HT System Design and Criteria

1.0 Introduction

Power supply to a new development can be taken in from TNB at 415V Low Voltage (LV) or 11kV High Voltage/Tension (HT) or 33kV HT depending on the estimated maximum demand and the acreage of the project concerned. Hence the determination of the MD is important for the long term planning of incoming supply.

2.0 11kV Intake

2.1 Criteria

Previously, 11kV intake is generally required for loads with estimated MD exceeding 1MVA. Since xxxxxx referring to TNB's Electricity Supply Application Handbook (ESAH) version.xxxxx, it clearly states that customers with MD approaching 1MVA have the option of taking supply at 11kV, if so desired. However, for MD ranging between 1000kVA to 5000kVA, the supply voltage must be at 11kV that is directly fed through TNB's 11kV switching station.

2.2 System

The 11kV distribution system consists of an 11kV main intake substation and a number of distribution substations belonging to the consumer. In the past, these consumer substations were known as JKR distribution substations because JKR was the party who designed, operated and maintained the substations and its LV switchboards. Nowadays, many consumers outsource the design, operation and maintenance to a third party. However for clarity, these distribution substations will be called JKR substations.

In its simplest terms the 11kV system involves selection of transformers, HT switchgears, cabling, protection system and making up the associated circuiting of schematic wiring diagrams showing how they are connected to the incoming supply and also how they are interconnected.

The DE shall also decide whether to have a single feeder or double feeder and whether to have a connection as a ring circuit or radial circuit. The decision made depend on the importance of the building function which cannot afford down time. The DE shall also limit the transformer to a maximum of 2000kVA only. It is recommended to use more than 1 transformer in this case. Mechanical loads should be supplied from a separate transformer than the other electrical loads. This is to safe guard the ICT load. However this consideration should take into account the constraints on site, loads, operational costs and overall budget.

A simple 11kV distribution system is shown in Figure 1 where it consists of the following:

a) Radial circuit - Substation 1

b) Ring circuit - Substation 2, Substation 3, Substation 4

c) Spur circuit - Substation 5

In the 11kV distribution system, ring circuits are preferred for the following reasons:

a) When the 11kV distribution network is connected as a ring circuit, it improves the reliability of the power supply. In the event of a cable fault, the fault can be isolated and supply can be restored as shown in Figure 2.

b) Easier to cater for any increase in loads. Additional loads can be tapped from the ring circuit as a spur circuit such as substation 5 in Figure 1. Alternatively, additional loads can be tapped by adding more substations in the ring circuit. In each case, it is subjected to the design maximum demand of the system.

As far as possible taking supply at 11kV is avoided due to the difficulty in getting Competent Personnel (charge man holding high pressure certificate issued by the Energy Commission) for the 11kV operation and maintenance. When the intake is at 11kV, the following practice is generally acceptable to TNB viz:

I. Supply authority gives 11kV supply up to the JKR 11kV main switchgear

II. HT bulk metering at either the JKR 11kV switchgear or the TNB's 11kV switch room

III. The 11kV distribution is done by JKR.

2.3 The Main Intake Substation

2.3.1 The standard design of the 11kV main intake substation

The standard design is usually a two chamber type i.e. one chamber houses the TNB 11kV switchgear and the other chamber houses the JKR 11kV switchgear as shown in Fig 3.

2.3.2 The 11kV Circuit Breaker (CB) Switchgear.

a) The CB is to perform very arduous duties under different circumstances.

b) The performance is to the large extent dependent on the nature of the circuits in which it is connected.

c) The ratings refer to the characteristic values that define the working conditions for which the CB is designed and built.

d) The CB must be capable of carrying continuously the full load (FL) current without excessive temperature rise and should be able to withstand the electrodynamics forces.

e) CB should also be in a position to interrupt fault current safely.

f) The standard ratings of different classes of CB are given in various International Standards e.g. BS 116 and IEC 56.

g) According to IEC Specifications 56-1(1954), an AC Circuit Breaker has the following ratings:

1. RATED VOLTAGE – is the highest RMS voltage above nominal system voltage fir which the CB is designed and is the upper limit for operation.

2. RATED CURRENT – is the RMS value of current in Amperes which the CB is capable of carrying continuously without exceeding the limit of observable temperature rise.

3. RATED FREQUENCY – is the frequency in Hertz (c/s) at which it is designed to operate.

4. RATED BREAKING CAPACITY:

   a) Symmetrical Breaking Capacity is the value of symmetrical breaking current which the CB is capable of breaking.

   b) Asymmetrical Breaking Capacity is the value of asymmetrical breaking current which the CB is capable of breaking.

   Conventionally, the Breaking Capacity (BC) is given by:

   $MVA = \sqrt{3}$ x Rated Voltage x Breaking Current (kA)

5. RATED MAKING CURRENT CAPACITIES: This value characterizes the capability of the CB to close the contact against short-circuit currents

   - Making current is the RMS value of total current (AC + DC) which are measured from the envelope of the current wave at the time of the major peak.

   - It may also be expressed in terms of instantaneous value of current which is measured at the first major peak of current wave (Ipk).

   - The making capacity of CB is the current that the CB is capable of making.

   - The absence of any indication to the contrary on the name-plate ratings implies that each rated capacity is the value given by:

     $\text{Rated Making Capacity} = 1.8 \times \sqrt{2} \times \text{Symmetrical Breaking Capacity}.$

     (Factor 1.8 is employed to account for the asymmetry present in the short circuit current).

6. RATED SHORT TIME CURRENT – is the RMS value of current that a CB can carry in a fully closed position without damage for the specified

short time interval under prescribed conditions. It is normally expressed in term of kA.

Generally there are three types of 11kV CB Switchgears:-

- SF6 Circuit Breaker
- Vacuum Circuit Breaker (VCB)
- Oil Circuit Breaker (OCB)

Example:

Data Given on Nameplate Rating of VCB:

RATE VOLTAGE	12 kV
RATED INSULATION LEVEL	75 kV Impulse
Rated frequency	50 Hz
Normal Current	630 A
Breaking Current	20 kA
Short Time Current (IEC 56)	20 kA (3 sec.)
Making Current	= 1.8 x √2 x 20
	= 51 kA
Breaking Capacity	= √3 x 12 x 20
	= 416 MVA

2.4 The JKR Distribution Substation

2.4.1 Standard design of distribution substation.

The standard design of the JKR distribution substation is shown Figure 4. The distribution substation is usually a three chamber type i.e. one chamber houses the 11kV switchgears, the second chamber houses the transformer and the third chamber house the LV main switchboard.

2.4.2 Types of 11kV Switchgears

a. Circuit Breakers

Similar to the Main Intake 11kV CB Switchgear.

b. Ring Main Units, RMU

The range includes extensible and non-extensible RMU suitable for outdoor or indoor Installations. Various switchboard configurations can be built up

- 2 x ring switch + 1 x circuit breaker
- 2 x ring switch + 2 x circuit breaker
- 2 x ring oil switch + 1 x oil switch fuse unit
- 2 x ring oil switch + 2 x oil switch fuse unit

Rated Voltage : 12kV

Frequency : 50Hz

Normal current, Ring Switch : 630A

Circuit Breaker : 630A

Short Circuit breaking current, CB : 20kA

Short time withstands current : 20kA, 3 seconds.

2.4.3 Transformer

a. Selection of Transformer

Size of transformer is chosen based on its capacity to meet the Maximum Demand on the LV side. It is a usual practice to size-up the transformer 10 to 25% more for future load growth. Power transformers used are usually of the oil-immersed type although cast-resin type is also specified. The vector group of the transformer is DYN. Commonly encountered 11kV/433kV transformer ratings are:-

Size (kVA)	H.T Current (A)	L.V Current (A)
100	5	139
200	10	278
300	16	417
500	26	696
750	39	1043
1000	52	1391
1250	66	1739
1500	79	2087

b. Example:

What is the size of transformer suitable to cater for MD = 350 kW with 20% future load increase.

Now, total load = 350 x 1.2

= 420 kW

= 494 kVA

Transformer size (11kV/433kV) is 500 kVA.

c. The JKR practice is for the DE to limit the transformer size to a maximum rating of 2000kVA only. If bigger sizes are required it is recommended to install more than one transformer e.g. It is a good practice that mechanical loads be supplied from a separate transformer than the other electrical loads. This safe guards the ICT load. However these considerations should take into account the constraints on site, loads, operational costs and overall budget.

2.5 Protection System and Practice

2.5.1 The Protection of Distribution Feeders

- Pilot wire Protection System
- Inverse Time over current and Earth Fault Protection
- Factors affecting the choice of distribution feeder protection.

2.5.2 The Protection of Transformer

The various forms of protection schemes for transformers are as follows:

1) Electrical Detection Scheme

   - Differential Protection
   - Restricted Earth Fault Protection
   - Over current and Earth Fault Protection

2) Non-Electrical Detection Scheme

   - Bucholz Gas & Oil Detection
   - Winding Temperature Alarm

2.5.3 **Earthing**

A common earth bar 25mm x 6mm is run along the walls of the transformer room. Earthing of non-current carrying metal parts are connected to the common bar with same sized copper tape. The neutral earth of the transformer secondary is to be by insulated earthing conductor. A common practice to ensure extra bonding is to solder the steel tape of HT cable with bare copper conductor, 50 mm2. The latter is bolted to be earth bar at the cable box. Earthing value is limited to 1 ohm max in order not to effect the grading on earth fault. Refer BS 162:1961.

2.5.4 Current and Voltage Transformer

The choice of a class of accuracy higher than is necessary is not economical and can result in transformer being excessively large requiring considerable space in the switchgear for its accommodation. The accuracy class and guidance on selection is given in the relevant British Standards which are reproduced for easy reference in Table 1, 2, 3, 4. The commonly used class is marked with an asterisk.

Table 1: **Voltage Transformer: BS 3941:1975**
Accuracy Class Designation

ACCURACY CLASS	PERCENTAGE VOLTAGE (RATIO) ERROR	PHASE DISPLACEMENT	
		MINUTES	CENTIRADIANS
0.1 0.2 0.5 1.0* 3.0	+ 0.1 + 0.2 + 0.5 + 1.0 + 3.0	+ 5 + 10 + 20 + 40 not specified	+ 0.15 + 0.3 + 0.6 + 1.2 not specified

Table 2: **Voltage Transformer: BS 3941:1975**
Guidance on the Application

APPLICATION	CLASS OF ACCURACY
Precision testing or as a standard for testing of Voltage Transformer.	0.1
Metering of precision grade in accordance with BS 37.	0.5
Meters of commercial grade in accordance with BS 37.	1.0
Precision measurements (indicating instruments, recorders And electronic integrating meters).	0.2 or 0.5
General Industrial measurements (indicating instruments & Recorders).	1 or 3
Approximate measurements	3

Table 3: **CURRENT TRANSFORMERS : BS 3938 : 1973**
Limits of error for Accuracy Class 0.1 to 1.0

Class	± percentage current (ratio) error at percentage of rated current shown below			± phase displacement at percentage of rated current shown below					
				minutes			Centiradians		
	10 up to but not incl 20	20 up to but not incl 100	100 up to 120	10 up to but not incl 20	10 up to but not incl 20	100 Up to 120	10 up to but not incl 20	20 up to but not incl 100	100 up to 120
0.1 0.2 0.5* 1*	0.25 0.5 1.0 2.0	0.2 0.35 0.75 1.5	0.1 0.2 0.5 1.0	10 20 60 120	8 15 45 90	5 10 30 60	0.3 0.6 1.8 3.6	0.24 0.45 1.35 2.7	0.15 0.3 0.9 1.8

Table 4: **CURRENT TRANSFORMERS : BS 3938 : 1973**
Limits of error for Accuracy Class 3 and Class 5

Class	± percentage current (ratio) error at percentage of rated current shown below	
	50	120
3 5	3 5	3 5

Table T: **CURRENT TRANSFORMERS : BS 3938 : 1973**
Limits of error for Accuracy Protective Class 5P and Class 10P

Accuracy Class	Current error at rated primary current %	Phase displacement at rated primary current		Composite error at rated accuracy limit primary current %
		minutes	centiradians	
5P 10P*	± 1 ± 3	± 60	± 1.8	5 10

4. **Selection of Class of Accuracy of measuring Current Transformers**

Application	Class of accuracy
(1) Precision testing, or as a standard for testing other current transformer	0.1
(2) Meters of precision grade in accordance with BS 37	0.2
(3) Meters of commercial grade in accordance with BS 37	0.5 or 1.0
(4) Precision measurement (indicating instruments and recorders)	0.1 or 0.2
(5) General industrial measurements (indicating instruments and recorders)	1 or 3
(6) Approximate measurements	5

2.6 The 11kV Underground Cable

For high voltage, the size of the cable is usually based on the SHORT CIRCUIT RATING of cable rather than the current carrying capacity.

At 11kV, the SHORT CIRCUIT RATING of the switchgear as required by the supply authority is 350 MVA for 3 seconds. Therefore the cable chosen shall be able to withstand short circuit current of 18.4 kA for 3 second. Reference to Figure 5 & 6, the suitable size of the 11kV cable is 400mm 3 core Aluminium PILCDSTAS or 240mm2 3 core Copper PILCDSTAS.

3.0 415 Intake

3.1 415 Intake with TNB Substation

a) Criteria

In the case of 415V intake, TNB generally would request for a substation if the estimated maximum demand of the load exceeds 200 kVA.

b) System

In this system, supply authority will give 415V supply up to the JKR Main Switchboard in the JKR main switch room which is usually annexed to the supply authority substation as shown in Figure 4.

It is a standard supply authority practice that consumer main switch room is annexed to the supply authority substation. The reasons for the above practice are:

1) To avoid excessive voltage drops

2) Supply authority use Single Core PVC cable for connection between transformer and consumer main switchboard.

For project with large acreage and loading between 500 kVA to 1.5 MVA, supply authority has given approval to give supply with more than one 415V intake. Each 415V intake would be separately bulk metered at the consumer Main switch room. LV distribution is done by JKR. This approval is given on a case by case basis.

A typical project example is the Kuala Lipis Infantry Battalion Complex where the estimated maximum demand is 1.5 MVA and supply authority agreed to give 2 substations. The LV distribution in the complex is done by JKR using overhead lines.

c) Standard design of supply authority substation with JKR switch room

The standard design of supply authority substation with JKR switch room annexed is shown in Figure 4.

3.2 415V intake without TNB substation

415V intake with no supply authority substation i.e. direct from the existing supply authority services usually is meant for small load an estimated maximum demand of less than 200 kVA.

4.0 Bulk Metering

4.1 In large complexes, the common practice is to take in bulk supply from TNB. TNB's bulk meter is installed in the JKR main switch room while the individual sub-meters are installed by JKR for every unit of the quarters, canteen, etc. These sub meters are read by the staff of the clients and the charges are recouped from the occupants.

For the armed forces projects, this bulk metering and sub-metering policy had been agreed and approved since 1980 by the following parties :

1) The Chief Electrical Inspector (via letter KPL.8/1/83 bhg. 1/95 dated 18.1.1980)
2) The Commercial Manager LLN (via letter CMD 14/15/44.5/159 dated 15.1.1980)
3) The Ministry of Defence
4) The Public Works Department

This request for the bulk metering and JKR sub-metering is from the Ministry of Defence for reasons as follows:

1) Armed forces personnel are always on the move such as transfer. Therefore, matters such as signing of the supply authority contracts, the paying of deposits would cause tremendous administrative problems to the supply authority as well as to the armed forces.

2) Armed forces personnel are always on temporary move such as operations. These operations may last a few months. Since the supply authority bill will not be paid for that few months, very often they may return and find that the electricity supply has been disconnected.

3) In the case of the married quarters, the Ministry of Defence provides free lighting for common areas such as staircase, entrance lobby, etc.

4.2 For other large complexes such as institutions of higher learning, the same practice / arrangement may not necessarily be acceptable to all parties. The DE shall be responsible to ascertain the metering arrangements required by the client and finalise them before the design can be completed.

5.0 33kV intake

5.1 For loads greater than 5000 kVA TNB normally requires a 33 kV Pencawang Pembahagian Utama, PPU. This PPU is known as Pencawang Masuk Utama, PMU to the consumer. However the DE should approach 33 kV PMU with caution. The DE must discuss/query whether the 33 kV PMU belongs to TNB or to the client because there are many other operational maintenance aspects that have to be taken into account e.g. the availability of the required competent person in the market to operate the PMU. In addition if it belongs to the TNB then decision/conditions should be made that the PPU shall cater only for that client and not for TNB to supply to other clients. The consumer may be metered at 11kV tariff or 33kV tariff. This must be discussed and finalized with TNB and made clear to the consumer.

Appendix

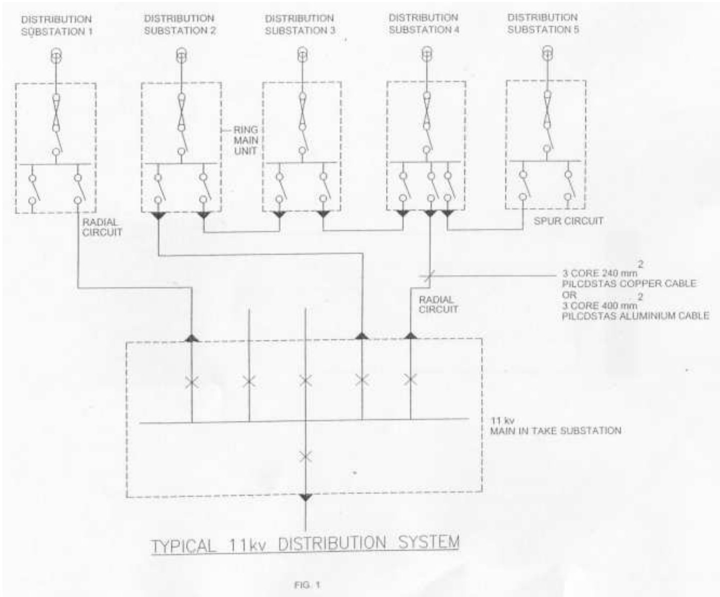

Figure 1

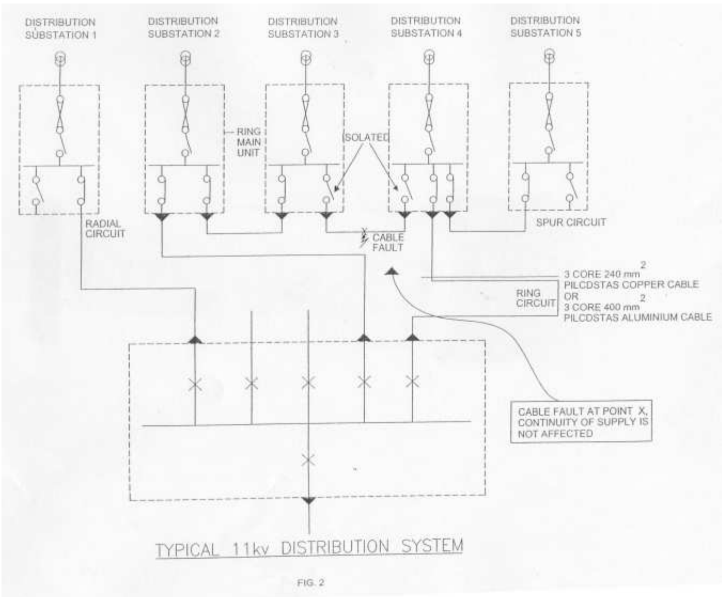

Figure 2

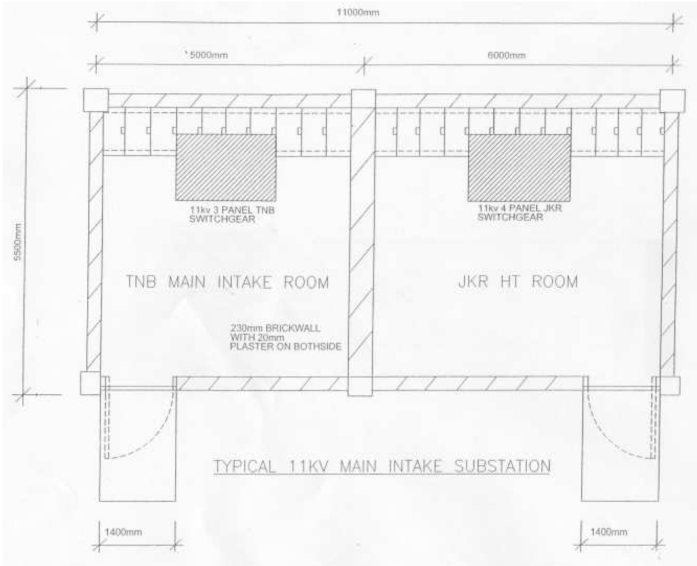

FIG. 3

Figure 3

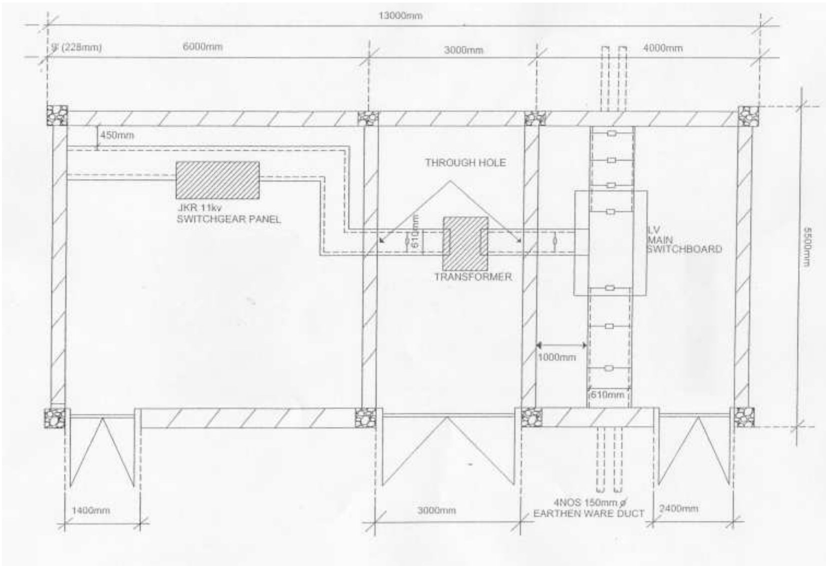

FIG. 4

Figure 4

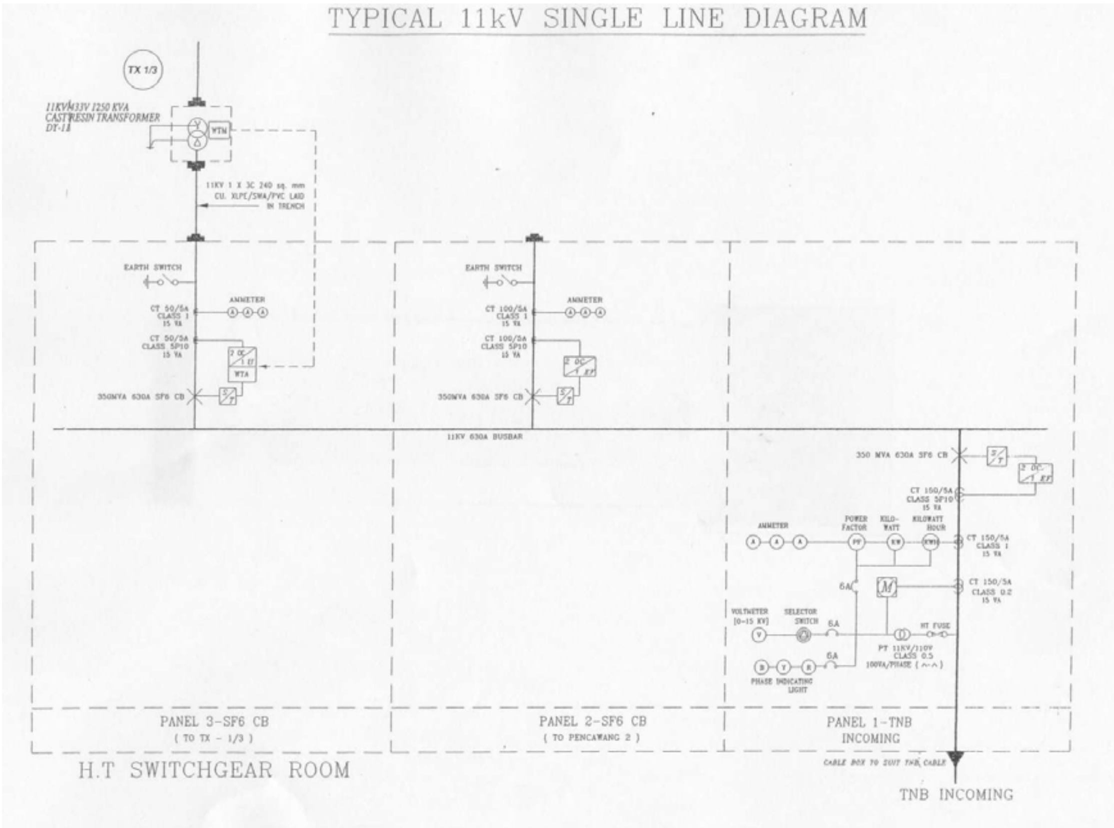

Figure 5: Typical 11kV Single Line Diagram