NYK Maritime College

NYK SHIPMANAGEMENT

NMC-29
6.6kV High Voltage Switchboard Familiarization Training

NYK SHIPMANAGEMENT PTE LTD
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Applicable Trainees: Engine Officers

Objectives of the Training:

At the end of the training, the trainees should understand the followings:

1) Personal Protective Equipment used in handling High Voltage System

2) Advantages of 6.6 kV compared to 440V system

3) Safety devices, installed in a 6.6kV Main Switchboard

4) Methods for using these safety devices, installed in the system

5) Operation of Vacuum Circuit Breaker

6) Recovery procedure in case of blackout

Duration of Training: 1 Day

Course schedule:

	Contents of the course		Contents of the course	
	AM	AM	PM	PM
1st day	Safety guidelines, Advantages of 6.6kV system	Main switchboard	Main Switchboard continue… & VCB	Battery charger, Case study and Assessment

Contents and Syllabus

1. Introduction:

What is High Voltage?

In Marine Practice majority of merchant ships have 3-phase 3-wire, 440 V insulated neutral earth power systems. This power system falls in the category of low voltage and meets the power demands of medium capacity motors up to 200 KW.

Voltages up to & including 1000 Volt is known as Low Voltage system and
Voltages above 1000 Volt is called as High Voltage system.

Why HV in Ships?

Higher power requirements on board vessels are the foremost reason for the evolution of HV in ships.
Higher power requirements have been necessitated by

- Development of larger vessels required for container transport particularly reefer containers.
- Gas carriers needing extensive cargo cooling
- Electrical propulsion.

For ships with a large electrical power demand it is necessary to utilize the benefits of a high voltage (HV) installation.
The design benefits relate to the simple ohms law relationship that current (for a given power) is reduced as the voltage is increased. Working at high voltage significantly reduces the relative overall size and weight of electrical power equipment.

2. Safety Guidelines:

These guidelines are to protect you from potentially deadly electrical shock hazards as well as the equipment from accidental damage. Note that the danger to you is not only to your body providing a conducting path but particularly to your heart.

Any involuntary muscle contractions caused by an electric shock, while perhaps harmless in them, may cause collateral damage. Further danger is posed by the presence of equipment, such as the switchboard, in the area. There are many sharp edges inside this type of equipment as well as other electrically live parts you may contact accidentally. The purpose of this set of guidelines is not to frighten you but rather to make you aware of the appropriate precautions.

- Switch off the electric power supply. Discharge the remaining electric power by earthing the wire and then confirm the voltage.

- Don't work alone - in the event of an emergency, another person's presence is essential.

- Wear rubber bottom shoes or sneakers.

- Wear eye protection – eyeglasses with large plastic lenses or safety goggles.

- Don't wear any jewelry or other articles that could accidentally contact circuitry and conduct current, or get caught in moving parts.

- Set up your work area away from possible grounds that you may accidentally be in contact with.

- Know your equipment, instrument and tools.

- When handling static sensitive components, an anti-static wrist strap is recommended. However, it should be made of high resistance materials with a high resistance path between you and the chassis (greater than 100K ohms). Never use metallic conductors, as you would then become an excellent path for live current.

- Don't attempt repair work when you are tired. Not only will you be more careless, but also your primary diagnostic tool - deductive reasoning – will not be operating at full capacity.

- Finally, never assume anything without checking it out yourself. Don't take shortcuts!

2.1 Risk Assessment and Permit- to-work:

The access procedure to HV switchboard and equipment must be controlled by using a risk assessment and permit to work system; isolation procedure must involve a safety key system and earthing down procedures.
A useful acronym is:
- **L**ocate - all points of isolation;
- **I**solate - to prevent accidental re-energizing:
- **V**erify - power is disconnected and that there is no secondary power source;
- **E**arth - using appropriate approved equipment;

In the Safety management system of our company we had already incorporated the permit to work system for low voltage and high voltage system.
Our sms ref,: S-091005-05CHK Permit to work electrical.doc

Note: Electrical Permits-to-Work mentioned above are to specify the period of validity. This period shall NOT exceed twelve hours. All Permits-to-Work are automatically suspended on the sounding of any ships emergency alarm, or if the task changes significantly.

Safety Measure: Only the work specified on the permit shall be undertaken. Before signing the permit the Safety Officer shall check that all the measures specified have in fact been taken and that all appropriate safety arrangements are maintained until the permit is cancelled.

2.2 Additional Safety Procedures to be implemented for HV system

For HV systems, additional procedures and precautions should be taken. These are as follows:

Sanction-to-Test System:
Following work on an HV system it is often necessary to perform tests. Usually testing may only be carried out after the circuit main earth (CME) has been removed. An example of this is insulation testing as it involves the system being checked for insulation t earth.
A sanction-to-test should be issued in a similar manner to a permit-to-work. A sanction-to-test should not be issued on any apparatus on which a permit-to-work is still in force, or on which another sanction-to-test is in force.
NOTE: Maintenance and repair can not be carried out under a sanction-to-test.

Limitation of Access Form:
When carrying out HV maintenance, it may be dangerous to allow unrestricted work to carry out nearby. Workers carrying out maintenance nearby may not have HV training and may not be familiar with the risks involved when working on or near HV equipment. Due to these risks the Limitation of Access form should be used. This form states the type of work that is allowed to be carried out nearby the HV work, the limitation imposed and the safety precautions taken.

Earthing Down:
Earthing down is required to ensure that any stored electrical energy in the inherent capacitance of the equipment insulation is safely discharged to earth after isolation. The higher levels of insulation resistance required on HV cabling lead to higher values of insulation capacitance (C). When this is coupled with the high voltage, it means that the energy stored (W) in HV equipment is far greater than that in LV system. This is clearly demonstrated by the electrical formula:

Energy stored (W) joules = (capacitance x Voltage2)/ 2

Earthing down also ensures that isolated equipment remains at a safe potential during work procedures.
These are two types of earthing down at an HV switchboard:

- **Circuit earthing – an incoming or outgoing feeder cable is connected by a heavy earth from earth to all three conductors after the circuit breaker has been racked out. This is done at the circuit breaker using a special key.This key is then locked in the key safe. The circuit breaker cannot be racked in until the circuit earth has been removed.**
- **Busbar earthing – when it is necessary to work on a section of busbar it must be completely isolated from all possible electrical sources. This will include generator incomers, section or bus tie breakers and transformers on that**

busbar section. The busbars are connected together and earthed down using portable leads which give visible confirmation of the earthing arrangement.

2.3 Personal Protective Equipment:

High Voltage Gloves

A high voltage energy source is classified as any voltage above 1000 volts. The first layer of gloves is a leather layer designed to absorb any moisture that would cause high conductivity. The second layer is the real insulating layer. It is a pair of lineman's 10,000 volt gloves made of tough rubber. Finally, on the outer layer, it has another leather pair to provide a final layer of insulation and to keep the rubber gloves from tearing.

- Insulating Rubber Gloves
- Insulating Sleeves
- Insulating Blankets
- Insulating Matting
- Hot Sticks and Hot Line Tools
- Dielectric Over Shoe Footwear

Some of the items mentioned above are not included in the Personal Protection Equipment spare box.

3. Advantages of 6.6 kV Voltage System:

- **Advantages / Disadvantages of using HV**

Advantages:

For a given power, higher voltage means Lower current, resulting in:

- Reduction in size of generators, motors, cables etc.
- Saving of space and weight.
- Ease of installation.
- Reduction in cost of installation.
- Lower losses- more efficient utilization of generated power.
- Reduction in short circuit levels in the system which decides the design and application of the electrical equipment used in the power system.

BUT WHY IS CURRENT LOWER WHEN VOLTAGE IS HIGHER ?????

6.6kV voltage system was derived from the theory similar to the transmission line. When the generated voltage is low (440V), the current and losses should be high to generate high power (3 Megawatts). Meanwhile, when the generated voltage is high (6.6 kV), the current should be low, to generate high power (3 Megawatts). Smaller current will require smaller bus bar, smaller circuit breaker and smaller wires and conduits. The following theory will explain this:
Power (watts) = √3 Voltage x Current x power factor

At low power 440V, 3 MW, 0.8 power factor
3,000,000 Watts = √3 (440V) x Current x 0.8

Current = 4026.15 Amp., it would require an ACB of 5000 ampere frame and the largest ACB is only 8,000 ampere-frame.

At high power 6.6 kV, 3MW, 0.8 power factor

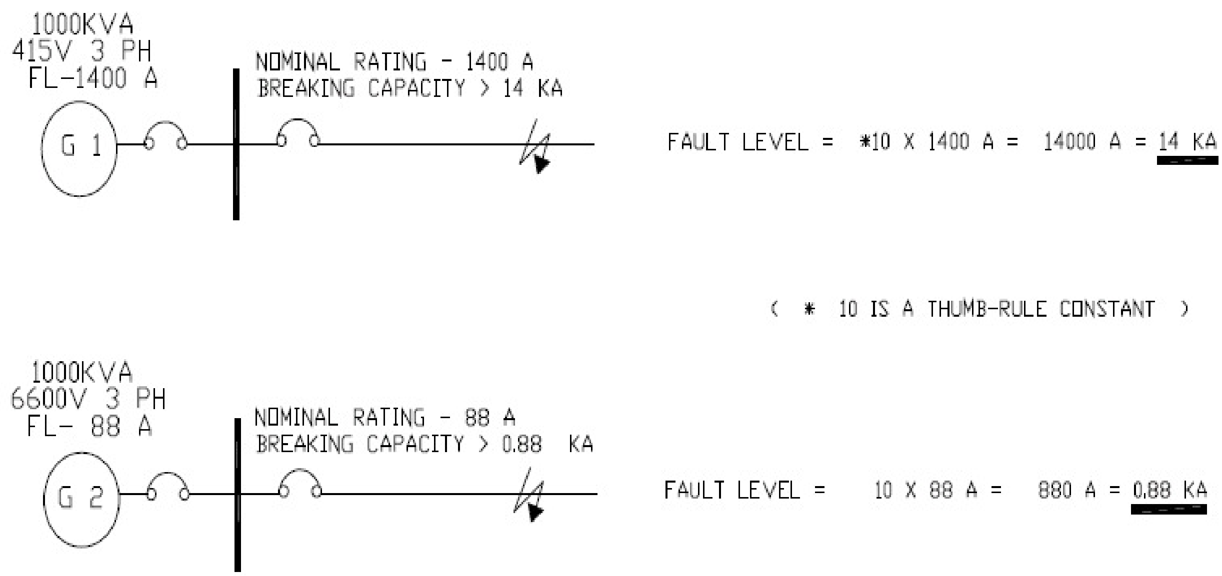
3,000,000 watts =√3 (6600V) x Current x 0.8
Current = 328.43Amp, it would require a VCB of 630 Amp. Frame

When there is small current, the size of the conductor and bus bar are smaller.

WHY REDUCTION IN SHORT CIRCUIT CURRENT WHEN VOLTAGE IS HIGHER ?????

Also there is Reduction in short circuit level current by using High Voltage as compared to low voltage system as can be seen in below example:

Reduction in S.C. Level by using HV An example:



WHY LOWER LOSSES??????

Assume the power to be transmitted is P, and the resistance of the transmission line is R. If the power transmitted **P(t)** is with voltage **V**; then the current flow through the transmission line is **I = P (t) / V**.

Higher the voltage lowers the current.
Power loss: **P(L) =I2*R = (P (t) / V)2*R**
Since P and R are fixed conditions, less power will be lost if high voltages V are used

Disadvantages:

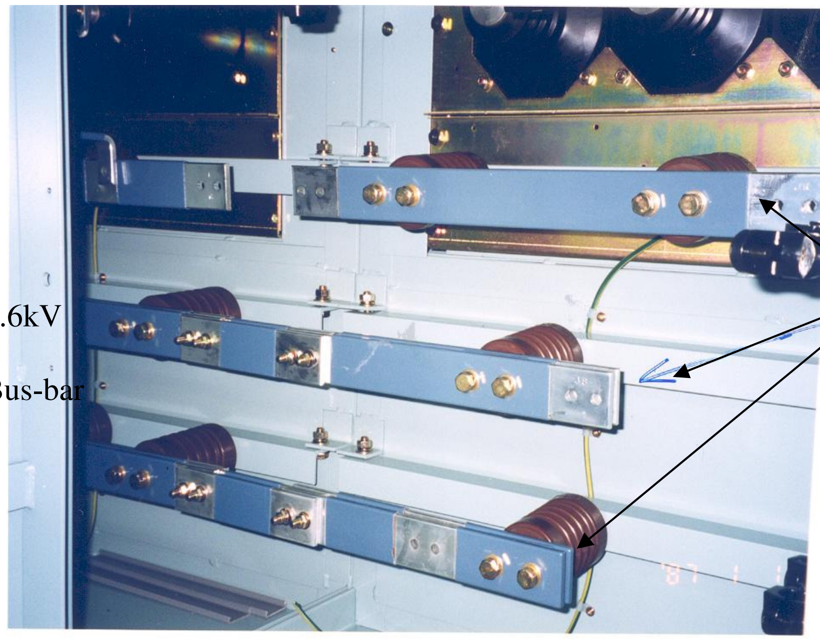
These are as follow**:**

- Higher insulation requirements for the cables & the equipments used in the system.
- Higher risk factor and the necessity for strictly adherence to stringent safety procedures.

Size of the Bus bar:

6.6kV

Bus-bar



8 mm x 50 mm x 2 bars

The bus bars are covered with steel plate compartment to avoid ingress of particles like dust, dirt and moisture. The said bus bar is being monitored by a Ground Over Voltage Relay (GOVR), which has an audible alarm. When the insulation level of the bus bar is less than the set point in the GOVR, it will trigger the alarm.

In the 6.6 kV systems, the main switchboard is wider because of the magnetic field of the 6.6 kV. Each of two pieces of bus bar is smaller, 8 mm x 50 mm x 2 bars, compared to 440V system; 8mm x 200mm x 4 bars, and the spacing between the bus bars is also wider.

Example: Main transformer primary side 6.6kV uses 8 mm x 30 mm x 1 bar / 1 phase = 240mm^2, secondary side 440V uses 6 mm x 200 mm x 4 bars / 1 phase = 4800mm^2. Thus the surface area is more than 20 times.

In 6.6 kV systems, the equipment used is smaller, light weight and compact. The cables and bus-bar are smaller and light weight compared to 440 V system. The Vacuum Circuit Breaker is light weight and compact.

3.1 Consideration for HV Power Distribution System:

We have seen that when we need high power high voltage is advantageous.
For a commercial vessel, HV power distribution is applied when:

- the total capacity of generators is over approx 8 MW
- Electric motors capacity over approx. 0.3 MW, and bow thrusters having a capacity over approx. 1MW as partial high voltage system.

When the voltage of the power distribution system for a vessel is to be determined:
We have to consider:

- Safety, reliability and cost effectiveness.
- The limitations below concerning low voltage power distribution systems
  1） Capacity limit of protective devices
  2） Production limit of electric motors
  3） Capacity limit of control equipment
  4） Selection of an earthing system
  5） Quantity of cables required for power distribution system

4. Outline of Main Switchoard:

4.1 Arrangement

The 6.6 kV high voltage main switchboard (HVSB) consists of measuring generator from instruments, indicators, switching devices, regulating devices, protective devices, etc. necessary for monitoring, controlling and protecting the electrical generating equipment, electrical loads and electrical power systems.

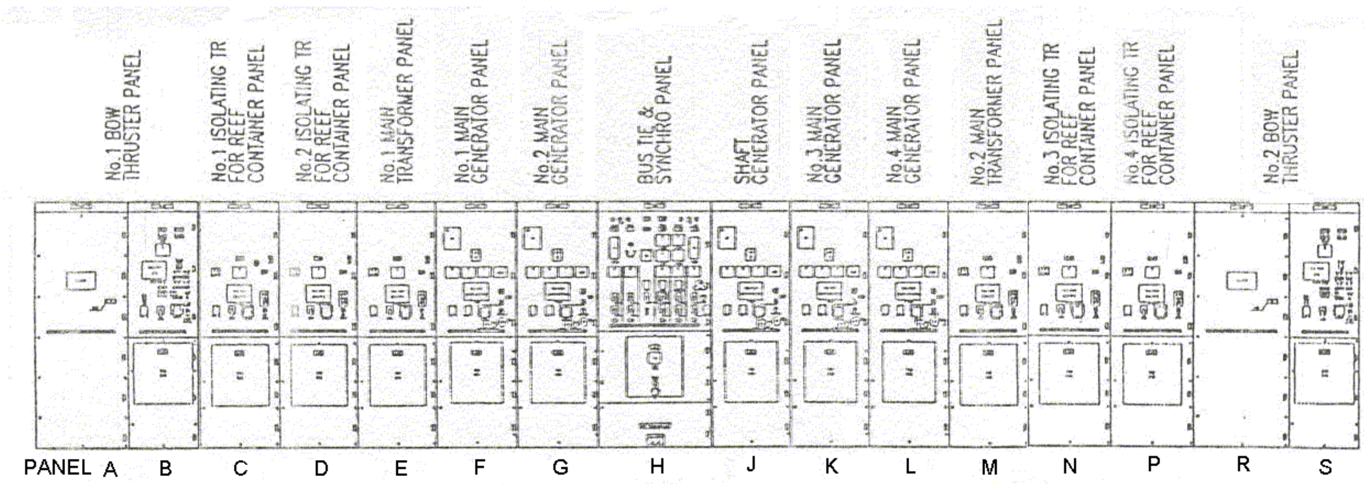


Fig.1 Main Switchboard Arrangement

As the brain of the electrical system, the high voltage main switchboard is essential for efficient and centralized control of the electrical system.

The panel name and the installed circuit breaker type are:

Panel

A: No.1 Bow Thruster Panel (compensating transformer panel) = VCT

B: No.1 Bow Thruster Panel (control panel) = VCB (630A)

C: No.1 Isolating Transformer for Reefer Container Panel = VCB (630A)

D: No.2 Isolating Transformer for Reefer Container Panel = VCB (630A)

E: No.1 Main Transformer Panel = VCB (630A)

F: No.1 Main Generator Panel = VCB (630A)

G: No.2 Main Generator Panel = VCB (630A)

H: Bus Tie and Synchro Panel = VCB (1,250A)

J: Shaft Generator Panel = VCB (630A)

K: No.3 Main Generator Panel = VCB (630A)

L: No.4 Main Generator Panel = VCB (630A)

M: No.2 Main Transformer Panel = VCB (630A)

N: No.3 Isolating Transformer for Reefer Container Panel = VCB (630A)

P: No.4 Isolating Transformer for Reefer Container Panel = VCB (630A)

R: No.2 Bow Thruster Panel (compensating transformer panel) = VCT

S: No.2 Bow Thruster Panel (control panel) = VCB (630A)

* Letters O, I and Q: Not Used

4.1.1 Bus Tie and Synchro Panel PANEL: H

Bus Tie and Synchro Panel are the main operational panels for controlling generators. The main equipment in / on the panel is as follows:

(1) Panel Front Outside = Low Voltage Side

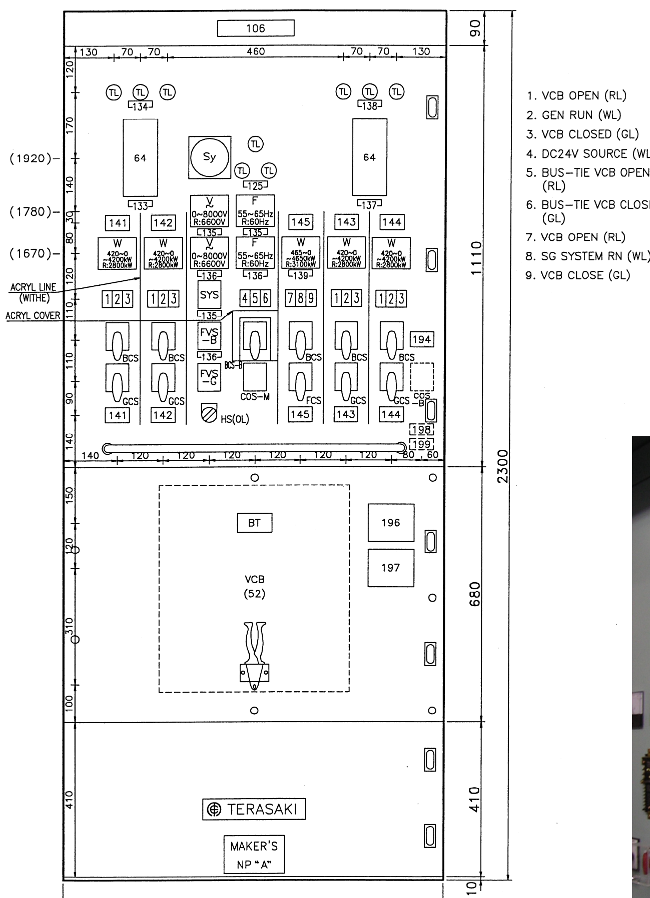


Fig.2 Panel "H" Bus-Tie and Synchro Panel

1) Change over switch for VCB control position (Engine Control Consol(ECR) – High Voltage Switch Board (HVSB))
2) VCB operation switch on HVSB
3) Earth lamp
4) Synchro lamp
5) Synchro scope
6) Ground voltage relay
7) Governor motor control switch
8) Meters (Wattmeter, Voltmeter and Frequency meter)

(2) **Panel Front Inside = Low Voltage Side**

1) VCB for Bus-tie
2) Fuses, installed in PMS power unit, control circuit and indicating lamp circuit etc.

To understand the fuses number and circuit name, refer to the drawing "6.6kV HIGH VOLTAGE MAIN SWITCHBOARD", TERASAKI ELECTRIC Co., Ltd, section "Bus Tie and Synchro Panel", Page "SOURCE CIRCUIT"

3) No.1 and 2 Central PMS (Power Management System) Unit

* Central = control each generator PMS = 2 units (main and back-up)

(3) Panel Rear Inside = High Voltage Side

1) GPT unit = Ground Potential Transformer unit
2) Current Transformer
3) Earthing Switch

4.1.2 Diesel Generator Panel PANEL: F, G, K, L

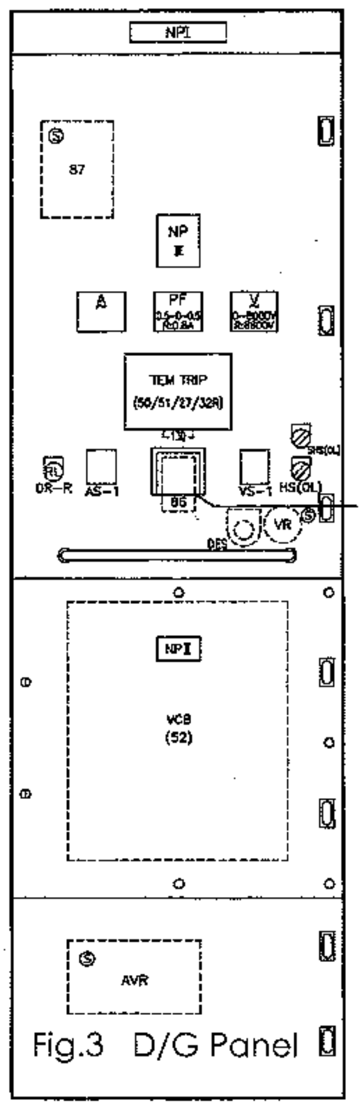


Fig.3 D/G Panel

The main equipment in/on the panel is as follows:

(1) Panel Front Outside = Low Voltage Side

1) TEM-TRIP
2) Meters (Ammeter, Voltmeter and Power factor meter)
3) Ammeter phase selector switch and Voltmeter phase selector switch
4) Locking-out relay switch, resetting VCB trip
   * This operation handle is covered with an acryl box. The function is the VCB "Reset", it is not "TRIP". If the VCB is tripped, the handle is changed to trip position. After confirming normal condition, it is possible to reset.
5) Differential relay reset PB
6) Space heater switch

(2) Panel Front Inside = Low Voltage Side

1) VCB
2) De-Excite key-switch
3) Voltage regulator
4) Generator PMS Unit
5) Digital Synchronizer "EAS-101"
6) Differential Relay

Differential relay monitors trouble the generating coil.
* Generating coil = Y (star) connect
U, V and W phase coils have output line and center connect line.
If electric current is leaking, the current between output line and center connect line are different.

(3) Panel Rear Inside = High Voltage Side

1) Current Transformer
2) Earthing Switch

4.1.3 Shaft Generator Panel PANEL: J

The main equipment in/on the panel is as follows:

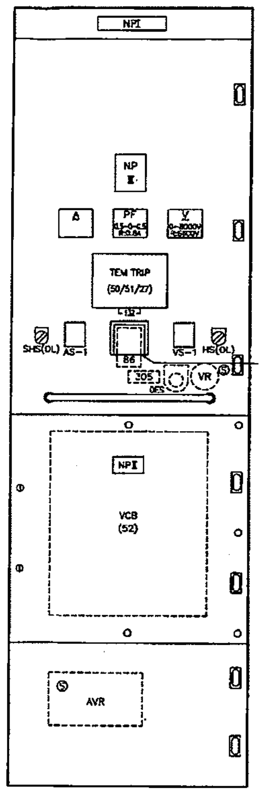


Fig. 4 Shaft Generator Panel

(1) Panel Front Outside = Low Voltage Side

1) TEM-TRIP
2) Meters (Ammeter, Voltmeter and Power factor meter)
3) Ammeter phase selector switch, Voltmeter phase selector switch
4) Locking-out relay switch , resetting VCB trip
5) Space heater switch

(2) Panel Front Inside = Low Voltage Side

1) VCB
2) De-Excite key-switch
3) Voltage regulator
4) Generator PMS Unit
5) Digital Synchronizer "EAS-101"

(3) Panel Rear Inside = High Voltage Side

1) Current Transformer
2) Earthing Switch

4.1.4 Feeder Panel PANEL: C, D, E, M, N, and P

The main equipment in/on the panel is as follows:

(1) Panel Front Outside = Low Voltage Side

1) TEM-TRIP
2) Ammeter
3) Ammeter phase selector switch
4 Locking-out relay switch, resetting VCB trip
5) VCB operation switch
6) Space heater switch
7) Indicator lamps
VCB open (RL), VCB closed(GL)

(2) Panel Front Inside = Low Voltage Side

1) VCB

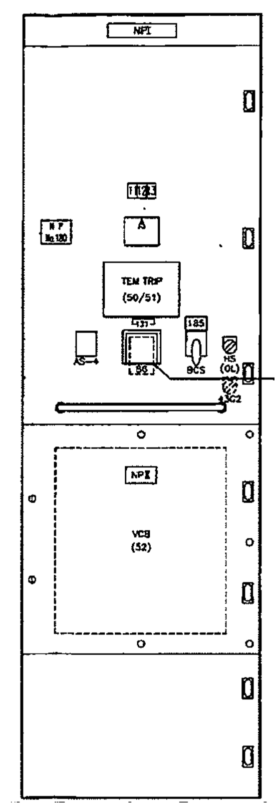


Fig. 5 Feeder Panel

(3) Panel Rear Inside = High Voltage Side

1) Current Transformer
2) Earthing Switch

4.1.5 Bow Thruster Panel, Control and Compensating Transformer Panel

PANEL: A, B, R, and S

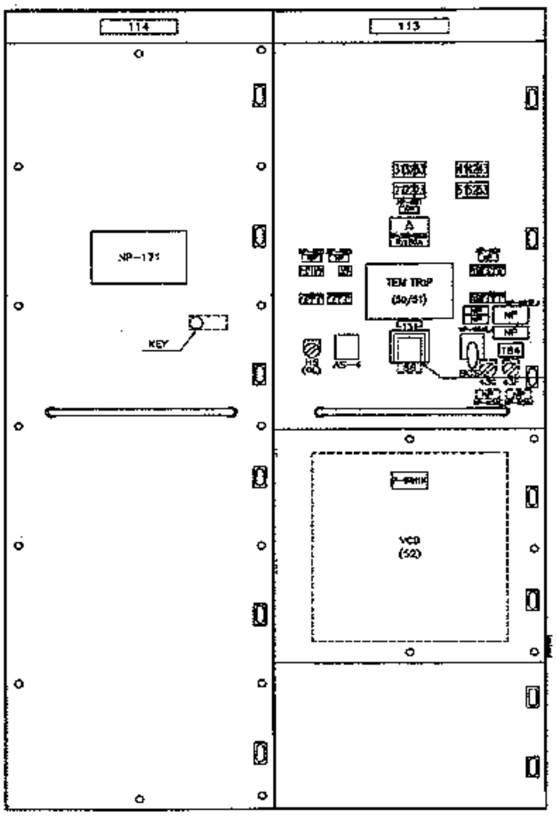


Fig. 6 Bow Thruster Panel

The main equipment in/on the panel is as follows:

(1) Panel Front Outside = Low Voltage

1) TEM-TRIP
2) Ammeter
3) Ammeter phase selector switch
4) Locking-out relay switch, resetting VCB trip
5) VCB operation switch
6) Control position change over switch == Remote - Local
7) Space heater switch
8) Indicator lamps VCB open (RL), VCB closed (GL), Main motor run (GL), Ready to start (WL), Start power avail (WL), Control source (WL), Main motor start fail (RL), Over load (RL), Main motor high temp (RL), Header tank low level (RL), Control oil pump low press (RL)

(2) Panel Front Inside

= Low voltage side
1) VCB
2) Generator interlock by-pass switch
3) Fan interlock by-pass switch

= High voltage side
1) Compensating transformer
* Reduced voltage for starting
2) VCT: Vacuum Contactor for running circuit and starting circuit.

(3) Panel Rear Inside = High Voltage Side

1) Current Transformer
2) Earthing Switch
3) VCT: Vacuum Contactor for motor main circuit.

4.2 Outline of Wiring Diagram:

The electrical generating equipment, for supply of electric power for the electrical loads on board the ship, consists of five (5) generators namely i.e. four (4) diesel generators and one (1) shaft generator (of high voltage main switchboard). One (1) emergency diesel generator (of Emergency switchboard) is automatically operated, when the electric power supply from the diesel generator power and shaft generator power becomes impossible.

*See Fig. 7

In the event of a fault in load circuit, an appropriate protective device will operate to clear the fault in order to protect both the circuit and equipment and to maintain the continuity of service.

One or more of the diesel generators can cover the total power demand. The diesel generator power is distributed to the individual feeder circuits from the feeder panels of the high voltage main switchboard.

Generators are normally controlled in automatic or semi-automatic mode. Even if generators are out of control in automatic or semi-automatic mode, they can be controlled in manual control mode. Main switch Board “MSB” is composed of two (2) parts, left and right MSB. The Bus-Tie VCB in the Bus-Tie and Synchro Panel connects both Main bus-bars. Each bus-bar is connected to the incoming generators VCB and the supplying VCB. For example, the left MSB is connected to the incoming No.1 D/G and No.2 D/G, the supplying No.1 Main Transformer, No.1 Reefer Transformer, No.2 Reefer Transformer and No.1 Bow thruster. If an equipment on one MSB encounters trouble, it is possible to isolate the MSB by opening the Bus-tie VCB. A generator can supply power through the normal MSB.

Generators

Type	Diesel Generator	Shaft Generator
Voltage	6600V AC 3-phase	6600V AC 3-phase
Capacity	2800 kW	3100 kW
Frequency	60 Hz	60 Hz
Quantity	4 sets	1 set

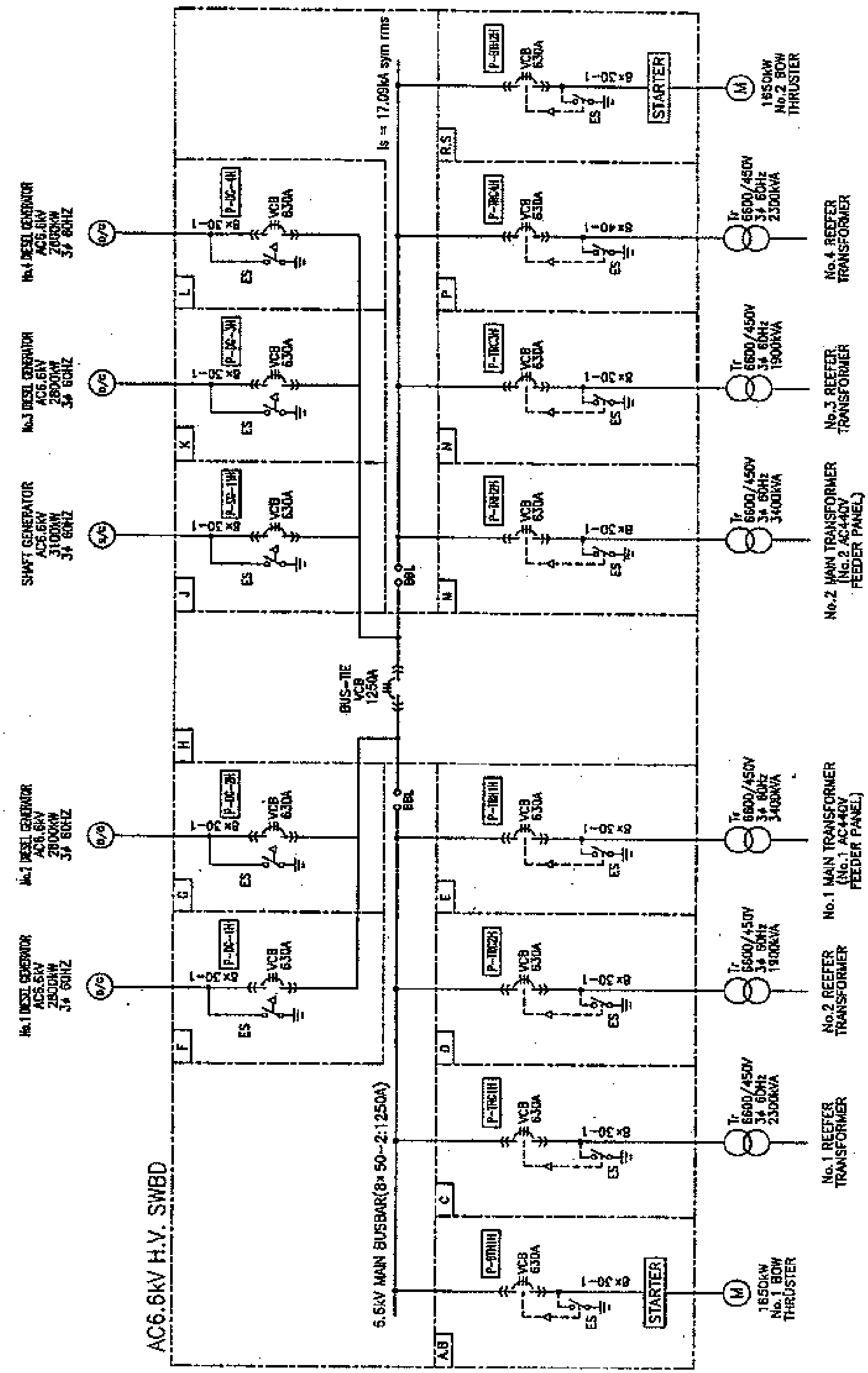


Fig.7 One Line Diagram HV

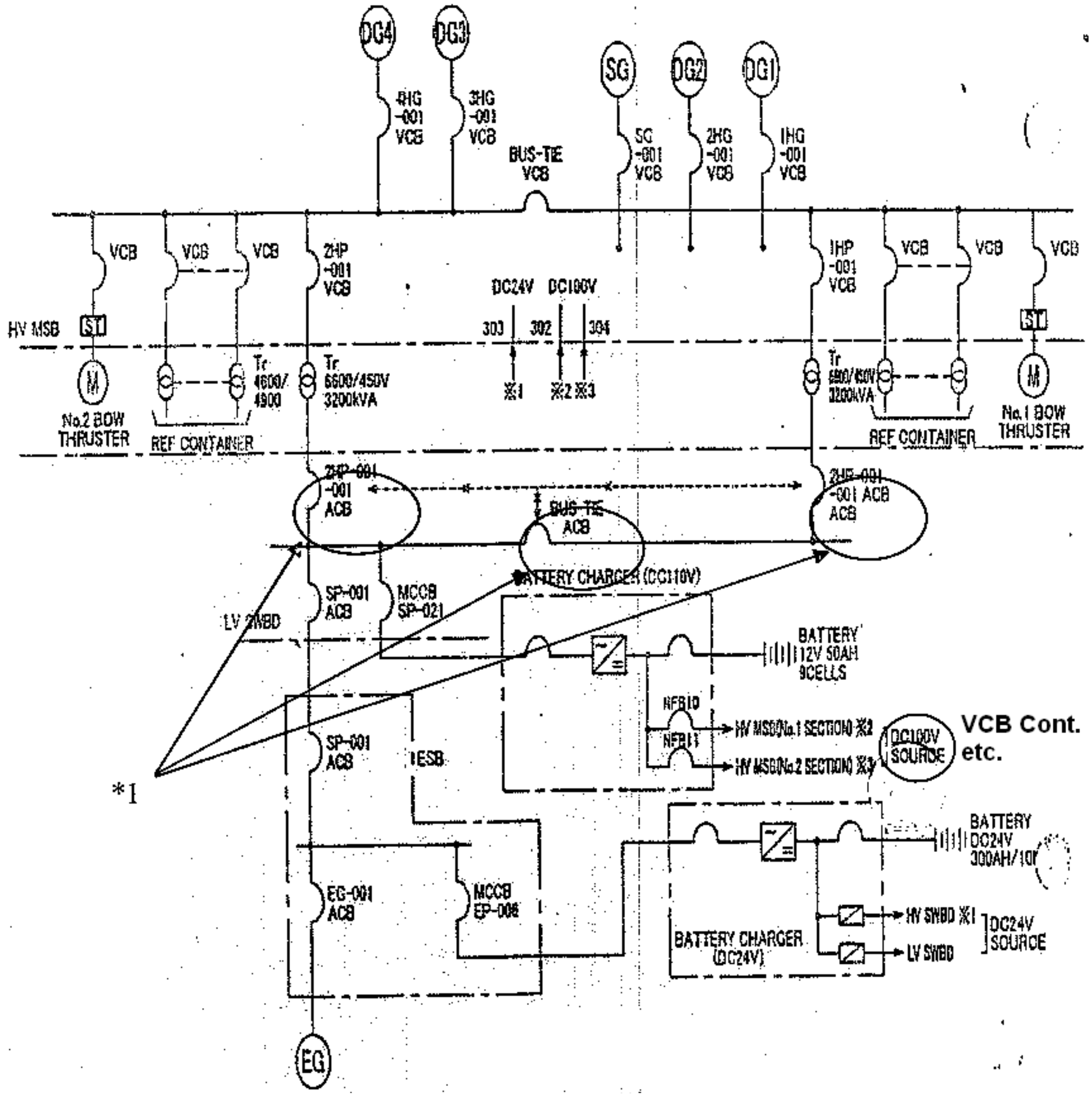


Fig.8 One line diagram HV and LV

*1 This ACB is provided with an electric interlock system. This system protects the three (3) ACB closing together at the same time. This interlock system requires a DC 24V power supply. If the DC 24V fails, visually check the ACB's open/close status. The 440V MSB is located at the opposite of 6.6 kV MSB

Note: The 440V MSB is not equipped with a synchroscope. So synchronization in the 440V MSB is not possible.

The closing interlock systems require two (2) ACB that can be closed, leaving the third one open.

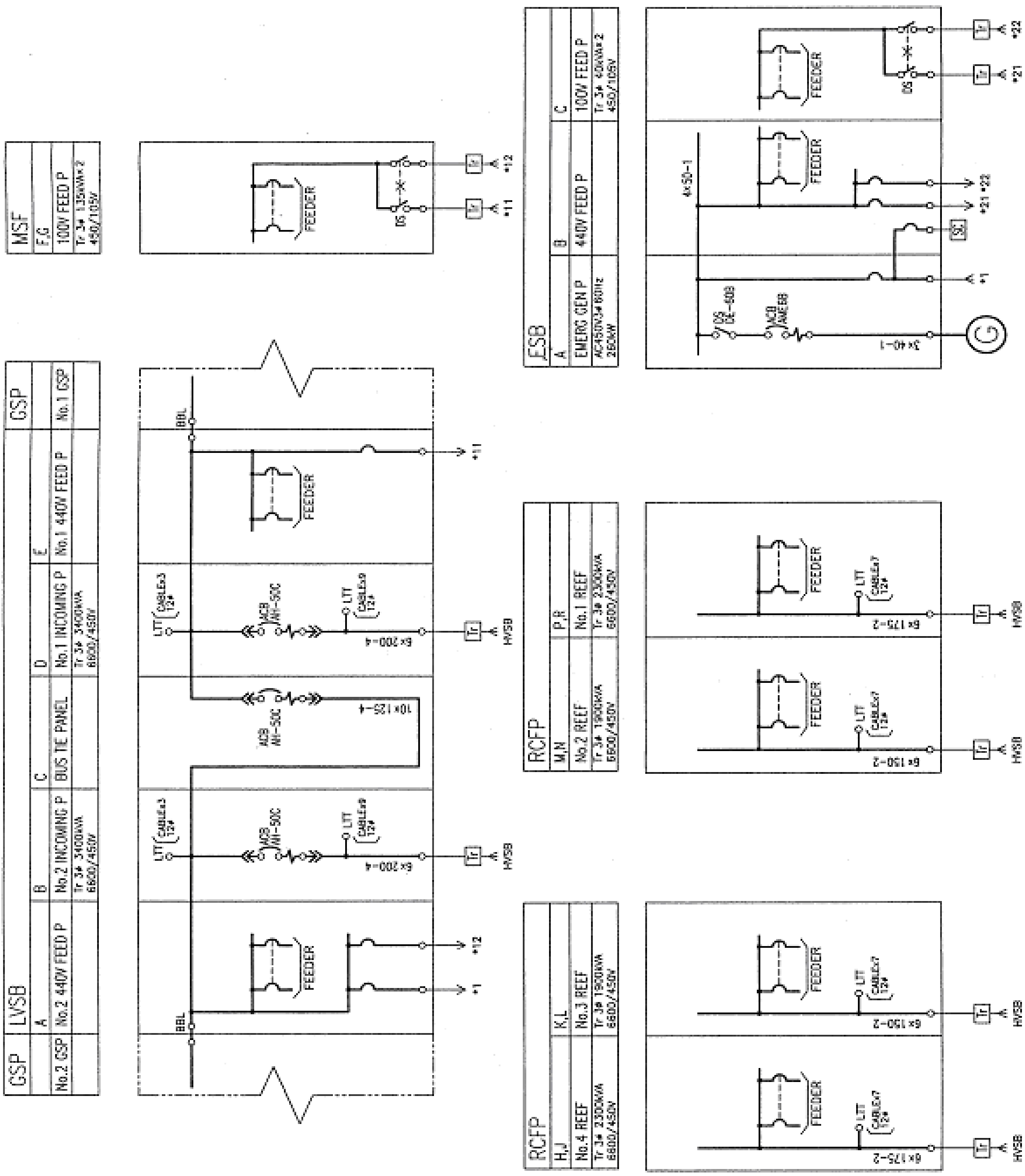


Fig. 9 One Line Diagram LV

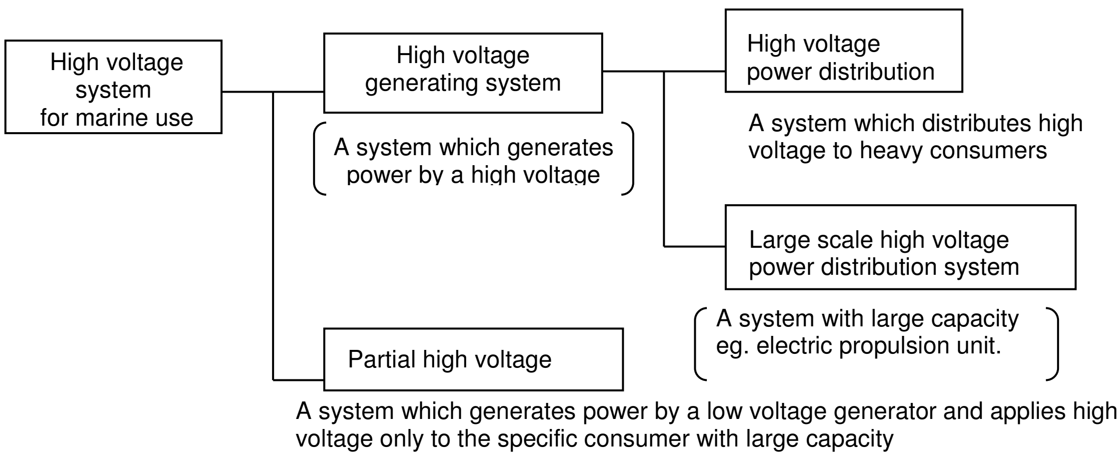
4.3 Power Distribution System

4.3.1 General

The power distribution plan of a vessel has to be decided considering:

- Onboard load
- Generator capacity
- Selection of applied voltage
- Power supply system
- Earthing system
- Protection system.

These have to be examined based on Regulations, Classification rules, type of vessel, and purpose.



4.3.2 Applied Voltage

Generally regulation specifies H.V. as over 1kV.

The choice of voltage, is selected considering:

1) Rated voltage and rated current of the equipment
2) Rated breaking capacity of the protective device
3) Rated voltage and the rated current of the cables

In most cases, the selection depends on the rated breaking capacity.

4.3.3 Type of Power Distribution System

HIGH VOLTAGE POWER DISTRIBUTION SYSTEM

Tree Net system
Most ships

- Low cost
- Possibility of blackout at bus bar fault
- Small quantity of protective devices. Simple protection

Ring Net system
Cruise & Naval ships

- Higher reliability
- Large quantity of protective devices with a complicated protection and control system
- High cost facility

Partial H.V. system
Special cases

- Specific consumer with large capacity long distance from MSB,
- Great advantage expected in cost and space reduction of wiring.

4.3.3.1 Tree-like Distribution System

According to SOLAS, Main bus bar to be divided into at least two bus bars, connected by a circuit breaker or other approved method.

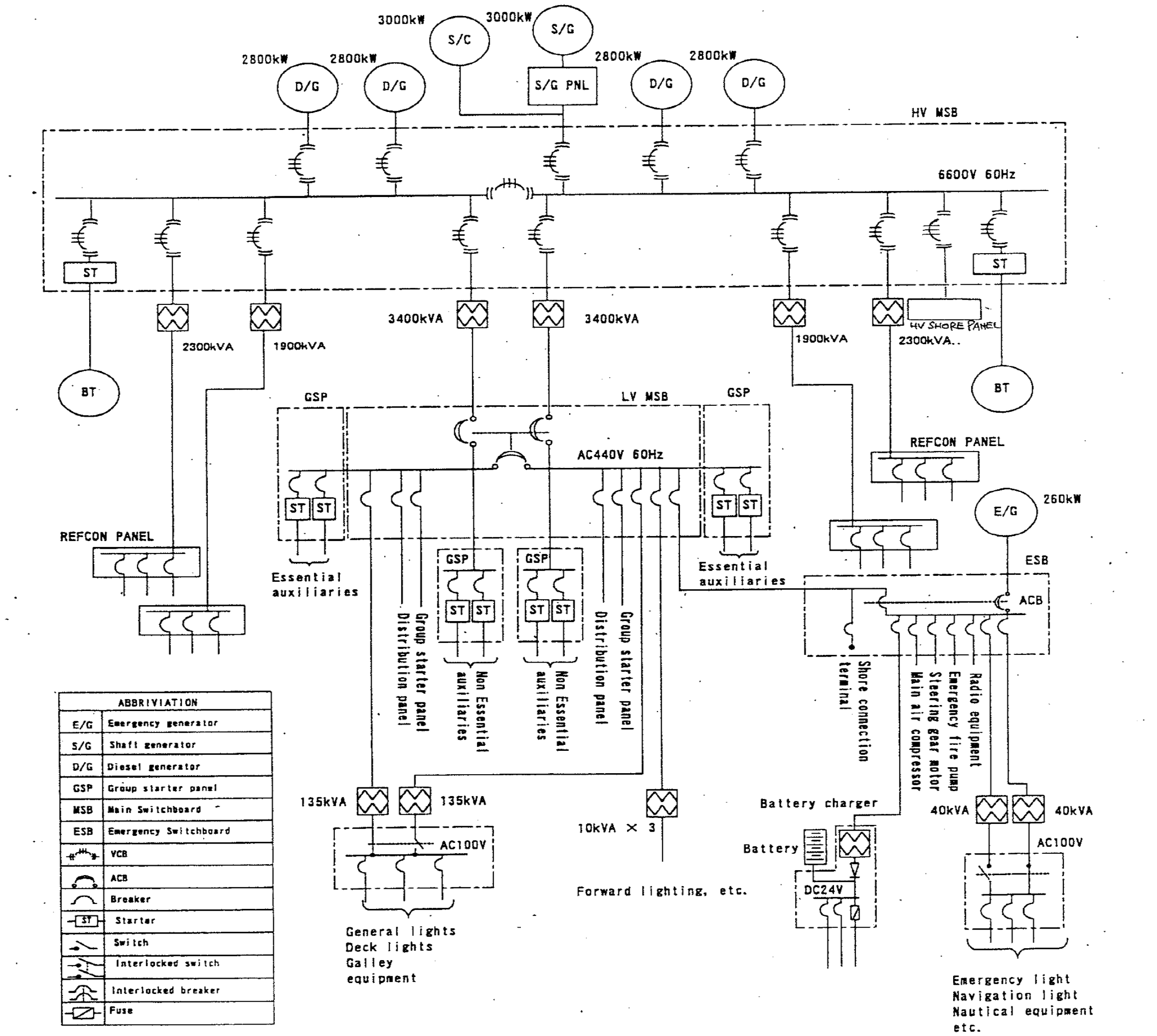
1) If practical the generator and vital equipment to be arranged equally in each bus bar for redundancy.

2) Several step-down transformers should be provided to supply power to low voltage consumers. Each should have enough capacity to supply power to the low voltage load individually.

3) A bus tie ACB should be provided for the low voltage bus bar. This will lead to a significant improvement in reliability.

4) A bus tie VCB on the H.V. side is installed to provide additional safety in the bus bar by dividing the whole system into two sections.

Normally in this power distribution system, the bus tie circuit breaker of the high voltage side is always closed and the bus tie circuit breaker at the low voltage side is always open.



4.3.3.2 Partial high voltage system

This system is used when:

- Specific consumer with a large capacity is a long distance from the MSB,
- Great advantage in the cost and space reduction of wiring.
- Commonly used for bow thruster.

If the capacity of the step-up transformer and the motor is large compared with that of the generator, the following points should be considered.

1) The exciting inrush current of the step-up transformer should not cause the ACB to trip; and the voltage drop of the bus bar should be within allowable level.

2) Reduced-voltage starting of the motor is performed, using tap changing of the step-up transformer leads to a cost reduction.

3) Countermeasures should be taken for the inrush current caused by tap changing.

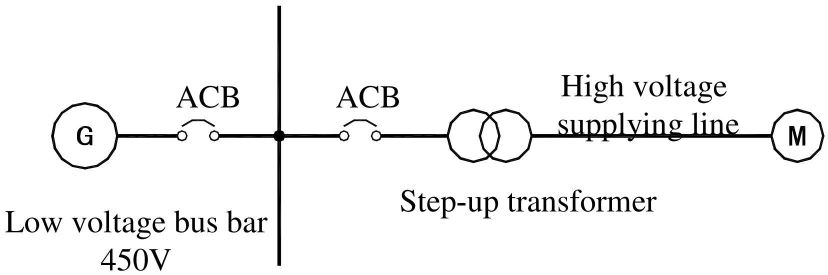
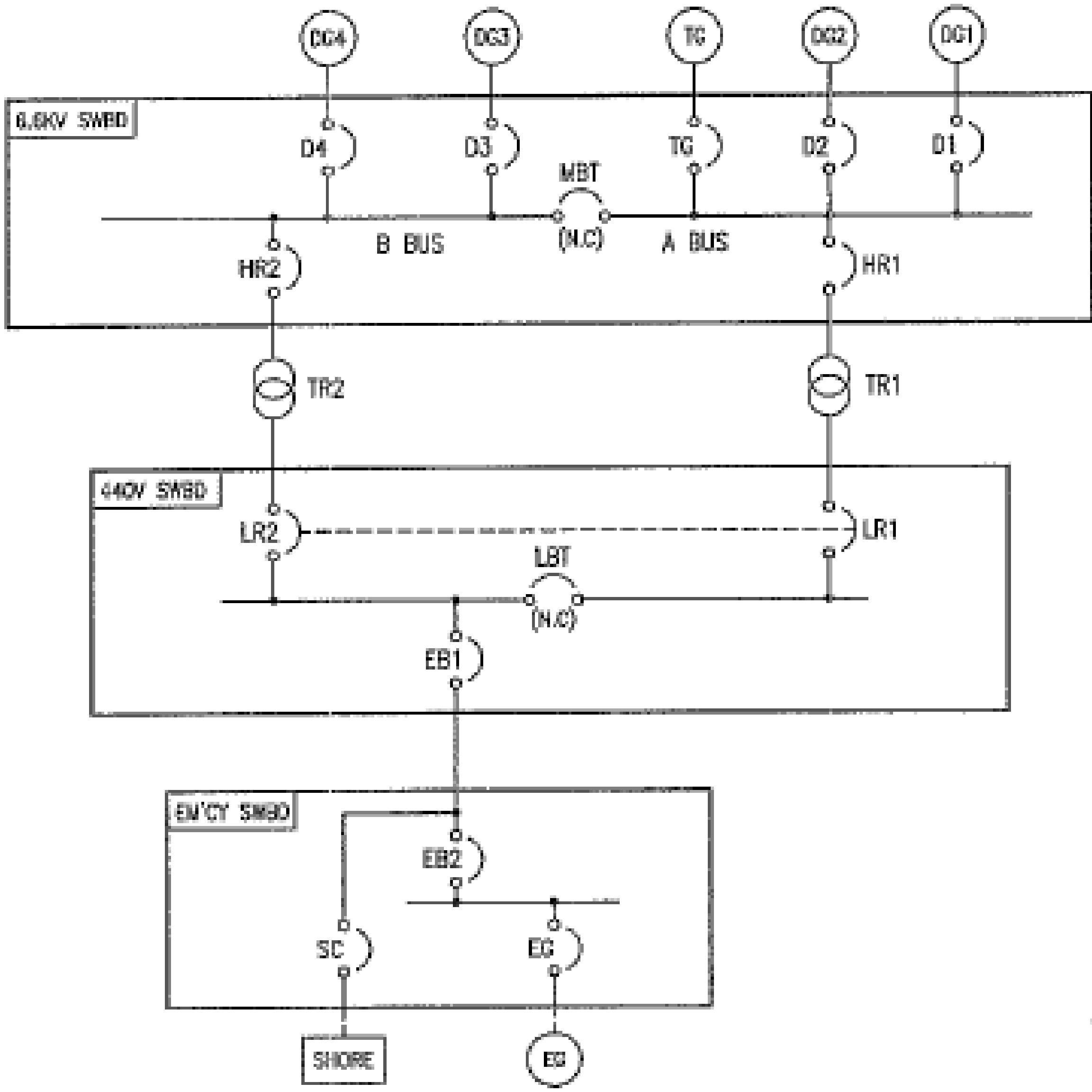


Figure 4; Partial high voltage system

Note: Ring net distribution system is not used for cargo vessels so needless to discuss here.

4.4 Procedure of changing Main Transformer Service



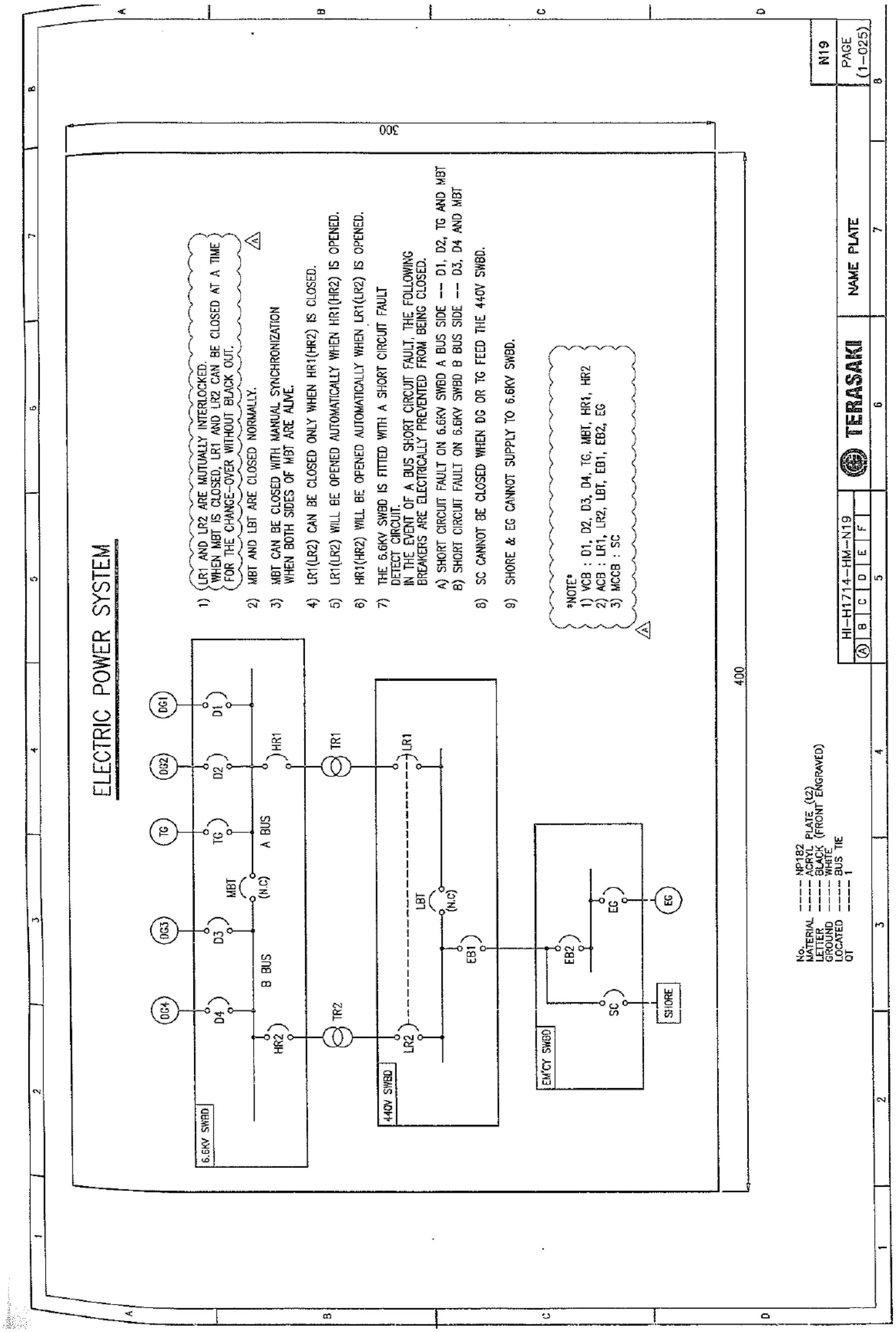
If suppose main transformer TR1 is in use & you would like to change to TR2.
Please follow the below procedure:
Normal condition TR1 in use
HVSB Bus tie MBT: Closed
HVSB HR1: closed (Main transformer TR1 in use)
LVSB LR1: closed (LR1 is interlocked with HR1, if HR1 open LR1 will also open & vice versa)
LVSB LBT: Closed

To change service from Main Transformer no.1 (TR1) to Main Transformer no 2 (TR2)

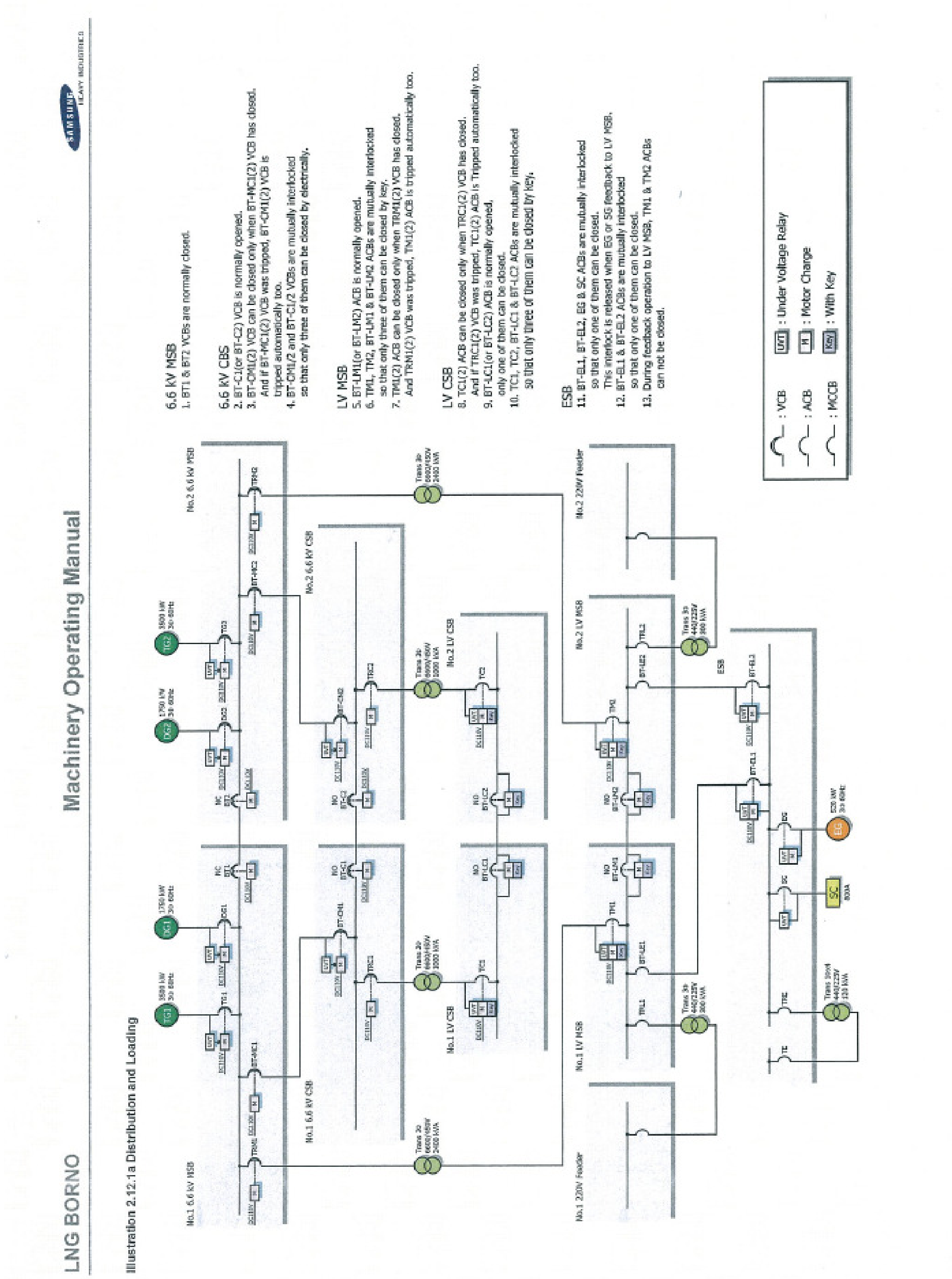
1) Please confirmed that MBT (Bus tie 6.6 KV HVSB) & LBT (440 V LVSB) are in closed condition.
2) The selector switch COS (Change Over Switch) provided on main transformer TR2 panel, put MAN from AUTO.
3) Close the VCB HR2 manually by BCS (Breaker control Switch) provided on main transformer TR2 panel.
4) After closing VCB HR2 manually, put back COS to AUTO from MAN on main transformer TR2 panel.
5) Automatically ACB LR2 will close due to interlock with closed VCB HR2 & same time ACB LR1 will open because ACB LR2 is closed (LR1 & LR2 these two ACB are also having interlock & at a time only one can be in closed condition. LVSB bus tie LBT was normally closed)
6) As ACB LR1 open, same time automatically VCB HR1 will also open due to interlock.
7) So now 440V LVSB is getting supply by main transformer TR2, via closed VCB HR2.

   ACB LR2 & LBT is closed supplying 440 volt.

4.4.1 Power distribution diagram Container ship



4.4.2 Power distribution diagram LNG ship



5. Structure of Main Switchboard:

5.1 Construction View:

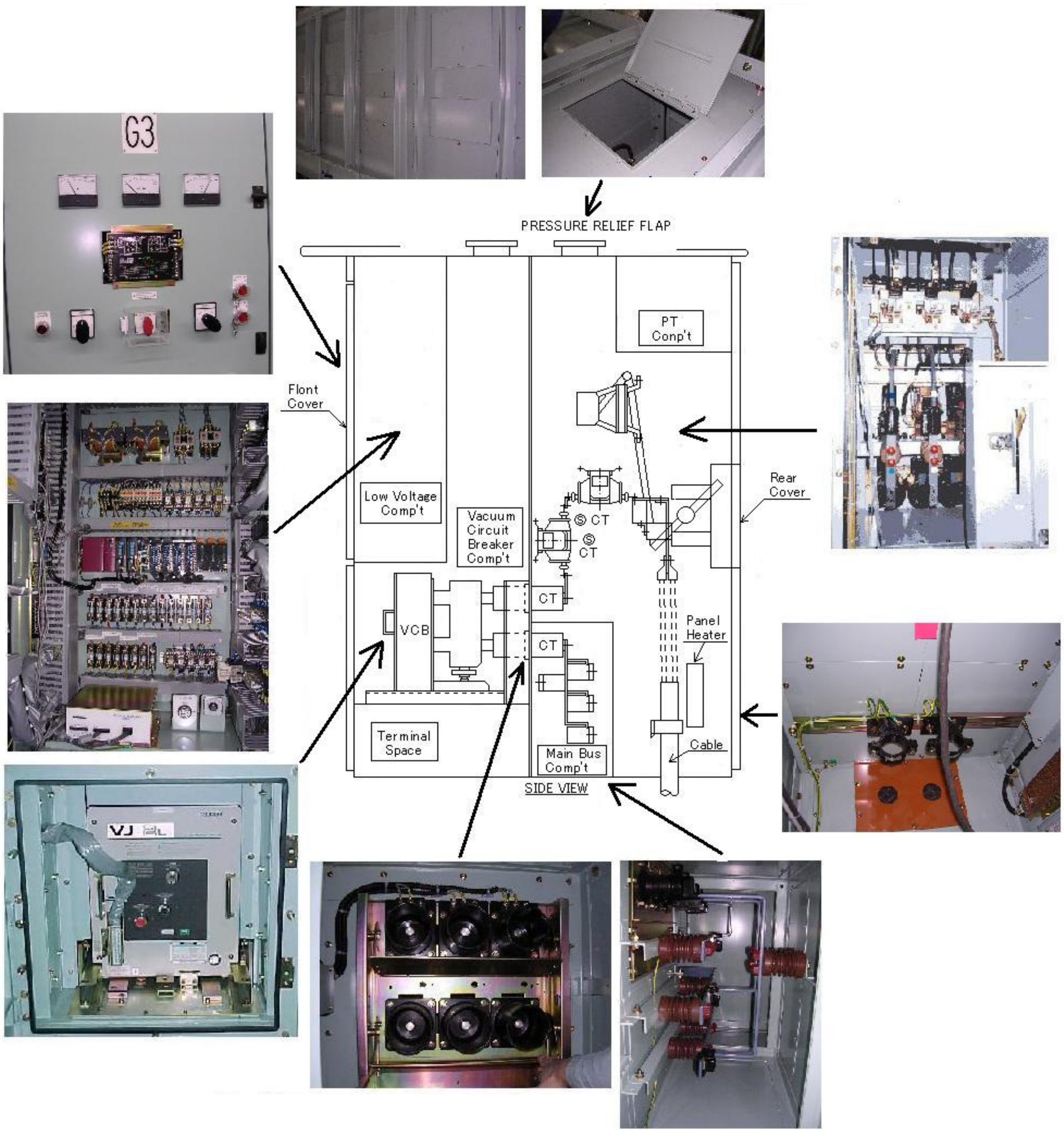


Fig. 10 Diesel and Shaft Generator Panel

5.2 Bus Tie:

The bus tie is installed to provide additional safety in the bus bar by dividing the whole system into two sections, connected by a vacuum circuit breaker. In case of damage in the three-phase fault on the bus bar, the other section can still be utilized to supply power to the motors and reefer containers. (Refer to 3.2 Outline of Wiring Diagram)

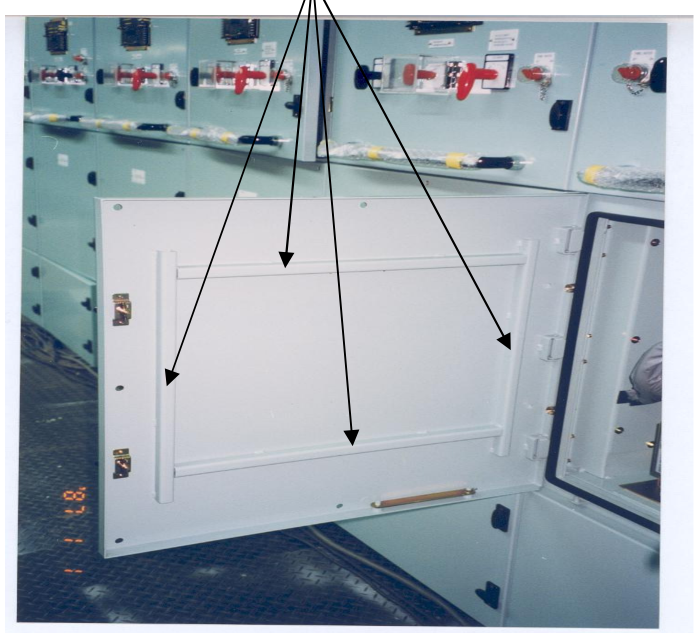
5.3 Switchboard Door:

The compartments are divided into sections namely, Low voltage compartment, VCB compartment, Bus Bar compartment and Cable Compartment.

When the front and rear doors are opened in the 440V system, we can see all parts. But we cannot see through in the 6.6 kV systems because of the divided compartments.

In case of short circuit in the high voltage compartment, an explosion may occur. Hence, the doors are of the reinforced type and heavily bolted to avoid the door from being thrown out.

The Reinforced Type

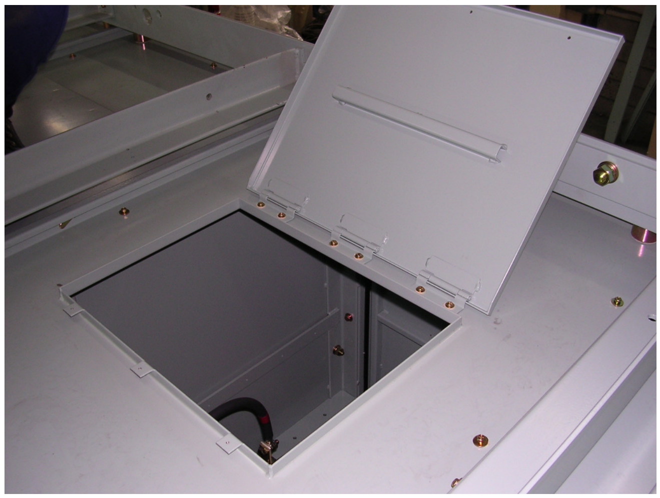


The doors have passed the explosion/destruction test conducted by TERASAKI.

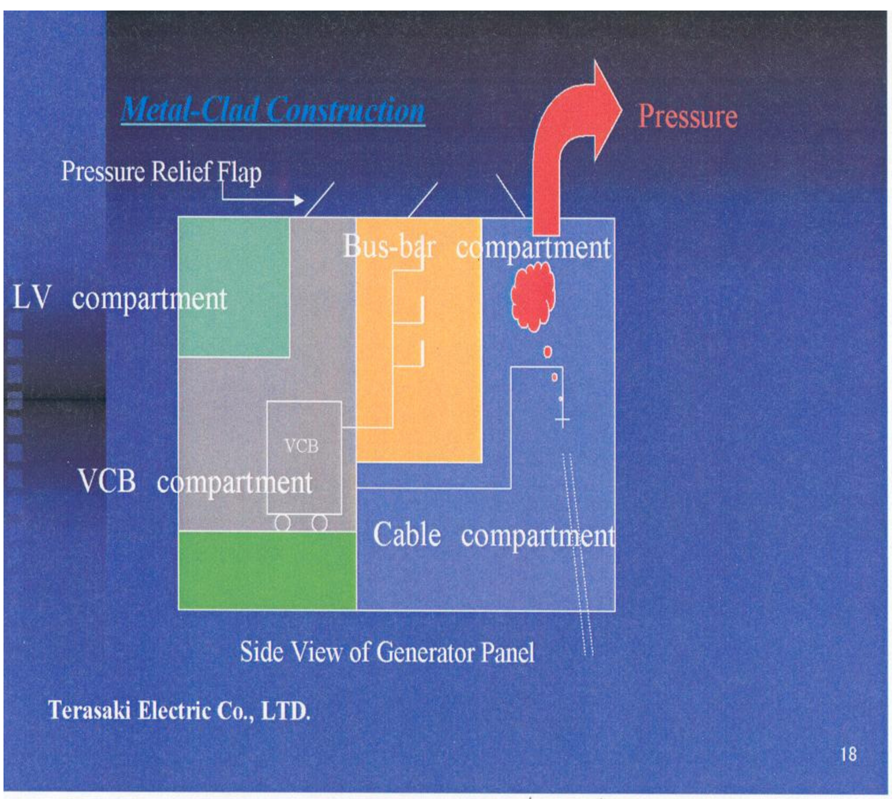
5.4 Pressure Relief Flap:

Pressure relief flaps are provided at the top of the main switchboard.

If arcing due to internal fault happens, it would explode. Pressure relief flaps release the explosion pressure.



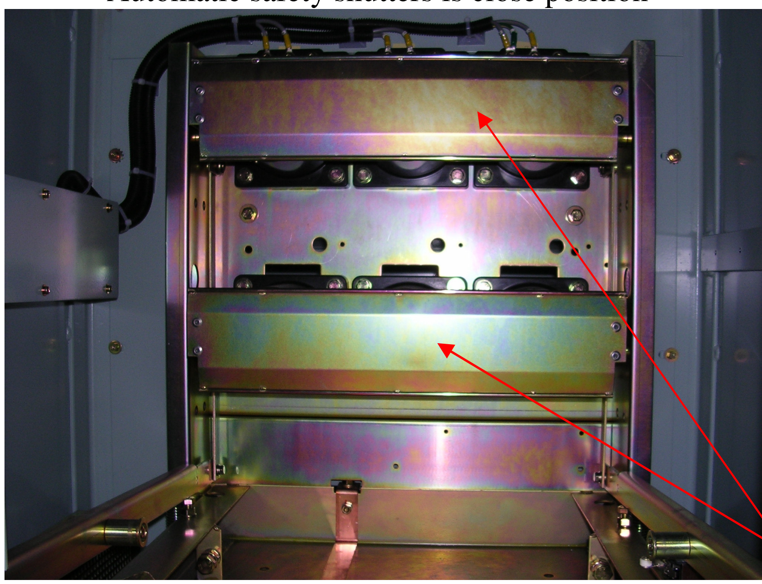
Pressure Relief Flap



5.5 Automatic Safety Shutter

Automatic safety shutters cover 6.6kV conductors when VCB is not set, for safety of the operating personnel.

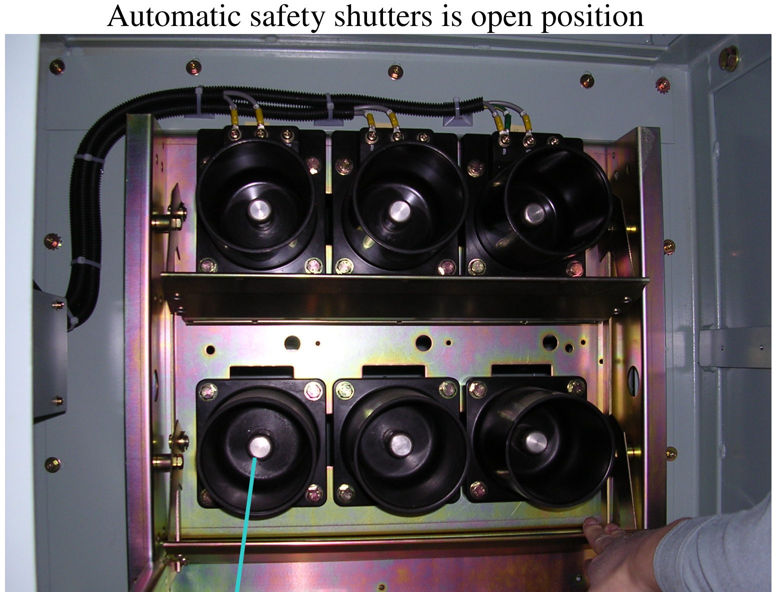
Automatic safety shutters is close position



Shutter

* When VCB is drawn out, the shutters closed.

Automatic safety shutters is open position



6.6kV conductor

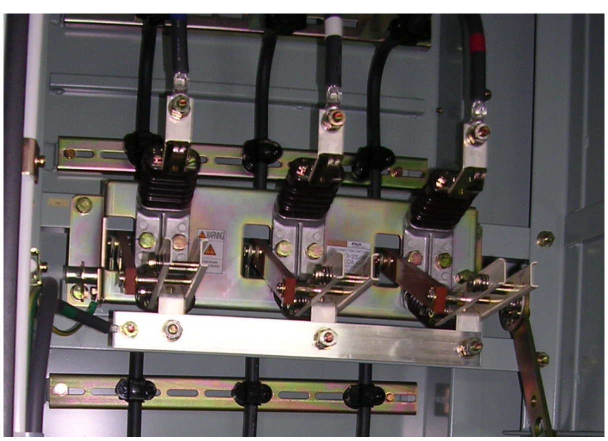
6. Equipment of Main Switchboard:

6.1 Earthing Switch:

It is very important to earth a circuit before maintenance, because the winding and cable do not only contain Resistance(R) and Inductance (L) but also contain Capacitance(C) which is permitted for the storage of electricity.

Earthing switches are of fixed type and they are installed in the high voltage cable compartment. Mechanical interlocks are provided for safety.

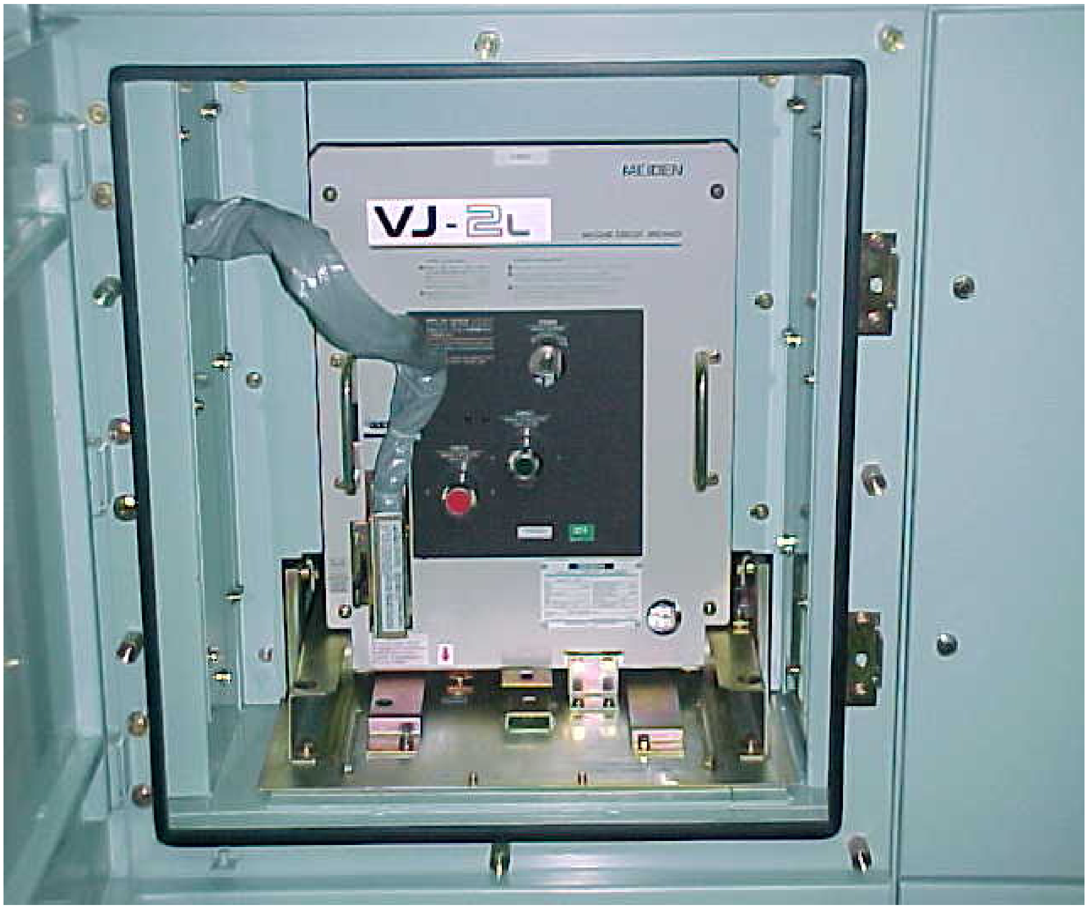
Release lever



Earthing Switches

Operating Lever for Earthing Switch

6.2 Vacuum Circuit Breaker (VCB):



6.2.1 Advantages of Vacuum Circuit Breaker:

1) Compact design and light weight
2) Short stroke of contact
3) Cu-Bi or Cu-Cr contact materials that provide long life and lower chopping current.
4) Minimal maintenance

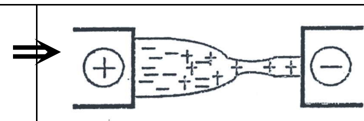
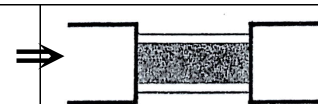
In an ACB, the arc is extinguished by arc chutes. The vacuum chamber is vacuumed up to 10^{-6} Torr (1.33×10^{-4} Pa). Hence, no gas like oxygen, carbon dioxide, nitrogen is inside the chamber.

6.2.2 Features of VCB

Contact Material:

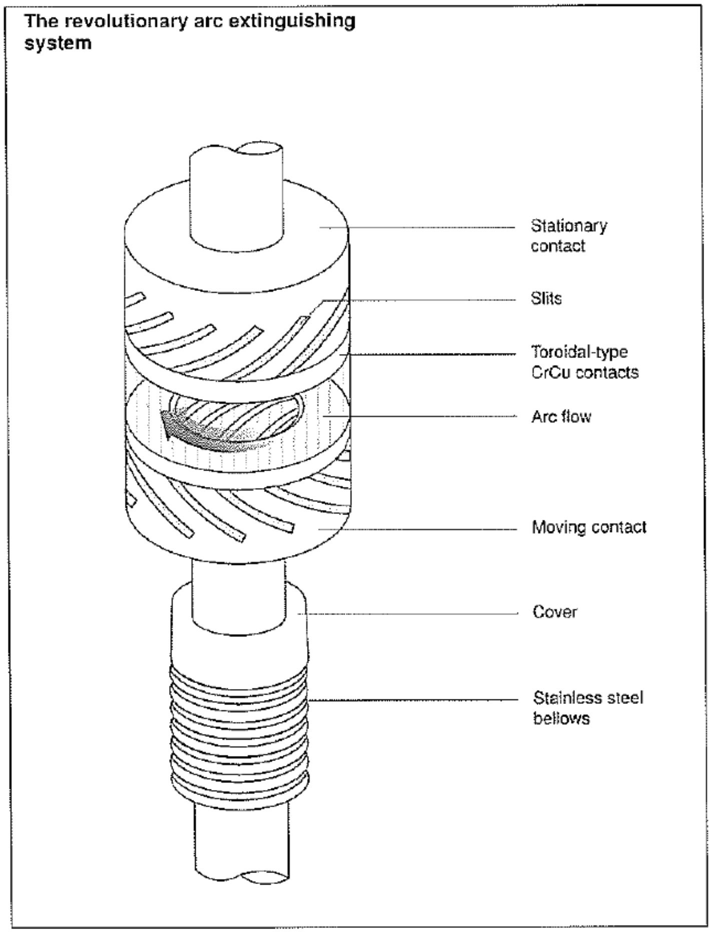
The properties of a vacuum interrupter depend largely on the material and form of the contacts. Over the period of their development, various types of contact materials have been used. At the moment, it is accepted that an oxygen free copper chromium alloy is the best material for high voltage circuit breaker. In this alloy, chromium is distributed through copper in the form of fine grains. This material combines good arc extinguishing characteristic with a reduced tendency to contact welding and low chopping current when switching inductive current. The use of this special material is that the current chopping is limited to 4 to 5 Amps.

Glow Discharge and Arc Discharge:

–	VCB	Other Circuit Breaker
ARC		
 (Townsend Discharge)	 (Glow Discharge)	 (Arc Discharge)
Arc Voltage		
	Under 10kA = 20 – 60V Over 10kA = 100 – 200V	GCB = about Rated Voltage x 2% ACB = about Rated Voltage x 3% OCB = about Rated Voltage x 7%

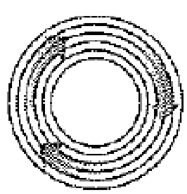
The main aim of any circuit breaker is to quench arc during zero crossing, by establishing high dielectric strength in between the contacts so that reestablishment of arc after current zero becomes impossible.
The dielectric strength of vacuum is eight times greater than that of air & four times than that of SF6 gas. This high dielectric strength makes it possible to quench a vacuum arc within very small contact gap. When two face to face contact areas are just being separated to each other, they do not be separated instantly, contact area on the contact face is being reduced and ultimately comes to a point and then they are finally de-touched. At this instant of de-touching of contacts in a vacuum, the current through the contacts concentrated on that last contact point on the contact surface and makes a hot spot. As it is vacuum, the metal on the contact surface is easily vaporized due to that hot spot and create a conducting media for arc path. Then the arc will be initiated and continued until the next current zero. At current zero this vacuum arc is extinguished and the conducting metal vapour is re-condensed on the contact surface. At this point, the contacts are already separated hence there is no question of re-vaporization of contact surfaces.
Above phenomenon gives rise overheating of contacts at its center.

In order to prevent this, the design of contacts should be such that the arc does not remain stationery but keeps travelling by its own magnetic field. Specially designed contact shape of VCB make the constricted stationery arc travel along the surface of the contacts, thereby causing minimum & uniform contact erosion. (Ref. Maker : Fuji)



The revolutionary arc extinguishing system

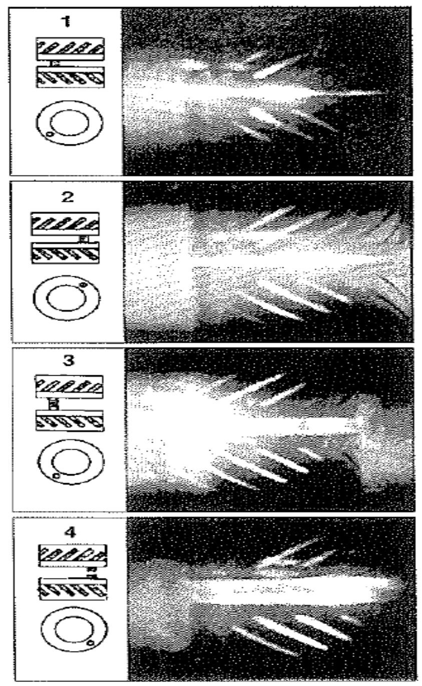
● Rotary



FUJI VCBs have employed a unique design principle in which the contacts are provided with a succession of slits having toroidal-type CrCu contacts mounted on them.
The arc is driven round the circular contact surface as it is being extinguished. Since the arc is not localized at one point there is no fear of overheating.
This results in much improved inter-electrode dielectric strength so ensuring excellent breaking capability. Moreover, uneven contact wear is minimized.

Process of arc extinction

Arcs generated by VCB's have inherent characteristics that change when approximately 10 kA is reached. Less than 10kA a dispersed arc occurs, over this valve the arc is concentrated. The photos were taken consecutively and illustrate an interruption in the 25kA range (concentrated arc). About 4.5 rotations occurred (10ms @ 50 Hz).



Explanation

1. The contacts begin to open and the arc moves from the center to the left hand side.
2. 3. The arc is driven round the toroidal-type contact surface.
4. The contacts are in the full open position just before interruption is completed.

Operating Energy Requirements

Operating energy requirements are low because the mechanism must move only relatively small masses at moderate speed over very short distances.

Arc Energy

Because of the very low voltage across the metal vapor arc, energy is very low.

Contact Erosion

Due to the very low arc energy, the rapid movement of the arc root over the contact and the fact that most of the metal vapor re-condenses on the contact, contact erosion is extremely small.

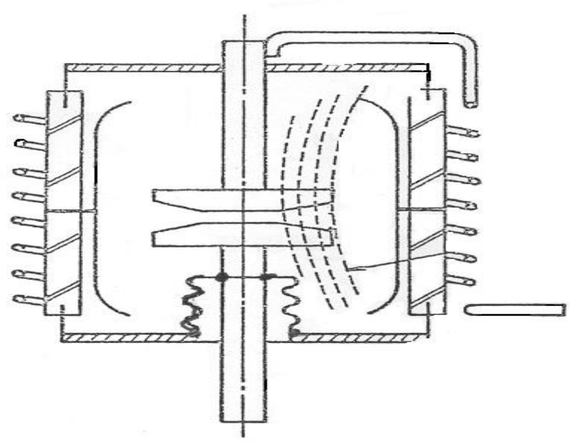
Arc Extinguishing Media

No additional extinguishing medium is required. A vacuum at a pressure of 10^{-6} Torr (1.33×10^{-4} Pa) is an almost ideal extinguishing medium. The interrupters are 'sealed for life' so that supervision of the vacuum is not required.

Switching Behavior in Relation to Current Chopping

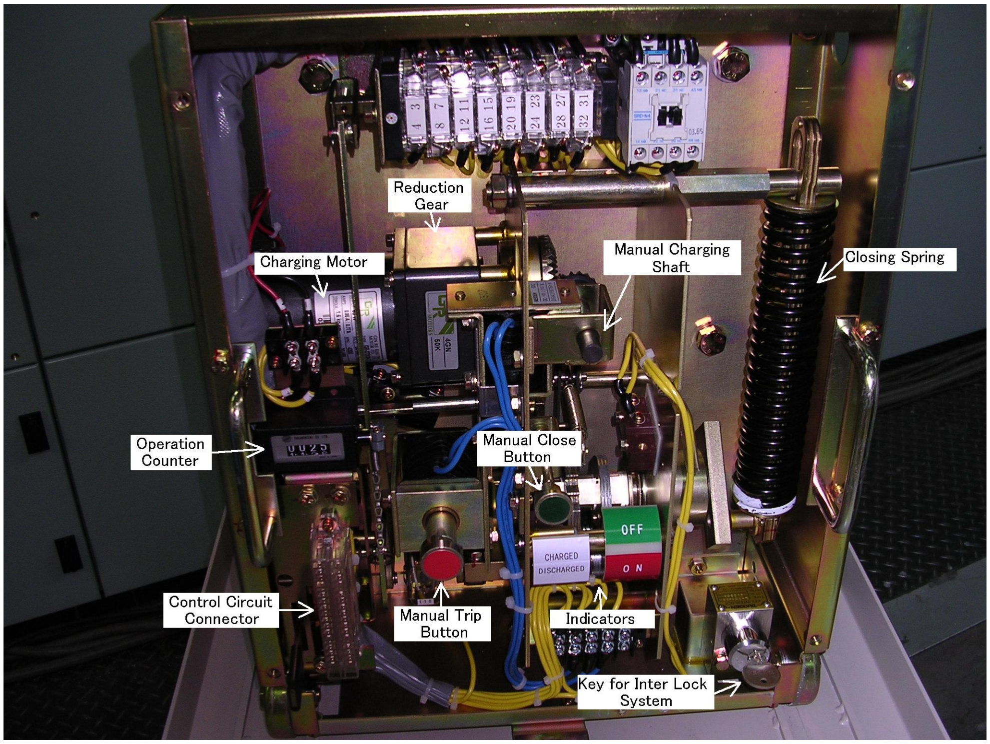
No flow of an 'extinguishing' medium is needed to extinguish the vacuum arc. An extremely rapid de-ionization of the contact gap ensures the interruption of all currents whether large or small. High frequency transient currents can be interrupted. The value of the chopped current is determined by the type of contact material used. The presence of chrome in the contact alloy with vacuum also.

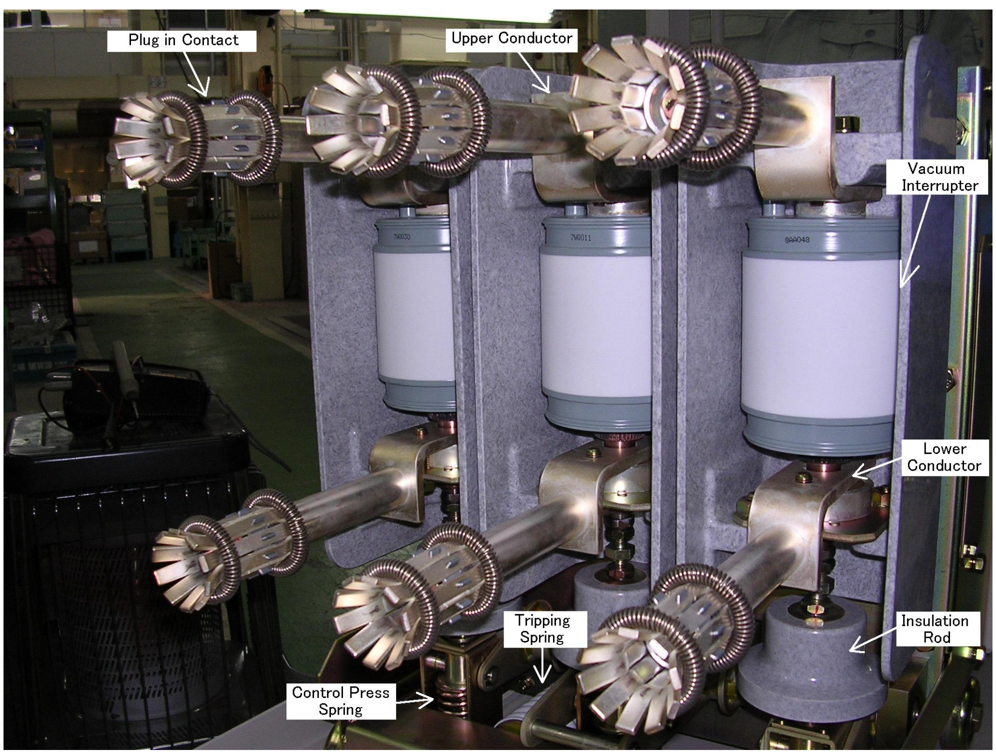
Bellows and Contact Assembly



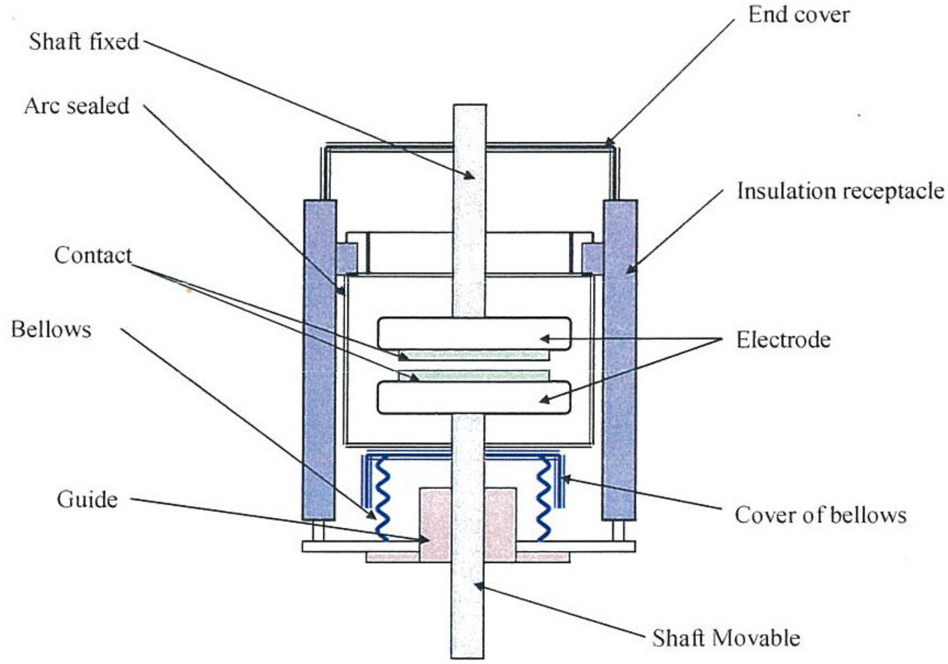
To keep the vacuum in the interrupter, the special bellows that go up and down with the moving main contact of the VCB are installed.

6.2.3 Structure





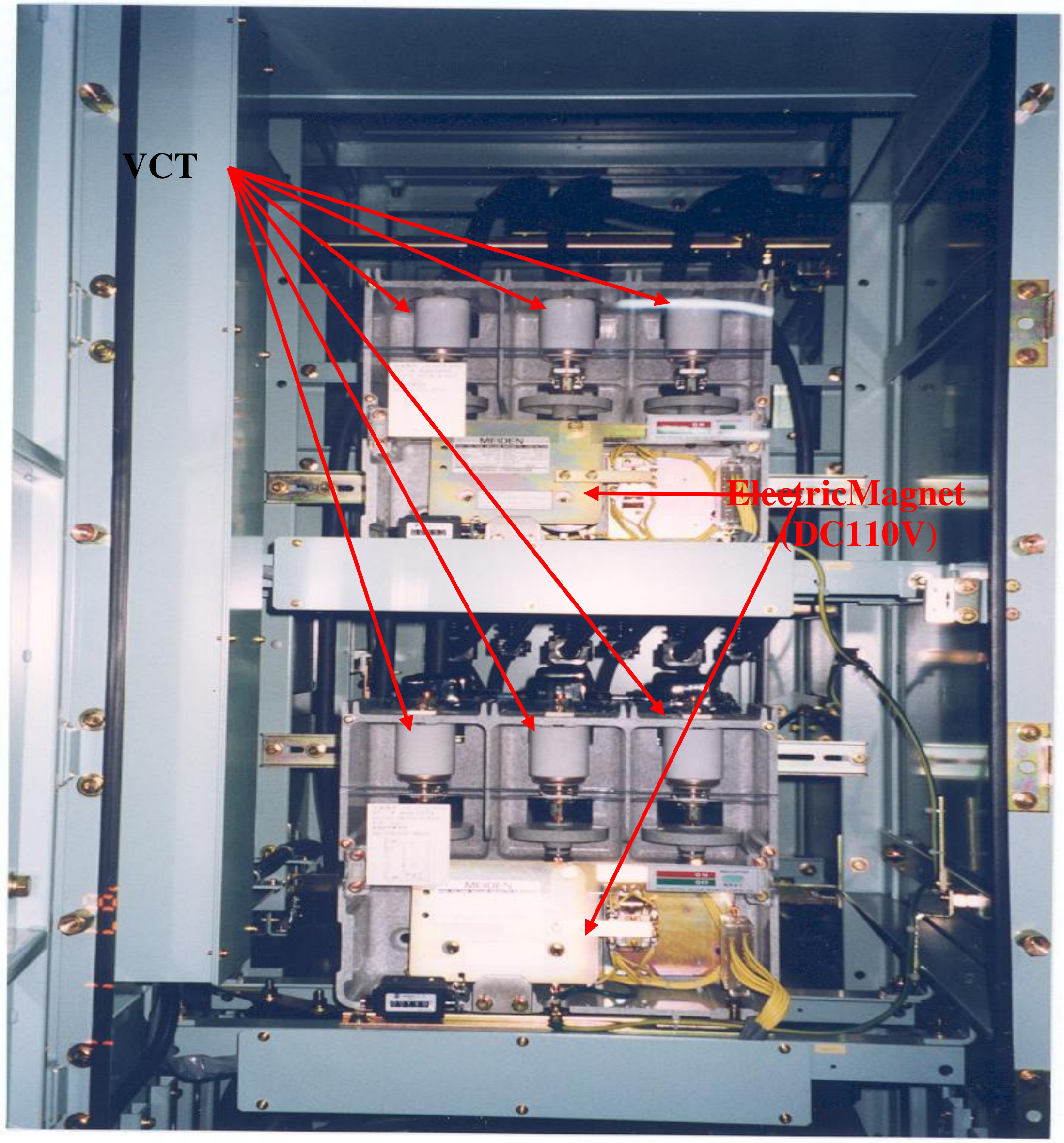
Internal structure of Vacuum Interrupter.



To keep the vacuum in the interrupter, the special bellows that go up and down with the moving main contact of the VCB are installed.

6.3 Vacuum Contactor (VCT)

(Bow Thruster Motor)



The contactors are of the vacuum type. This is used for bow thruster motor control circuit only. The contactors are of fixed type. They are operated by a magnetic coil. Control voltage of the circuit breaker is 110V DC. The advantage of DC is its steady power supply, whereas, AC has a fluctuating power supply.

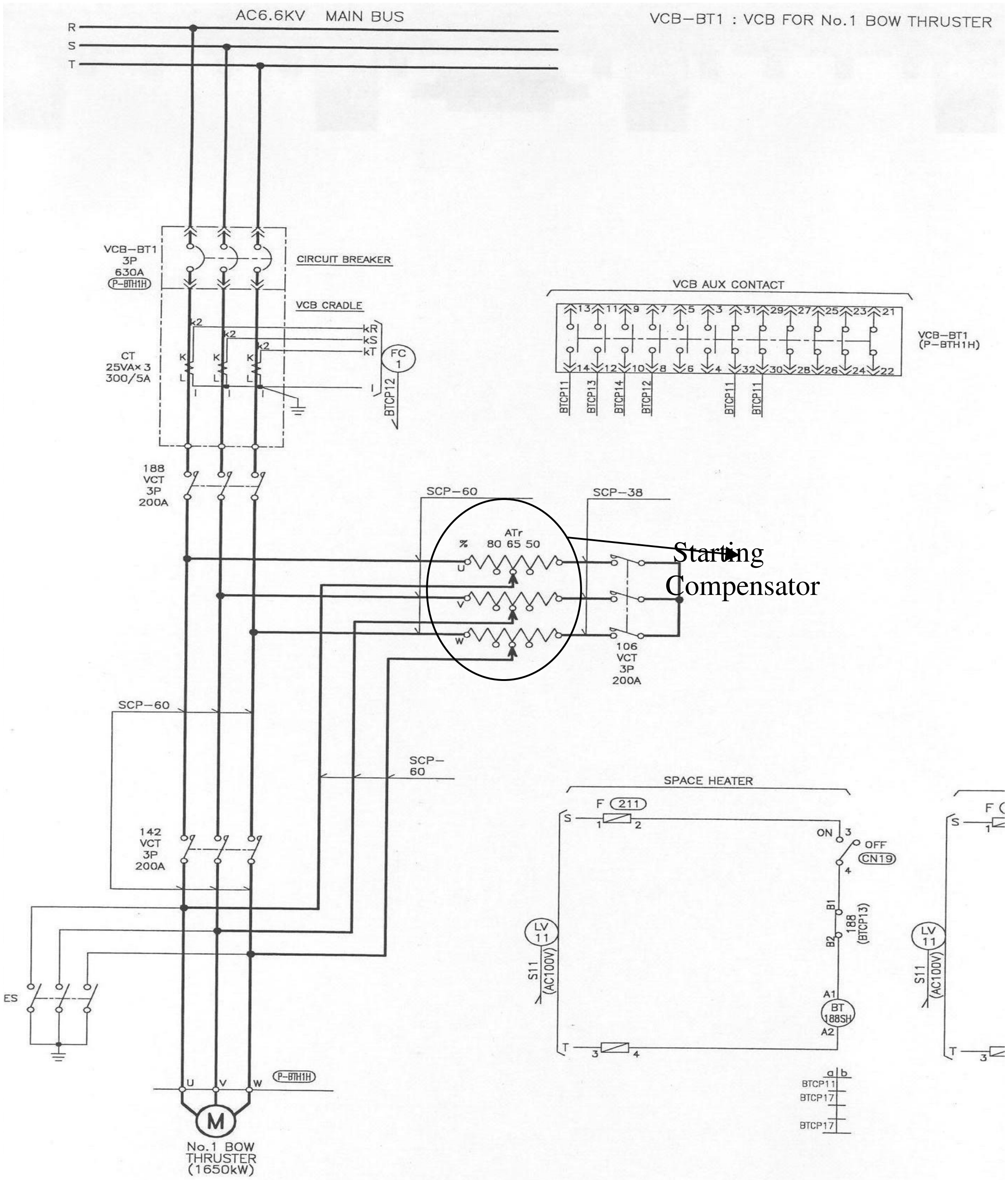


Fig. 11 Power Circuit Diagram of Bow Thruster

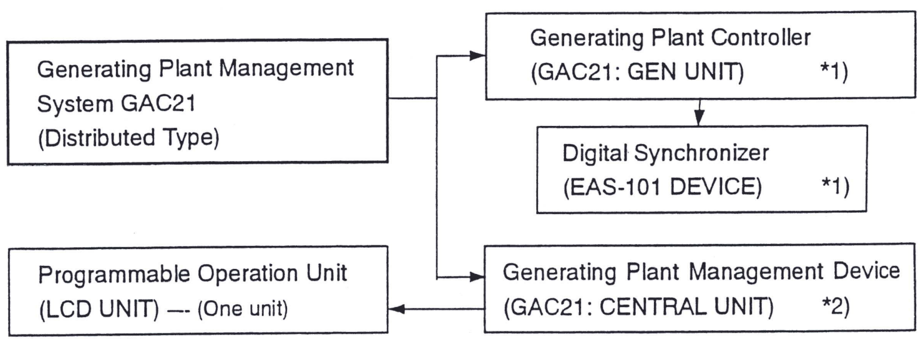
The first contactor is started slowly by the thruster motor, supplying the reduced voltage (autotransformer method), and then the motor supplies the rated voltage by the second contactor.

Note: Auto transformer is the electrical transformer with only one electrical winding. In an autotransformer, portions of the same winding act as both the primary and secondary sides of the transformer. The winding has at least three taps where electrical connections are made. Autotransformers have the advantages of often being smaller, lighter, and cheaper than typical dual-winding transformers.

6.4 Generating Plant Management System, GAC 21 (Distributed Type)

The Generating Plant Management System, GAC21 (Distributed Type) is composed of three (3) control units, GAC21 Generating Plant Controller, Digital Synchronizer and GAC21 Generating Plant Management Device.
The Programmable Operation Unit (LCD UNIT) is connected to the GAC21 Generating Plant Management Device and it allows us to display various kinds of information.

The system GAC21 has achieved a very high level of reliability for electric power supply by dispersing each generating plant for its independent operation.



Remarks :
*1) One unit is installed for each generator,
*2) Which means that two units are used for the entire system (one unit for standby).

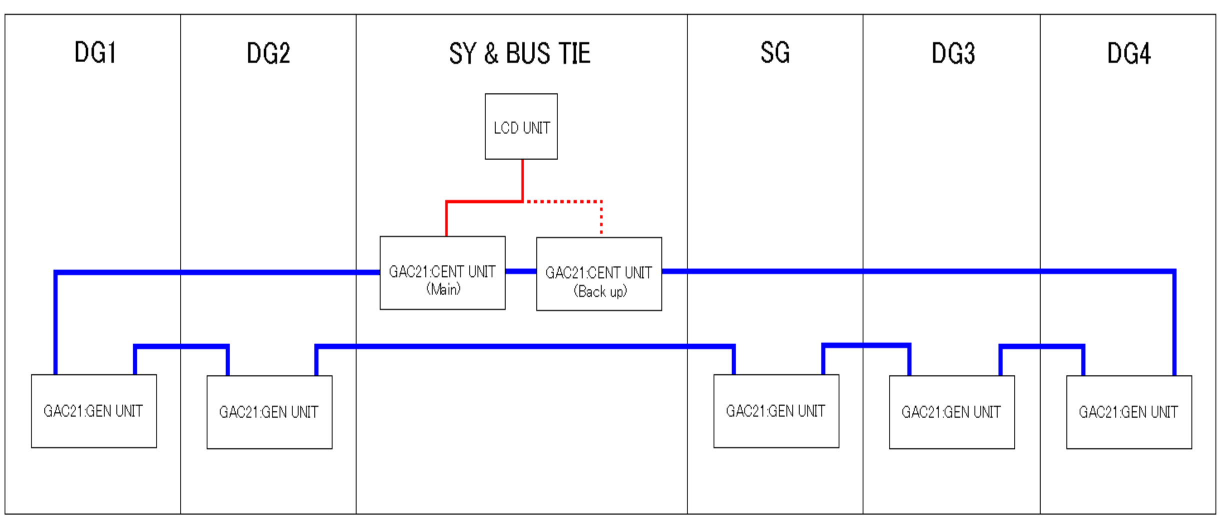
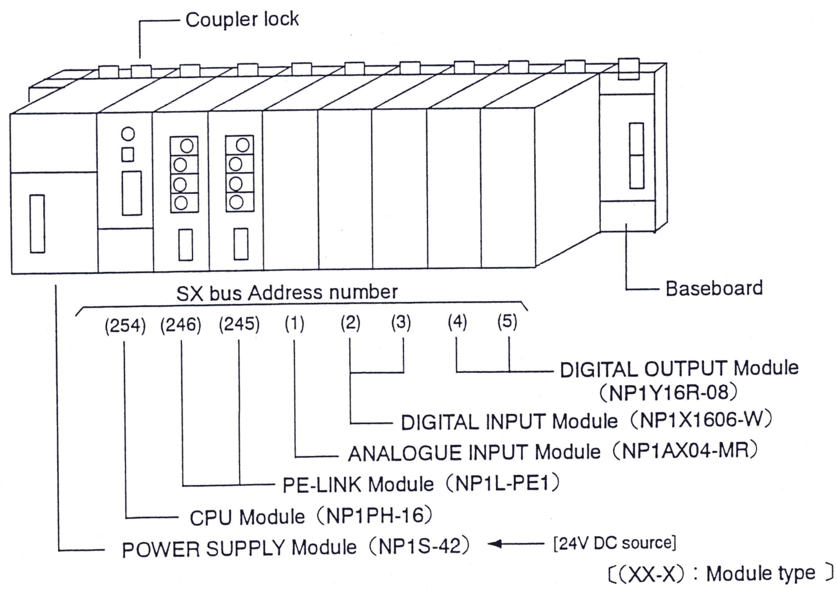


Fig. 12 Generating Plant Management System, GAC 21

6.4.1 GAC21 Generating Plant Controller (GAC21 : GEN UNIT)

GAC21:GEN UNIT uses a programmable controller to control each generating plant including the generator, the generator engine and the generator VCB. If an accident occurs at any generator plant, the other generator plant will be able to continue its power supply service without being affected by the accident.

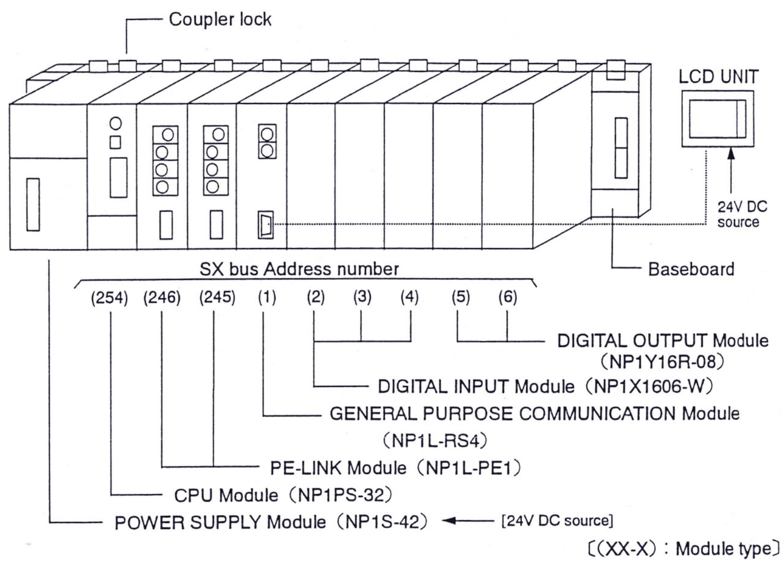


Appearance of GAC21 Generating Plant Controller
(GAC21:GEN UNIT)

Fig. 13 GAC 21 Generating Plant Controller

6.4.2 GAC21 Generating Plant Management Device (GAC21 : CENTRAL UNIT)

GAC21: CENTRAL UNIT uses a programmable controller to carry out the general management of the generating plant including the automatic load sharing function, the automatic start, the automatic changeover instruction and the power management.



Appearance of GAC21 Generating Plant Management Device
(GAC21: CENTRAL UNIT)

Fig. 14 GAC 21 Generating Plant Management Device

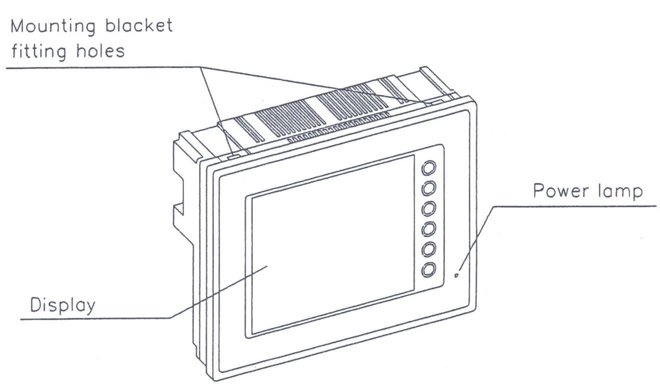
When the Generating Plant management system (GAC 21) is not operational, the 6.6 kV can still be operated manually.

6.4.3 Digital Synchronizer (EAS-101 DEVICE)

Digital synchronizer has two (2) functions, the synchronous closing control function and the synchronous detection control function.

6.4.4 Programmable Operation Unit (LCD UNIT)

Programmable Operation Unit (LCD UNIT) displays various kinds of information on the generator and the self-diagnostic information allows the setting and display of various parameters related to power distribution control.



Appearance of Programmable Operation Unit
(LCD UNIT)

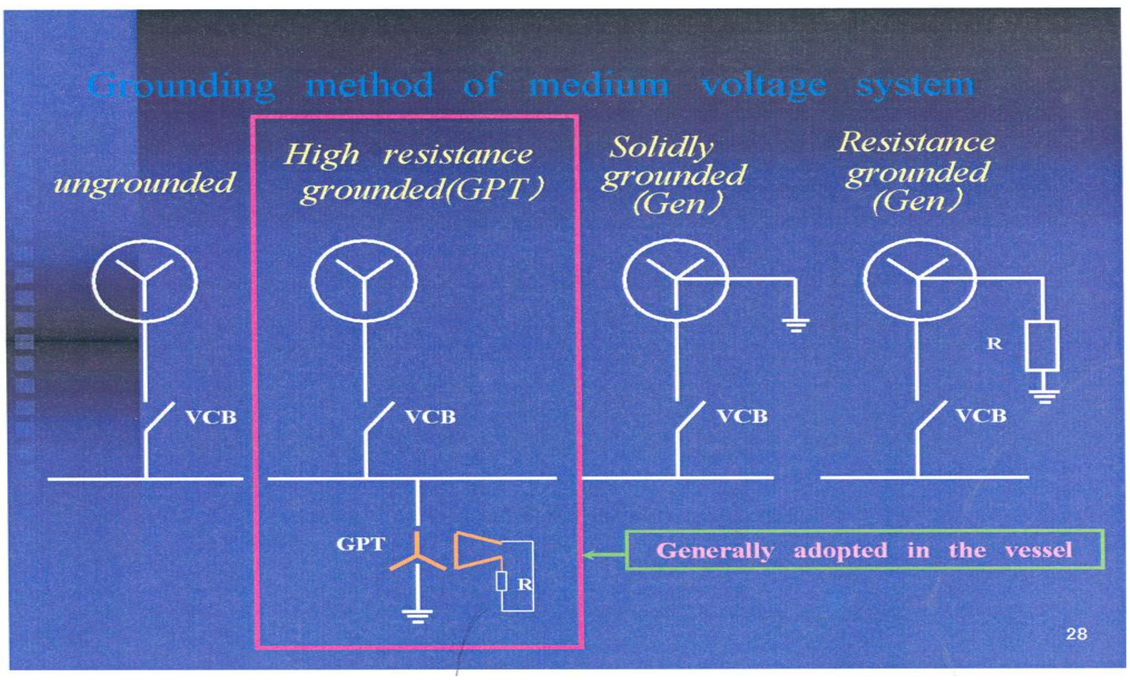
6.5 Automatic Voltage Regulator (AVR)

An Automatic Voltage Regulator (AVR) will control the generator voltage to plus or minus two and half percent (or better) of its set value over the load range. An AVR senses the generator output voltage and acts to alter the field current to maintain the voltage at its set value. A hand trimmer regulator fitted to the generator control panel provides the set voltage level.

6.6 Safety Device

6.6.1 Monitoring of insulation level and detection of earthing phase

The ground over voltage relay (Earth-fault voltage relay) and earth lamp are equipped respectively on Bus-tie and Synchro panel, and detect the insulation level and earthing phase of respective 6.6kV system.



Zero-Phase Voltage Monitor

This monitor consists of an Earth fault voltage relay (Ground overvoltage relay) and a ground potential transformer (GPT). The monitor enables continuous monitoring of insulation level. The relay monitoring the HVSB No.1 & No.2 main bus system ground fault and monitoring the zero-phase voltage (Vo) generated at complete ground fault. GPT's are provided in each phase of the 6.6kV line and transform the voltage 6.6kV to 190V.

Earth fault Voltage Relay

This relay indicates the active state of zero-phase voltage (Vo) and light emitting diode lights when the setting value is reached and automatically goes out below the setting value.

Earth Lamp

The Earth Lamp consists of a display lamp having three transparent lenses.

Three earth lamps are Y (star) connected among the phases. Each earth lamp is turned on with the same degree of brightness.

If ground fault occurs in R-phase, the earth lamp on R-phase goes dark while the earth lamps on S-phase and T-phase go bright.

When R-phase is completely in the ground fault state, the earth lamp on R-phase is turned off.

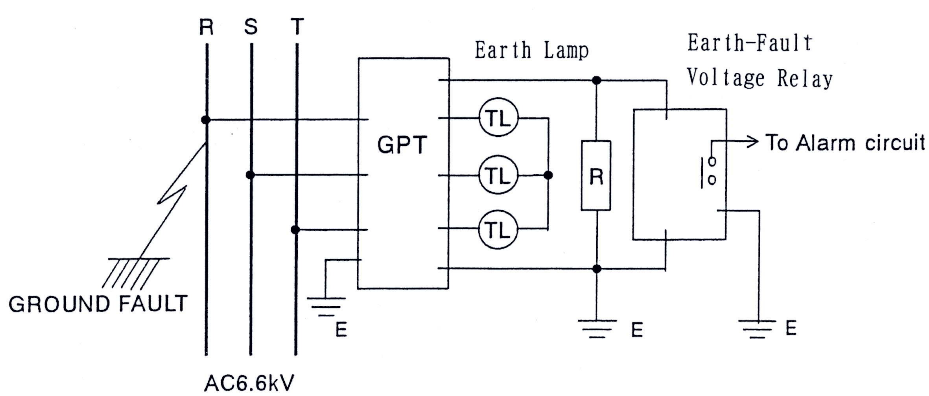
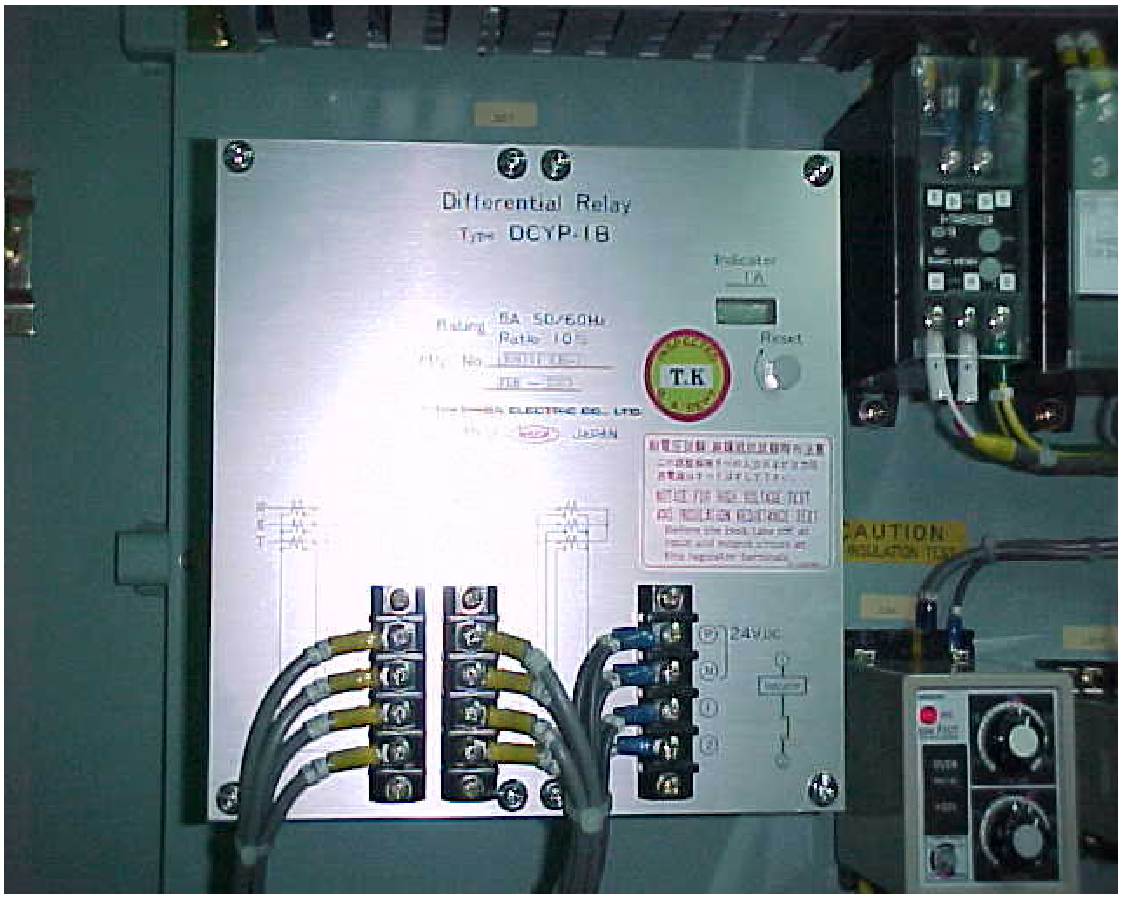


Fig. 15 Ground Fault Detection Circuit

The ground fault will be trouble shoot by one by one switching off the loads in the 6.6 kV system. The same procedure is done in the 440V system. In the 440V system, earth lamps and high resistance earth monitoring system is used but in the 6.6 kV system, only the Earth-Fault Voltage Relay is used. It has the same function as the two devices in the 440V system.

6.6.2 Differential Relay

In case of short circuit trouble of the generator cable or the generator winding, this relay operates to trip the generator VCB.



It also helps avoid single phasing in the supply of the generator side. The power is supplied by 24V DC line.

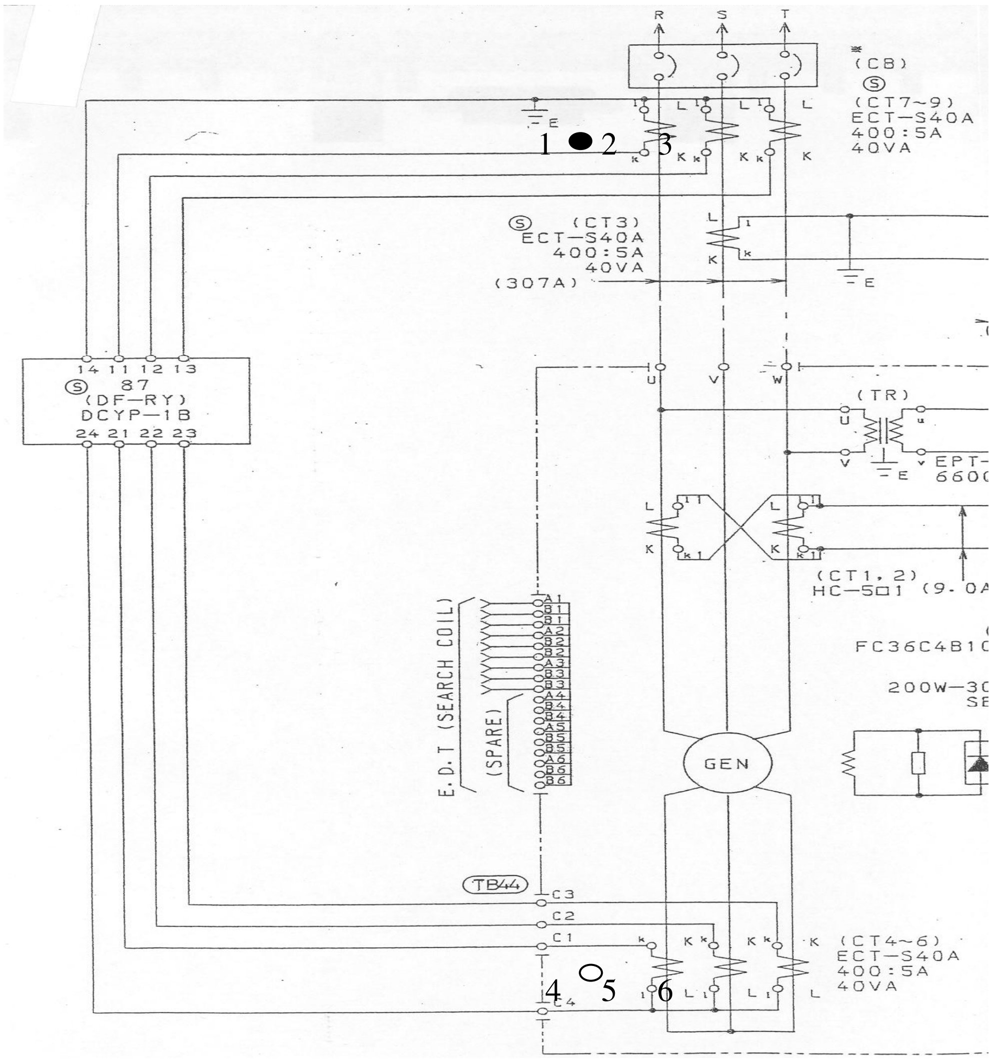
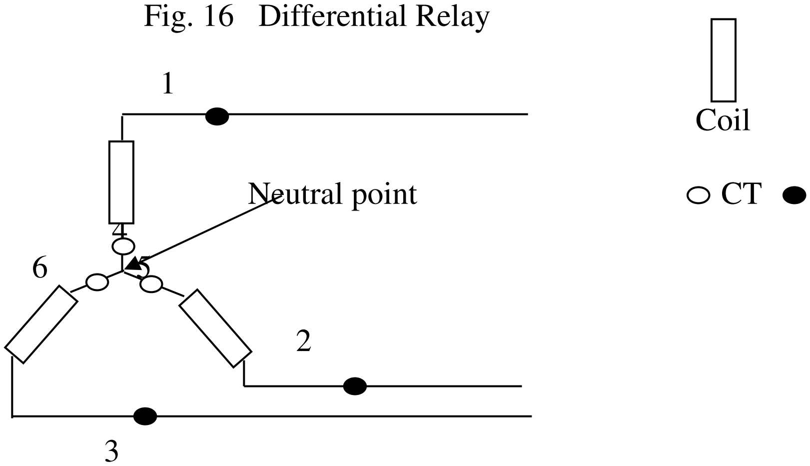


Fig. 16 Differential Relay

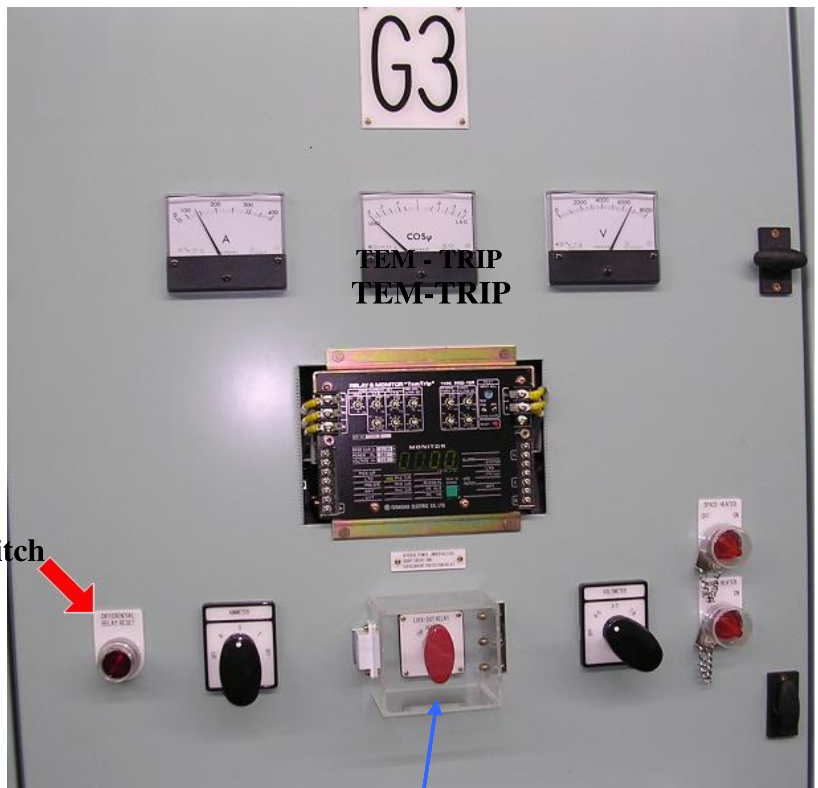


This system compares the current between the neutral point and the output of coils. If short circuit trouble occurs, these currents are different.

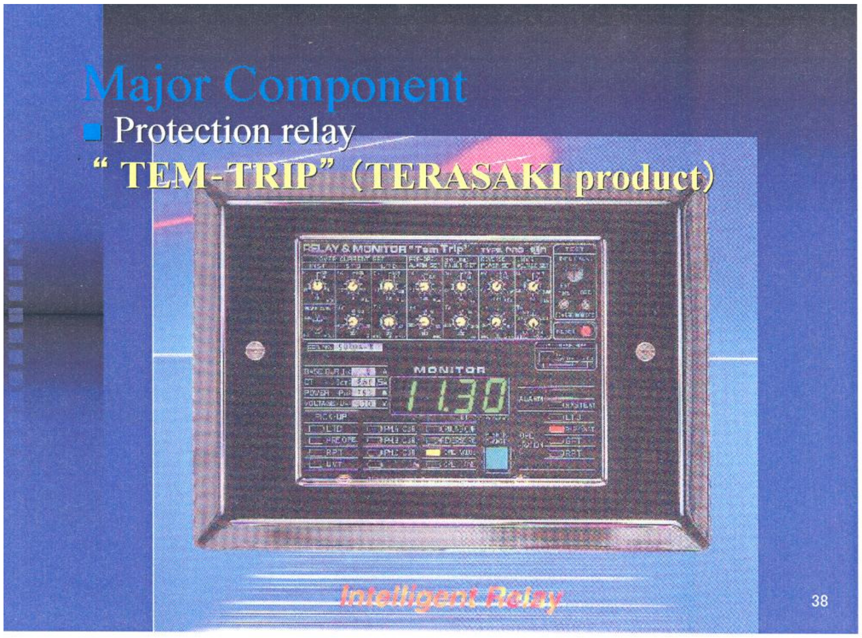
Differential Relay Reset Illuminated Push-Button Switch

When the relay is operated, it outputs the de-exciting signal and operates the de-excitation of the generator excitation circuit. The illuminated push-button switch lights on and self-hold of de-exciting circuit is operated.

If after finding out the cause of trouble and repairing it, this push-button switch is pressed, the self-hold of de-exciting circuit will be reset and the illuminated push-button switch will light off.



6.6.3 TEM-TRIP



(1) Outline

The TEM-TRIP has protection against over current (long time delay trip, short time delay trip, instantaneous trip and ground faulty trip). Other protection functions include reverse power trip protection or under voltage trip protection at the time of parallel operation of transformers or power generators. The TEM-TRIP also has built-in monitoring and display functions and self-diagnosis function. These functional features offer easy field-testing.

(2) Function

The TEM-TRIP has the following six (6) functions.

1) Long Time Delay Trip Device (LTD)
2) Short Time Delay Trip Device (STD)
3) Instantaneous Trip Device (INST)
4) Preferential Trip Alarm (PRE-TRIP)
5) Reverse Power Trip Device (RPT)
6) Under Voltage Trip Device (UVT)

When VCB is tripped by the cause of these functions, the Locking - out relay switch position changes to "TRIP". After we return it to normal, we turn the Locking – out relay switch to "RESET" position.

(3) Preferential Trip System

When the running generators are overloaded, non-essential services are tripped by the preferential trip system to reduce the load of generators. Thus, the generators can be running continuously and it can supply electric power to essential services.

The preferential trip system provides two kinds of “Trip”.

1) The overload of generator
2) The VCB trip of generator during parallel running

(4) Overload Protection of Generation

After the preferential tripping described in (3), when the generator is further overloaded, Long Time Delay Trip (LTD) functions. This prevents damage to the generator.

(5) Under Voltage Trip

An under voltage release is fitted to all generator breakers. Its main function is to trip the breaker when a severe voltage dip (around 50%) occurs. The U/V released on a generator voltage is very low or absent.

The under voltage relay also provides back-up to short-circuit protection. As an example, the operator attempts to close the wrong circuit-breaker that is the circuit–breaker of a stopped and dead generator, during generator paralleling procedures. If this circuit-breaker was closed, the dead generator would be the equivalent of a short-circuit fault on the bus-bars that can cause a blackout. The under voltage relay prevents the closure of the circuit-breaker.

7. Operation and Maintenance of Vacuum Circuit Breaker

7.1 Operation of Vacuum Circuit Breaker

7.1.1 Automatic Operation

(1) Charging Operation (Fig.17-20)

When the charging motor (2-4) equipped with the closing hook roller (2-11) is excited, the bevel gear (2-13) fitted to the driving shaft (2-12) starts rotating for swinging the ratchet wheel (2-16).

When the driving pawl (2-14) moves in the direction of arrow, the ratchet wheel (2-16) fitted to the camshaft (2-15) turns clockwise. At this time, the cam clutch (2-23) engages with the camshaft (2-15) to prevent reverse rotation.

Then, the driving pawl moves back to the left and engages with the next ratchet wheel (2-16). With this operation repeated, the ratchet wheel advances tooth by tooth to rotate the camshaft (2-15). When the camshaft (2-15) starts rotating, the crank (2-20) fitted together is rotated to compress the closing spring (2-1).

When the crank (2-20) is further rotated and passes the dead point, the closing hook roller fitted to the camshaft engages with the closing hook to complete the charging operation. In this case, the closing spring (2-1) is set in charging mode.

The two sets of spring (tripping and closing) are charged simultaneously.

At the completion of charging operation, the limit switch (2-3) is reset by the cam (2-19) fitted to the camshaft to de-energize the charging motor (2-4), whereby the charging motor (2-4) stops running. When the charging motor (2-4) de-energizes, it still keeps running for few seconds by means of inertia, but the driving pawl (2-14) slides over the ratchet pawl dead portion (2-17) to prevent over-charging.

On the other hand, the charge-discharge indicator (2-5) is operated by the lever (2-22) to indicate “charging.”

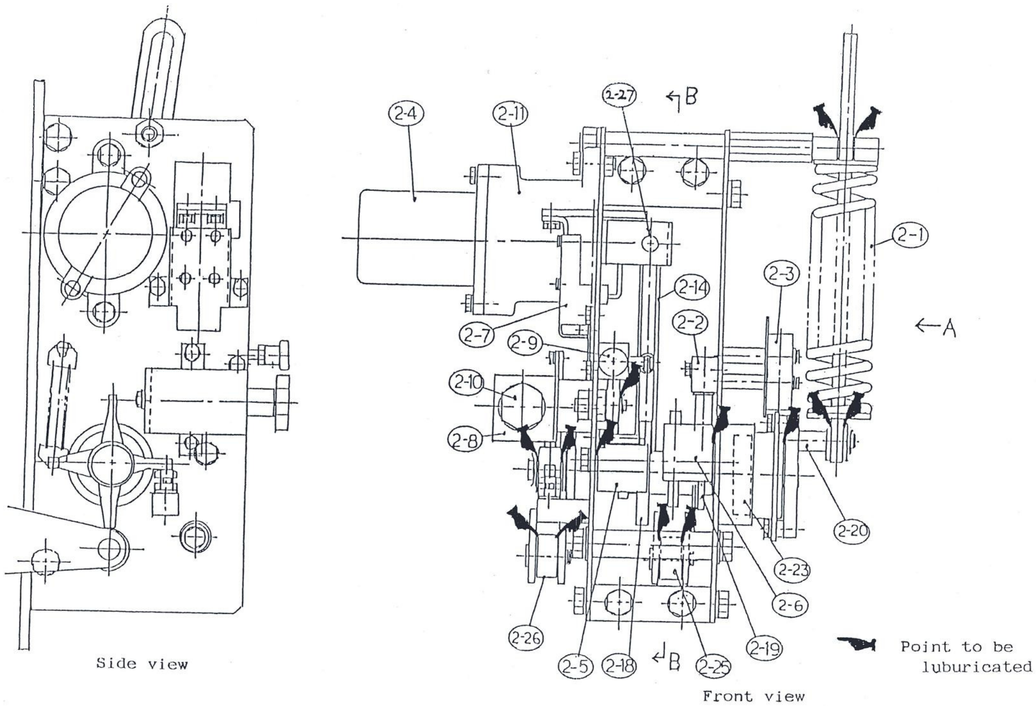
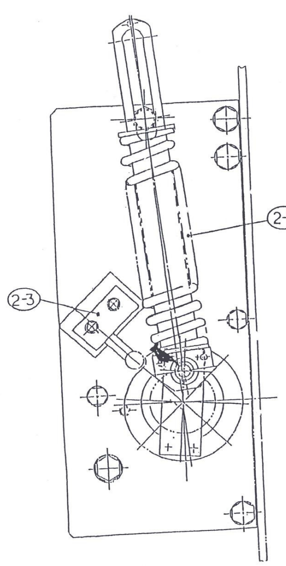


Fig. 17 Operating Mechanism



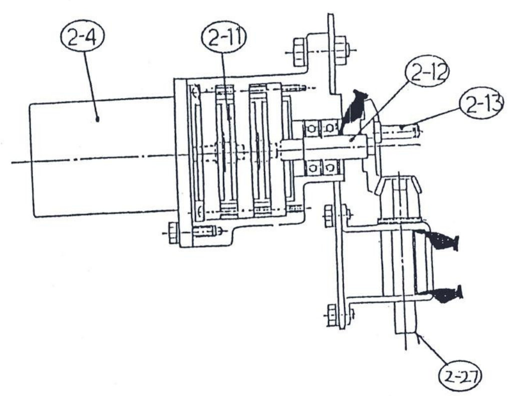


Fig. 18 Operating Mechanism (View A) Fig.19 Operating Mechanism (Reduction Gear)

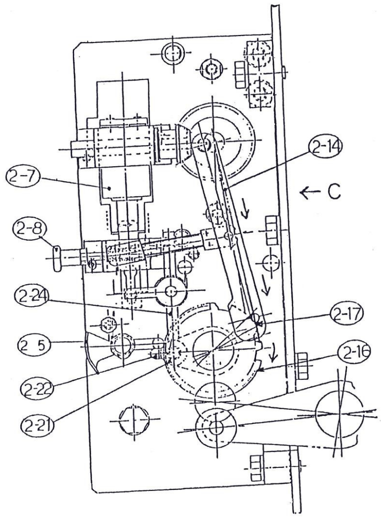


Fig. 20 Operating Mechanism (B-B)

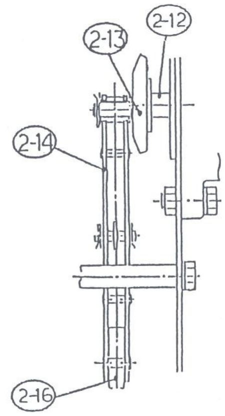


Fig. 21 Operating Mechanism (View C)

(2) Closing Operation (Fig. 22-24)

The closing spring (2-1) is charged and the vacuum circuit breaker is opened. At this time, if a closing command is given, the closing coil (2-7) is activated to disengage the closing hook from the closing hook roller (2-7), thus, discharging the closing spring (2-1). When the closing spring (2-1) is discharged, the camshaft (2-15) is rotated by the crank (2-20). Since the closing cam (2-18) fitted to the camshaft (2-15) moves down, the cam follower fitted to the operating shaft (3-1) starts rotating. At the same time, the lever (3-2) fitted to the operating shaft closes the vacuum interrupter (4-1) via the insulation rod (3-16).

At the completion of closing operation, the trip hook roller (2-26) fitted between the trip hook (2-28) and the operating shaft (3-1) is engaged to hold the closing condition. The tripping spring (3-7) is charged during this closing operation. At the completion of charging, the pole is given a contact pressure by the compression spring. When the closing spring is discharged, the limit switch (2-3) is activated to again charge the closing spring (2-1).

(3) Opening Operation (Fig. 22-24)

Under the close condition, when the tripping coil (2-8) operates, the trip hook (2-28) is disengaged from the trip hook roller (2-26) so the operating shaft is rotated clockwise by the tripping spring and the contact press spring (3-8). In this way, the vacuum interrupter (4-1) opens and sets in opening condition.

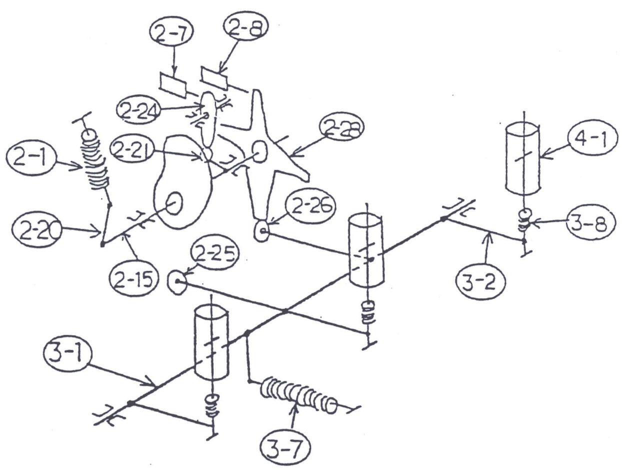


Fig.22 Breaker is closed. Closing spring is charged.

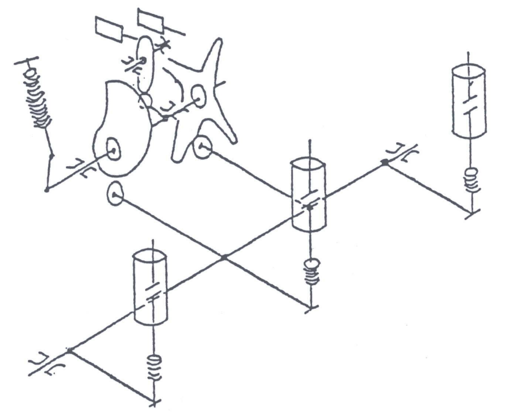


Fig.23 Breaker is opened. Closing spring is discharged.

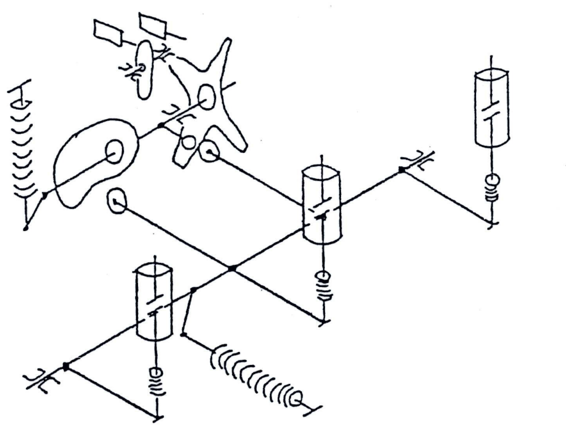
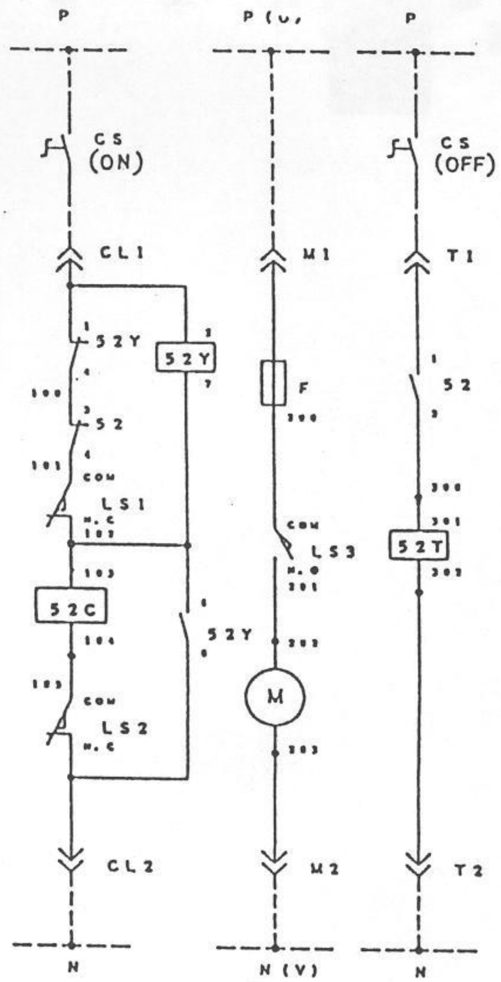


Fig. 24 Breaker is opened. Closing spring is charged.



Symbol

CS	Control Switch
52	Auxiliary Switch
52C	Closing Coil
52T	Tripping Coil
M	Motor (For spring charge)
LS1	Limit Switch (For Spring Charge)
LS2	Limit Switch (For Interlock.)
LS3	Limit switch (For motor)

Notes

1. Control circuits work on DC, motor work on DC or AC.
2. Auxiliary switch has six normally opened (6a) and six normally closed (6b) contacts for the use of user.
3. Polyvinyl-sheathed vires(KIV) are used for viring. The sheath color is blue. The vire size is $2mm^2$.
4. Pover frequency vithstand voltage of control and auxiliary circuit are as follows;
   Auxiliary and control circuit: 2000VAC-1minute. (Except motor circuit.)
   Motor circuit : 1500V AC-1 minute.

Fig. 25 VCB Electric Control and Sequence Operation

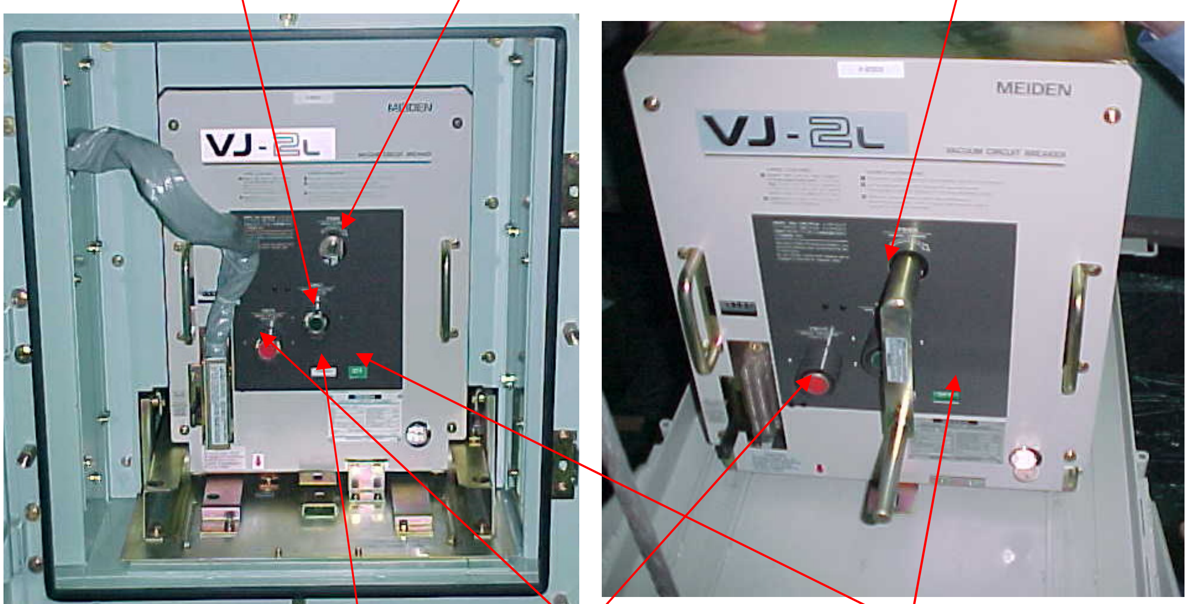
7.1.2 Manual Operation:

(1) Charging Operation

The operator sets the manual charge handle to the manual-charging shaft and turns it clockwise. Charging is completed at about 10 turns. The charge-discharge indicator should indicate “Charging” at the same time. During manual charging operation, the operator is not in danger even if the charging motor starts, because the charging handle is equipped with a one-way clutch.

Manual charge handle

Manual closing button Manual-charging shaft



Charge-discharge indicator Manual trip button ON/OFF indicator

(2) Closing Operation

When the operator pushes the manual closing button, the vacuum circuit breaker is closed and the ON/OFF indicator shows “ON”, as well as the charge – discharge indicator shows “Discharge”.

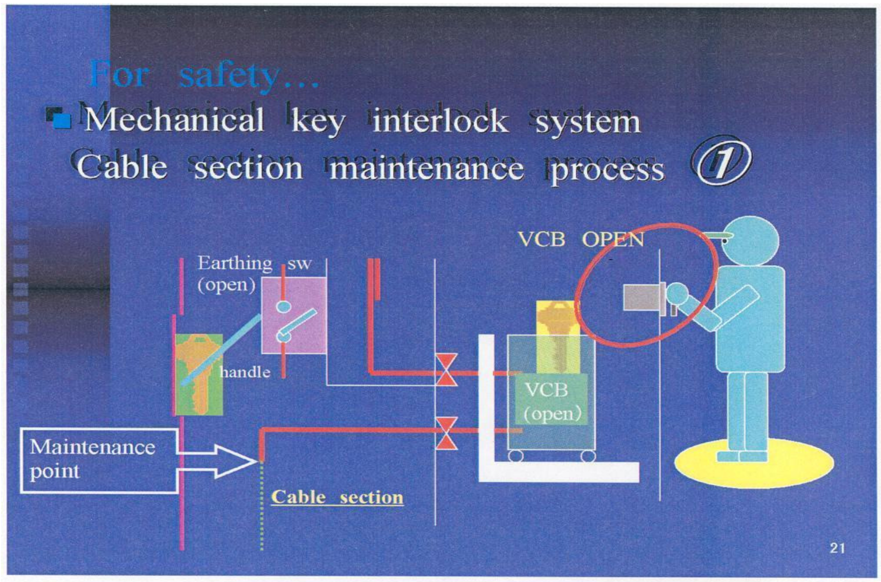
(3) Opening Operation

When the operator pushes the manual trip button, the vacuum circuit breaker is open and the ON/OFF indicator shows “OFF”.

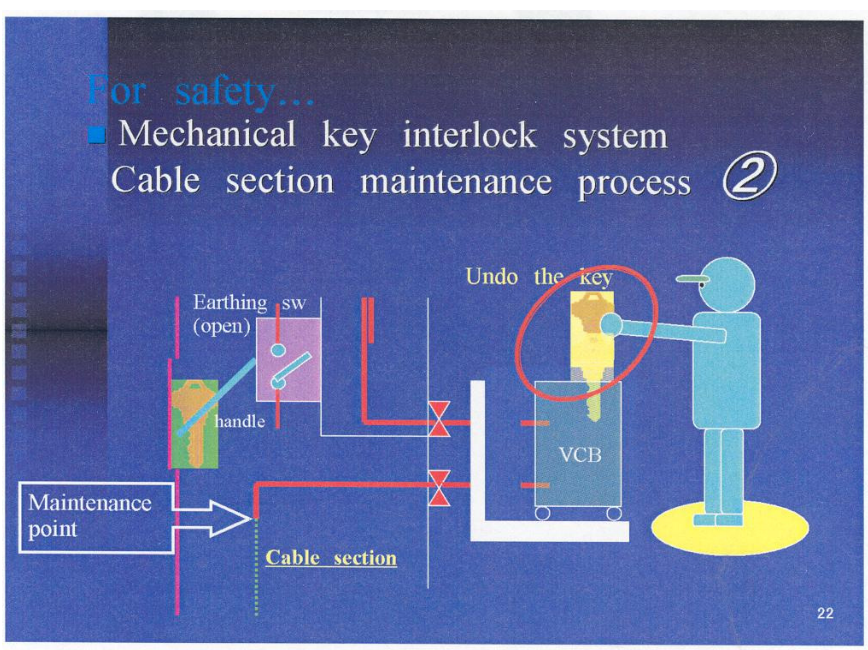
7.2 Maintenance and Inspection of VCB:

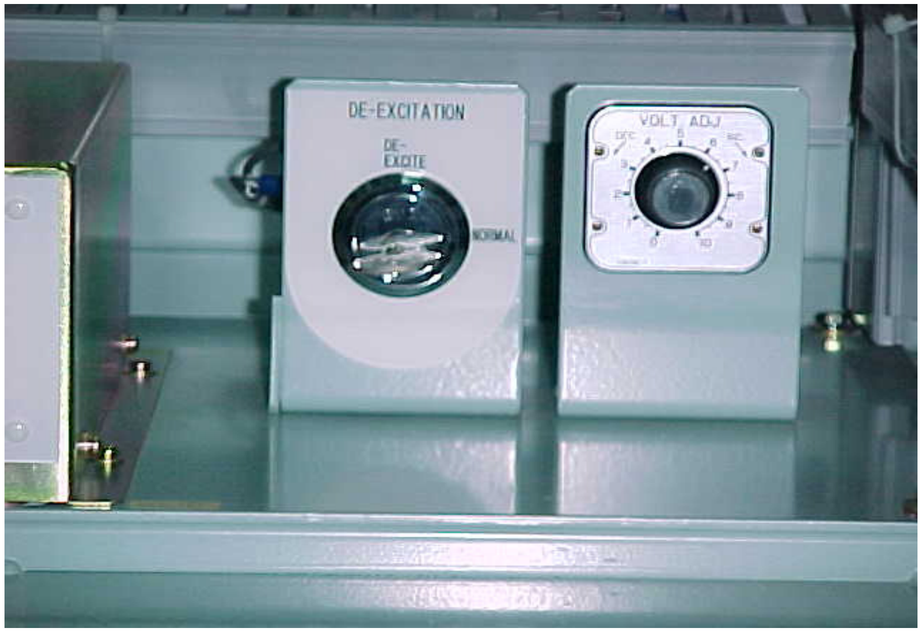
7.2.1 Mechanical Key Interlock System:
(Opening the rear side door of the main switchboard)

(1) Open VCB.



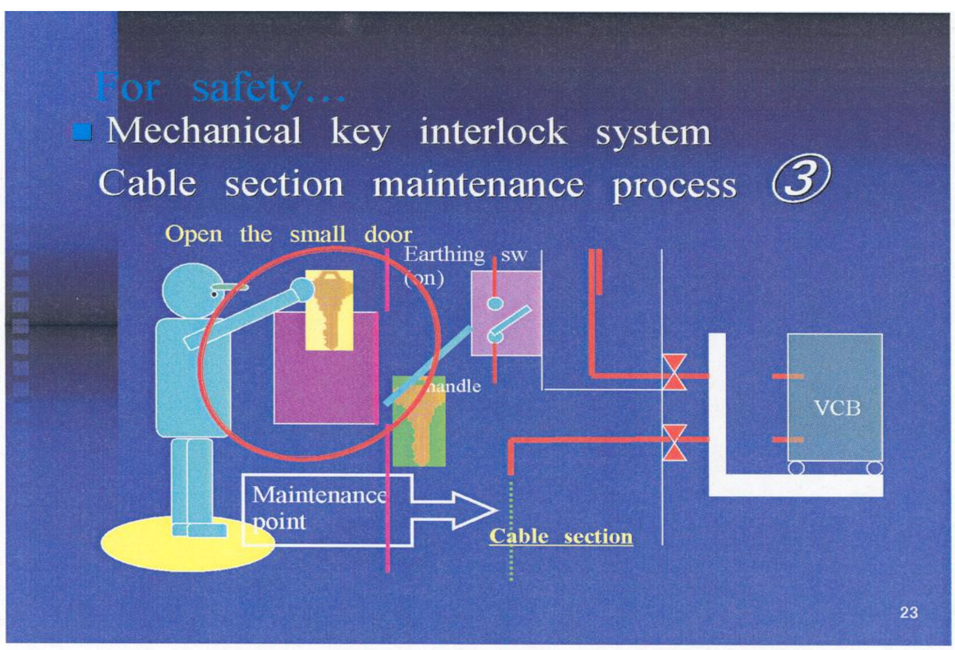
(2) Undo the key.



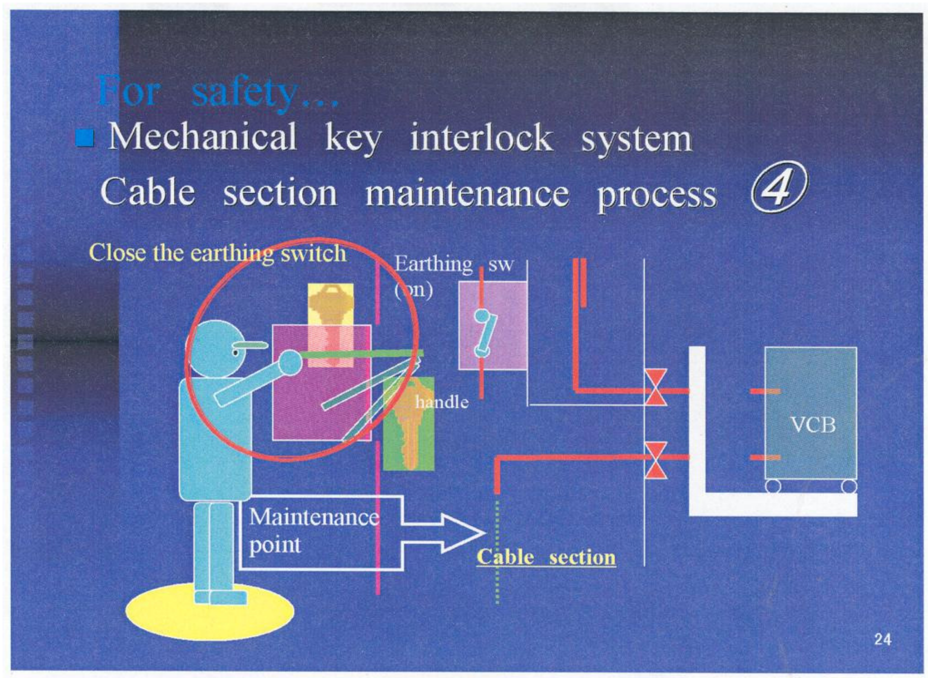


When the operator opens the rear door of Bow Thruster Panel, it is necessary to use the VCB key. On the other hand, when the operator opens the rear door of Generator Panel, it is necessary to have the VCB key and the De – Excitation key.

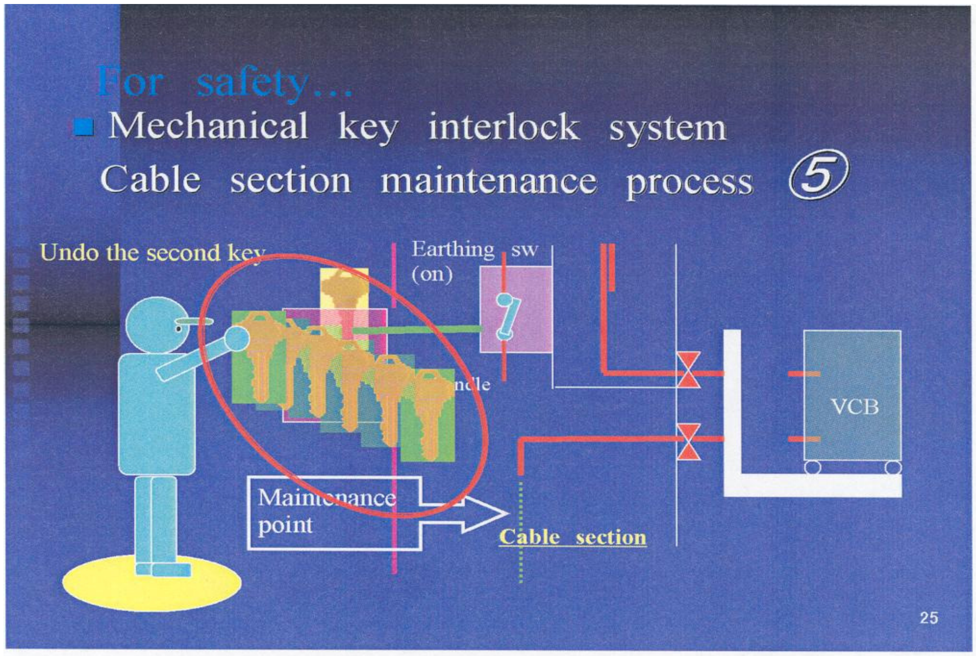
(3) Open the small door.



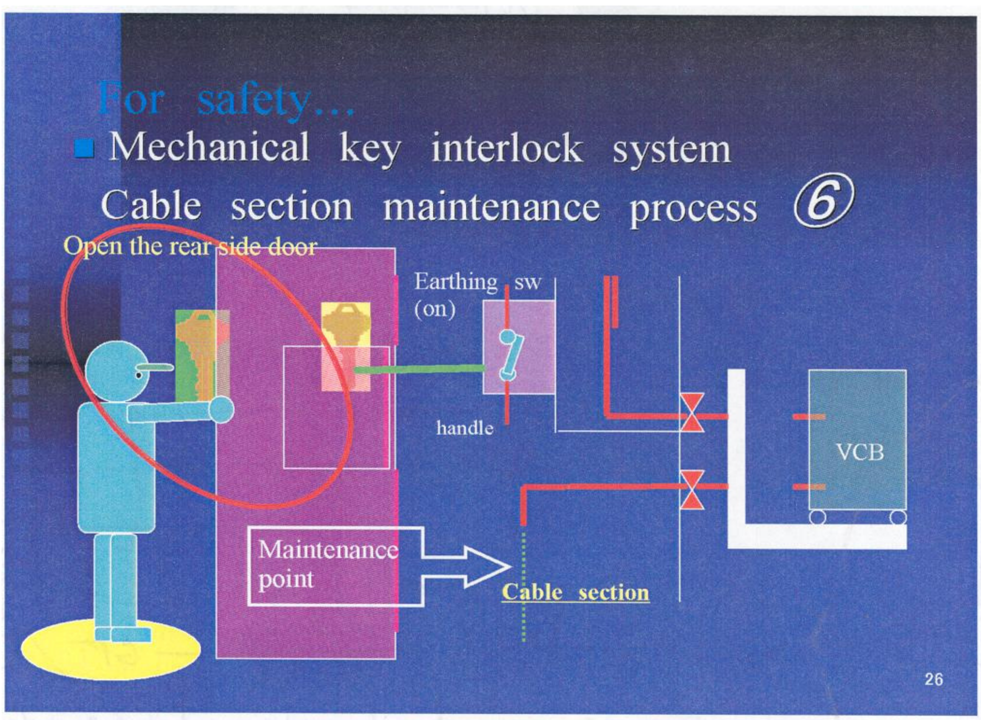
(4) Close the earthing switch.



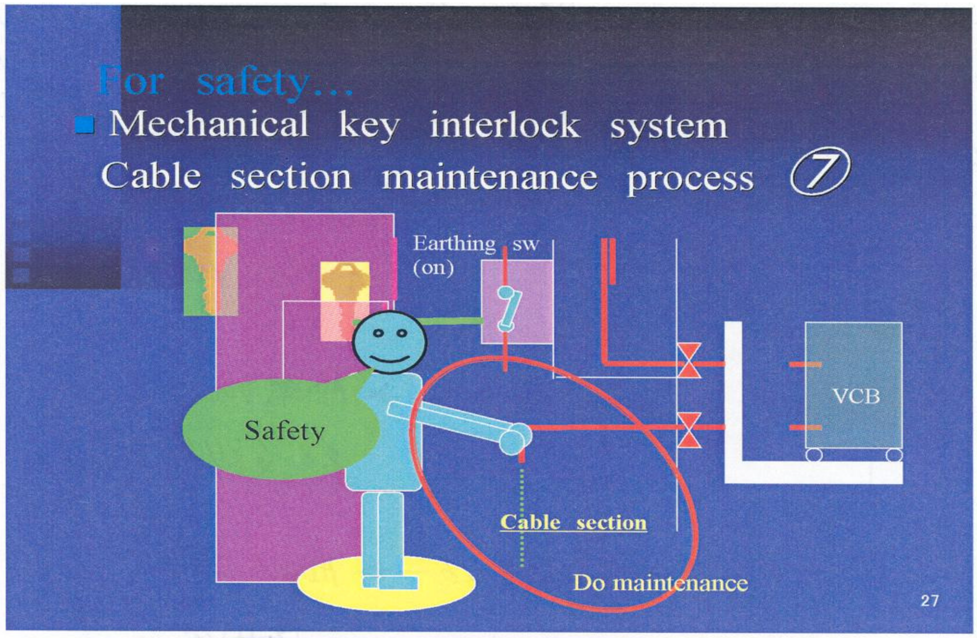
(5) Undo the second key.



(6) Open the rear side door.



(7) Inspect / Maintenance of Cable section.



7.2.2 Draw out of VCB:

(1) Open the Vacuum circuit breaker, if the breaker is closed.
(2) Remove the securing bar.
(3) Set the lifter.
(4) Insert the draw out handle into the hole.
(5) Pull up the interlock handle, and then operate the handle “Disconnection” position.
(6) Pull out the VCB.
(7) Disconnect the control circuit connector.
(8) Put the VCB on the lifter.

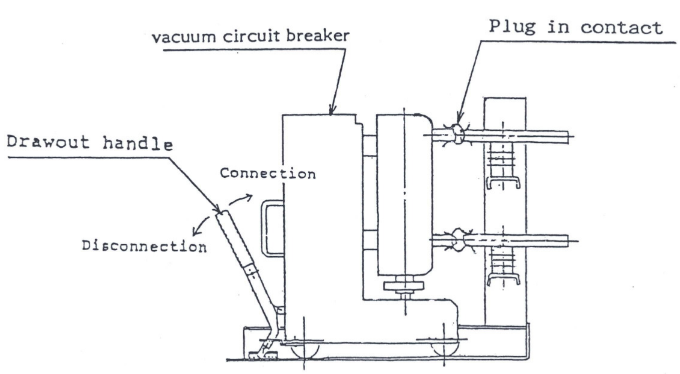
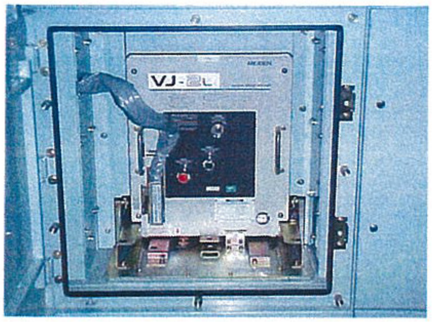
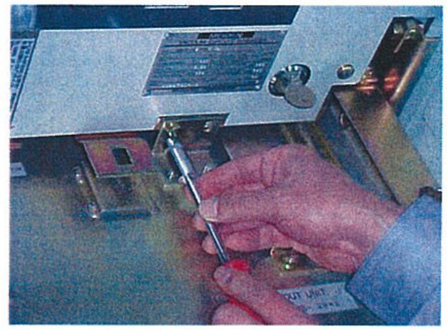


Fig. 26 VCB Connect Position

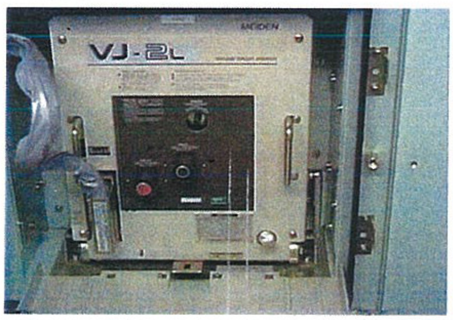
(1)



(2)

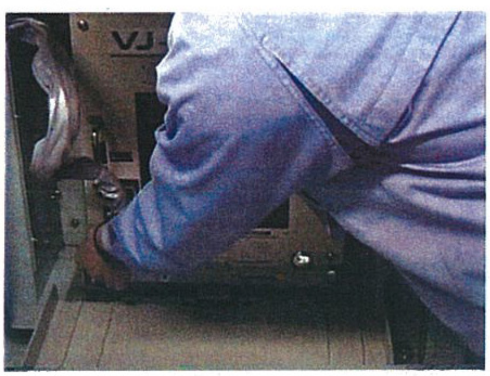


(3)

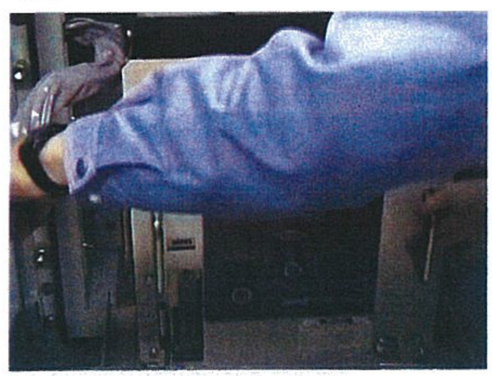


(4)

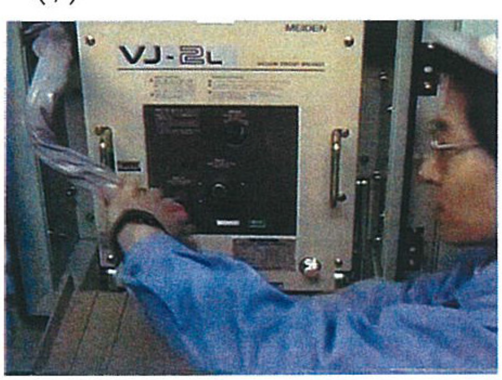
(5)



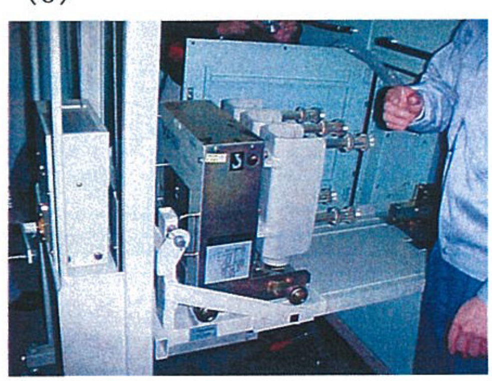
(6)



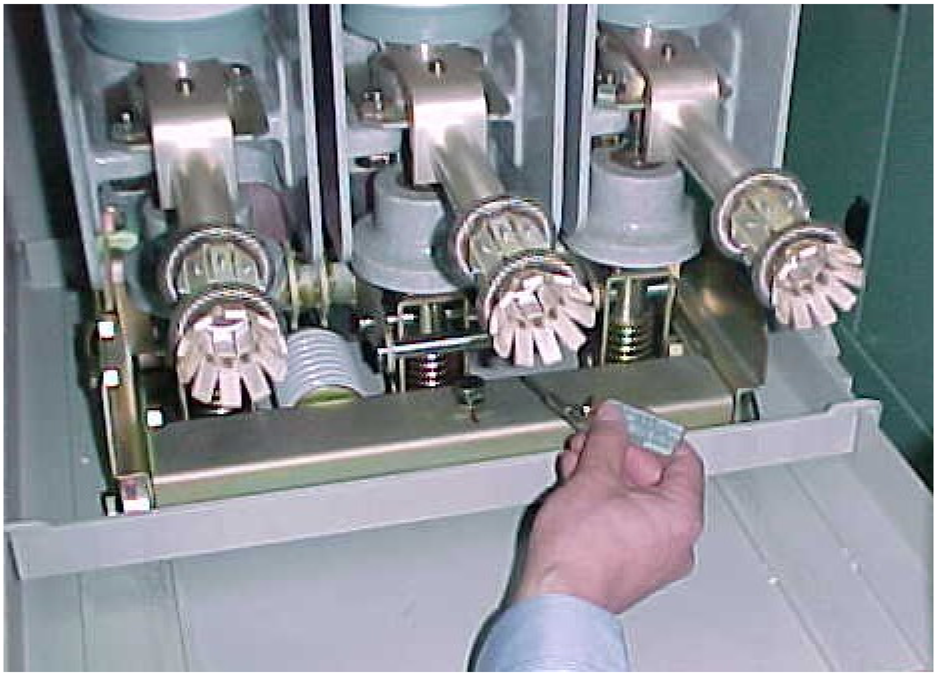
(7)



(8)



7.2.3 Measurement of Contact Wear of Vacuum Interrupter:



Vacuum interrupters should be replaced with new parts when the specific gap gauge is not able to insert to the gap.

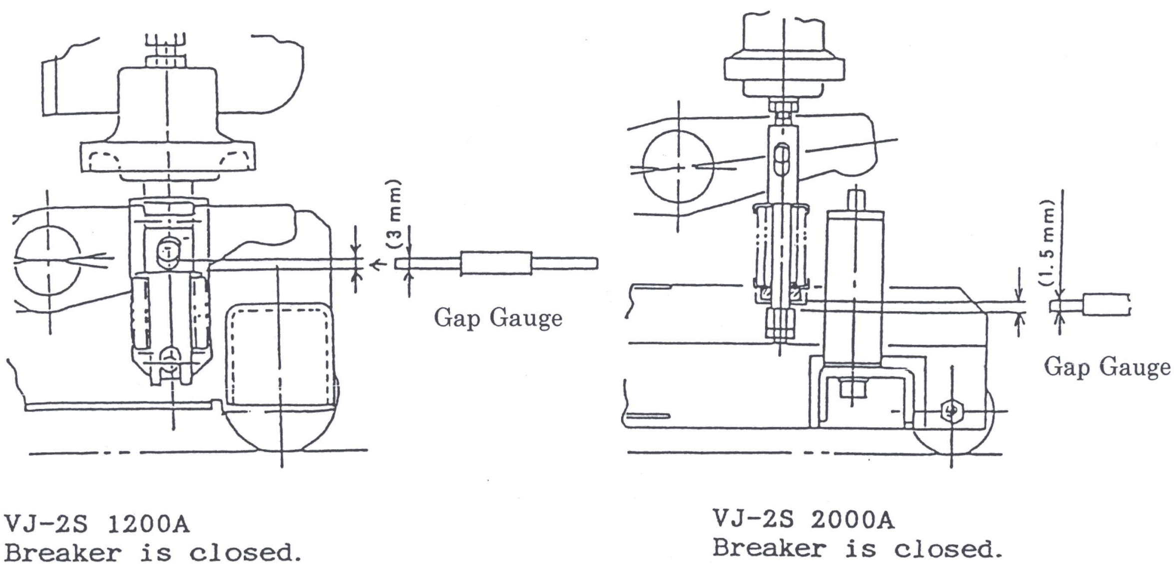
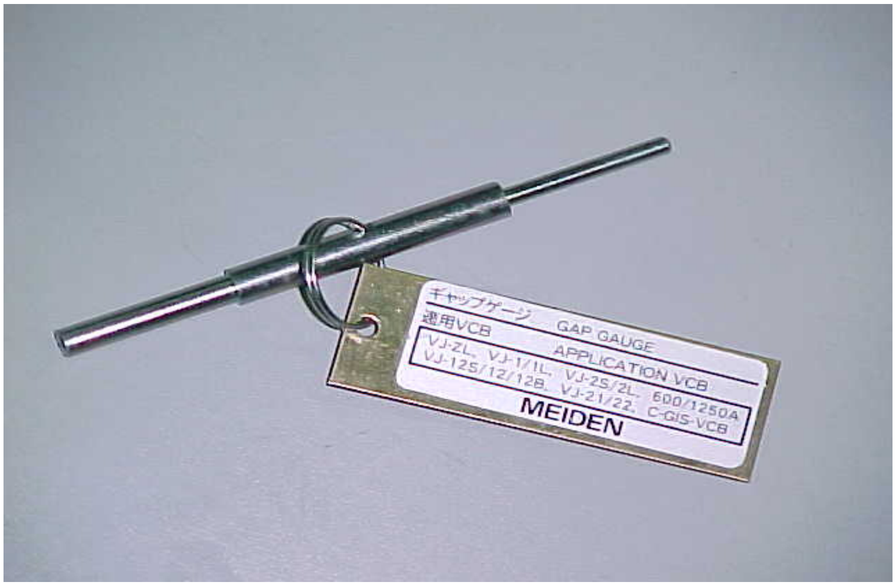
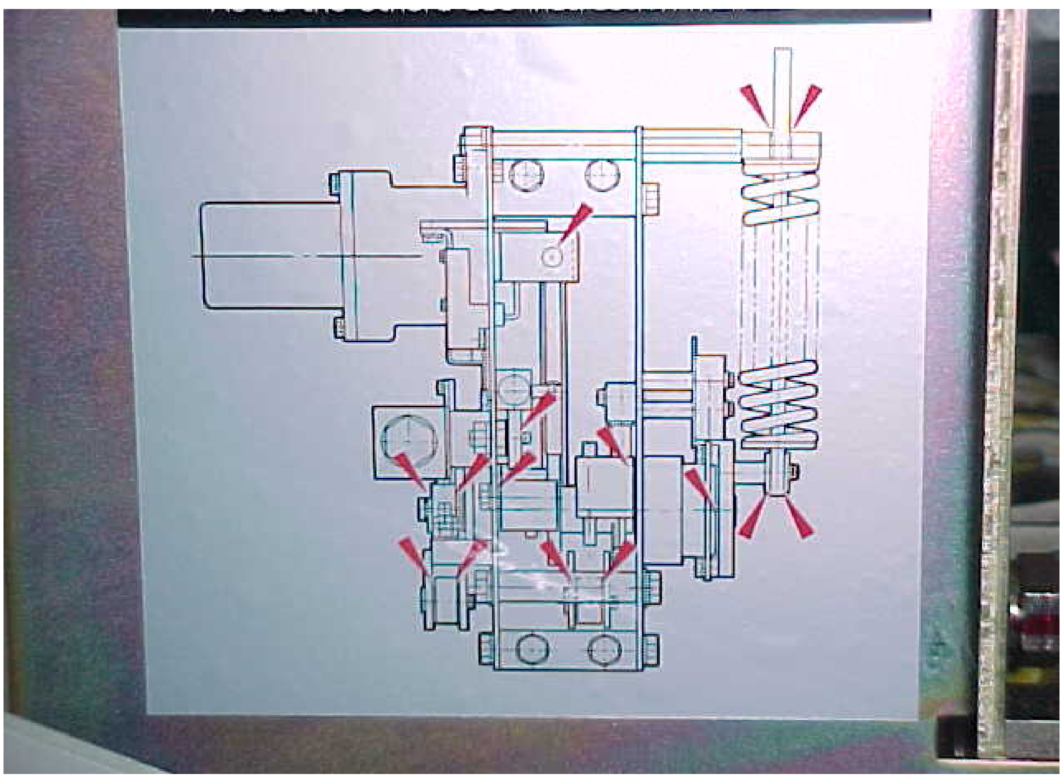


Fig. 27 Measurement of Contact Wear of Vacuum Interrupter



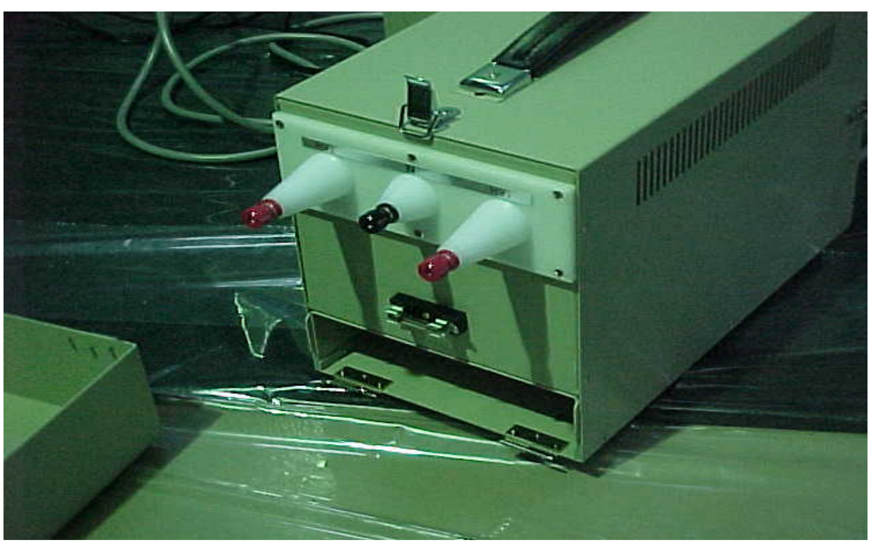
Gap Gauge

When the VCB is pulled out, the lubrication points should be oiled.

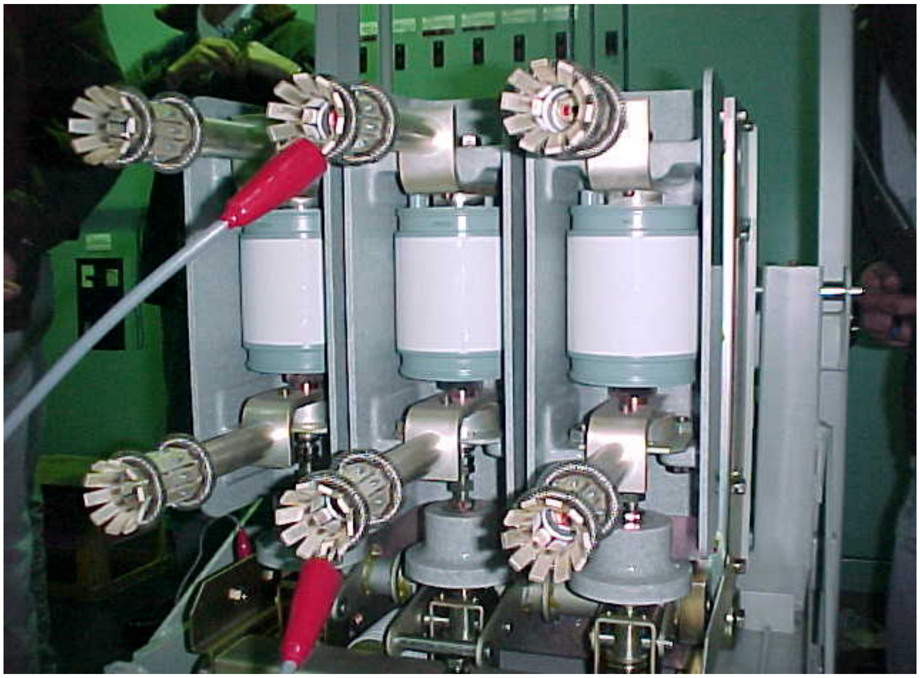


7.2.4 Operation of Vacuum Checker:

Looking at the photo, the left has the supply cable connected to the source (100V AC). The green lamp indicates that there is a supply going to the vacuum checker. An on-off switch is provided for power of the vacuum checker. In the center, an analog meter shows a scale of green and red. Green means the vacuum chamber is in good condition. Red means it is time to replace the vacuum chamber. A main breaker is located at the center supplying voltage of 22 kV or 11 kV for the vacuum chamber. In the right portion, the red lamp indicates that there is power going to the vacuum chamber. The ground is located at the bottom for the chassis of the Vacuum Circuit Breaker



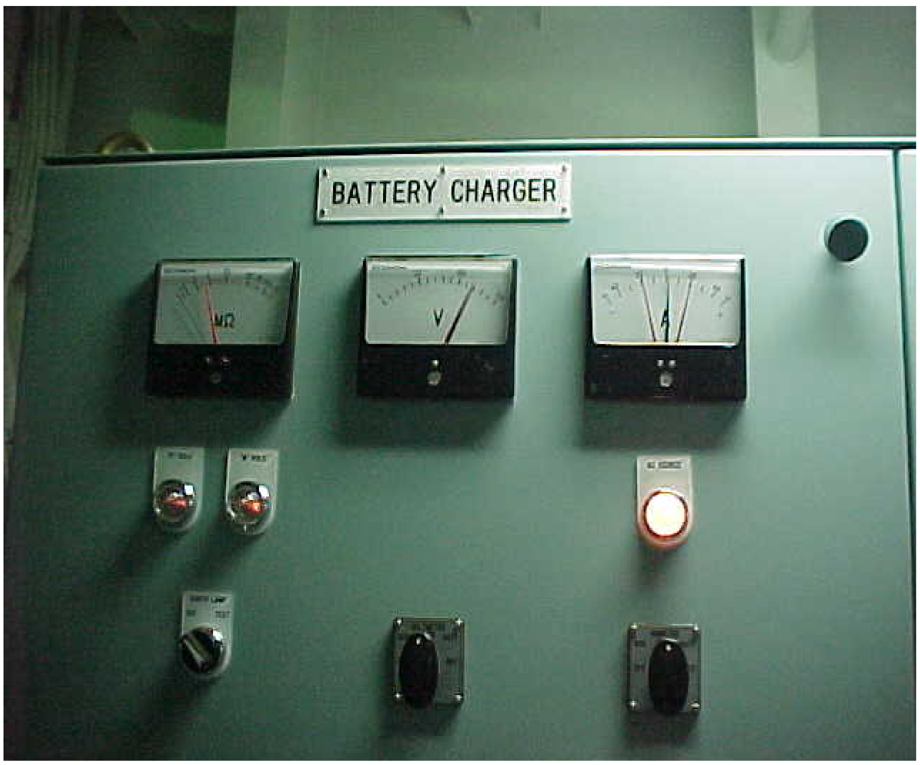
The rear has 3 pin connectors. When the connection is red to red the output voltage is 22 kV. When the connection is red to black the output voltage is 11 kV.



The connection shown above is done when the VCB is in trip condition. For VCB, the supply voltage is 22 kV. For the vacuum contactor, the supply voltage is 11 kV. The test is done for 60 seconds. After testing, earth/ground the contact pins with the earthing wire.

8. Battery Charger

VCB control is 110V DC compared to 24V DC for ACB. In the ACB, the protective device is in the same unit, but in VCB the protection device is located outside. To maintain the 110V DC, maintenance free battery is used and being charged by a battery charger.



Note that the voltage in the voltmeter is slightly higher than 100V DC (approx. 110 V DC). If the DC Voltage fluctuates or goes up and down, that means the battery charger is not in good condition.

TABLE of COMPARISON BETWEEN 6.6 kV and 440V VESSEL

	6.6 kV High Voltage	440 V
Current	Low	High
Type of Circuit Breaker	VCB	ACB
ACB/VCB Maintenance	Vacuum Checker and gap gauge	Visual Check
Safety Device Location	Separate Protection (TEM-Trip)	Included inside ACB
Control Circuit Voltage	DC 110V	DC 24V
Bus-Bar	Small (8mmx50mmx2 bars)	Large (8mmx200mmx 4 bars)
Bus-Bar Distance	Wider	Narrow
MSB Protection	With Compartment Can't see through from front to rear due to division	Without Compartments Can see through
When short circuit occurs	Explosion	No Explosion
Protection from Explosion	With pressure relief flap Panel door is secured with bolts and locks Panel door is reinforced type	Without pressure relief flap Panel door has locks only Panel door has no reinforcement bar
Circuit Breaker Connector	Equipped with automatic safety shutter	Not Equipped with automatic safety shutter
Earthing Device	With earthing switch	No earthing switch
MSB Door	Mechanical key interlock system	No need for interlock system

CONCLUSION

1. 6.6 kV system is a safe system.
2. DC 110V supply is critical supply.
3. A VCB safety device (TEM-Trip and HIMAP) is external type.
4. Even without PMS, we can operate 6.6 kV MSB.

9. Troubleshooting:

According to the guideline set by NYK SHIPMANAGEMENT PTE, LTD, the following instructions should be followed in case of blackout:

9.1 Basic Guideline on Procedure in Case of Abnormal Blackout and Restoration of Electrical Power

Although proper and conscientious maintenance are always undertaken in order to keep all engine machineries and equipment in good working condition, unavoidable and unforeseen circumstances such as BLACKOUT may occur and sometimes may be of a very peculiar nature.

Taking into consideration the seriousness of the matter which may put the ship into a dangerous situation, these WORK INSTRUCTIONS are being issued for immediate and speedy recovery of main electric power supply, main propulsion and other machinery of critical importance so that the ship can be easily maneuvered to a position of safety.

When such incident occurs the following immediate actions are to be undertaken:

(1) The duty engineer, when he becomes aware of the BLACKOUT, must proceed immediately to the ECC/ECR to inform the Chief Engineer and Officer on Watch.

(2) Establish a channel of communication using walkie-talkie or the sound-powered telephone system between bridge and ECR and among the engineers.

(3) The Chief Engineer, when he becomes aware of the BLACKOUT, shall immediately proceed to ECR/ECC to take over command from duty engineer and instruct temporary measures to engineer and crew.

(4) Off duty engineer and engine crew, after being aware of the BLACKOUT, must quickly but safely proceed to E/R and follow the temporary measures as instructed by Chief Engineer.

(5) The duty engineer, electrician and/or the rest of the engineers must confirm the following:

a. Communication channel with bridge and rest of the engineers.
b. If emergency generator has started automatically.
c. If power is supplied to emergency lighting system.
d. If power is supplied to communication system.
e. If power is supplied to steering gear and navigational instruments.
f. If power is supplied to engine control console.
g. If power is supplied to emergency batteries.
h. Investigate the cause of BLACKOUT.

If the trouble is not on the main switchboard and if the standby generators have failed to start automatically, proceed by starting manually on local, transfer control to the

Main Switch Board (MSB) and close its air circuit breaker or Vacuum Circuit Breaker on the main switchboard.

(6) In case of BLACKOUT, the D/G in service and D/G first stand-by are both auto-stop <u>do not attempt</u> another starting of another generator until and unless the root cause of failure has been identified so as to avoid loss of starting air in the air reservoir. **<u>One air reservoir must always be in full condition. This important fact must be appreciated.</u>**

(7) Once the main power supply is restored, the engine crew with their respective duties should carry out the check of equipment assigned to them. If the ship is equipped with a Shaft Generator or Turbo Generator or both and any of them or both are in use at the time of the BLACKOUT, proceed to follow the above instructions Nos. 1 to 7. Bear in mind the difference between the Vacuum Circuit Breaker and the Air Circuit Breakers and their respective locations.

9.2 Manual Operation:

If the system does not reset or DC110V source fails, keep all controls on Manual and on MSB control.
And in case of maneuvering in and out of port, narrow passage, etc. the following procedures in manual operation should be done:

(1) Preparation or confirmation before starting the generator
- Confirm that all VCB for generator are open.
- Carry out (steps 2 to 6 and step 7) the following procedures:

1.1 Change control position.
Take control of all generators to MSB from ECC by changeover switch (COS-M) located on Bus-Tie and Synchro Panel (MSB Panel H).

See Fig. 28

1.2 Change control mode.
Transfer control of all generators to manual from automatic by changeover switch (COS-A) located on ECC.

1.3 Isolate the High Voltage Bus: Open the Bus Tie VCB.
Open the High Voltage Bus Tie VCB between the no.1 bus and no.2 bus by changeover switch (BCS-B) located on Bus-Tie and Synchro Panel (MSB Panel H) or manually press push button switch on VCB (MSB Panel J).

See Fig. 28

1.4 Isolate the Low Voltage Bus: Open the Bus Tie ACB. Open the Low Voltage Bus Tie ACB located in Low Voltage Switch Board (LVSB) Panel C on the 440V Bus Bars.
See Fig. 29

1.5 Shut down and reset the control and protection system.
Remove the 8 fuses located in Panel H (Bus Tie and Synchro Panel)
- 278 Earth (Grand) Fault Over Voltage Relay input signal from GPT Unit for No. 1 Bus
- 279 Earth (Grand) Fault Over Voltage Relay input signal from GPT Unit for No. 2 Bus
- 286 No.1 Central PMS Unit Source (DC 24V), one pair
- 287 No.2 Central PMS Unit Source (DC 24V), one pair
- 292 Ground Voltage Relay Source (DC 110V), one pair

The control and protection system will shut down.
Reinstall the fuses and reset the control and protection system on the soft touch panel.

If the system resets, proceed directly to steps 2 to 4.

If the system does not reset, remove and reinstall the 10 fuses from each of the generators PMS power units located as follows:
- 281 located in Panel F (No.1 D/G), one pair of fuses
- 282 located in Panel G (No.2 D/G), one pair of fuses
- 283 located in Panel K (No.3 D/G), one pair of fuses
- 284 located in Panel L (No.4 D/G), one pair of fuses
- 285 located in S/G Panel (Panel J), one pair of fuses

(2) Start the generator and take on load.

- Start the first one of the generator at local side by manual operation.
- And then close the VCB of starting D/G by starting D/G panel VCB manual closing operation.
- Take it on load manually.

(3) Start another generator and take on load.

- Start another generator at local side by manual operation on the other side of 6.6V bus tie.
- And then close the VCB of starting D/G by the starting D/G panel VCB manual closing operation.
- Take it on load manually.

(4) Close the bus tie.

The system will be supplying 2 independent feeders on each of the feeder panels. If operation is normalized then bus tie on the 440V bus bars can be closed. The one on the 6.6kV bars can be closed by synchronization to run the systems as parallel.

All manual operation is done when the battery charger fails and the source of the failure of the PMS is known. This measure will reduce the downtime.

9.3 Shaft Generator is in operation and Power fails for a particular reason.

The following is the procedure for restoring power in a ship equipped with four DG's & one SG.

In the event of failure of the shaft generator caused by PE Link Module in the PMS unit, power cannot be restored automatically if the standby generators trip and cannot be reset. This is a built-in safety procedure.

<u>Case1: Power Failure occurs while a SG is running to supply power</u>

A blackout occurred when SG and DG1 were operated in parallel and load consumption in the ship was approx. 3000KW.
The VCB for Dg1 tripped open & one for SG remained closed.
No Standby DG started.

1. Transfer control from ECC to HVSB by changing the position of switch COS-M on panel H of the HVSB, and change the mode of all generators from AUTO to MANUAL.
2. Make sure the VCBs for all generators are open (OFF).
3. Use the engine side to manually start engine and transfer control to HVSB.
4. Check the voltage of the running generator and then, using switch BCS, close the VCB to start supplying power.
5. If using BCS on Dg panel, VCB does not close, Make sure the closing spring of VCB is charged. If not manually charge the closing spring and press the closing button on the VCB.

<u>Case2: A "PE-LINK error" occurs while a SG is running to supply power</u>

1. Transfer control from ECC to HVSB by changing the position of switch COS-M on panel H of the HVSB, and change the mode of all generators from AUTO to MANUAL.
2. Remove fuses used to supply power to the equipment where a "PE LINK error" occurred, wait for approx. 5 seconds, and reinstall the fuses.

- PMS for DG1 : Fuse 281 in panel F
- PMS for DG2 : Fuse 282 in panel G
- PMS for DG3 : Fuse 283 in panel K
- PMS for DG4 : Fuse 284 in panel L
- PMS for SG : Fuse 285 in panel J
- PMS for Central 1: Fuses 286/287 in panel H (Be sure to remove both the fuses)
- PMS for Central 2: Fuses 286/287 in panel H (Be sure to remove both the fuses)

See Fig. 31

3. Reset the microprocessor using the soft touch panel.
4. If the microprocessor cannot be reset, remove the fuses listed in step 2 above and replace the PE-LINK module with a spare, then reinstall the fuses.

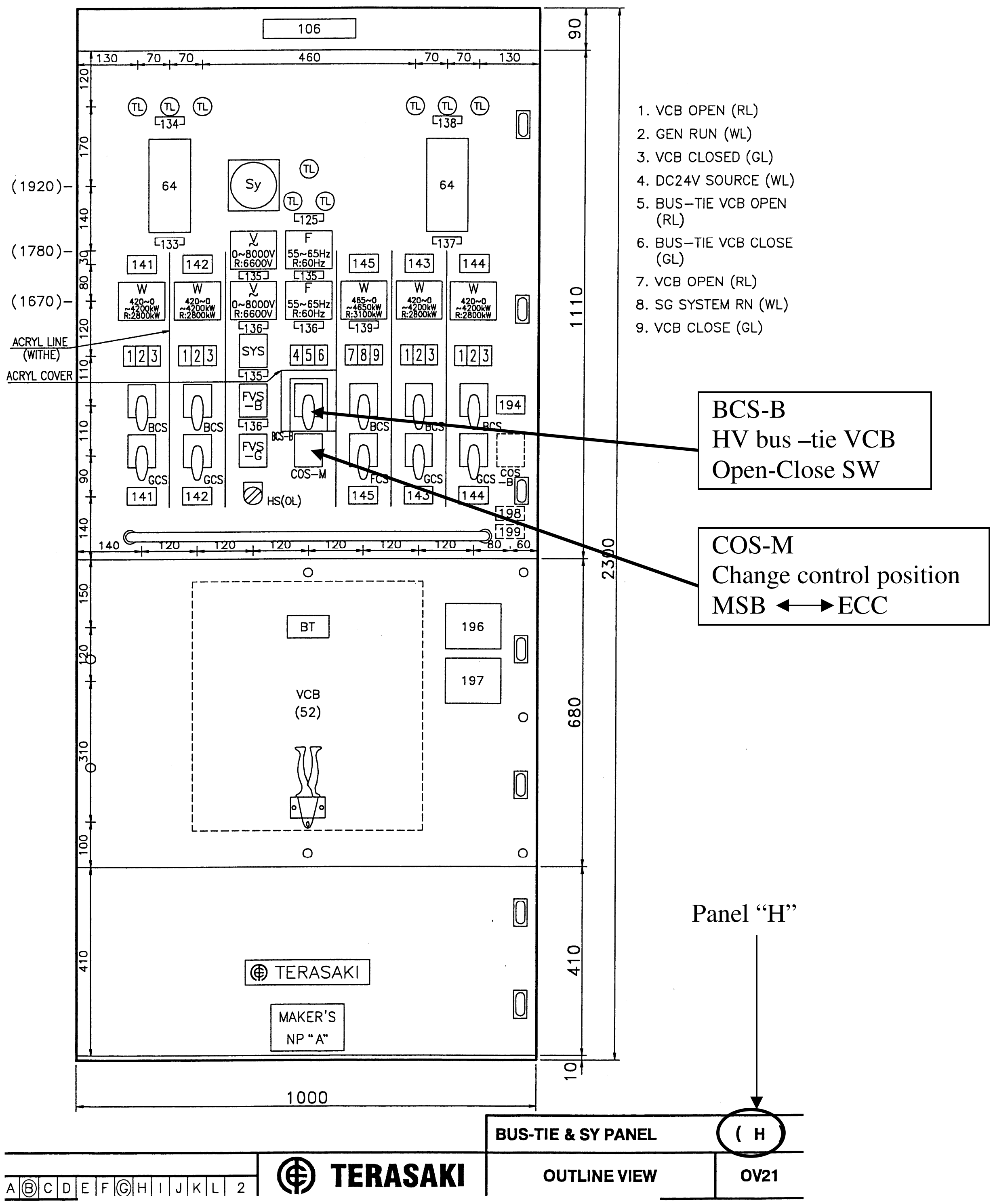


Fig. 28 Bus Tie and Synchro panel

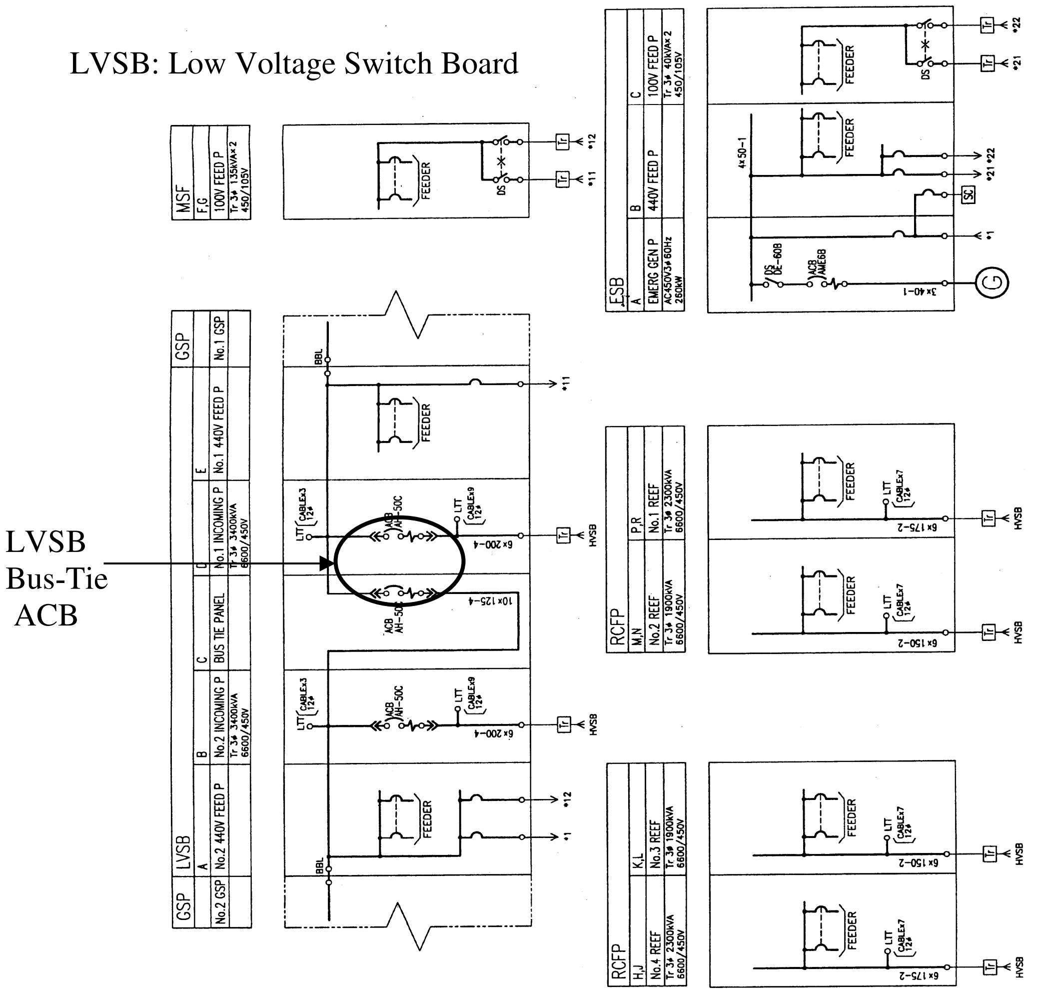


Fig. 29 Low Voltage Bus Tie ACB

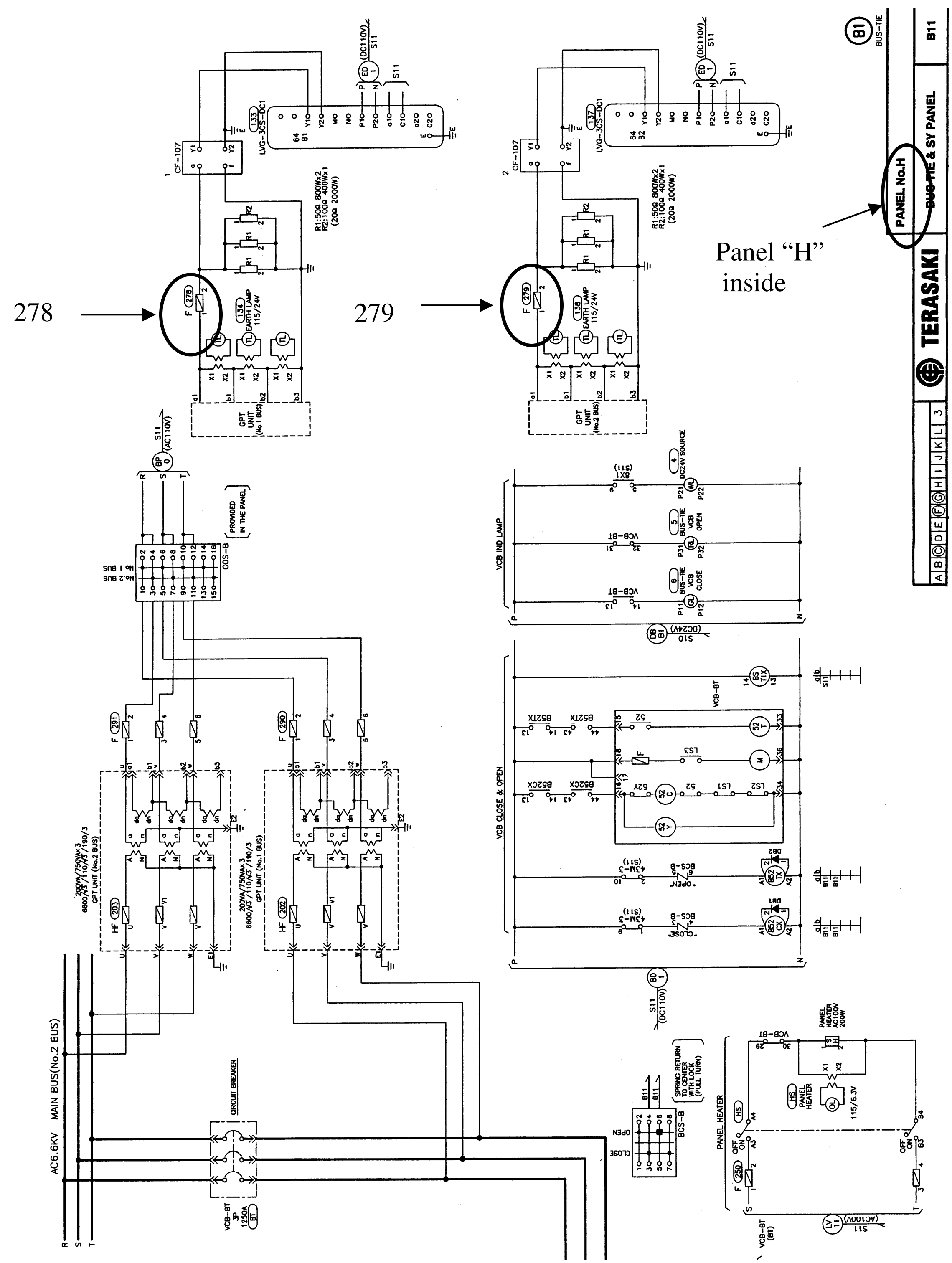


Fig. 30 Bus Tie and Synchro Panel Fuse Arrangement

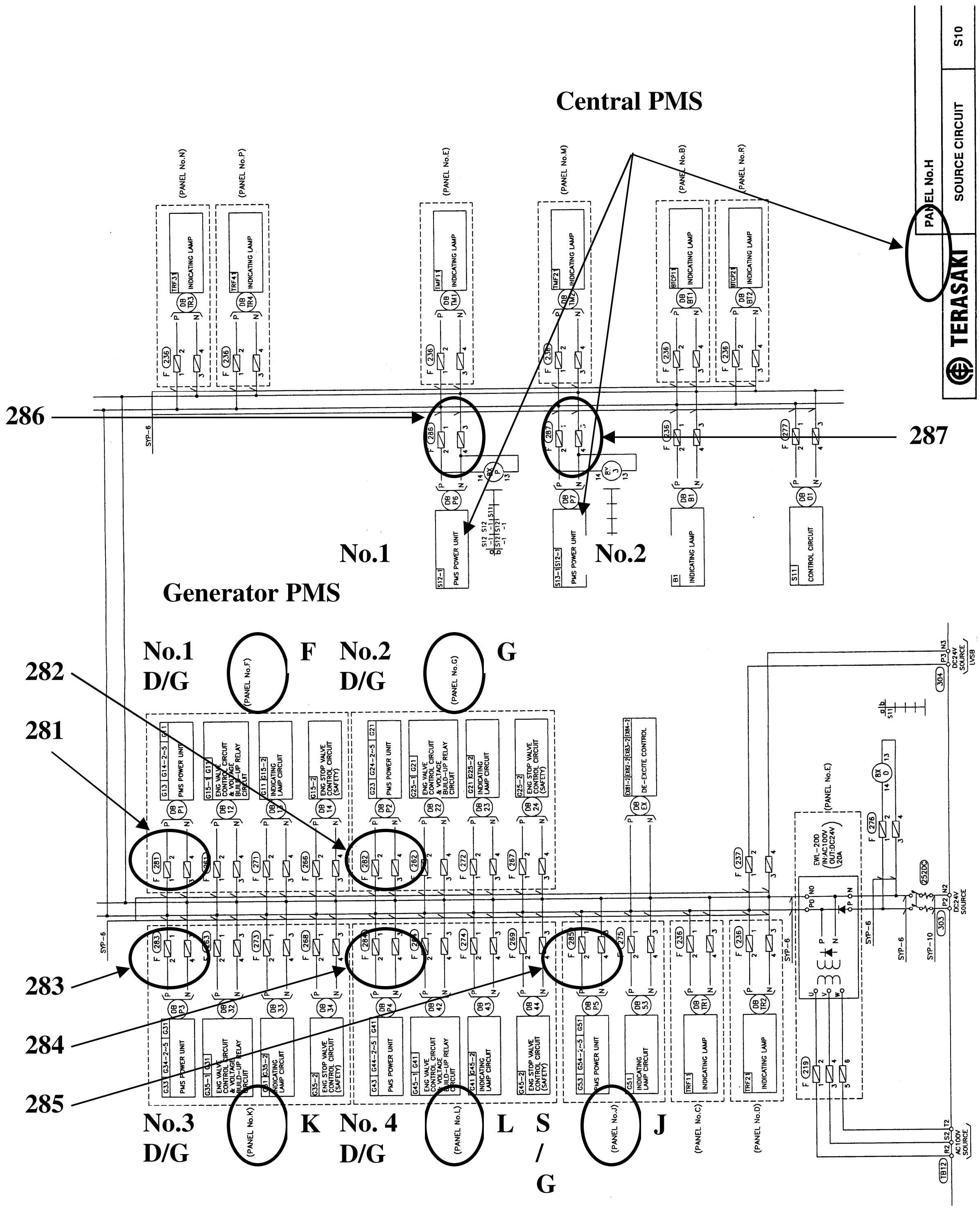


Fig. 31 Source Circuit of PMS and DG

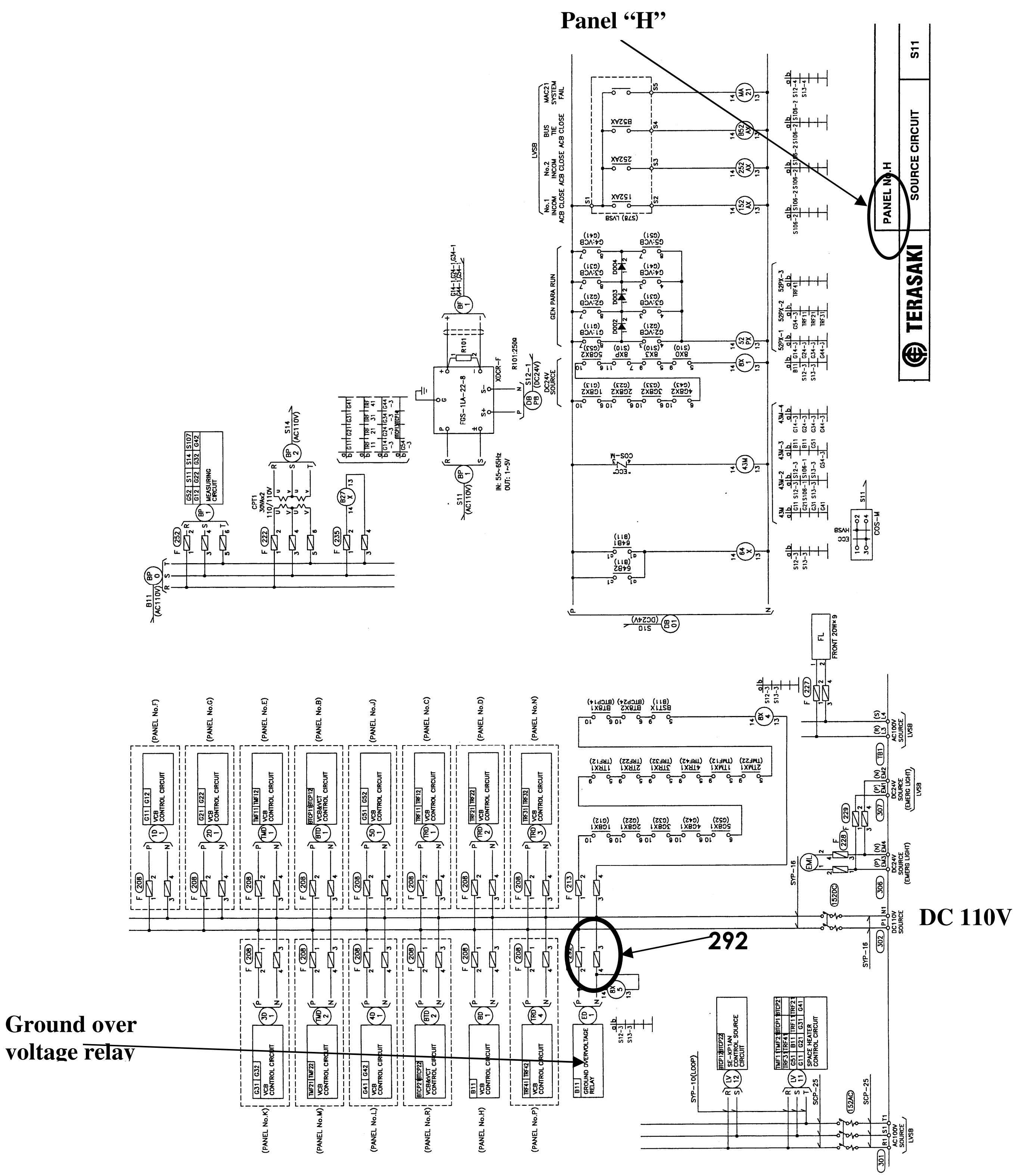


Fig. 32 Source Circuit of Ground Over Voltage Relay

9.4 Case studies:

<u>Case 1:</u>

<u>NYK LODESTAR, 29TH JAN 2015</u>

On 29th Jan'15/0709 LT, while on passage from Xiamen to Yangshan, vessel had a short blackout.

DG3 and DG4 were running in parallel at the time of the incident.

DG3 unit 4 fuel pump inlet pipe banjo bolt sheared off causing a loss in common line HFO pressure.
DG3 tripped on low frequency followed by DG4 due to starvation of fuel.

DG1 (1st standby) and DG2 (2nd standby) started on auto and both VCB's closed automatically; however there was no power supply for No. 1 GSP and No. 2 GSP in the 440 MSB.
On checking, the following ACB's were found open:
(a) "E" which connects Main transformers from AC 6600 V to 450 V in the AC 440 V MSB.
(b) "D" which connects No 1 GSP and No 2 GSP and has interlock with "E".

Vessel manually closed the ACB "E" and the power supply was restored. (See the fig.1)

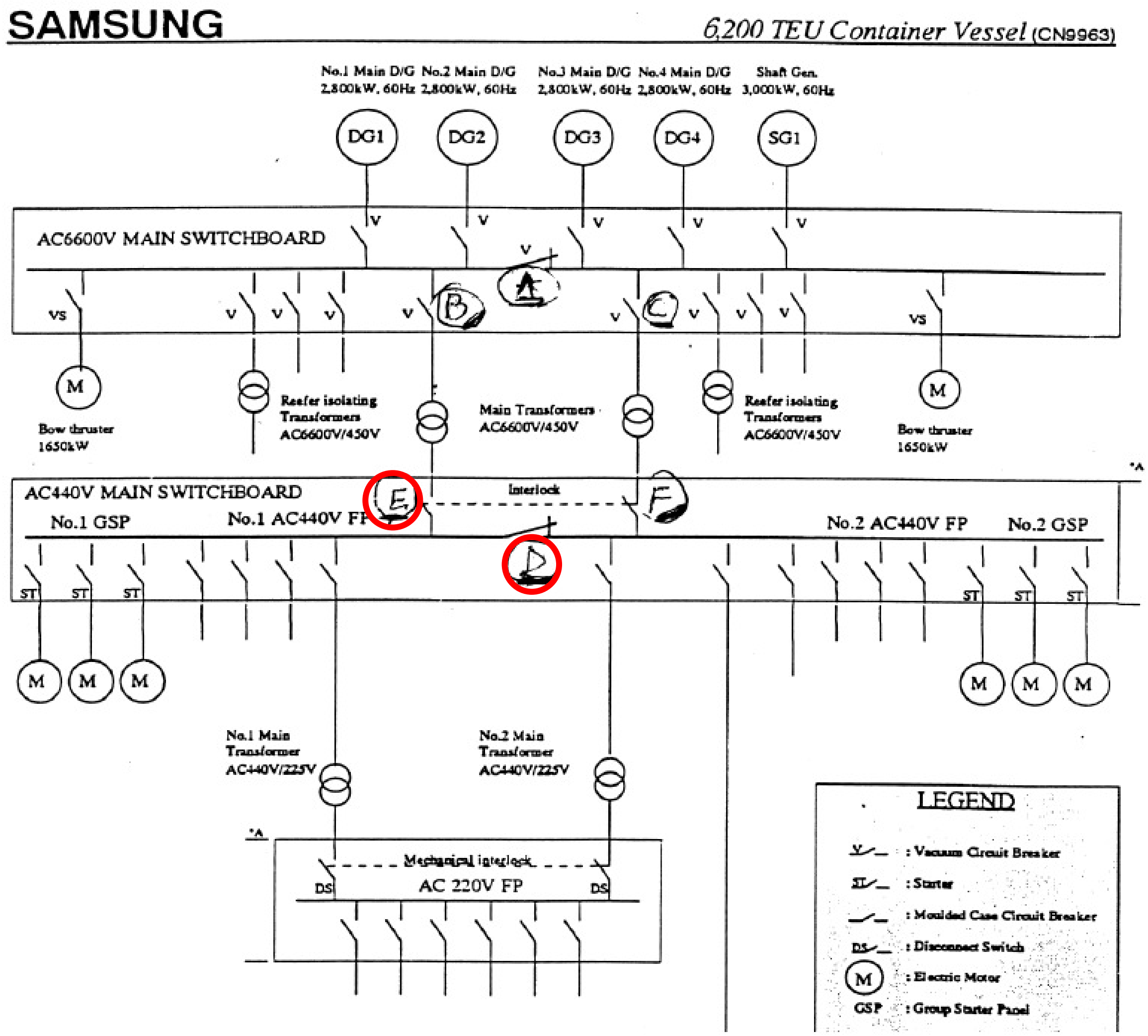


Fig.1

On investigation ,it was suspected that Timer Relay 166T which activates the ACB closing relay 152CC was defective & could have been the reason why ACB"E" did not self-close after power recovery. See fig.2

Vessel staff checked the functioning of timer 166T at Manzanilo on 19th feb '15 and No defect was observed.

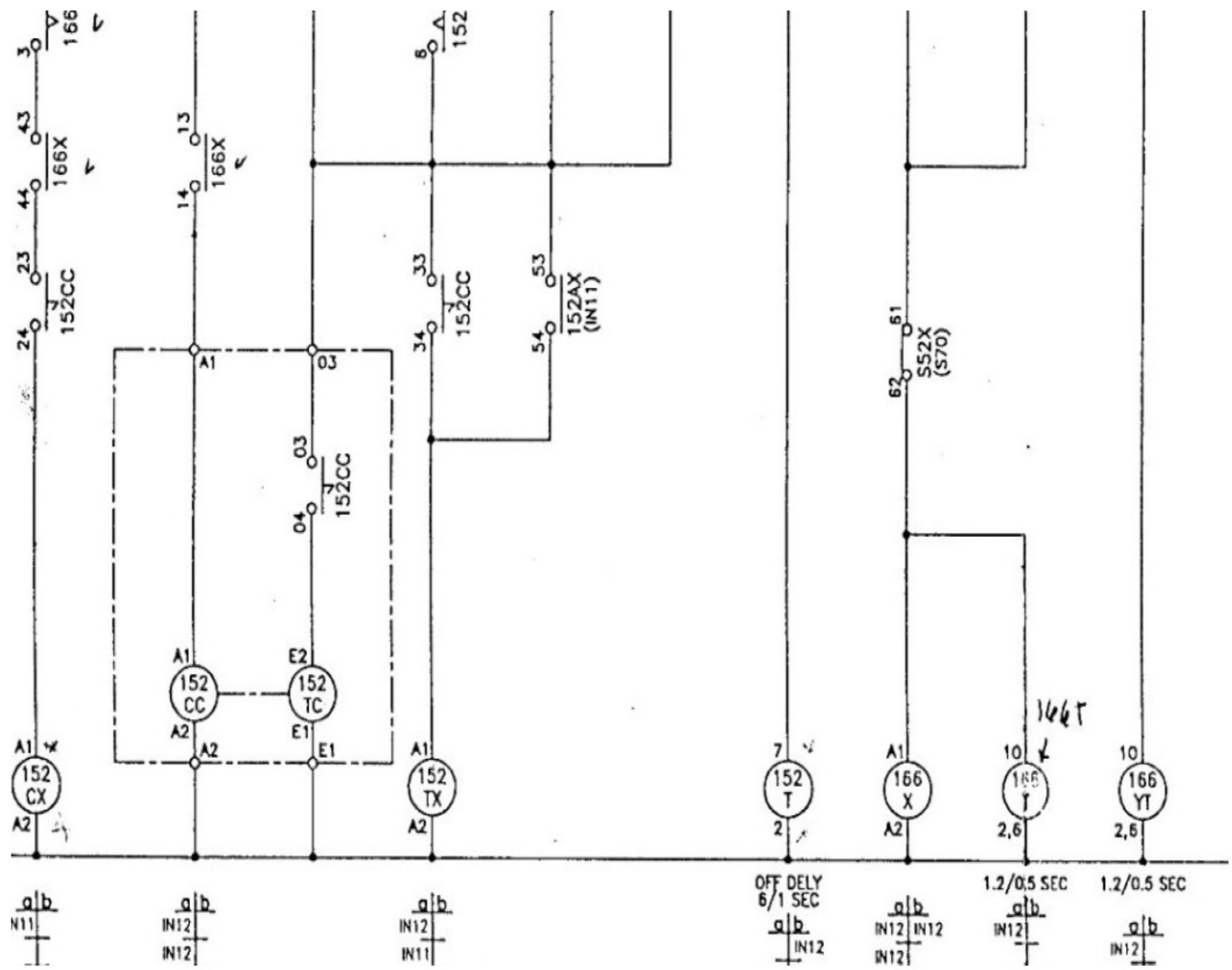
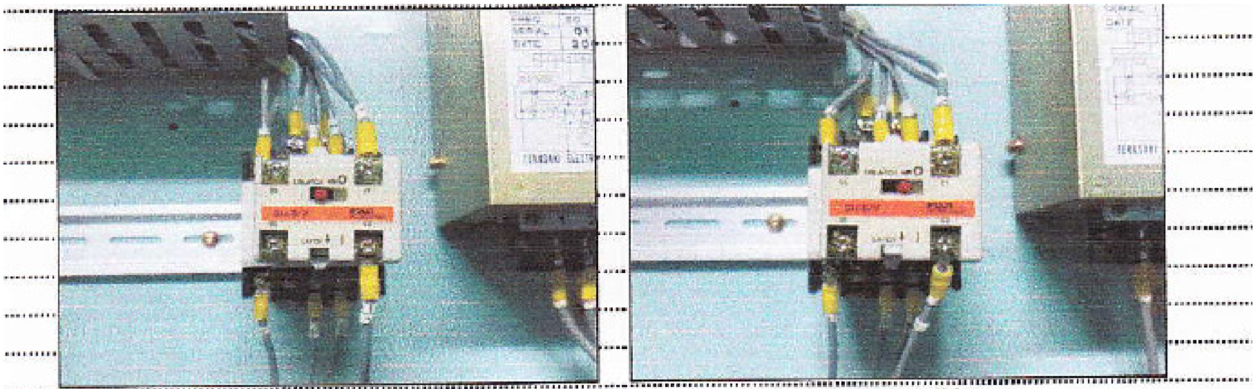


Fig.2

Maker Teratec service engineer attended at Tokyo on 6th Apr'15 & found that No.1 incoming ACB i.e. ACB"E" was kept in "Unlatched" condition at the time of last blackout. Under this condition, the ACB will not close automatically in case of blackout.

Corrective measure:

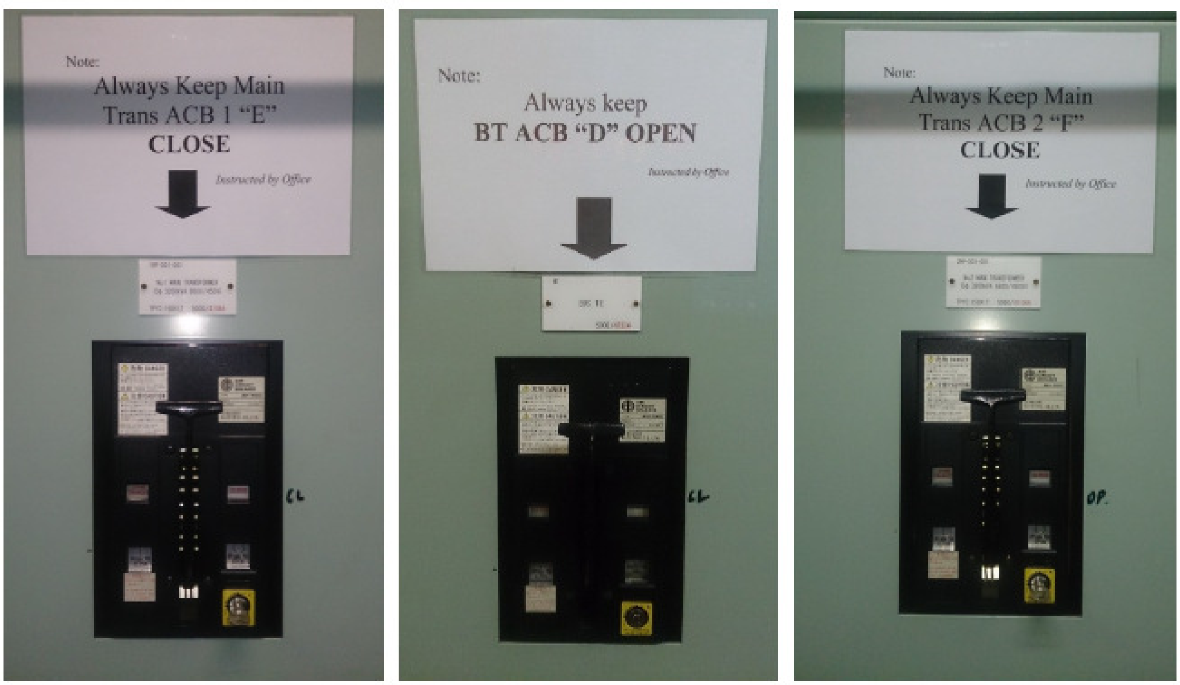
1) Please check & confirm for keep relay when carry out blackout test, if the position is UNLATCH, the ACB does not close automatically. Vessels are to ensure that the incoming ACB's are kept in a "LATCHED" condition at all times.
The location of Keep relay are in NO.1 & 2 Incoming & Bus tie panel.



Latch condition Unlatch condition

2)Information sharing to be sent to the vessels indicating the importance of keeping the incoming ACB in "Latched" condition and change in timer settings as advised by TERATEC (applicable vessels L-Class and Old A-Class)

3) Applicable vessels **(L-class & old A-class)** are to use both the transformers & a suitable notice/placard is to be placed as a reminder.



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4) Vessel is required to change the timer settings for 166T, 266T & B66T to 5 seconds as per Terasaki recommendation. This are the timers for automatic closing of ACB.

5) A laminated notice/placard is to be posted near the incoming ACB as a reminder to keep the ACB in Latched condition.

Please install following caution plate near the manual closing push button of ACB.

-Applicable ACB-

1) No.1 MAIN TRANSFORMER INCOMING ACB

2) No.2 MAIN TRANSFORMER INCOMING ACB

3) Bus-Tie ACB

- CAUTION -

ACB must be closed by BCS (Breaker Control Switch).
Otherwise, at the time of the restoration
after the blackout, ACB is not closed automatically.

Case 2:

BLACKOUT NYK VENUS 12TH MARCH 2015

During arrival PORT SAID anchorage vessel suffered Blackout.
Initially there was an alarm under of frequency 6.6 KV and LV SWBD FREQUENCY LOW).
At the time of blackout DG No.2 & 3 were running and operational.

Later Vessel restored power and anchored safely.

In order to confirm the cause of trouble, the malfunction of pressure control valve in DG FO system was suspected.
However it was observed that pressure control valve is functioning satisfactory.

Service engineer from Terasaki arranged @ Singapore on 27th Mar-15. As per service report, there was large difference of power factor between all DG's which could cause over current trip of DG. Service engineer adjusted power factor setting by regulating AVR in HVMSB.

No trouble observed thereafter and vessel staff now are closely monitoring the power factor.

Causes & Contributing factors:
The large difference of power factor between all DG's which would have caused over current trip of DG.

Corrective measure:

1. All vessels to check the power factor meter reading at every opportunity to ensure that there is no large difference.
2. Power factor meter reading must be included in the MO checklist for frequent checking.

Reference: HSEQ/BLT/011/15- Incident Bulletin

Case 3:

BLACKOUT NYK VENUS 5TH MAY 2015

On 5th May 2015, at sea, DG-2 & DG-4 were running in parallel.

Both VCBs suddenly opened due to under frequency which caused black out.
Vessel staff tried to take load on DG-1 but without success. DG-3 fuel pumps were under maintenance & Staff was unable start the generator immediately to take load on DG 3.

Above incident thoroughly analyzed & concluded that the blackout occurred due to fuel starvation in the system. It was observed that FO system was under low pressure due to malfunction of return line pressure regulating valve as per attached drawing.
Also it was noted that the return globe valve 183V was kept close about 75% to maintain the pressure in the FO system.
There was lack of oil in the FO return pipe (mixing column) due to throttling of above mentioned valve resulting to starvation of fuel thus causing Black out.

Additionally stand-by DG did not start as black out condition was not recognized by HIMAP. HIMAP control system failed due to faulty power module.

On further investigation found that
Stand by DG-1 did not start due to trouble with HIMAP F1. This HIMAP had power module fault which did not allow it to recognize that blackout has taken place.
Due to this, D/G No.1 which was the stand by D/G did not start automatically.
HIMAP F1 has already been supplied & same has been replaced.

Further investigations also revealed that power module of other HIMAP (Bow Thruster /Main transformer / Reefer Transformer) needs to be replaced.
It is not recommended to try out black out test without replacement of these power modules as HIMAP will not recognize the faulty condition of switchboard & breakers will not trip.
We have placed order for these power modules & expected to be ready on mid Dec-2015.

Corrective measure :
-The Information to be shared among all vessels.
-Pressure regulating valves need to be overhauled every 3 years and same to be included in the PMS.
-HIMAP F1 power module voltage to be checked monthly & to be replaced if required.

9.4.1 Instruction for Periodic Check of HIMAP-BCG Power Supply Module

At first we should know, what is meaning of faulty power module & how it happened. As per Maker Terasaki investigation, the trouble was caused by the failure of "**CAPACITOR**" that is installed in the power supply unit. The capacity of capacitor will reduced & will cause voltage drop of power source unit.
The following are the indications of capacitor failure:
1."SYS FAIL" lamp on front panel will lit & becomes in freeze condition.
2. Resetting process is repeated.
3. Backlight of LCD is flickering or its display will become dark.

Depend on the output voltage of power source unit, more than two kind of indications may be observed at the same time.
This trouble is caused by the dropping of the output voltage of power source unit. The decrease of capacity of capacitor that is installed in DC/DC converter in the power source unit leads to the voltage drop.
Procedure for checking power source unit:
The capacitor, which is installed in the DC/DC converter is molded, and we can't check from outside. So we have to judge the condition by the voltage drop of the power source unit.
If the measured voltage of power source unit is below 4.9 V, it is recommended to replace the power source unit.
This check must be done on monthly basis.

1. Preparation
   - Confirm that the generator is not running.
   - If the generator is running, start another generator & shift the load & open the VCB before measurement.
   - Prepare the TESTING CABLE (TERASAKI Supply) for measurement. Please ref to picture 1.

Picture 1 TESTING CABLE

   - Prepare the Digital Multi Meter. (Always use the same instrument to reduce the measurement error).

2. Measurement
   Carry out measurement once a month according to following steps:
   a) Connect the TESTING CABLE with connector on HIMAP-BCG

b) Connect the TESTING CABLE with Digital Multi Meter.
c) Turn on Backlight by pressing the “ACK” button.
d) Record the reading data of Digital Multi Meter in the excel sheet.

3. Judgement of the measured data.
   If the measure voltage data is below 4.9V, it is recommended to replace the parts (Power source unit of HIMAP-BCG) or complete HIMAP-BCG.

NYK XXXXXXX MONTH: JANUARY, 2016

HIMAP CPU VOLTAGE MEASUREMENT DATA SHEET

S.N.	PANEL NAME	SERIAL NO.	CRITERIA	READING DATA V	REMARKS
1	NO.1 DIESEL GENERATOR		MORE THAN 4.9V	5.14V DC	
2	NO.2 DIESEL GENERATOR		MORE THAN 4.9V	5.01V DC	
3	NO.3 DIESEL GENERATOR		MORE THAN 4.9V	5.08V DC	
4	NO.4 DIESEL GENERATOR		MORE THAN 4.9V	5.12V DC	
5	TURBO GENERATOR		MORE THAN 4.9V	5.11V DC	
6	NO.1 MAIN TRANSFORMER		MORE THAN 4.9V	1.91V DC	
7	NO.2 MAIN TRANSFORMER		MORE THAN 4.9V	1.72V DC	
8	NO.1 REFER TRANSFORMER		MORE THAN 4.9V	1.91V DC	
9	NO.2 REFER TRANSFORMER		MORE THAN 4.9V	1.73V DC	
10	NO.3 REFER TRANSFORMER		MORE THAN 4.9V	1.69V DC	
11	NO.1 BOW THRUSTER		MORE THAN 4.9V	1.90V DC	
12	NO.2 BOW THRUSTER		MORE THAN 4.9V	5.06V DC	

NOTE: CONFIRM THAT GENERATOR IS NOT RUNNING.
IF READING IS BELOW 4.9V THAN IT IS RECOMMENDED TO REPLACE THE POWER SOURCE UNIT.

CHECKED BY: E/E NOTED BY: C/E

Case 4: NYK LODESTAR Blackout

1. Symptoms

31st Dec 2004

1. The generator automation suffered a PE-Link failure between SG-DG2.
2. D/G Stand-by indicator on the console (ECR) was off.
3. Replacement of the PE-Link module by a crew resolved the PE-Link failure.

2. Causes

(1) PE-LINK failure

(2) The Stand-by indicator off
This symptom is assumed to be caused by a generator automation communication error between generators and failure in selecting a Stand-by generator.

Finding from the PE-LINK module inspection

(1) From the result of PE-LINK module inspection - PE-LINK failure
a) Poor soldering of a capacitor caused fluctuations of 3.3V power voltage for the PE-Link module control circuit, resulting in unstable operation of internal control Elements (processor bus control LSI)

b) The unstable operation of the LSI produced erroneous data on the communication line (PE-Link).

(2) CENTRAL 1 or 2 received the erroneous data and assumed the bus suffered a short circuit, thus,
a) Provided a trip signal to all generator VCBs (a Blackout occurred), And
b) tripped open all lockout relays of the generator VCBs (lockout relays were all in the TRIP position)

(3) Subsequently the DC24V sequencer power fluctuated causing the PE-Link failure indicator to turn off.

3. Countermeasure

A memory separation capability was added to the communication module in order to prevent erroneous data from being produced. The debugging device proved to be effective in the presence of representatives of the module manufacturer.

9.5 APPENDIX A
INSULATION RESISTANCE TEST OF HV EQUIPMENT

A 5000 Volt DC Megger, Hand cranking or electronic can be used for equipment's up to 6.6 KV.
For routine testing of IR 5000 Volt DC must be applied for 1 minute either by cranking at constant speed with a hand cranking megger or by maintaining a constant 5000 Volt DC continuously by PB in an electronic megger.
Before applying an IR test to HV equipment its power supply must be switched off, isolated, confirmed dead by an approved live-line tester and then earthed for complete safety.
The correct procedure is to connect the IR tester to the circuit under test with the safety earth connection ON. The safety earth may be applied through a switch connection at the supply circuit breaker or by a temporary earth connection local to the test point.
This is to ensure that the operator never touches an unearthed conductor. With the IR tester now connected, the safety earth is disconnected (using an insulated extension tool for the temporary earth).Now the IR test is applied and recorded. The safety earth is now reconnected before the IR tester is disconnected.
This safety routine must be applied for each separate IR test.

9.6 APPENDIX B
MAINTENANCE & INSPECTION CHART

MAKER Ref: TERASAKI ELECTRICAL CO.LTD

9.6.1 Periodical Inspection

It is recommended to carry out periodical inspection on the vacuum circuit breaker each 3 years basically.

No.	Classification	Items	Contents	Basic period
1	Circuit breaker general	General	Record No. of operation. Clean dust, dirt, moisture with dry clean cloth. Check breakdown or damage.	Once every three years
2	Pole unit	Vacuum interrupter	Clean VI with dry clean cloth. The detail is shown in Fig. 21	Once every three years
		Insulating	Clean dust, dirt, moisture with dry clean cloth. The detail is shown in Fig. 21	Once every three years
		Main circuit conductor	Check loose fitting of bolts and nuts.	Once every three years
3	operating mechanism	General	Clean all parts, check loose fitting of bolts and nuts. Check loss or damage of retaining ring and etc.	Once every three years
4	Control device	General	Check rust or loosening of connection at terminal.	Once every three years
5	Operation test	ON/OFF operation	Operata manual and electrically few times each,and check opeartion of oll parts. Check ON/OFF and charge-discharge indicatior.	Once every three years
6	Insulation resistance	Main circuit	Measure insulation resistance with 1000V meggar. If below 500MΩ for phase to phase and phase to earth, clean the surface of VI	Once every three years

6	Insulation resistance	Control circuit	and insulation frame with dry clean cloth. Measure insulation resistance of control circuit to earth with 500V meggar. If below 2M , check rust or loosening of connection at terminal.	

9.6.2 Detail Inspection

Inspect the following items in addition to the periodical inspection every six years.

No.	Classifi-cation	items		Contents	Basic period
1	Pole unit	Contact wear of vacuum inter-rupter	VJ-Z VJ-1 VJ-2S VJ-Z1	Replace Vacuum interrupter when the specific wipe gauge is not able to insert, to the gap specified. Refer to the Fig.20.	Once every six years or 5,000 operations
			VJ-1L VJ-2L	Replace Vacuum interrupter when the lower side of the wear guide line reches the lower flange. Refer to the Fig.20.	
		Vacuum degree		Use vacuum checker or apply AC22kV for 1 minute across the contact. No frashover : good	Once every six years
2	Operating mechanism	Dimensions		Check gap between tripping coil and trip hook and other gaps.	Once every six years
		Springs		Check rust, flaws or deformation.	Once every six years
		Coils		Check continuity and loose terminal.	Once every six years
3	Operation test	Operating character-istics		Confirm no abnormality with manual operation and test with electrical operation. See the criteria below and if execeed the limit, investigate the cause.	Once every six years

Item	Criteria	
Spring charge	MIN. operation voltage	Less than 85%
	Charging time	Less than 10sec
Closing operation	MIN. operation voltage	Less than 75%
	Closing time	Less than 60ms
Opening operation	MIN. operation voltage	Less than 60%
	Opening time	Less than 50ms

9.6.3 Special inspection

This test shall be carried out before detail inspection,when No. of current interruption of vacuum interrupter is reached to the following figure:

No. of interruption	Items
Fault current about 20 times.* Load current about 5000 times. (Lagging small current inclusive)	Check vacuum degree

* Low surge type : 10 times

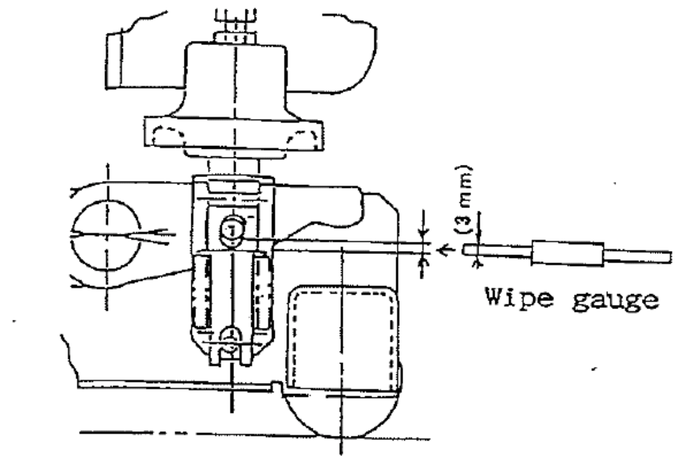
9.6.4. During normal round inspect followings:

It is recommended to inspect the alive vacuum cirucit breaker visually keeping off dangerous zone on each patrol.

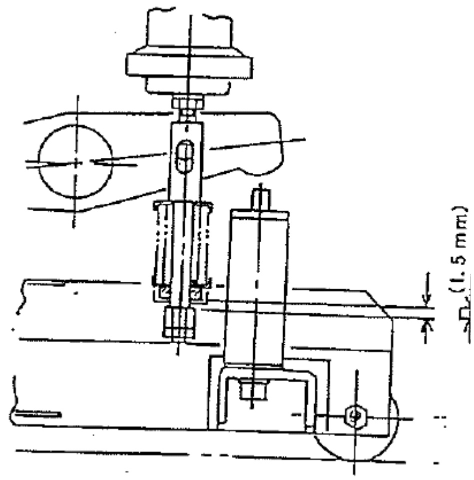
If any abnormality is found,stop operation immediatery and investigate the vacuum circuit breaker .

No.	Item	Contents	Remarks
1	General	Condensation, ingress of dust, rain. Abnormal sound, smell color.	
2	ON/OFF indicator	Normal or not	
3	Charge-Discharge indicator	Normal or not	
4	Operation counter	Check No. of operation	Replace vacuum circuit breaker, if the No. is 10,000 or more.

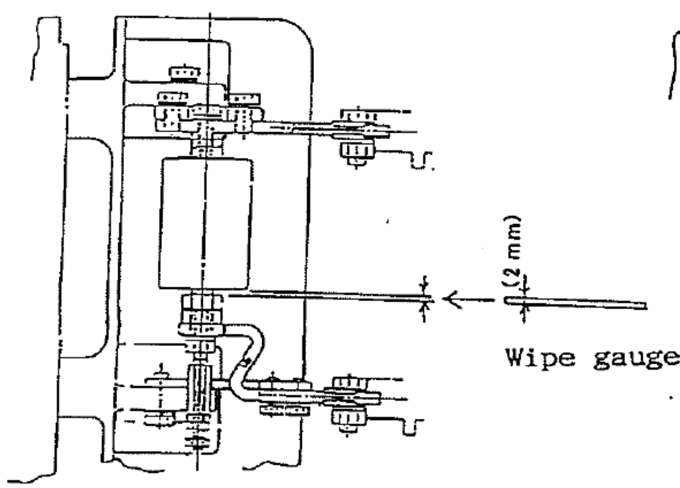
Fig 20 CONTACT WEAR OF VACCUM INTERRUPTER



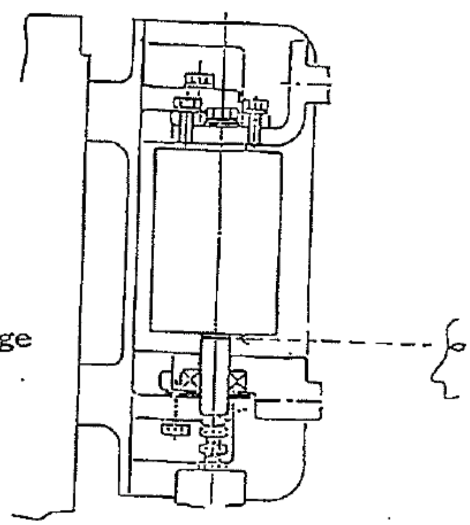
VJ-2S 1200A
Breaker is closed.



VJ-2S 2000A
Breaker is closed.



VJ-ZL
Breaker is closed.



VJ-1L/2L
Breaker is closed.

Fig 21 POLE UNIT