CHAPTER 2

POWER TRANSFORMERS AND ASSOCIATED FAULTS

2.1 Transformer Definition

A transformer is an essential static electromagnetic device consisting of two or more windings wounded on a laminated magnetic core which link with a common magnetic field, insulated from iron and from each other. (Sawhney , 1983.)

Primary winding will be connected to the alternating voltage source, the other windings will be induced and the voltage and current values will be changed from the differences of winding turn ratio. Types of transformers can be categorised according to the changes as mentioned in topic 2.3.1

2.2 Power Transformers Definition

Power transformers are the devices for transforming electricity from low voltage to higher voltage for using in transmission system and transforming high voltage to lower voltage for using in distribution system. (Stigant and Lacey , 1965.)

Power transformers are used in subtransmission circuits and distribution system of substations, primary-feeder circuits of high voltage substations, power plants and some types of typical substations. The power transformers are placed at each end of transmission line for stepping up and stepping down the voltages which need power rating of transformers above 200 kVA.

An example of power transformers placed in the power system in Thailand is as shown in Figure 2.1, and Figure 2.2 shows an example of power transformers in a high voltage substation of metropolitan area's transmission system.

The list of overall power transformers in metropolitan area and central region are as shown in Appendix B.

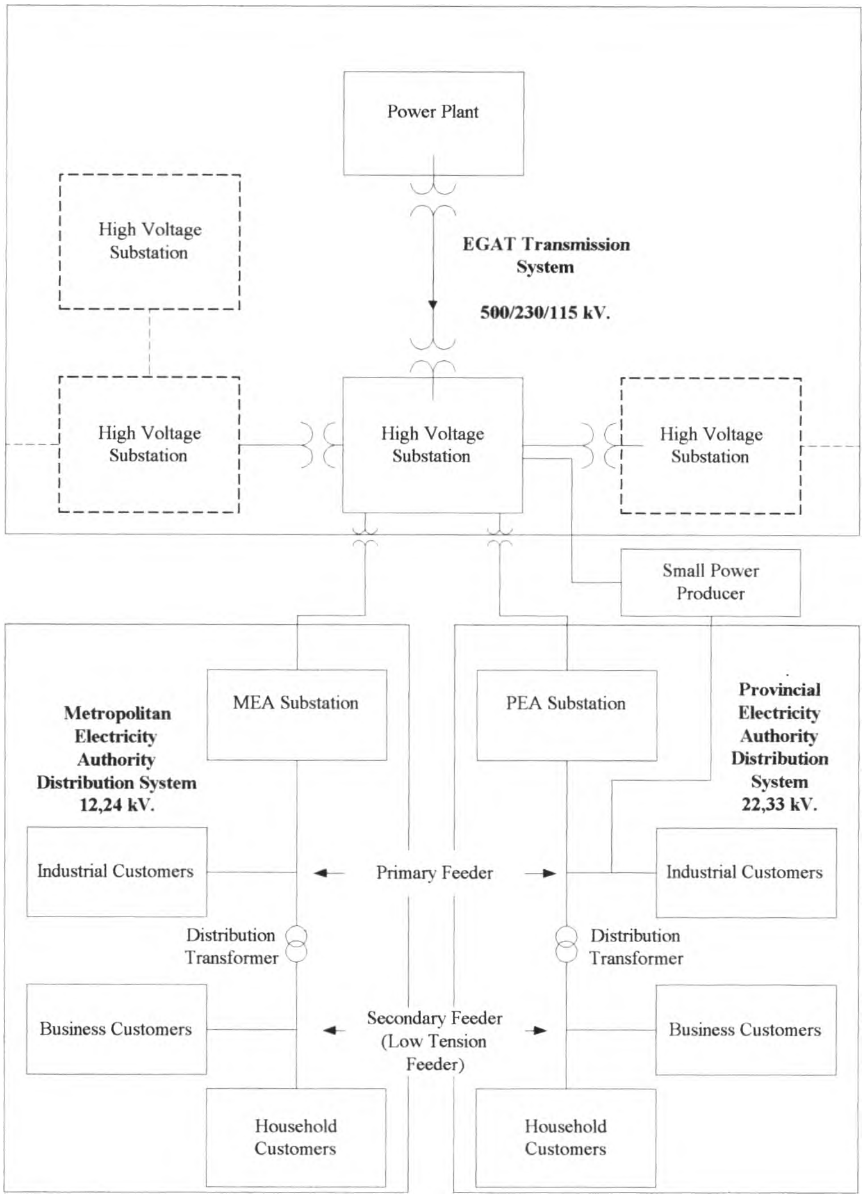


Figure 2.1 An Example of Power Transformers Placed in the Power System

Two main customers of EGAT are Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA), receiving electric energy from transmission line at the their terminal stations for controlling, distributing, and transforming of the electric energy to appropriate for entering to their distribution system by passing their high tension feeders to their substations.

The terminal stations consist of 10 terminal stations of MEA (Rangsit terminal, Ladprao terminal, North Bangkok terminal, Bangkok Noi terminal, Chitlom terminal, Bangkapi terminal, Bangpli terminal, South Thonburi terminal, Nongchok terminal, and South Bangkok terminal) located in some districts of metropolitan areas which are Bangkok province, Samutprakarn province, Nonthaburi province, Thonburi province, and Meenburi province, and terminal stations of PEA located at each province of Thailand.

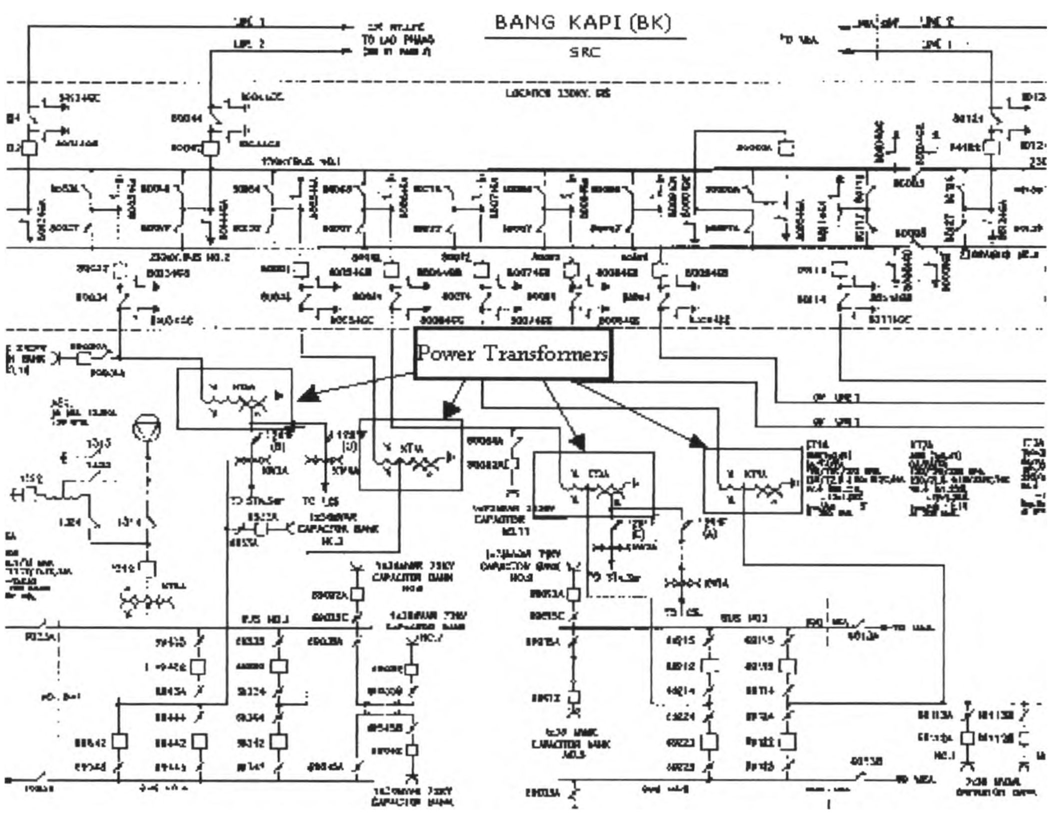


Figure 2.2 Power Transformers in a High Voltage Substation of Transmission System

Because EGAT transmission system connects to MEA and PEA distribution system, and other customers. So, EGAT transmission system is always affected from faults happened in customer system when they can be supervised by EGAT protection system from many reasons such as customer's protection system failure, losses of control from customer's protection system, and etc.

2.3 Transformer Types

2.3.1 Types of Transformers According to Application

2.3.1.1 Step-up Transformers : Transformers which raise the output voltage up.

2.3.1.2 Step-down Transformers : Transformers which lower the output voltage down.

However, each type of the transformer can be used theorically as both step-up transformer and step-down transformer because of its bi-directional property. (Sawhney , 1983.)

2.3.2 Types of Transformers According to Service in Transmission System

Transformers for service in transmission system can be categorised into instrument transformers and power transformers as described follows :

2.3.2.1 Instrument Transformers

There are two types of instrument transformers which are :

2.3.2.1.1 Current transformers (CT.) : Transform high current to lower current (standard current 5 amperes).

2.3.2.1.2 Potential transformers (PT.) : Transform high voltage to lower voltage (standard voltage 120 volts).

The function of instrument transformers is transformation of high current (CT.) or high voltage (PT.) down to lower values for using in metering system, protection system, and controlling instruments. (Stigant and Lacey , 1965.)

2.3.2.2 Power Transformers : Transform low voltage to higher voltage for using in transmission system and transform high voltage to lower voltage for using in distribution system.

2.3.3 Types of Transformers According to Service in Power System

2.3.2.1 Distribution Transformers : For used to step-down the voltage in distribution areas, a size of transformers is up to about 200 kVA.

2.3.2.2 Power Transformers

- Generator transformers : used in power plants for connecting between generation system and transmission system.
- Tile transformers : used in high voltage substations

Power transformers are placed at each end of transmission line for step-up and step-down the voltages which need power rating of transformers above 200 kVA.

2.3.4 Types of Transformers According to Cooling Types

The heat established from core losses and copper loss in the transformer are needed to be considered on cooling system design for satisfied efficiency and operating life, the types of transformers according to cooling system types are :

2.3.4.1 Dry Type Transformers

Dry type transformers use air and inert gases such as SF6 as system coolant and insulator, appropriating for hazard areas and small space areas.

2.3.4.1.1 Self Air Cooled Transformers (AA.) use the ambient air as the cooling medium. The natural circulation of surrounding air is utilised to carry away the heat generated by natural convection.

2.3.4.1.2 Self Cooled/Forced Air Cooled or Air Blast Cooled Transformer (AA/FA.) use circulation of air employed for better heat dissipation.

2.3.4.2 Oil-Immersed Transformers

The oil-immersed transformers are immersed in oil and passed heat on to oil which has a better heat conductivity than air and it also has a high co-efficient of volume expansion according to temperature.

2.3.4.2.1 Oil-Immersed Self Cooled with Air Transformers (OA.) : The heat will pass on to oil and transferred to the tank walls by natural oil circulation.

2.3.4.2.2 Oil-Immersed Self Cooled with Air Blast for Additional Cooling Transformers (FA.) : The heat will be transferred by oil circulating to the inner tank walls of hollowed transformer tank or radiator banks of corrugated or elliptical tubes and blown by fan.

2.3.4.2.3 Oil-Immersed Self Cooled with Water Transformers (OW.) : Water-circulated copper cooling coils are mounted above the transformer core and below the surface of oil level assisting heat exchange to cool the transformer by conducting the heat via water to external environment, this cooling type is cheaper than the others especially at the higher natural water head areas.

2.3.4.2.4 Oil-Immersed Forced-Oil Cooled with Air Blast for Additional Cooling Transformers (FOA.) : The heated oil is cooled in external heat exchangers using air blast produced by fans when heat rises to rated temperature at higher loads, and it will become to operate as oil-Immersed self cooled with air transformers (OA.) at the load below a half time of rated load for higher efficiency for the system from mixing cooling condition. This method is the usual one for transformers of capacities 30 MVA upwards.

2.3.4.2.5 Oil-Immersed Forced-Oil Cooled with Forced Water Transformers (FOW.) : The heated oil is cooled in a water heat exchanger, the pressure of oil is kept higher than water to prevent leakage from water to oil, appropriating for generating stations, especially hydroelectric plants.

2.3.5 Types of Power Transformers According to Construction Types

2.3.5.1 Shell Types : The windings of shell type transformer are put around the central limb and the flux path is completed through two side limbs as shown in Figure 2.3 :

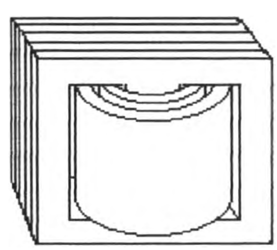


Figure 2.3 Shell Type Transformer

2.3.5.2 Core Types : The magnetic core of core type transformers is built of laminations to form a rectangular frame and the windings are arranged concentrically with each other around the legs or limbs of the core as shown in Figure 2.4 :

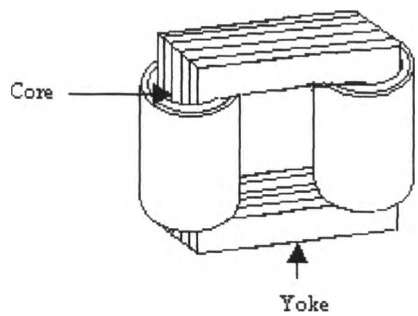


Figure 2.4 Core Type Transformer

2.4 Important Parts of Power Transformer and Related Equipment

2.4.1 External Parts of Power Transformers

The positions of important parts of power transformers are as shown in Figure 2.5 :

2.4.1.1 Transformer Tank

Tank bodies of the transformers are made from rolled steel plates which will be leakproof-fabricated to form the container. The tank should be strong enough to withstand stresses and hydrostatic pressures of oil not less than 1 kg/cm^2. The tank size is depended on rated power of transformer capacity to accommodate cores, windings, internal connection and clearance.

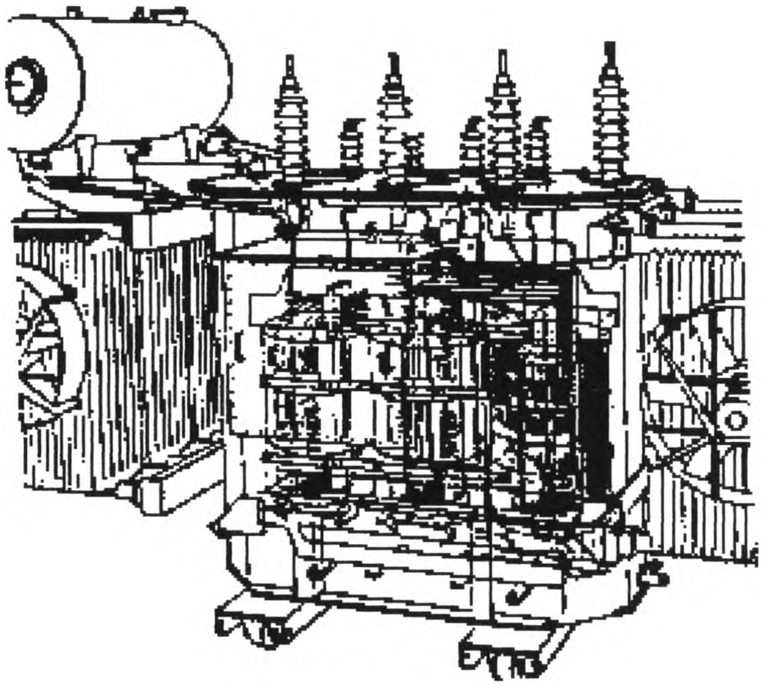


Figure 2.5 The Positions of Important Parts of Power Transformers

2.4.1.2 Transformer Oil

Transformer oil is mineral oil refined from crude petroleum which is easy to prepare and cheap, or synthetic oil as an important factor of power transformer for transformer life and reliability in operation. The functions of transformer oil are to create the acceptable level of insulation in conjunction with insulated conductors and coils as dielectric insulation and to provide a cooling behaviors without deterioration as heat transfer agent.

The consideration on physical, electrical, and chemical properties of oil depending on contamination and deterioration from oxidation are color, resistance to emulsion, viscosity, purity, electric strength, gas tendency, flash point, service-aged time, and sludge formation.

The way to evaluate transformer oil condition periodically is to test on DGA., breakdown voltage, and water content between filling and refilling. Examples of DGA test results are as shown in Table 2.1 :

Table 2.1 Examples of DGA Test Results

Abnormal	Dissolved Gas
Overheat	H_2, CH_4, $\mathbf{C_2H_4}$, C_2H_6, C_3H_6
Arcing	H_2, CH_4, C_2H_4, $\mathbf{C_2H_2}$, C_3H_6
Partial discharge	$\mathbf{H_2}$, CH_4, C_3H_8, C_2H_6
Solid insulator (paper) damaged or deteriorated	**Co**, $\mathbf{CO_2}$

Transformer oil of the important power transformers should be tested every year and the ordinary power transformers will be tested every two years.

If the transformer oil condition cannot satisfy, it will be replaced or reconditioned by separating moisture and solid materials. Acidic, oxidation products, and colloid contaminants in transformer oil will be absorbed chemically following reclaiming procedures. Regeneration of transformer oil will separate all mentioned including adding inhibitor and decolorising for properties like original oil.

2.4.1.3 Oil Gauge

Oil gauge or temperature indicators is placed near conservator tank for indicating hot oil temperature, two types of oil gauge are rod-type oil gauge and dial-type oil gauge.

2.4.1.4 Conservator Tank

The conservator tank is an airtight cylindrical drum mount on or near the cover of transformer and connected by pipe. The oil level of transformer changes with changes of the temperature. So, The conservator tank as provision must be made to take up the expansion and contraction of oil when hot.

2.4.1.5 Breather

Breather is a vent pipe with a set of extracting system for air drawing into transformer from atmosphere and also air expelling out. The breather can extract moisture by using dehydrating material such as silica gel crystals impregnated with cobalt chloride which is blue when dry and pink when damp. The dust is prevented by oil in oil pot mount at the bottom of baffle plate and polyvinyl sponge filter.

The illustration of breather construction is as shown in Figure 2.6 :

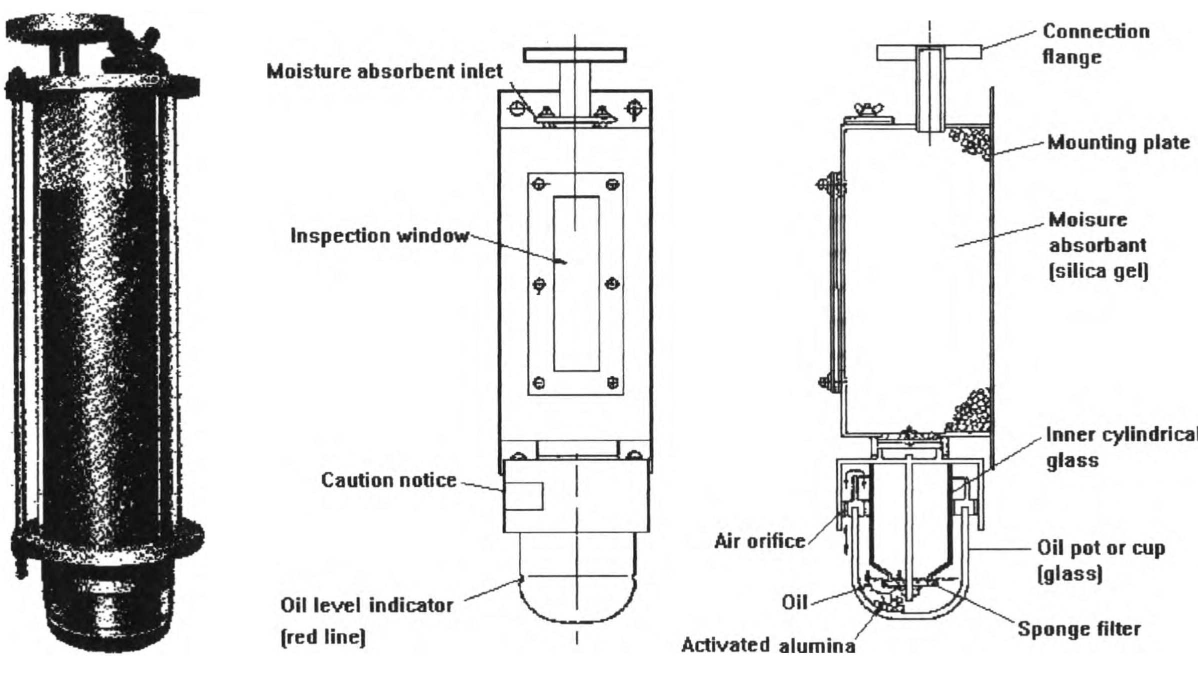


Figure 2.6 The Construction of Breather

2.4.1.6 Pressure Relief Vent or Explosion Vent

In order to prevent sudden high pressure happened from breakdown or short circuit of transformer windings, a diaphragm relief device is used to be burst when pressure inside the tank becomes excessive.

2.4.1.7 Protection

Protection of transformers can prevent difficulty which can happen to transformers in many cases, power transformer protection will be described descriptively in section 2.5.

2.4.1.8 Thermometer

Thermometer is an instrument for measuring transformer temperature of oil and windings, usually placed near the nameplate of transformers.

2.4.1.9 Remote Temperature Monitoring System

Oil temperature and winding temperature can be monitored by human operators easily at switchboard in control room by installing temperature sensitive element.

2.4.1.10 Ventilator

Ventilator or radiator is the equipment for transferring heat from oil to the atmosphere by increasing air attachment areas of metal elements from the areas of conventional transformer tank body.

2.4.1.11 Fans

Fans are used when additional cooling system is needed, the fans can change cooling types of transformer from self-cooled types to force-air cooled types by installing them at the radiator fins or radiator banks and operating them as automatic control or manual control.

2.4.1.12 Oil Circulating Pump

Oil circulating pump can fasten the flowing of oil in order to increase the efficiency of transformer cooling system instead of using natural rising of oil cooling phenomena.

2.4.1.13 Bushing

Bushing is an insulator mount between transformers and leading cable from high voltage lines to prevent flashover from the high voltage connection to the earthed bank, the bushing is filled with elastoberic compound and durable to weather.

The illustration of bushing is as shown in Figure 2.7 :

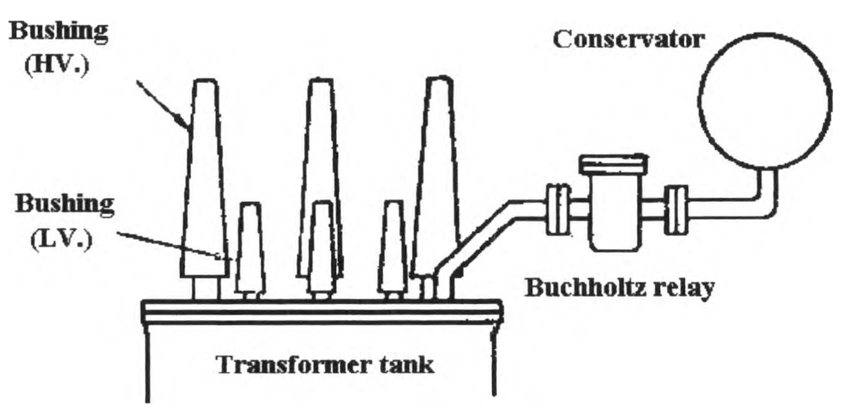


Figure 2.7 The Illustration of Bushing

2.4.2 Parts Between Internal and External Section of Power

Transformers

2.4.2.1 Leading Cables and Cable Poles

Leading cables are the conductor connected to transformer by using cable poles which are the rod-shaped insulator devices for connecting between power transformer circuits via leading cables and busbar.

2.4.2.2 Switch and Tap Changer

The voltage of power system can be controlled constantly into standard values by changing the ratio of transformation of the transformers. The tapping is connected on different places in the windings which can provide different voltage at different tapping positions.

2.4.2.2.1 Off Load Tap Changing : The tapping can be changed for occasional adjustments while the transformer is disconnected from the supply.

2.4.2.2.2 On Load Tap Changing : The tapping can be changed daily for short time voltage adjustments I order to maintain normal voltage under load conditions by on load tap changing gear operation while the transformer is energised to the supply.

2.4.3 Magnetic Circuit Parts of Power Transformers

2.4.3.1 Metal Core

Metal core is the main part of transformer, the characteristics of laminated core are a closed magnetic circuits through the mutual flux two main types of metal core are core type and shell type as mentioned before.

2.4.3.2 Yoke and Leg

Yoke and leg are stack multilayer metal sheets as shown in Figure 2.4 but the number of yoke layers may be less than leg layers whenas the thickness of yoke is about 15 percent greater than the thickness of leg. This reduces the flux density in the yoke which in the reduces the magnetising current and iron losses.

2.4.4 Electrical Circuit Parts of Power Transformers

2.4.4.1 Windings

Windings are the path of electrical current which consist of conductor, insulator, tap, capacitive protection ring, electrostatic shield, and terminal. Two main parts of transformer windings are primary winding and secondary winding employed different arrangement of coils as mentioned before and also tertiary winding in some types of transformers.

2.4.4.2 Insulators

Insulators prevent short circuit between different potential sources, transformer insulators consist of solid insulation barriers such as paper, transformer board, and etc. and liquid insulator which is oil as mentioned before.
from abnormal range of frequency or voltage

2.5 Power Transformer Faults

Power transformer faults can be happened unpredictably from many causes of them. The summary of causes of abnormal events for using in power system, between power system, and transmission system equipment such as power transformer, capacitor banks, and other related equipment can be categorised into the Table shown in Appendix D.

From Appendix E, the main causes of power transformer faults happening to power transformers in power system of central region and metropolitan areas of Thailand past 2 years mostly result from faults in power system of customers which are MEA and PEA, and various kinds of animal such as snakes, cats, birds, lizards, and etc.

2.5.1 Internal Short Circuit

2.5.1.1 Ground Fault Short Circuit

Ground fault short circuit is the short circuit of current leaking from any position of windings to ground. The short circuit current varies depending on transformation ratio between primary winding and short circuit turns effecting on the winding resistance left between fault position in the winding and neutral point.

2.5.1.2 Interturn Fault Short Circuit

Interturn fault have been reported its happening about more than 70 percent which is very high percentage of all transformer failures arise from current fault between turns loop. It occurs to the end turns of transformer windings from risk on steep fronted impulse voltages from overhead transmission line connected to transformer.

2.5.1.3 Phase to Phase Fault Short Circuit

Phase to phase faults in the transformer are rarely happened. If it is occurred, the substantial current will activate overcurrent relay instantaneously on the primary side as well as the differential relay.

2.5.1.4 Core Fault Short Circuit

Core faults happen from defective core insulation or laminated structure of the core is bridged by any conducting material which can permit current leakage which will produces severe localised overheating unnoticeable from outside to breakdown transformer oil with evolution of gas, including increasing of oil temperature and winding temperature.

2.5.2 External Short Circuit

External short circuits are mostly happened from various kinds of animal such as snakes, cats, birds, lizards, and etc. The other causes of external short circuit are trees, equipment failure such as insulators, lightning arrester and circuit breakers, transmission line swing or breaking, transmission tower collapse, human deeds, smoke of forest burning, and etc.

The external short circuit can cause excessive current passing transformer in the short time which may cause serious damaging from internal mechanical stress between the first cycle. The violence of external short circuit faults depends on the characteristics of winding, location and types of fault, and power system condition.

2.5.3 Overload

Overload events may be happened from the excessive demands of electricity in the area of a transmission line for a period which can cause power system unstable and transmission system equipment overload.

When transformer overloads, the increased copper loss will increase transformer temperature. The temperature should be controlled not exceed the maximum setting point for continuous excessive load supplying (about 105 percent of rated load) and short period excessive load in the proportional setting time which is the consideration on cooling system design and its efficiency.

2.5.4 Overvoltage

2.5.4.1 Transient Surge Overvoltage happened from Switching and Lightning

The surge in the system may arise from atmospheric disturbances , switching operation, and arcing grounds if neutral point is isolated. When they reach to the windings of transformers, the breaking down of insulation between turns adjacent to line terminal, causing short circuit between turns and producing extensive damage to the transformer winding. External results from lightning may cause flashing over at the surface of insulators. So, the surge diverter or lightning arrester are needed to protect the transformers.

2.5.4.2 Power Frequency Overvoltage

Power frequency overvoltage, including frequency reduction, built up voltage in long transmission line when no load at the other end, and resonance will cause an increase in the stress of insulation and working flux which make an increasing of magnetising current and diverting of flux to the core laminated structure producing rapid heat which can cause damage to the winding insulation.

2.5.5 Inrush Current

Magnetising inrushing current or exiting inrush current is the most significant transient current happened by rapid flowing of current at the beginnings when transformers are first energised which has the same appeared characteristic as an internal short circuit fault to the factors controlling the duration and magnitude of the magnetising are :

- Size and location of power transformers.
- Size of power system.
- Resistance in the power system from the source to the power transformers.
- Type of iron used in the transformer core and its saturation density.
- Prior history, or residual flux level, of the power transformers.
- How the power transformers are energised.

2.6 Power Transformer Protection

The protection of power transformer used by utilities is different from industrial and commercial transformers in their protective schemes which are functions of several major factors, the signal can be presented as alarm and trip respectively to important levels.

The selection on protection system for power transformers depends on the importance and the power rated or size of the power transformers.

2.6.1 Mechanical Relay

Mechanical Relaying system is installed inside the power transformers for detecting internal disturbances.

The mechanical relay consists of :

2.6.1.1 Sudden Pressure Relay

Sudden pressure relay is a rate-of-rise-of-pressure relay located at a sealed air or nitrogen chamber above the oil level. The function of sudden pressure relay is to detect the sudden exploding of gas pressure happened inside transformer tank from arcing faults in oil, especially for abnormal high potential in tap changing equipment.

The sudden pressure relay will operate together with the operation of other related protective equipment, and it also detects other light internal faults, and to neglect the regular increase and decrease of static air pressure or pressure changes resulting from normal operation of power transformers.

2.6.1.2 Buchholtz Relay

Buchholtz relay is a protective device for signaling actuated by surge of oil from main tank to conservator, and accumulated gas from low magnitude fault conditions from flashing over inside power transformers which is important to be inspected firstly before making determination such as interturn faults, incipient winding faults, and core faults.

The illustration of position of buchholtz relay is as shown in Figure 2.8 and The illustration of consistency parts of buchholtz relay is as shown in Figure 2.9.

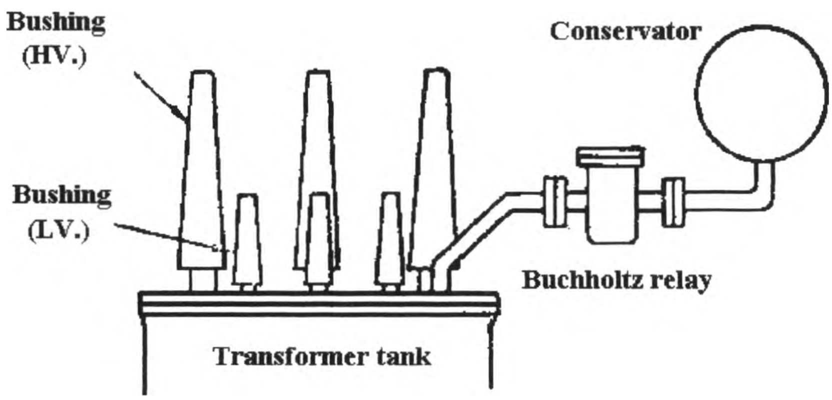


Figure 2.8 The Illustration of Position of Buchholtz Relay

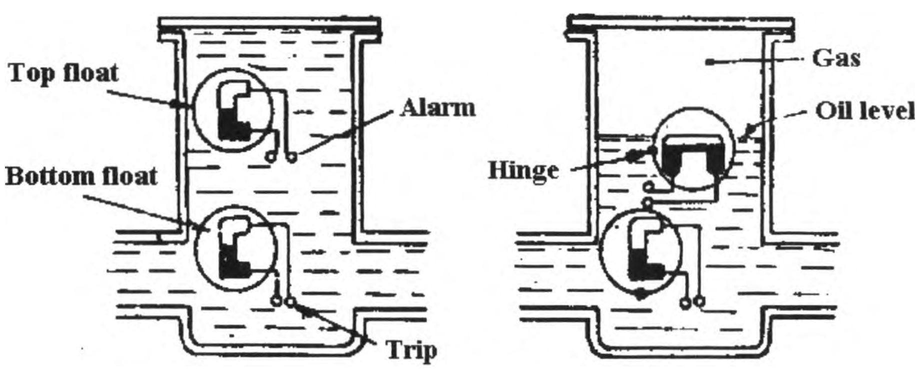


Figure 2.9 An illustration of the Consistency Parts of Buchholtz Relay

2.6.1.3 Thermal Relay

Thermal relay is installed at an external side of transformers isolated from environment vibrating and atmosphere disturbance or weather proof.

The function of thermal relay is to alarm and send signals to the other related instrument such as interrupters or automatic cooling device when the temperature of oil and winding reach to maximum setting points.

2.6.2 Electrical Relay

Power transformers fault happened from distribution system or power transformer can be detected by the combination of relay and current transformer design, along with proper application and connections.

The signals used for electrical relay operation are the abnormal changes of electrical current, voltage and frequency.

2.6.2.1 Overload Protection

Overload protection uses excessive current to detect overload and send alarm and signals. A through faults from external to power transformers result in overload that can cause power transformer failures from thermal and mechanical effects if the fault is not clear promptly.

The mechanical effect has well known as a major concern of power transformer failure, especially insulation compression, insulation wear, and friction-induced displacement. The violence of damage depends on magnitude, duration, and total number of such faults.

A considered characteristic of overload protection is to have the capability to distinguish on faults between overload current and short circuit current. In order to allow power transformers overload when necessary, the pickup value of phase overcurrent relays must be set above their overload current.

2.6.2.2 Overcurrent Protection

Over current protection can be operated by using fuse for small rated transformers and using overcurrent relay for detecting external short circuit in normal situation and protecting abnormal events happened when energising on faults as backup system of differential relay. On the other hand, the other types of relay such as distance relay can also be backup for overcurrent protection system.

Overcurrent relays cannot be used for primary protection without the risk of internal faults causing extensive damage to the power transformers. Fast operation for heavy internal faults is obtained by using instantaneous trip units in the overcurrent relays.

The phase faults can be detected by over current relay and ground faults can be detected by overcurrent ground relay.

The tertiary windings may carry very heavy currents during ground faults happened to power transformer. So, tertiary overcurrent protection must be provided to prevent mechanical strengths at first step and to prevent thermal damaging by time duration at second step for completeness of overcurrent protection on power transformer.

2.6.2.3 Earth Fault Protection

The earth fault protection system will operate by detecting the changes between conventional phase current and summarised ground current when the internal fault happened. The changes derive from comparing between two different positions of current transformer which are placed at conductors of each phase and ground conductor.

2.6.2.4 Differential Protection

Differential relays are the principal form of basic fault protection for power transformers which are an sensitive device for detecting short circuit inside power transformers or in the differential zone by comparing unbalanced current of each phase between input side and output side but less sensitive than differential relay used for generator protection. An important consideration for differential relay characteristics, selection, and operation is the severity of inrush current and operating speed requirements.

The causes of faults should be identified and corrected firstly before making next determination.

Inrush current will be happened at the beginning of energising procedures which needs to be neglected by using time delay setting to reduce sensitivity of differential relay operation, harmonic restraint or a supervisory unit, desensitisation of the differential relay during power transformer energisation, or applying kick fuse operates with instantaneous differential relay.

2.6.2.5 Overfluxing Protection

Overfluxing of power transformer may result in thermal damage to core due to excessively high flux in the magnetic circuits. Flux is directly proportional to voltage and inversely proportional to frequency. Excess flux saturates the core steel and flow into adjacent structures that can cause high losses in the core and adjacent conducting materials.

Overfluxing Protection will not operate as instantaneous tripping but it will trip on momentary system disturbances which can be born safely. Normal condition must be restored or the transformer must be isolated before significant damage is done to insulation structure. If the condition persists for a long time, the transformer should be disconnected from the system to protect it from severe damage which can cause equipment failure.

The related additional description of overfluxing is as described in section 2.5.4.2.

2.7 The annunciation of power transformers

At the side of all power transformers, there is an annunciation panel used to show the happening events of power transformer by lighting pilot lamp. The standard signal names are as shown in Figure 2.10 :

WIND. TEMP TRIP	BUCHHOLTZ TRIP	DIV.SW. OIL.FLOW RELAY TRIP	SUDDEN PRESS. RELAY TRIP	TX. OIL LEVEL	LTC.DRIVE MOTOR BKR.
WIND. TEMP ALARM	BUCHHOLTZ ALARM	OIL TEMP	TX.PRESS RELIEF DIV.	DIV. SW. OIL LEVEL	LTC. O/C DURING TP.CH.
AC. CONTROL FAIL	DC. CONTROL FALL	FAN THERM. RELAY STG.1	FAN THERM. RELAY STG.2	DIV.SW. OVER PRESSURE TRIP OR RELIEF	TAP CHANGE RELAY
AC.SUPPLY FAIL	BUCHHOLTZ ALARM	FAN BKR. STG.1	FAN BKR. STG2	AC. REGULATION	TAP DIFF.
-	RUBBER BAG RUPTURE	-	-	-	-

Figure 2.10 Annunciators at the Transformer Panel

The meaning of each alarm signal as shown in Table 2.1 :

Table 2.2 The Meaning of Each Alarm Signal

Annunciator	Meaning
Buchholtz trip	: Showing oil rushing from main tank to conservator tank.
Winding temperature trip	: Showing temperature exceeding of winding temperature.
Diverter Switch oil flow relay trip	: Showing oil rushing from diverter switch compartment to conservator of diverter switch.

Annunciator	Meaning
Sudden pressure relay trip	: Showing the metering pressure from internal gas happened from flashing over or shocking of power transformer.
Transformer oil level	: Showing the below minimum level of power transformer oil quantity.
Load Tap Changer drive motor breaker	: Showing overload status at motor of Load Tap Changer.
Winding Temperature alarm	: Showing the winding Temperature meets the first setting point.
Buchholtz alarm	: Showing gas happening in Buchholtz relay happened from incipient fault inside power transformer or happened from leaking gas left during oil filling procedure at main tank.
Oil Temperature	: Showing the oil temperature level meets the maximum setting point.
Transformer Pressure Relief device	: Showing instantaneous high pressure happened in main tank of power transformer.
Diverter switch oil level	: Showing the oil level in diverter switch compartment reduces below minimum setting point.
Load Tap Charger Over Current during Tap Charger	: Showing over current events happened in feeder during tap charge operation.
AC Control fail	: Showing the tripping of no-fuse breaker of control current of AC source.
DC Control fail	: Showing the tripping of no-fuse breaker of control current of DC source.
Fan Thermal Relay Stage 1	: Showing the abnormal operation of fan motor in stage 1 from overcurrent
Fan Thermal Relay Stage 2	: Showing the abnormal operation of fan motor in stage 2 from overcurrent
Diverter Switch Overpressure Trip or Relief	: Showing overpressure established in diverter switch compartment
Tap Change Delay	: Showing on status of load tapping uses excessive time that causes operating interrupted before operation complete.
AC Supply fail	: Showing the tripping of no-fuse breaker of AC part.
DC Supply fail	: Showing the tripping of no-fuse breaker of DC part.
Fan Breaker Stage 1	: Showing overcurrent happening in fan circuit of fan stage 1
Fan Breaker Stage 2	: Showing overcurrent happening in fan circuit of fan stage 2
AC Regulating Fail	: Showing loss of PT potential.
Tap Differential	: Showing the difference of tapping position between two paralleled transformers.
Rubber Bag Rupture	: Showing the blowing of rubber bag in conservator.

2.8 Electricity Generating Authority of Thailand and Related Department

2.8.1 Electricity Generating Authority of Thailand

Electricity Generating Authority of Thailand or EGAT, established on the first of May, 1969, is one of the first-class state enterprise which has been entrusted with electricity generation and transmission from increasing of generating capacity, improving the transmission system and upgrading the efficiency of employees in order to provide a firm, adequate and reliable electricity supply to meet the whole kingdom of Thailand's requirement at all time at the most reasonable price and preventing power shortages by construction large and modern power plant to fulfil the mushrooming demand for electric power which is accompanying development of the country.

The businesses of EGAT concerning on electric energy and other businesses are generating, transmitting and selling the bulk energy and products after generating process (such as stream, lignite ash and etc.) to the two distributing entities namely the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA), other energy consumption consumers and customers as prescribed by the Royal Decree, and neighboring countries.

To meet the future power business challenge, EGAT modifies its administrative structure from conventional structure into small business units to be much more business-oriented companies enterprise, operating on a business's competitive basis for more decentralised and streamlines operation, and become a public company being listed on the Stock Exchange of Thailand (SET) in the near future.

The new EGAT's organisation structure appropriated for internal operation consists of 6 BUs and 5 OUs is as shown in Figure 2.11.

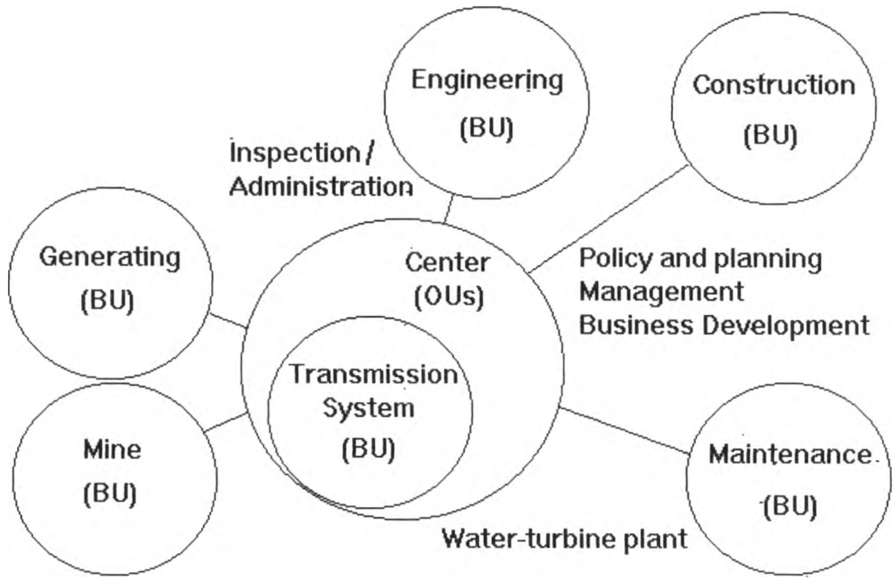


Figure 2.11 EGAT's Organisation Structure

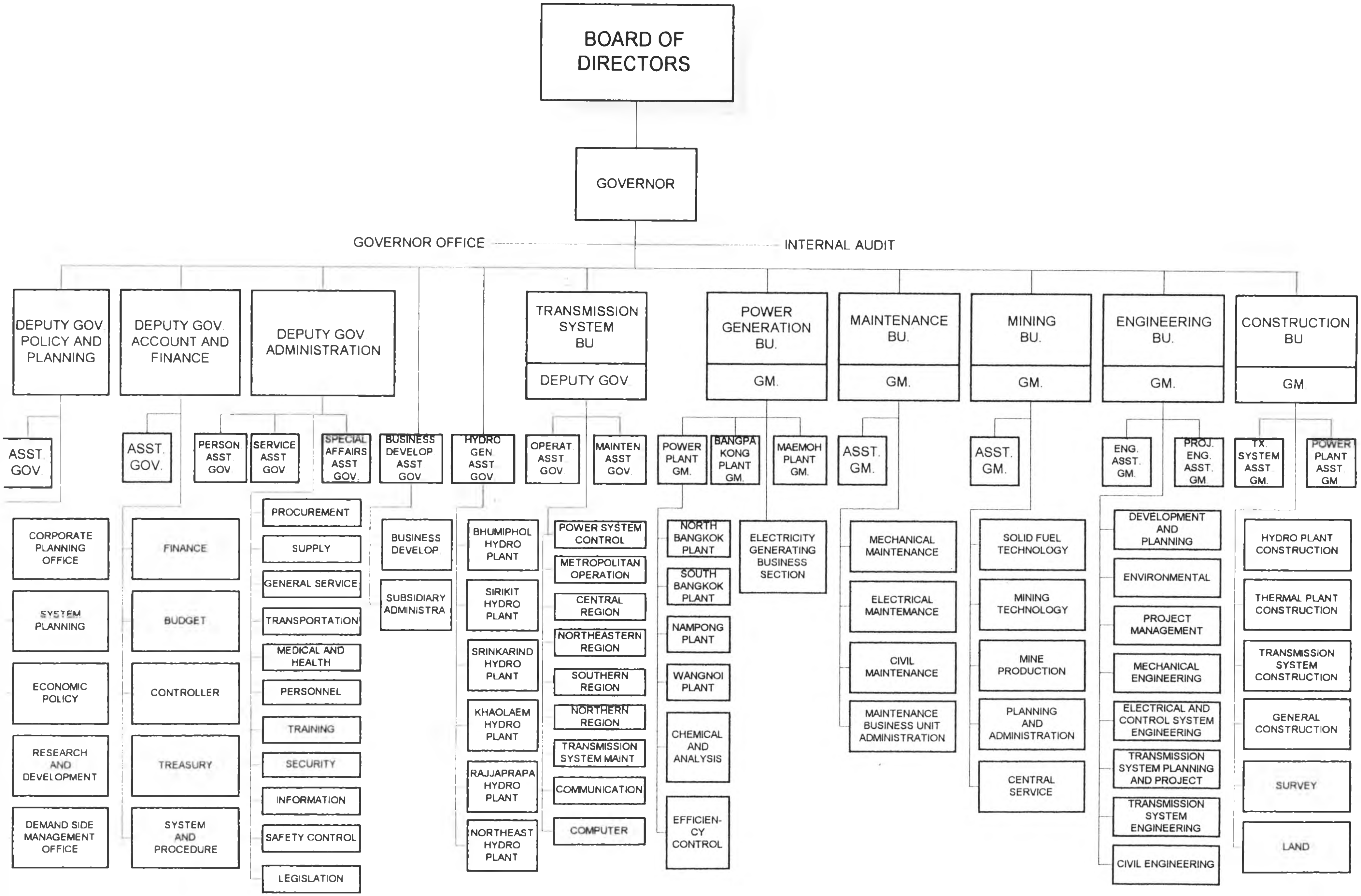
Business Units - operating as profit center, they have own financial statement, and should have the most independent structure as possible. 6 BUs are :

1. Electricity Generating BU.
2. Mine BU.
3. Maintenance BU.
4. Engineering BU.
5. Construction BU.
6. Transmission system BU.

Operation Units - operating as technique and service units with have their own service charges are :

1. Policy and planning OU.
2. Finance and fund OU.
3. Administrative OU.
4. Business development OU.
5. Water-turbine plant OU.

Figure 2.12 Organisation Chart of Electricity Generating Authority of Thailand


BOARD OF DIRECTORS
GOVERNOR
GOVERNOR OFFICE
INTERNAL AUDIT
DEPUTY GOV POLICY AND PLANNING
DEPUTY GOV ACCOUNT AND FINANCE
DEPUTY GOV ADMINISTRATION
TRANSMISSION SYSTEM BU.
DEPUTY GOV
POWER GENERATION BU.
GM.
MAINTENANCE BU.
GM.
MINING BU.
GM.
ENGINEERING BU.
GM.
CONSTRUCTION BU.
GM
ASST. GOV.
ASST. GOV.
PERSON ASST GOV
SERVICE ASST GOV
SPECIAL AFFAIRS ASST GOV.
BUSINESS DEVELOP ASST GOV
HYDRO GEN ASST GOV
OPERAT. ASST GOV
MAINTEN ASST GOV
POWER PLANT GM.
BANGPA KONG PLANT GM.
MAEMOH PLANT GM.
ASST. GM.
ASST. GM.
ENG. ASST. GM.
PROJ. ENG. ASST. GM.
TX. SYSTEM ASST GM.
POWER PLANT ASST GM
CORPORATE PLANNING OFFICE
SYSTEM PLANNING
ECONOMIC POLICY
RESEARCH AND DEVELOPMENT
DEMAND SIDE MANAGEMENT OFFICE
FINANCE
BUDGET
CONTROLLER
TREASURY
SYSTEM AND PROCEDURE
PROCUREMENT
SUPPLY
GENERAL SERVICE
TRANSPORTATION
MEDICAL AND HEALTH
PERSONNEL
TRAINING
SECURITY
INFORMATION
SAFETY CONTROL
LEGISLATION
BUSINESS DEVELOP
SUBSIDIARY ADMINISTRA
BHUMIPHOL HYDRO PLANT
SIRIKIT HYDRO PLANT
SRINKARIND HYDRO PLANT
KHAOLAEM HYDRO PLANT
RAJJAPRAPA HYDRO PLANT
NORTHEAST HYDRO PLANT
POWER SYSTEM CONTROL
METROPOLITAN OPERATION
CENTRAL REGION
NORTHEASTERN REGION
SOUTHERN REGION
NORTHERN REGION
TRANSMISSION SYSTEM MAINT
COMMUNICATION
COMPUTER
NORTH BANGKOK PLANT
SOUTH BANGKOK PLANT
NAMPONG PLANT
WANGNOI PLANT
CHEMICAL AND ANALYSIS
EFFICIEN-CY CONTROL
ELECTRICITY GENERATING BUSINESS SECTION
MECHANICAL MAINTENANCE
ELECTRICAL MAINTEMANCE
CIVIL MAINTENANCE
MAINTENANCE BUSINESS UNIT ADMINISTRATION
SOLID FUEL TECHNOLOGY
MINING TECHNOLOGY
MINE PRODUCTION
PLANNING AND ADMINISTRATION
CENTRAL SERVICE
DEVELOPMENT AND PLANNING
ENVIRONMENTAL
PROJECT MANAGEMENT
MECHANICAL ENGINEERING
ELECTRICAL AND CONTROL SYSTEM ENGINEERING
TRANSMISSION SYSTEM PLANNING AND PROJECT
TRANSMISSION SYSTEM ENGINEERING
CIVIL ENGINEERING
HYDRO PLANT CONSTRUCTION
THERMAL PLANT CONSTRUCTION
TRANSMISSION SYSTEM CONSTRUCTION
GENERAL CONSTRUCTION
SURVEY
LAND

The similar operation of each department will be categorised into the same group. The complete organisation chart of Electricity Generating Authority of Thailand is as shown in Figure 2.12

EGAT's first subsidiary is the Electricity Generating Company Limited or EGCO operating as a public holding company with subsidiaries which are Rayong Electricity Generating Company Limited or REGCO and Khanom Electricity Generating Company Limited or KEGCO managing individual power stations and selling electric energy back to EGAT under the long term agreement.

In order to encourage a greater role of private sector in power industry by promoting the other firms to join the power business with low risk, and fringe profits, EGAT has launched a programme to purchase electricity from Independent Power Producers (IPP) in December 1994. In the first phase, private developers are invited to supply 3800 MW of power capacity to EGAT, the first 1000 MW by the year 2000 , the next 1400 MW in 2001 and another 1400 MW in 2002. The IPP programme will serve as a new way on financial source management for the investment in a new capacity and reinforce the national grid system in the long run.

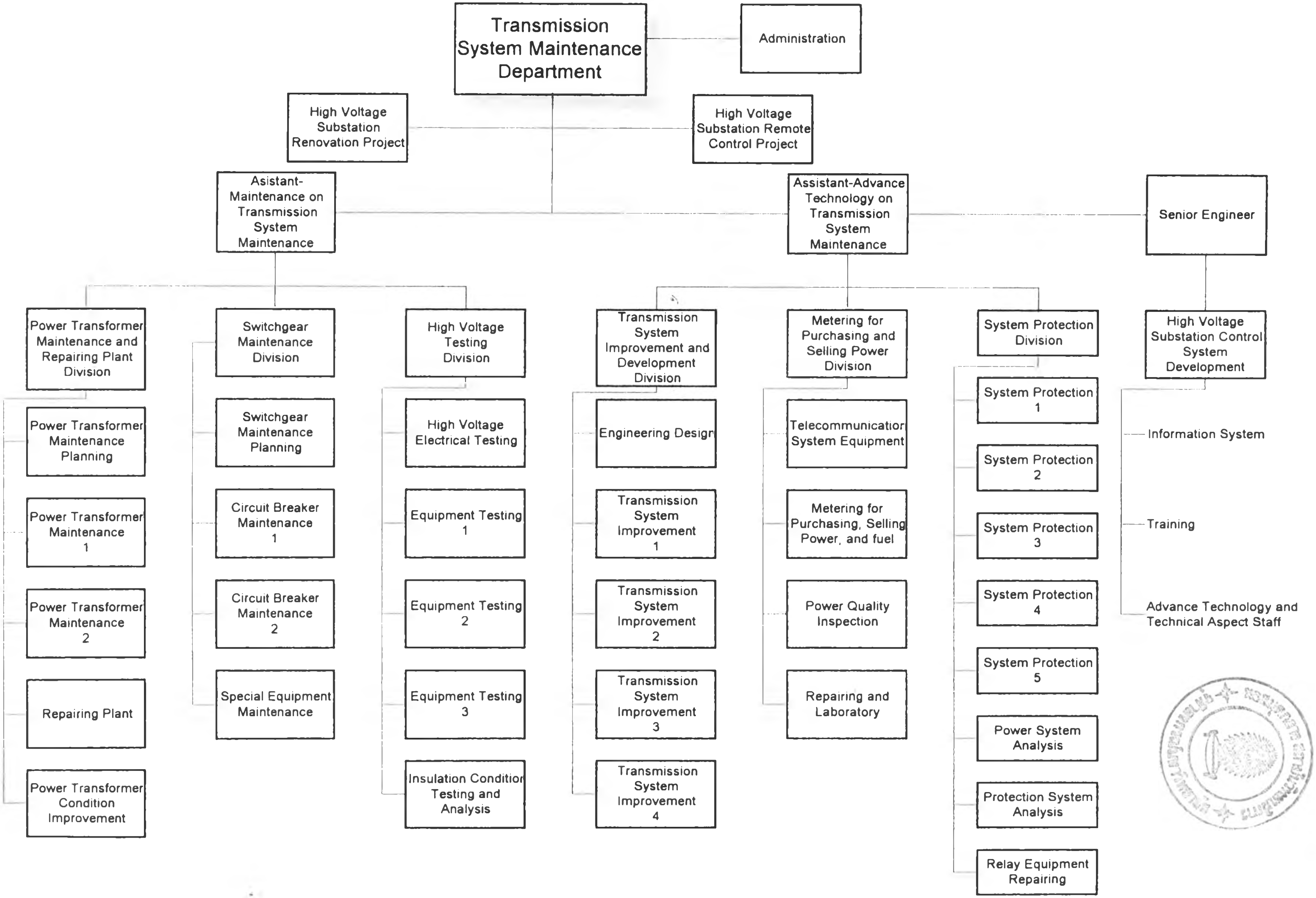
From the organisation chart, the names of department of EGAT related to power transformer acivities directly are the Transmission System Maintenance Department, Metropolitan Region Operation Department, Central region operation department, Northeastern Operation Department, Southern Region Operation Department, Northern Region Operation Department, and the Power System Control Department which will be described descriptively as follows :

2.8.2 Transmission System Maintenance Department

Transmission system maintenance and operation are responsible for all kinds of business related to transmission system equipment such as maintenance, testing, and etc. The responsibilities are covered 169 High-Voltage substations, 740 units of power transformers, 2,061 units of circuit breaker, 9,148 units of instrument transformers, 3 static Var systems, with 22,105 kilometres length of transmission line.

Organisation Chart of Transmission System Maintenance Department is as shown in Figure 2.13

Figure 2.13 Organisation Chart of Transmission System Maintenance Department


Transmission System Maintenance Department
Administration
High Voltage Substation Renovation Project
High Voltage Substation Remote Control Project
Asistant-Maintenance on Transmission System Maintenance
Assistant-Advance Technology on Transmission System Maintenance
Senior Engineer
Power Transformer Maintenance and Repairing Plant Division
Power Transformer Maintenance Planning
Power Transformer Maintenance 1
Power Transformer Maintenance 2
Repairing Plant
Power Transformer Condition Improvement
Switchgear Maintenance Division
Switchgear Maintenance Planning
Circuit Breaker Maintenance 1
Circuit Breaker Maintenance 2
Special Equipment Maintenance
High Voltage Testing Division
High Voltage Electrical Testing
Equipment Testing 1
Equipment Testing 2
Equipment Testing 3
Insulation Conditior Testing and Analysis
Transmission System Improvement and Development Division
Engineering Desigr
Transmission System Improvement 1
Transmission System Improvement 2
Transmission System Improvement 3
Transmission System Improvement 4
Metering for Purchasing and Selling Power Division
Telecommunicatior System Equipment
Metering for Purchasing, Selling Power, and fuel
Power Quality Inspection
Repairing and Laboratory
System Protection Division
System Protection 1
System Protection 2
System Protection 3
System Protection 4
System Protection 5
Power System Analysis
Protection System Analysis
Relay Equipment Repairing
High Voltage Substation Control System Development
Information System
Training
Advance Technology and Technical Aspect Staff

From the chart, the division of transmission system maintenance that relates to power transformer directly is power transformer maintenance and repairing plant division which consists of 5 divisions as follows :

- Power transformer maintenance and planning division
- Power transformer maintenance 1 division
- Power transformer maintenance 2 division
- Repairing plants division
- Power transformer condition improvement division

2.8.3 Power System Control Department

Power System Control Department is responsible for monitoring and controlling the overall power system of Thailand, the related division is transmission system operation planning division which prepares descriptive information of power system such as evaluation of transmission system performance, planning, studying, and diagnosing results on power system and related equipment, and etc.

2.8.4 Other Operation Department

The Substation equipment maintenance division in each region is responsible for power transformer maintenance, the personnel of the division in each maintenance section consist of :

- Chief of sections.
- Assistant chiefs.
- Engineers or supervisors as experts on working experiences and technical aspects
- Group leaders or foramen.
- Employees.

Substation operators are also responsible for the jobs as employees and maintenance personnel staying at each substation for monitoring jobs and supporting teams from substation equipment maintenance division, the personnel of substation operation consist of :

- Group of substations (1-3 substations) leader.
- Head of substations.
- Operators.

Personnel in a 115 kV. high voltage substation consist of a head of substation and an operator. Personnel of the moderate size of a 230 kV. high voltage substation consist of a head of substation and two operators. Personnel of the large size of a 230 kV. high voltage substation as important junction consist of a head of substation and three operators. Personnel of a 500 kV. high voltage substation and a substation near power plants consist of shifts of operator which have two operators per shift.