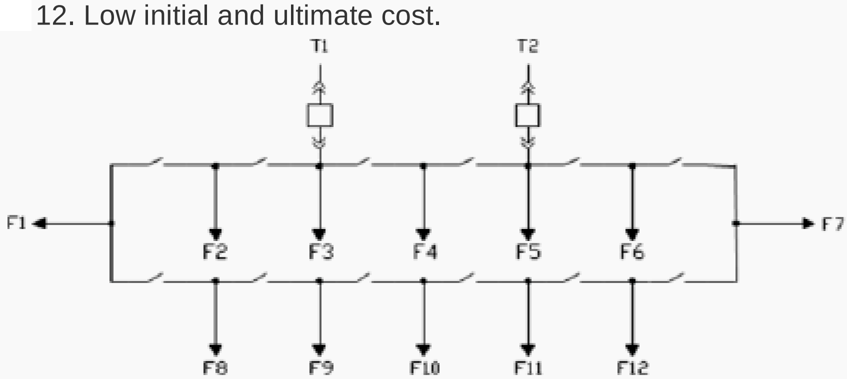

Figure 5: Ring Bus Scheme

Maintenance on a disconnect switch requires an outage of both adjacent circuits. The inability of disconnect switches to break load current is also an operational disadvantage.

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4. Double Busbar

Transfer Bus

A typical transfer busbar arrangement is shown in ***Figure 6***.

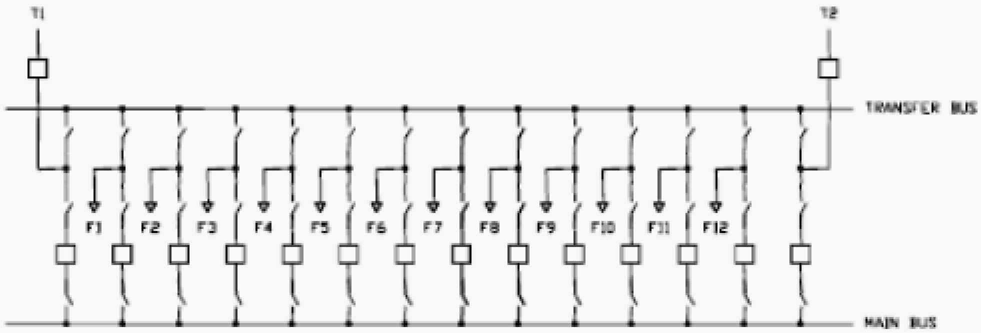

Figure 6: Transfer Bus Scheme

1. This is essentially a single bus scheme with bus section breaker and an extra bus coupler breaker with bypass disconnect switch facilities. When circuit breakers are under maintenance the protection is arranged to trip the bus-coupler breaker.
2. Failure of bus or any circuit breaker results in shutdown of half of the substation.
3. Any breaker can be taken out of service for maintenance,
4. The use of circuit breaker bypass isolator facilities is not considered to offer substantial benefits since modern circuit breaker maintenance times are short and in highly interconnected systems alternative feeder arrangements are normally possible.
5. The system is considered to offer less flexibility than the duplicate bus scheme shown in***Figure 7***.
6. Potential devices may be used on the main bus for relaying.
7. Low initial and ultimate cost.

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5. Duplicate Bus (Double Bus Single Breaker) scheme

The duplicate bus scheme has the flexibility to allow the grouping of circuits onto separate busbars with facilities for transfer from one busbar to another for maintenance or operational reasons. A typical duplicate busbar arrangement is shown in ***Figure 7***.

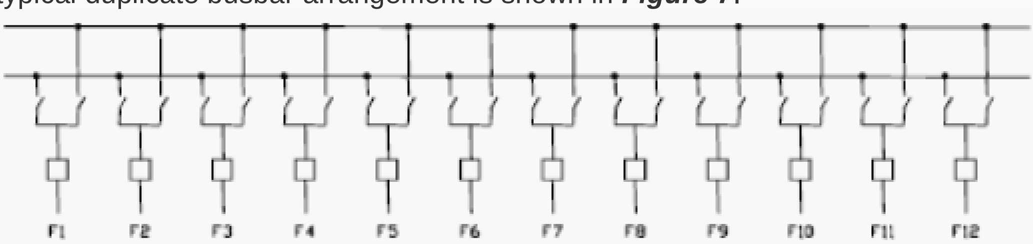

Figure 7: Duplicate Bus Scheme

1. Each circuit may be connected to either busbar using the busbarnselector disconnect switches. On-load busbar selection may be made using the bus-coupler circuit breaker.
2. Feeder breaker failure takes all circuits connected to that bus section out of service.
3. Bus-tie breaker failure takes entire substation out of service.
4. One extra breaker is required for the bus tie on the duplicate bus,
5. Either main bus may be isolated for maintenance.
6. Permits some flexibility with two operating buses.
7. Circuit can be transferred readily from one bus to the other by use of bus coupler breaker and bus selector disconnects switches.
8. Busbar and busbar breaker maintenance may be carried out without loss of supply to any circuit.

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6. 1 ½ Circuit breaker Scheme

The arrangement is shown in ***Figure 8***. It offers the circuit breaker bypass facilities and security of the mesh arrangement coupled with some of the flexibility of the double busbar scheme. The layout is used at important high voltage substations and large generating substations where the cost can be offset against high reliability requirements.

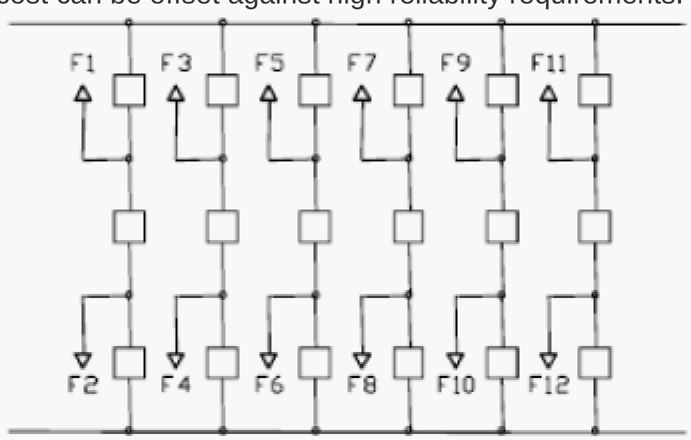

Figure 8: 1 ½ Breaker Scheme

Essentially the scheme requires 1 ½ circuit breakers per connected transmission line or transformer circuit and hence the name of this configuration:

1. High security against loss of supply.
2. Bus failure does not remove any feeder circuits from service.
3. Breaker failure of bus side breakers does not remove any other circuit from service.

4. Either main bus can be taken out of service at any time for maintenance.
5. Most flexible operation.
6. Simple operation; no disconnect switching required for normal operation
7. The circuit breakers and other system components must be rated for the sum of the load currents of two circuits.
8. Relaying and automatic reclosing are more complex since the middle breaker must be responsive to either of its associated circuits.
9. Additional costs of circuit breakers are involved together with complex protection arrangements.

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7. Single feed scheme (Primary)

The single feed scheme, shown in **figure 9**, offers savings in land area together with less switchgear, small DC battery requirements, less control and relay equipment, less initial civil works together with reduced maintenance and spares holding in comparison with the double feed scheme.

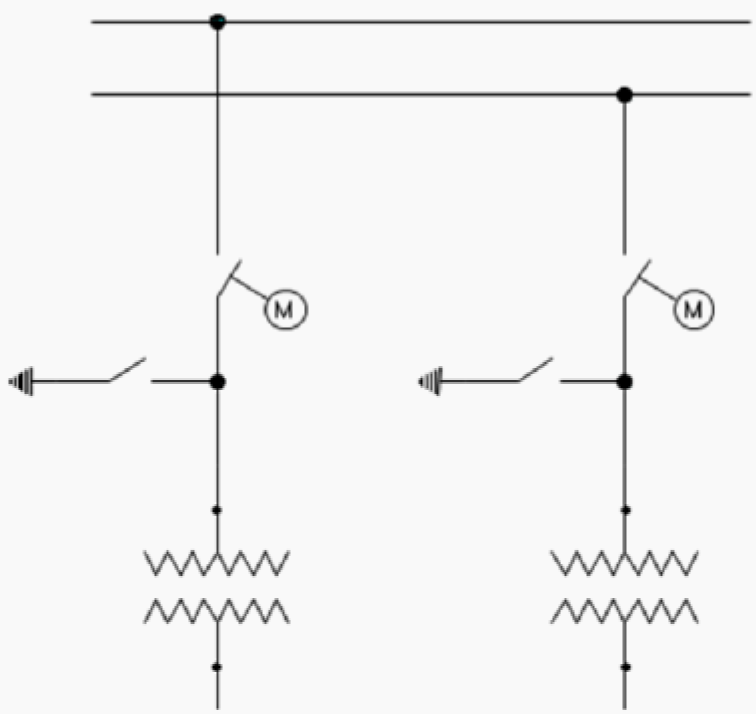

Figure 9: Single feed Scheme

An isolator and earth switch may be added at the transformer HV connections depending upon the electrical supply company's operational procedures.

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8. Double feed Scheme (primary)

A simplified H arrangement of double feed is shown in Figure 10. The scheme offers better features and facilities than the two single feed schemes. Two motorized disconnect switches, three manual gang operated disconnect switches and two circuit switchers are used in this scheme.

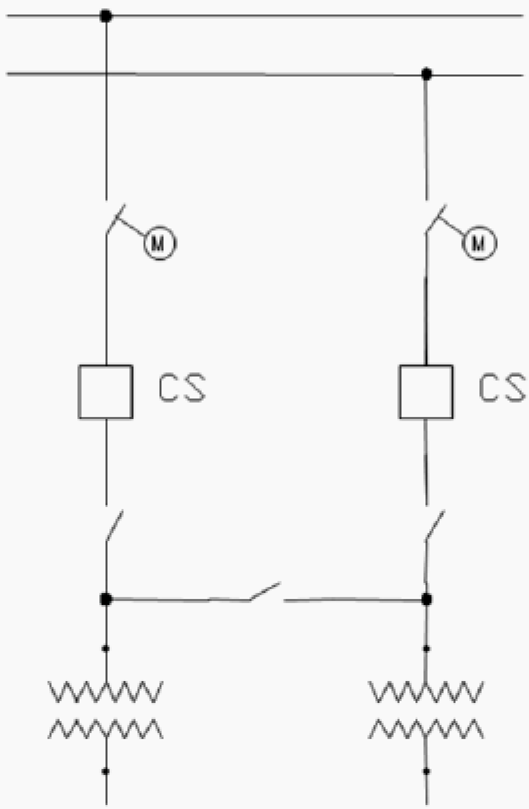

Figure 10: Double feed Scheme

1. Any circuit switcher may be maintained at any time without disconnecting that circuit. In order to allow for all operating and maintenance conditions all busbars, circuit switchers and disconnect switches must be capable of carrying the combined loads of both transformers and line circuit power transfers.
2. Normal operation is with the bypass disconnect switches open so that both transformers are not disconnected for a single transformer fault.
3. A fault on one transformer circuit disconnects that transformer circuit without affecting the healthy transformer circuit.
4. Under no circumstances the tie disconnecting switch shall not tie two overhead lines together.

Resource: *Substations Switching Scheme by M. Boloorchi*

Source:

http://electrical-engineering-portal.com/substation-switching-schemes