DIRECTORATE GENERAL OF SEA TRANSPORTATION (DGST)
MINISTRY OF TRANSPORTATION
THE REPUBLIC OF INDONESIA

INDONESIA LIGHTNING PROTECTION DESIGN SURVEY FOR VESSEL TRAFFIC SERVICE EQUIPMENT REGARDING TECHNICAL COOPERATION PROJECT ON ENHANCING OF VESSEL TRAFFIC SERVICE SYSTEM MANAGEMENT CAPACITY IN INDONESIA

FINAL REPORT

MARCH 2013

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS CO., LTD. (OC)
JAPAN AIDS TO NAVIGATION ASSOCIATION (JANA)

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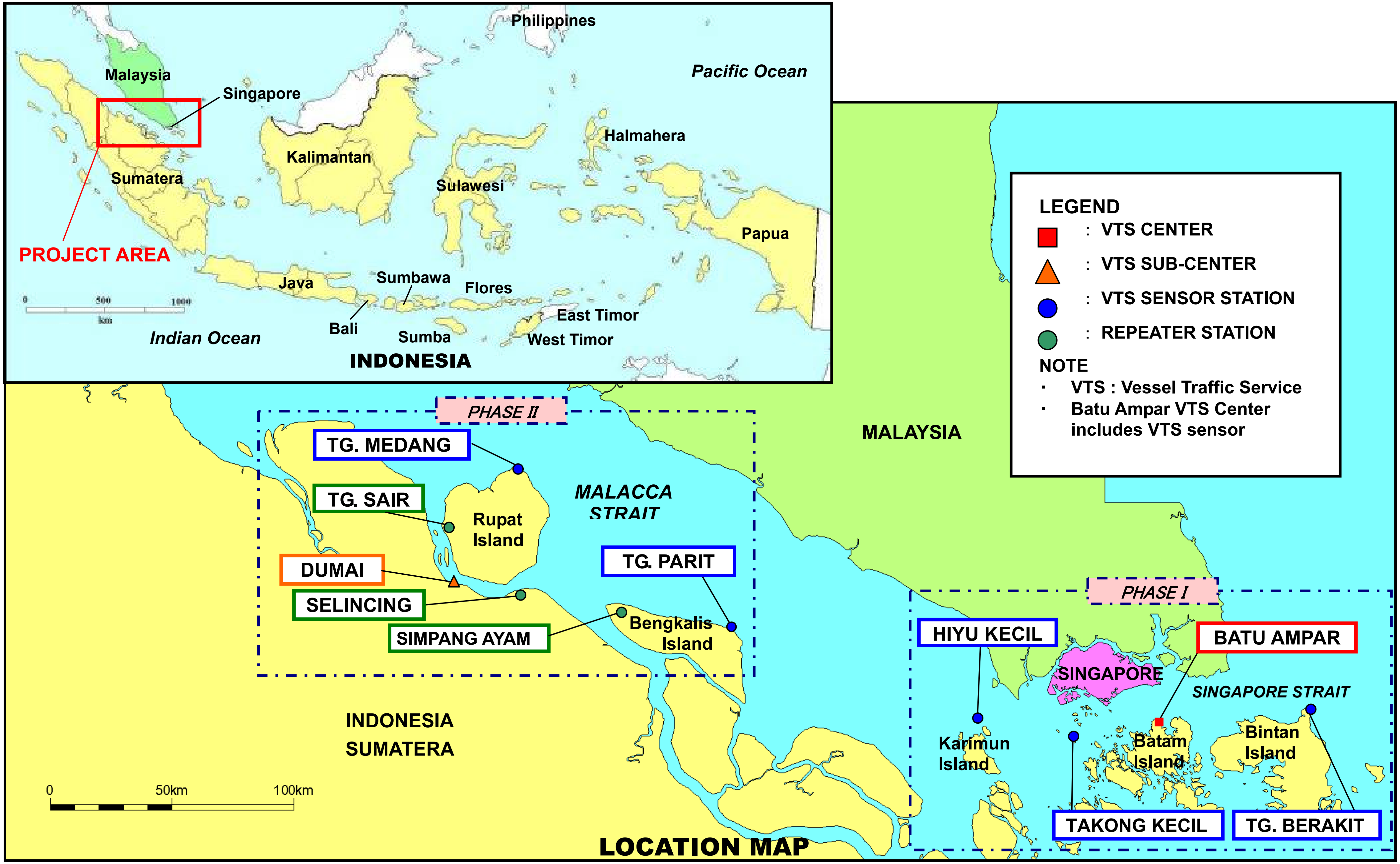


LOCATION MAP

CONTENTS

LIST OF FIGURES AND TABLES

LIST OF PHOTOGRAPHS

ABBREVIATIONS

A	AC	Alternating Current
	AIS	Automatic Identification System
C	CCTV	Closed-circuit Television
D	DC	Direct Current
	DGST	Directorate General of Sea Transportation
G	GMDSS	Global Maritime Distress and Safety System
	GPS	Global Positioning System
H	HF	High Frequency
I	IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
	IDU	In-door Unit
	IEC	International Electrotechnical Commission
	IMO	International Maritime Organization
J	JIS	Japanese Industrial Standards
L	LAN	Local Area Network
	LCD	Liquid Crystal Display
	LED	Light Emitting Diode
M	MCCB	Molded Case Circuit Breaker
	MEH	Marine Electric Highway
	MPA	Maritime Port Authority
	MPU	Micro-Processing Unit
P	PDB	Power Distribution Board
	PLN	PT. Perusahaan Listrik Negara
	PPS	Puls per Second
S	SPD	Surge Protective Device
T	TSS	Trafic Separation Scheme
	TTEG	Tripartite Technical Expert Group
U	UPS	Uninterruptible Power Supply
V	VHF	Very High Frequency
	VTS	Vessel Traffic Service

Chapter 1 Background and Aim of the Survey

1-1 Background and Aim of the Survey

To contribute to vessel traffic safety in the Malacca and Singapore Straits, the Project for Enhancement of Vessel Traffic System in Malacca and Singapore Straits has been conducted through Japan's Grant Aid (hereinafter called "the Grant Aid Project") since 2009. The aim of the Grant Aid Project was to establish a VTS system to be used to monitor small vessels, particularly those crossing the Traffic Separation Scheme (TSS), which pose dangers to the navigation safety of large ships passing along the TSS.

The Grant Aid Project was composed of two (2) phases. Four (4) VTS sensor stations, Hiyu Kecil, Takong Kecil, Batu Ampar and Tg. Berakit, including one (1) VTS Center at Batu Ampar, were established in Phase 1. The Phase 1 Project was completed in March 2011 and the VTS system commenced operations.

However, at three (3) VTS sensor stations, among the established four (4) stations, main equipment was damaged and function improperly due to lightning, which frequently strikes the surrounding area of Indonesia. The Directorate General of Sea Transportation (DGST), who is the operating agency, surveyed the damaged conditions and attempted to perform restoration works; however, the VTS system problems were not completely fixed. Hence, some of the VTS functions are not working properly at present.

Enhancements of the VTS operation environment of Indonesia are one of the important tasks to contribute to vessel navigation safety in the Malacca and Singapore Straits. Normal operations of the VTS system are an indispensable matter to achieve Project objectives and contribute to the safety of navigation in the Straits. In this regard, the Survey for recovery and improvement of the VTS system, which was established in the Grant Aid Project, Phase 1, is to be conducted.

1-2 Objectives

1-2-1 Survey Locations

The Survey locations are the three (3) VTS sensor stations at Hiyu Kecil, Takong Kecil and Tg. Berakit, which were damaged by lightning, and Batu Ampar VTS Center. The locations are indicated in Figure 1-1.

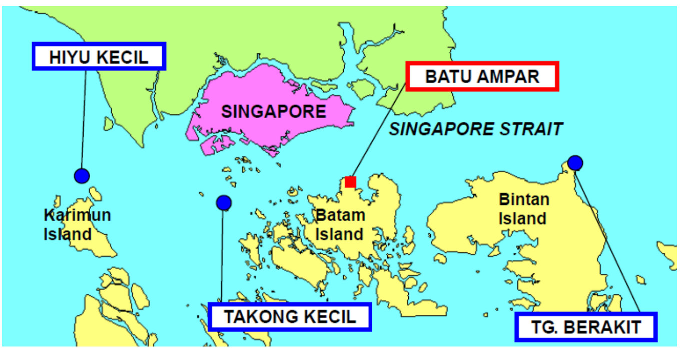


Figure 1-1 Survey Locations

1-2-2 Survey Scope

Survey scope is as follows:

- Survey of damaged conditions of the VTS equipment and system
- Available data collection of natural conditions (topography and meteorological), frequency of lightning, lightning conditions of surrounding area of the site
- Survey for availability of insurance against lightning damage
- To collect any other related information

1-3 Present Conditions of Each Site

(1) Overviews

VTS equipment is not in a normal state due to troubles. It was observed that these troubles have been caused not only by lightning, but also by the lack of tuning during periodical equipment maintenance. However, the cleaning of the VTS equipment was properly conducted and the VTS was operating under the limited conditions. According to these circumstances, the equipment and system may be normalized by repairing the damaged parts as necessary.

Outlines of equipment damage due to lightning are as follows. Further details will be described in "2-1-1 Present Conditions due to Lightning Damage" in Chapter 2.

(2) Batu Ampar VTS Center

During the Survey, DGST informed the Survey Team that automatic switching devices between the PLN and backup generator were damaged due to lightning that occurred at the end of November 2012.

Based on the Survey, it was found that the automatic switch did not function after the lightning, but on the other hand, VTS equipment was not damaged.

DGST requested the Survey Team to include the repair of the damage in Batu Ampar VTS Center although this was not included in the original request.

(3) Tanjung Berakit

The radar system, AIS base station equipment, meteorological observation devices and air conditioner were damaged by lightning.

(4) Hiyu Kecil

The radar system, AIS base station equipment, meteorological observation devices, UPS system, multiplex communication devices, air conditioner, aviation obstruction lights and fuel supply pump system were damaged by lightning. Burning in the equipment rack was also found.

(5) Takong Kecil

Damage was found in the radar system, CCTV camera system and air conditioner.

1-4 Other Latest Information

Although not related to the scope of this work, the following latest conditions were observed in this Survey.

(1) Marine Electronic Highway (MEH) Project

The MEH Project office was established by modifying the existing office building of the Navigation District in Batu Ampar. Navigation safety information, such as tides, currents, air temperature, and other AIS information are provided through the website by the Project.

(2) VTS System Improvement

The following improvement works are conducted by DGST under their own effort.

1) VHF radio communication equipment

New VHF radio communication equipment was purchased and installed on the 3rd floor of the VTS Center building. This function and operation was moved from the former old building to the 3rd floor of the VTS Center building.

2) Data transmission from Batu Ampar VTS Center to DGST Jakarta

Additional router installation work was under progress for data transmission from the VTS Server in Batu Ampar to the DGST Jakarta office through Internet transmission lines.

3) Improvement of VHF performance of VTS system

One VHF radio receiver was installed to cover the existing non-communicable VHF area near Takong Kecil.

4) Surveillance system and additional CCTV camera in Batu Ampar

One (1) additional CCTV camera was installed at the top of the steel tower in the Batu Ampar VTS Center. CCD cameras for surveillance in the VTS Center and a monitoring system were additionally established at the Batu Ampar VTS Center.

Chapter 2 Survey Results

2-1 Survey Results of Lightning Damage at Four (4) Sites

2-1-1 Present Conditions due to Lightning Damage

(1) Conditions when the lightning happened

According to interviews with the staff and officers of DGST, Navigation District in Tg. Pinang and other sites, the conditions when the lightning strikes occurred were clarified.

1) Batu Ampar

Date and Time of Lightning Occurrence: at 15:00 on November 21, 2012

After the lightning, automatic switching between commercial power (PLN) and the backup generator did not function because the switching control unit was damaged. In addition, lamps in the MEH office and the garden in front of the office were blown out by the strike.

2) Tanjung Berakit

Date and Time of Lightning Occurrence: at 13:00 on April 26, 2012

The radar interface was damaged at about 13:00 on April 26, 2012. Simultaneously, VTS functions terminated immediately after the lightning strikes with a loud explosion.

3) Takong Kecil

Date and Time of Lightning Occurrence: at 23:55 on March 30, 2012

The thunderstorm on March 30 was recorded by the CCTV camera system. Several flashes of lightning were recorded from about 23:00. The system devices may have been damaged by the lightning at 23:55 since the CCTV camera recording stopped at this time.

Date and Time of Lightning Occurrence: at 01:00 on April 25, 2012

A lighthouse keeper at Takong Kecil witnessed that a thunderbolt occurred about 01:00 a.m. on April 25, 2012 and radar scanner rotations were stopped by this event.

4) Hiyu Kecil

Date and Time of Lightning Occurrence: about 00:30 on May 24, 2011

A thunderbolt may have occurred at 0:30 a.m. since meteorological sensor function was terminated at this time.

Date and Time of Lightning Occurrence: June 9, 2011, No information on time

Thunderbolts occurred several times that day and a person testified that spark runs were seen on the rocky ground when the thunderbolt struck. On the same day, a power cable was connected between the generator house and residence for the lighthouse keeper and power was supplied. It was observed that a socket was unplugged immediately after the thunder and lightning was seen; however, after the thunderbolt struck, the socket was burned out. Furthermore, the television and lamps in the house were also burned black.

Date and Time of Lightning Occurrence: June 15, 2011, before dawn (daybreak)

Details have not been clarified since the lightning occurred in the middle of the night.

(2) Outline of the Lightning Damage of the Equipment

Equipment damage due to lightning is similar at three (3) sensor stations except Batu Ampar VTS Center. The radar system, which is a major device of the sensor stations, did not function due to i) stoppage of the radar antenna scanner at the top of the steel tower, ii) trouble of both of main and sub radar TRX, iii) damage of circuit boards inside of the terminal box and iv) termination of the radar signal processor (RSP). These troubles are found similarly at three (3) sensor stations.

The radar system is composed of radar antennae, radar TRX, radar processors and other parts and functions through data communications among these components. The radar system trouble is caused by damage to a part of the circuit for data communications due to lightning.

Main damage of the equipment at each VTS Sensor Station is as summarized in Table 2-1.

Table 2-1 VTS Equipment Damage at Each Site

Equipment	Station Name （ — : Not Equipped）		
	Hiyu Kecil	Takong Kecil	Tg. Berakit
1. Radar Antenna			
1.1 Radar Scanner	Did not rotate	ditto	ditto
1.2 Performance Monitor	Fused of circuit board	ditto	ditto
1.3 Radar TRX	Did not function	ditto	ditto
1.4 Terminal Box	No signal out	ditto	ditto
1.5 Radar Signal Processor（RSP）	No data communication among components	ditto	ditto
2. AIS Base Station	No.1 PPS not functioned	———	No.1& 2 PPS not functioning
3. VHF Radio Communication System	Normal	———	Normal
4. Meteorological Observation System			
4.1 Data Logger	LCD invalid indication	———	LCD invalid indication
4.2 Barometer	Did not function	———	Normal indication of LCD
5. CCTV Camera (Camera Body & Housing)	———	Did not function	———
6. Equipment Rack	Trace of electrical discharge	No trace of electrical discharge	No trace of electrical discharge
7. UPS Device (Warning Indicator)	Abnormal noise (Relay)	Normal	Restored by reset
8. Multiplex Radio Communication Link	Abnormal noise	Normal	Normal
9. Air Conditioner	Cannot operate (No.1)	Cannot switch on (No.2)	Cannot operate (No.1)
10. Aviation Obstacle Light	Cannot switch on	Normal	Normal
11. Fuel Pump System	Damaged pump power source	Normal	————————

(3) Outline of Each Equipment Damage

1) Radar system

Radar antennas did not rotate due to damage of the circuit board for data transmission for operation. Termination of the radar system is due to MPU board damage on a part of the interface inside of the radar signal processor and circuit board for main control. In this regard, the ANT-OPT TX (Antenna Optical Transmitter) in the antenna, the ANT-OPT RX (Antenna Optical Receiver) in the terminal box, and the T/R CONT (Transmitter/Receiver Control) unit in the transmitter and receiver have also been damaged.

Device damage in the circuit board of the performance monitor was found in all stations except Batu Ampar VTS Center.

The radar system did not function because data communication through the radar interface among the radar system components is not possible. Therefore, these components were damaged by lightning surges.

2) AIS Base Station

AIS Base Station devices are the equipped two (2) units in Hiyu Kecil and Takong Kecil. PPS (time signal) receiving errors occurred in No. 1 equipment in Hiyu Kecil and both Nos. 1 and 2 equipment of Takong Kecil. It was clarified that this error is due to lightning damage of the receiver in the GPS antenna installed at the middle of the steel tower.

3) VHF Radio Communication System

A VHF system is installed at Hiyu Kecil and Takong Kecil. The system is functioning normally and no damage has been found at either site.

4) Meteorological Observation System

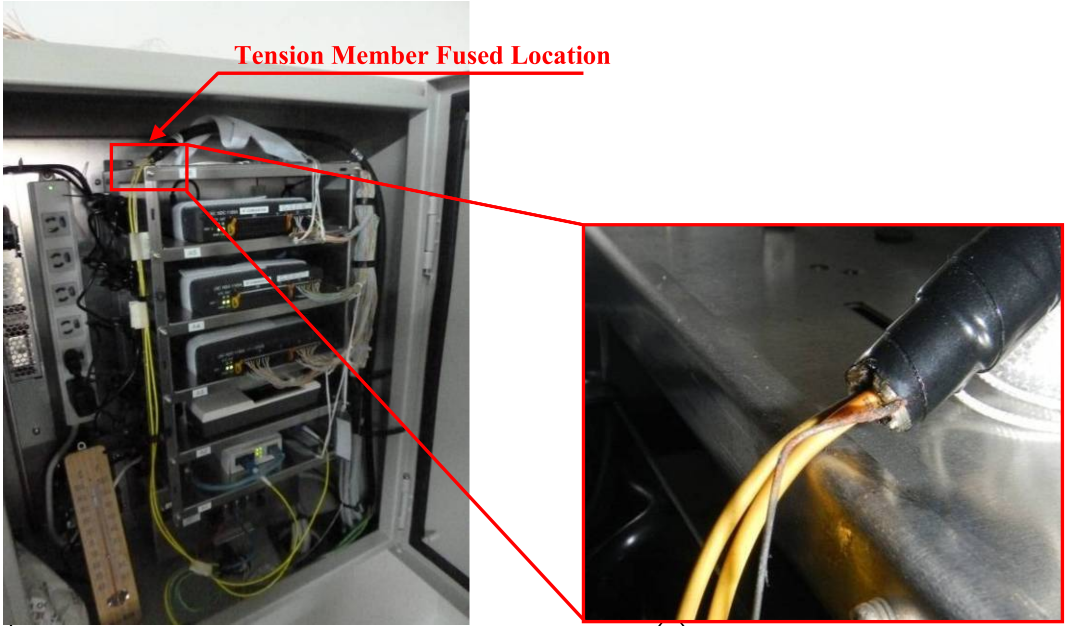
The system is installed at two (2) stations in Hiyu Kecil and Tg. Berakit. Indicators of the LCD panels and network communications are damaged. The barometer of the system did not function at Hiyu Kecil station.

5) CCTV Camera

LED LAN indicators at the camera interface did not turn on. The CCTV camera body, pan and tilt functions of the housing and web encoders are damaged due to invasion of lightning surges.

6) Electrical Discharges in Equipment Rack

In Hiyu Kecil, the tension members of optical cables connected between the rack in the equipment building and the generator house are fused. Evidence of sparks was found at the cable fixing plate and the LAN cable beside the optical cables. The sparks may have occurred due to lightning surge invasion through tension members of the optical cable when the lightning strikes hit the steel tower. The fused conditions are as shown in Photo 2-1.



(1) Equipment Rack in Hiyu Kecil **(2) Fused Obtical Fiber Cable**

Photo 2-1 Fused Condition of Optical Fiber Cable in Equipment Rack in Hiyu Kecil

7) UPS System

Inverter stoppage, voltage reduction and over-current alarm indications were found at Tg. Berakit. These troubles were fixed by resetting the electrical power supply.

Due to invasion of lightning surges, the lead relay on UPS control board is repeatedly going on and off periodically on about a 0.5 second cycle.

On the other hand, no damage was found in Takong Kecil.

8) Multiplex Communication Devices

An oscillated sound (electronic alarm) induced by IDU in Hiyu Kecil was observed. By the remote operation test controlled from Batu Ampar VTS Center, it was confirmed that the data transmission is normal; however, other parts are damaged due to lightning. No damage or troubles were found in other sites.

9) Air Conditioner

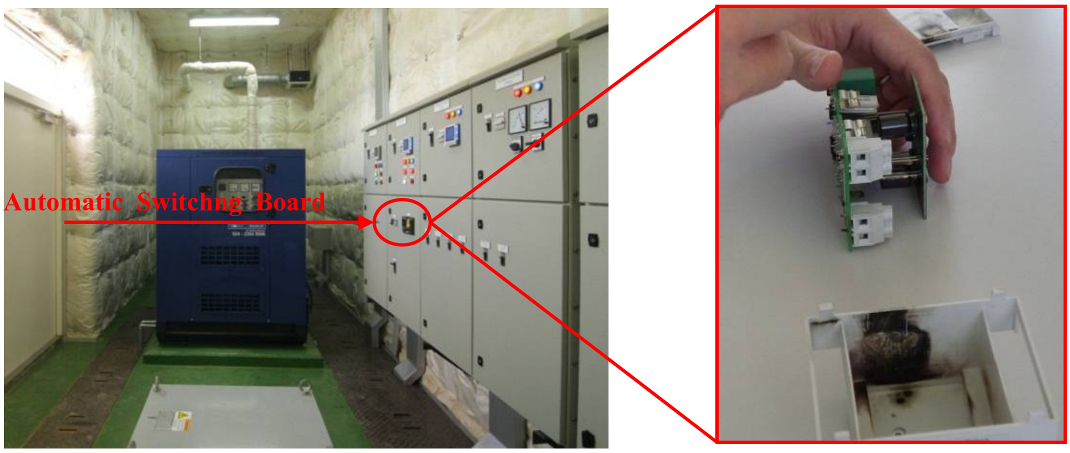
One (1) of two (2) of the air conditioning units cannot be switched on at all sites.

10) Aviation Obstruction Lights

Due to damage of the switching device (MCCB), the obstruction light cannot be switched on at Hiyu Kecil. This trouble was induced by an invasion of the lightning surges to the power supply devices. There are no troubles at other sites.

(4) Damage in Batu Ampar VTS Center

Damage by the lightning that occurred in November 2012 is concentrated in the power supply system. Photo 2-2 (2) shows damage of a control device for an automatic switcher between commercial power supply and emergency power supply that was installed on the control panel as shown in Photo 2-2 (1). On the other hand, there is no damage on the radar system and other communication systems.



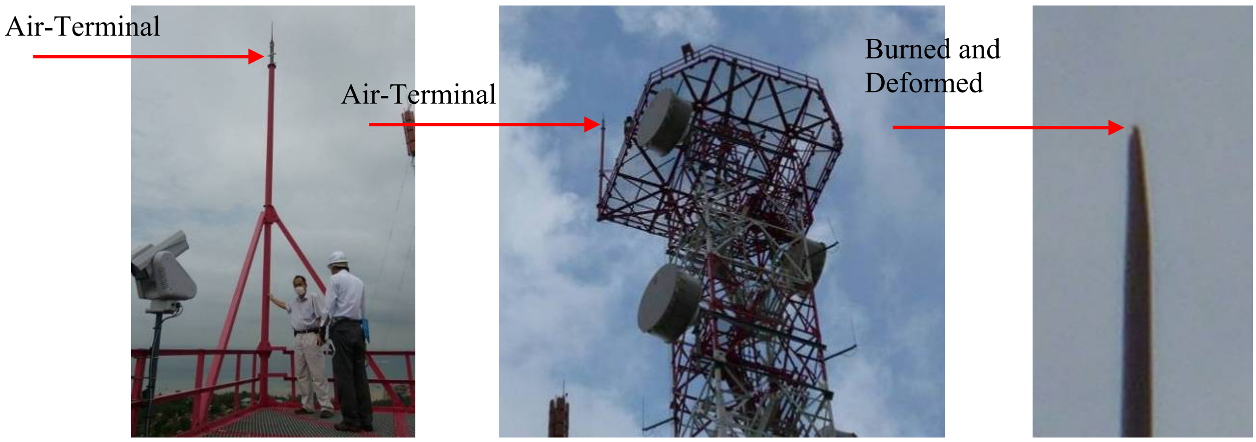
(1) Switching Panel in VTS Center **(2) Fused Switching Board**

Photo 2-2 Fused Condition of Switching Board in Batu Ampar VTS Center

2-1-2 Conditions of Existing Lightning Projection System

(1) Air-termination System (Lightning Rod)

An air-termination system at VTS Center and each sensor station is installed at the top of the steel tower with a protection angle of 60 degrees based on JIS A4201 (1992). The air-terminal installed conditions at Batu Ampar VTS Center are as shown in Photo 2-3. Other stations have the same conditions. It was surmised that direct lightning to the air terminal might have occured because deformation and burned trace were found at the top of the air terminal as shown in Photo 2-3 (3).



(1) Overall View **(2) Air Terminal** **(3) Toe Condition**

Photo 2-3 Present Conditions of Air-Termination System

(2) Down-conductor and Earth-termination System

One (1) down-conductor is installed. It is connected to the air-termination system by copper wire and bonded at the leg of the steel tower near the concrete foundation. Earth terminals are provided at two (2) legs near the foundation and one of them is bonded with a down-conductor. Conditions of earth termination are as shown in Photo 2-4.

(1) Hiyu Kecil

(2) Tanjung Berakit

Photo 2-4 Present Conditions of Down-Conductor

In Hiyu Kecil, measures were conducted on trial by DGST after the damage in May 2011. Earth terminations were installed at four (4) legs as shown in Photo 2-5 by adding two (2) legs.

(1) Earth Terminal at Steel Tower Leg

(2) Earth Terminal at Steel Tower Leg

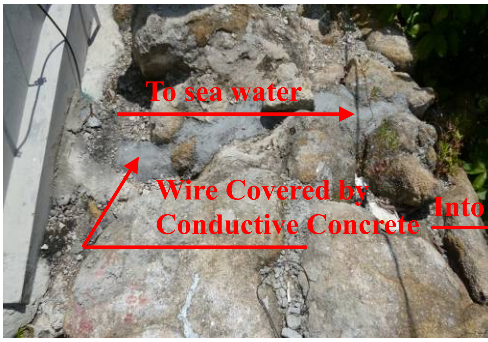
Photo 2-5 Present Conditions of Earth Terminals in Hiyu Kecil

(3) Earth-termination System

1) Present Conditions

A radar wave guide and control cables, which lead into the equipment building from the outside, are connected to earth terminals inside of the building. These terminals are connected to the earth electrodes of the steel tower, generator building and the equipment building.

In Hiyu Kecil, ring earth electrodes were adapted for the generator house, equipment building and the steel tower considering the rocky ground conditions. Since these electrodes (wires) cannot be installed underground due to the rocky ground surface, they are to be covered by conductive concrete as shown as Photo 2-6.



(1) Covered Concrete **(2) Wiring Conditions** **(3) Earth Terminal**

Photo 2-6 Present Conditions of Underwater Earth Electrode in Hiyu Kecil

Soon after the construction of the facilities (before lightning damage), earth terminals were connected with other conductive wires and the end of the wire (earth electrode) was earthed into soils near shore. Earth resistance was 2.8 ohms, which is lower than the 5 ohms of the technical specifications and lower than 10 ohms as specified by JIS A4201 (1992), immediately after the construction works were completed.

After lightning damage in May 2011, terminal wire extension into seawater and two (2) additional extended earth terminals installations were conducted on trial by DGST. The present conditions of the underwater earth electrodes are shown in Photo 2-6.

2) Earth Resistance

Earth resistances were measured at all sites as shown in Photo 2-7. The results are as shown in Table 2-2 below.

(1) Earth Tester **(2) Earth Rod**

Photo 2-7 Measurement of Earth Resistance

Table 2-2 Earth Resistance at Each Site

Site	Batu Ampar	Tg. Berakit	Hiyu Kecil	Takong Kecil
Earth Resistance (Ω)	2.30	4.20	0.26	0.54

According to the requirements of JIS A4201 (1992), earth resistance shall be lower than 10 ohms. The requirement of the Technical Specifications of the Phase 1 Project was the resistance shall be less than 5 ohms.

Earth resistances are lower than 5 ohms and the above requirements are satisfied at all sites. In conclusion, earth-termination system and earth resistance are in good condition at all sites.

3) Ground Resistivity Testing

Ground resistivity testing was performed by the Wenner 4-Pin method. Test results are as shown in Table 2-3 to Table 2-5. Ground resistivities are appropriate values in Batu Ampar, Tangjung Berakit and Takong Kecil.

At Hiyu Kecil, the gournd resistivity testing could not be conducted because sufficient test space could not be reserved due to the narrow, steep and rocky ground state of the site.

Table 2-3 Ground Resistivity at Batu Ampar

Date of Measurement	09 December 2012			Name	Sankosha Corp.
Measurement location	BATU AMPAR			Weather	Fine
4-Point Electrode Method by Wenner			Input	Yokogawa TYPE-3244	
spacing(Depth)	Distance from G-Point		Soil	soil	Remark
	P-point	C-point	Resistance	Resistivity	
(m) 0.5	0.25	0.75	44	138.2	
1	0.5	1.5	37	232.5	
2	1	3	33	414.7	
3	1.5	4.5	17.8	335.5	
5	2.5	7.5	10.9	342.4	
7	3.5	10.5	7.6	334.3	
10	5	15	5	314.2	
15	7.5	22.5	2.5	235.6	
20	10	30	1.62	203.6	
30	15	45	–	–	
40	20	60	–	–	
50	25	75	–	–	
60	30	90	–	–	
70	35	105	–	–	
80	40	120	–	–	
90	45	135	–	–	
100	50	150	–	–	

REMARKS

Draw a Rough Map

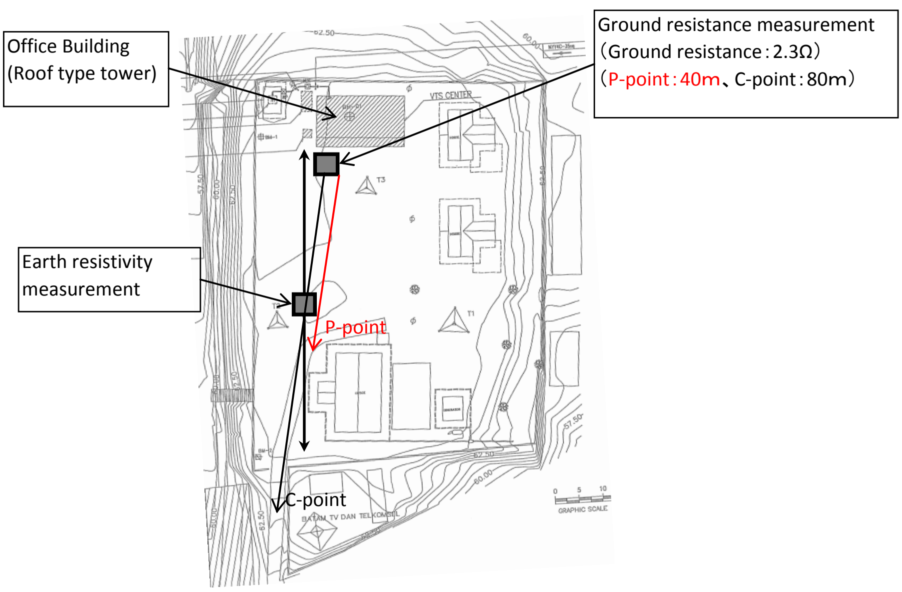


Table 2-4 Ground Resistivity at Tanjung Berakit

Date of Measurement	08 December 2012			Name	Sankosha Corp.
Measurement location	TANJUNG BERAKIT			Weather	Fine
4-Point Electrode Method by Wenner			Input	Yokogawa TYPE-3244	
spacing(Depth)	Distance from G-Point		Soil	soil	Remark
	P-point	C-point	Resistance	Resistivity	
(m) 0.5	0.25	0.75	70	219.9	
1	0.5	1.5	39	245.0	
2	1	3	17.9	224.9	
3	1.5	4.5	10.5	197.9	
5	2.5	7.5	6.4	201.1	
7	3.5	10.5	5.2	228.7	
10	5	15	4.3	270.2	
15	7.5	22.5	3.3	311.0	
20	10	30	3	377.0	
30	15	45	2.24	422.2	
40	20	60	–	–	
50	25	75	–	–	
60	30	90	–	–	
70	35	105	–	–	
80	40	120	–	–	
90	45	135	–	–	
100	50	150	–	–	

REMARKS

Draw a Rough Map

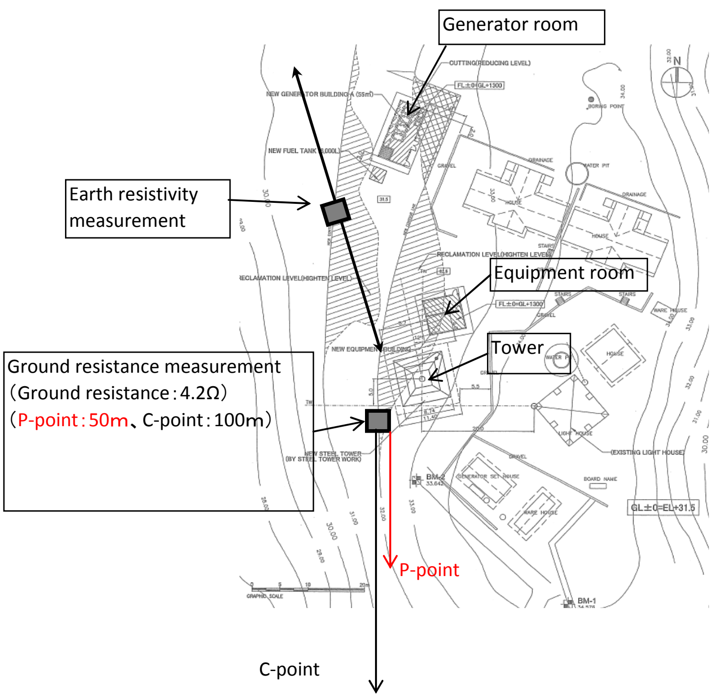
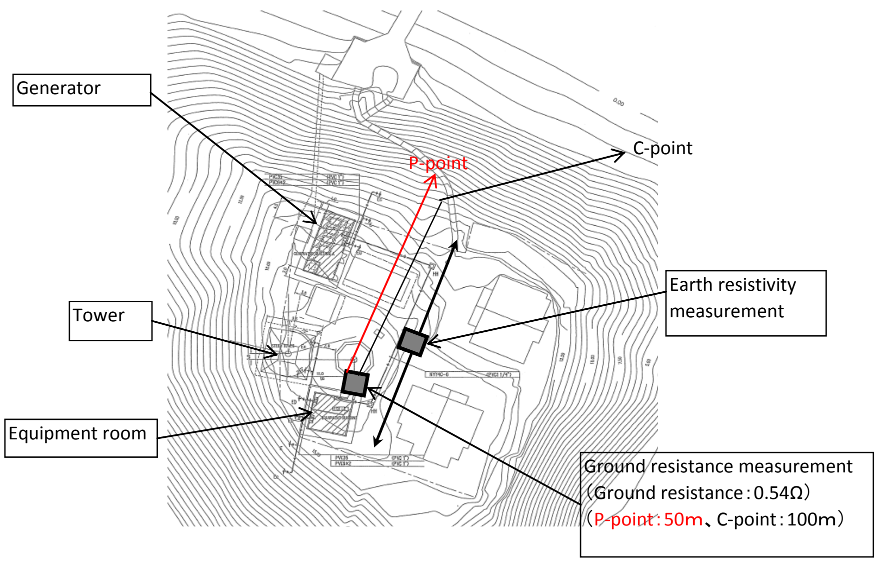


Table 2-5 Ground Resistivity at Takong Kecil

Date of Measurement	12 December 2012		Name	Sankosha Corp.	
Measurement location	TAKONG KECIL		Weather	Fine	
4-Point Electrode Method by Wenner			Input Soil Resistance	Yokogawa TYPE-3244	
spacing(Depth)	Distance from G-Point			soil Resistivity	Remark
	P-point	C-point			
(m) 0.5	0.25	0.75	127	399.0	
1	0.5	1.5	55	345.6	
2	1	3	16	201.1	
3	1.5	4.5	9.2	173.4	
5	2.5	7.5	3.7	116.2	
7	3.5	10.5	1.69	74.3	
10	5	15	0.62	39.0	
15	7.5	22.5	0.26	24.5	
20	10	30	0.18	22.6	
30	15	45	–	–	
40	20	60	–	–	
50	25	75	–	–	
60	30	90	–	–	
70	35	105	–	–	
80	40	120	–	–	
90	45	135	–	–	
100	50	150	–	–	

REMARKS

Draw a Rough Map



(4) Lightning Protection Measures by Equipment

It was confirmed that the following measures have been taken inside of the equipment.

1) Surge protection devices (SPD) installations

Surge protection devices (SPD) are installed at the necessary position for protection against lightning strikes.

2) Isolation transformer installation

An isolation transformer was installed at the cable between the motor for radar scanner circulation (AC220V, 50/60Hz, 3 Phase) at the top of the steel tower and power supply devices in the equipment room to protect against the invasion of lightning surges.

3) Applying the optical cables

To avoid lightning surge invasion, optical cables are used for some of the signal transmissions instead of metal wire cables.

2-1-3 Cause of Lightning Damage at Each Site

Based on the field survey results, cause of lightning damages can be considered as follows.

(1) Batu Amar VTS Center

Damage at Batu Ampar VTS Center was found only in the power distribution devices while no damage was found in VTS equipment. According to the field survey, direct lightning might have struck the air terminal since there was deformation and burned traces were found its top. However, because of the equipment's condition, the cause of damage may not be due to direct lightning that might have hit the tower and/or the VTS Center building. Lightning surges induced by lightning near the site may invade through public power transmission cables to the building.

(2) Tg. Berakit, Hiyu Kecil and Takong Kecil

The circuit board inside the radar equipment installed at the top of the tower and other VTS system devices were damaged. According to these circumstances, it can be judged that the tower may have been directly struck by lightning. Lightning surges due to the direct lightning may have invaded the electronic devices inside the building through the metal lines that connect radar equipment at the top of the tower and equipment devices inside the equipment room of the building.

Equipment installed at the steel tower's top was not damaged when lightning struck. Therefore, it can be said that the equipment is protected from direct lightning by the air terminal.

2-2 Lightning Damage and Measures to be taken at the Surrounding Area of the Site

2-2-1 Coastal Radio Stations near the Site Managed by the Navigation District

No statistical records or systematical reports were found. According to an interview with the staff at the site and the navigation district, the following general information was obtained.

1) The rainy season is from November to February but occasionally (some years), it is from October to April.

2) Lightning occurs almost every day in the rainy season.

3) Lightning strikes occur two (2) to three (3) times per month in the rainy season.

4) Number of occurrences of lightning is about 120 to 130 days per year.

2-2-2 Conditions of Private Companies and other Organizations

An interview was done with the private companies in Batam Island including Malacca Strait Council, who have conducted maintenance of navigation aids in the Malacca and Singapore Strait areas for many years, and MPA Singapore, who has and manages their own VTS equipment. The frequency of lightning occurrences, conditions of damage and other related information was surveyed.

(1) Private company near the site (Batam TV)

There are several steel towers near Batu Ampar VTS Center. Among these, there are two (2) towers owned and managed by Batam TV. The tower heights are 70 m and 80 m. The towers are owned by the TV company; however, other TV companies and telecommunication companies such as Media Link, ANTV, TV1, Telekomsel, Smart Friend, etc. use these towers on a contract basis for data communication.

According to the interview with the site officer who maintains the tower, the following information was obtained.

(1)：Steel Towers near VTS Center

(2)：Steel Towers beside VTS Center

Photo 2-8 Steel Towers in the Surrounding Area of VTS Center

1) The 70 m steel tower is owned by Batam TV and is used for local TV broadcasting, internet and cellular phone communications.

2) According to the current experiences on damage and troubles due to lightning strikes, if a thundercloud is observed, the power supply for broadcasting is shut off manually to protect the devices. In general, broadcasting is terminated for about two (2) hours about six (6) times per month during the rainy season.

3) The power panel box on the wall was blown about 5 m away from the original position due to a lightning strike in 2009.

4) Circuit boards for broadcasting devices are damaged by lightning three (3) to four (4) times

per month. The damaged parts are replaced with spares every time.

(2) Malacca Strait Council

The following information was obtained by an interview survey.

1) Hiyu Kecil and other lighthouses in Malacca and Singapore Straits are damaged by lightning one (1) to two (2) times per year. In cases where annual lightning was rather frequent, the damage occured more than two (2) times.

2) Lightning damage of the lighthouses near the steel towers that were constructed by this project seem to have decreased after the construction of the towers.

3) Examples of damage include burning out of the condenser of the breaker of the electrical power supply, the voltage regulator of power generator and control devices of LED lights.

4) There has been lightning damage to the floating beacon in Malaysia.

5) Arresting equipment, which is made by ERICO, is used for lighthouses in Malaysia as shown in Photo 2-9.

6) VTS equipment maintenance is conducted by private companies under a contract basis in Malaysia. If the VTS system has some trouble, the functions shall be recovered in the specified period, which was agreed and stated in the contract.

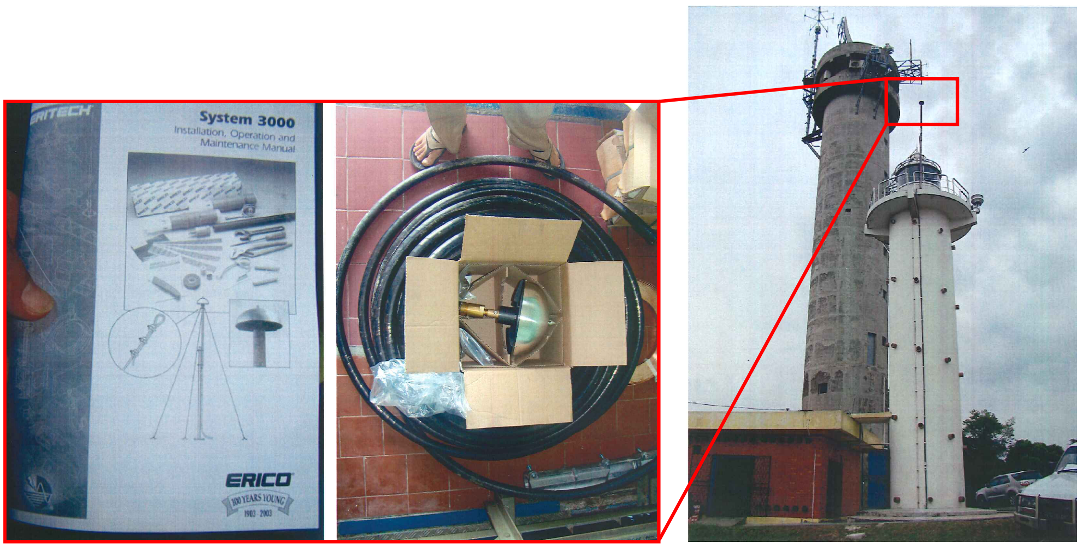


Photo 2-9 Arresting Equipment made by ERICO Adopted in Malaysia

(3) MPA Singapore

The following information was obtained by an interview with the officers in MPA Singapore.

1) MPA Singapore has a VTS system that is under operation in the port area. Damage by lightning has occurred in recent years resulting in small problems.

2) Main problems are lightning surges through the electrical power supply, Internet connections and other communication devices. There has been no damage by direct lightning strikes.

3) Maintenance of the arrester system is periodically conducted every year.

4) An annual budget is reserved for maintenance including lightning damage; however, the amount only for lightning is not clear.

5) Lightning damage is mostly due to lightning surges so SPDs are installed at connecting points.

6) A dissipation array system (made by Hitachi) was introduced in 2005. Since the introduction, lightning strikes have not occurred.

7) A combination of a dissipation array system, mesh earthing and SPD is important against lightning damage. At present, minimizing damage by lightning is the result of trial and error.

8) Earth resistance is generally regulated at smaller than 10 ohms; however, it is maintained at lower than 1 ohm in MPA facilities.

9) An underwater grounding system has not been adopted in MPA.

10) If there are any requests by the Indonesian side, it is possible to explain the measures against lightning taken in MPA at any time.

Photo 2-10 Dissipation Array System (made by Hitachi) used in MPA Singapore

2-3 Operation and Maintenance of VTS Equipment

According to the present conditions of operation and maintenance of the VTS system at the site, after lightning damage occured, cleaning of the equipment was properly conducted; however, unfortunately, the system has not been restored yet. Therefore, limited operations using the remaining functions of VTS are still continuing now. From a navigation safety point of view, it is desired that the VTS system will be normalized as soon as practical. Considering this, the following matters are some considerations to avoid similar conditions in the future.

<u>Financial matters:</u> In general, for restoration works of the system, budget allocations are necessary. If the equipment is damaged by natural disasers or other incidental reasons, restoration funds may be required suddenly and immediately; however, obtaining supplementary budget and/or provisional budget allocation takes time and is sometimes rather difficult. Resultantly, if a problem such as one where the VTS system cannot be fixed immediately or appropriately occurs, proper VTS operation may not be available for quite a long period. It may be one of the options that the necessary funds for restoration works due to natural disasters be covered by insurance as presented in Section 2-4.

Operation: Because operation works are a higly specialized job, obtaining the required and sufficient number of exclusive staff for operation is necessary. In addition to this, it may be effective that these personnel be organized for VTS operation work exclusively, and their assignment should be long term and include periodic training.

Maintenance: There is an option that VTS equipment maintenance be conducted by a private company under a contract basis. As an example, in Malaysia, if the VTS system has some trouble, the functions must be recovered within a specified period that was agreed on and stated in the contract.

2-4 Insurance

(1) Background

VTS system troubles due to lightning and other natural disasters are not 100% preventable and the occurrence of these troubles cannot be expected. From the safety navigation point of view, immediate repair and/or recovery of such troubles are necessary and to do this, it is necessary to prepare sufficient funds.

Such funds may be required suddenly and immediately; however, obtaining a supplementary budget and/or provisional budget allocation takes time and is sometimes rather difficult. Resultantly, if a problem such as one where the VTS system cannot be fixed immediately or appropriately occurs, proper VTS operation may not be available for quite a long period.

As an option, if the required cost for restoration works can be covered by insurance, the above-mentioned problem may be avoided. Considering this, the availability of insurance schemes was surveyed.

(2) Survey method

The availability of insurance was surveyed by interviews over telephone and/or e-mail to insurance companies. Since insurance by overseas companies against properties in Indonesia such as buildings and equipment is prohibited by Indonesian law, a list of insurance companies that have obtained a license from the Government of Indonesia was made for the survey works. During the survey, survey team members visited some insurance companies to collect information as necessary. The questionnaires to the insurance companies included the following.

Assets to be insured	:	VTS System (vessel monitoring system for the vessels passing through the Malacca and Singapore Straits)
Risk Location	:	Batu Ampar, Hiyu Kecil, Takong Kecil and Tanjung Berakit
The Insured	:	Directorate General of Sea Transportation
Interest Insured	:	1) VTS Equipment: about Rp. 40,000,000,000 2) Building Facilities: about Rp. 40,000,000,000
Purpose	:	Repair and/or recovery cost to be covered by the insurance when the VTS equipment and building facilities are damaged due to lightning.

(3) Survey results

Through the survey, the availability of insurance such as fire insurance, all risks insurance, electronic equipment insurance and others was clarified. The assets of the VTS system (equipment and buildings) can be covered by these insurance schemes.

The survey results are summarized in the following table. The table presents the surveyed insurance companies, their reply, and their availability to insure the VTS system assets.

Table 2-6 Insurance Companies and Availability of Insurance

No.	Company Name	Answer	Insurance	Remarks
1	PT. Asuransi Tokio Marine Indonesia	Yes	N/A	
2	PT. Tugu Pratama Indonesia	Yes	N/A	
3	PT. Asuransi Jasa Indonesia (Persero) (Asuransi Jasindo)	Yes		Pending*
4	PT. Asuransi MSIG Indonesia	Yes		Pending*
5	PT. Asuransi Allianz Utama Indonesia	Yes	Available	
6	PT. Asuransi Axa Indonesia	Yes	N/A	
7	PT. Asuransi Wahana Tata	Yes	Available	
8	PT. Asuransi Umum Bumiputera Muda 1967	Yes	Available	
9	PT. Toyota Tsusho Insurance Broker Indonesia	Yes	Available	

- PT. Asuransi Jasa Indonesia (Persero) and PT. Asuransi MSIG Indonesia requested further detailed cost information about equipment. Based on the considerations that although detailed information about the equipment was not disclosed and effective answers were obtained by other companies, the survey team did not disclose such information. Therefore, final answers were not received.

(4) Insurance schemes to insure the VTS System

According to the survey, the following insurance schemes are able to insure the VTS system against lightning damage risks. As shown in the following table, the premium is about 0.1% to 0.3% of the total assets (sum of insured).

Insurance survey was included in this study for purposes of examining the availability and possibility of insurance coverage for lightning damage risks, and to collect and present general information on insurers. Information provided by the insurance companies that participated in the survey are presented in Table 2-7.

If DGST or other designated authority will intend to establish an agreement with an insurance company, more detailed information such as equipment number, specifications and corresponding costs, items to be insured (list of equipment, buildings, and other items to be covered by the insurance), required conditions for the insurance coverage, etc. may be necessary.

Table 2-7 Available Insurance Schemes

Company Name	Type of Insurance	Period	Premium	Other Conditions
PT. Asuransi Allianz Utama Indonesia	Property All Risks Insurance including Earthquake, Volcanic Eruption, and Tsunami (EQVET)	One Year	Rp. 80,047,000 Sum of Insured x 0.1% + Policy Cost & Stamp Duty	Deductibles: Fire, Lightning, Explosion, Aircraft Impact; NIL Riot, Strike and Malicious Damage; 10% of claim, etc.
PT. Asuransi Wahana Tata	Building: Property All Risk and Earthquake Insurance Equipment: Electronic Equipment Insurance	One Year	Building: Rp. 50,070,000 Sum of Insured x 0.125% + Policy Cost & Stamp Duty) Equipment: Rp. 70,070,000 Sum of Insured x 0.175% + Policy Cost & Stamp Duty)	Deductibles: Buildings; Fire, Lightning, Explosion, Impact of Falling Aircraft and Smoke: NIL Riot, Strike and Malicious Damage: 10%, etc. Equipment; Earthquake, Tsunami, Volcanic Eruption, Flood, Water Damage, Subsidence, Inundation, Hurricane, Cyclone and Typhoon: 15% or less Strikes, riots and Civil Commotion: 10% Lightning & Theft: 15%, etc.
PT. Asuransi Umum Bumiputera Muda 1967		One Year	Rp. 80,102,000 Sum of Insured x 0.1% + Policy Cost & Stamp Duty	
PT. Toyota Tsusho Insurance Broker Indonesia	All Risk Insurance （Equipment Insurance） (Possible to design according to the request)	One Year	Sum of Insured x 0.3%	Insurance can be designed according to the Client request.

Chapter 3 Plan of Lightning Protection System

3-1 Outline

3-1-1 Basic Concept

Lightning protection plan will be established based on field survey results, such as actual conditions of the damaged equipment, proneness of the area of lightning, existing damages caused by lightning strikes within the concerned area, and other conditions verified through survey.

From the stand point of improving the lightning protection system and reducing the risk of damages caused by lightning strikes, in addition to the repair works on the damaged equipment, additional measures for lightning protection will be considered.

3-1-2 Discussions with DGST

DGST requested the following matters to the Survey Team in the meeting held in December 2012, after the field survey.

- In order to prevent similar damage in the future, the results of these survey works are to be reflected in the Phase 2 Project (The Project for Enhancement of Vessetl Traffic System in Malacca and Singapore Straits, Phase 2), which is currently being conducted through Japanese Grant Aid.

- DGST intends to restore the VTS system as soon as possible because the Indonesian government has an obligation to report on their activities regarding VTS operations from January to September, 2013 in the TTEG Meeting. The Indonesian government also has the intention to present a formal declaration to international organizations such as IALA and IMO. In the same TTEG meeting, the Indonesian government will also formally declare provision of VTS services in territorial waters and the surrounding area of Batu Ampar Port outside of the TSS.

3-1-3 Design Philosophy

(1) Consideration of Operation and Maintenance Aspects

The operation and maintenance system including the organization, staff and budget allocations by DGST are, perhaps, still under development. For developing and/or improving the skills of the VTS operators and maintenance staff, on-the-job training is practical and effective. From this viewpoint, it is desirable that the damaged VTS system is recovered as soon as is practical.

On the other hand, if the system has a problem and/or damage in the near future, necessary actions for recovery works such as budget allocations, establishing a repair plan and actions following the plan may take a rather long period or may not be conducted. Resultantly, VTS operation may be terminated for a certain period. In fact, the present damaged VTS system has not recovered its functions since being damaged by lightning.

Considering the above-mentioned situations, it is practical to reduce the risk against future damage by lightning strikes. Therefore, the initial investment cost may be expensive; however, in order to provide a system highly resistant against lightning stikes, not only the repair, but also additional measures against thunderbolts will be included in the basic design.

(2) Consideration of Technical Aspects

As mentioned above, aside from repair works additional measures will be considered to improve the lightning protection performance and to reduce the risk of damage due to lightning strikes. Additional measures are planned based on the cause of damage, which was stated in 2-1-3, verified by the field survey works. The following are the basic considerations in planning the additional measures.

In Batu Ampar VTS Center, the damage is concentrated on the power distribution system and the cause of damage might have been induced by lightning surge invasion through public power transmission cables due to lightning strikes near the site. No damages of VTS equipment due to lighting strike to the air-terminal and steel tower were found, although direct lightning might have occurred. In these circumstances, protection against surge invasions to the power supply system is considered an additional measure.

In Tg. Berakit, Hiyu Kecil, and Takong Kecil, lightning surges due to direct lightning that struck the air terminal or steel tower might have invaded the electronic devices inside the building through the metal lines connecting the radar equipment at the top of the tower and the equipment devices inside the building's equipment room. Considering these circumstances, improvement of air-terminal and earth-termination system against direct lightning and of SPDs and/or isolation transformers to prevent surge invasion are considered.

Based on the above-mentioned considerations, in addition to restoration of damaged parts, apparatus, and/or equipment; the following were studied to establish a basic plan for lighting protection system: (i) improvement of SPDs and isolation transformers (Additional Measures I), since the damages were mostly due to surge invasions into the equipment, (ii) improvement of air termination system (Additional Measures II) because lightning surges which cause equipment damage might have been induced by direct lightning strikes to the air terminal or steel tower body; and (iii) improvement of earth-termination system (Additional Measures III) to maintain equipotential state and to minimize the risk of surge invasion to the equipment. Furthermore, in order to enhance lightning protection performance of the system, (iv) relocation of the equipment and/or apparatus on the steel tower (Additional Measures IV). And (v) dissipation array system, which is used in MPA Singapore, (Additional Measures V) were also studied.

Among these items, restoration works in item (i) are indispensable, and improvement of SPDs and the isolation transformers is considered as a necessary item to be conducted based on the fact that many pieces of equipment in all the sites are damaged due to lightning strikes and thunderstaorms may occur more than 120 days per year in this region.

Regarding the air-termination and earth-termination systems of items (iii) and (iv), the existing system was designed based on JIS A 4201:1992 and it was confirmed that earth resistance is sufficiently small and equi-potential bondings are also conducted at an acceptable level. These systems satisfy the requirements of the relevant standards and the technical specifications at the construction stage. However, considering the fact that the equipment is damaged, improvement of the system is considered together with SPDs and isolation transformers. Regarding item (v), it is considered that the apparatus should be relocated to a position that is free from lightning strikes and does not influence the functions of the apparatus.

Furthermore, the dissipation array system, which is used in the VTS system in MPA Singapore, is considered as one of the effective methods to reduce the risk of lightning damage on the equipment. Therefore, effectiveness of this system is also studied.

In addition to the above, according to the request by DGST, repair and additional measures in Batu Ampar are included in this basic design.

3-2 Basic Design

3-2-1 Study for Repair Method and Additional Measures

(1) Basic Principles

To establish a restoration plan for the damaged VTS system, not only repair works of the damaged equipment, but also some additional measures are considered to reduce the risk against lightning damage in the future. The measures including repair works to be studied are roughly classified into six (6) categories of repair works and Additional Measures I to V.

Items to be repaired and to take measures are selected based on a study of cost effectiveness against risk reduction of lightning damage.

The basic concepts to establish a basic plan of repair and additional measures are as described below.

(2) Repair Works (Restoration of Damaged Parts, Apparatus and/or Equipment)

Restoration of VTS system functions are an indispensable matter. Troubles stated in Section 2-1 need to be restored.

As an example, radar function trouble is caused by damage to only a few parts on the MPU circuit board in the radar signal processor unit. Most of the other parts on the MPU board do not have any fused damage; however, the performance of these parts may be reduced due to lightning surges. Therefore, the entire board must be replaced with a new one.

(3) Additional Measures I (Improvement of SPDs and Isolation Transformers)

In order to prevent lightning surge invasion, SPDs and isolation transformers are improved and/or additionally installed at an appropriate position along the power supply cables and/or signal transmission lines between indoor and outdoor equipment. Modifications of these cables to the magnetic shielded type cables are also considerd in order to prevent lightning surges from invading the equipment. Details are as follows.

1) Improvement and addition of SPDs

Optimization and alteration of the SPD model and/or additional installation of SPD is considered.

2) Improvement and addition of isolation transformers

Additional installations of isolation transformers are considered along the power supply cable lines to improve the ability of surge invasion prevention for the equipment.

3) Shield treatment of cables

Shielded cable (magnetic shield) is additionally applied against the electromagnetic induction induced by lightning strike. In order to prevent invasion of lightning surges, application of non-metal optical cables and insulation and/or grounding of tension members are also considered.

(4) Additional Measures II (Improvement of Air-termination System)

Lightning protection systems of existing facilities are composed of one lightning rod at the top of the steel tower. Lightining rods are to be improved to expand the protection area against lightning strikes.

1) Air-terminal (Lightning rod)

The present lightning rods fixed to the existing steel tower facilities are designed based on JIS A 4201:1992. JIS A 4201 was amended as JIS A 4201:2003 in 2003, considering IEC 61024-1:1990, Protection of structures against lightning – Part I: General Principles. However, both versions of JIS A 4201:1992 and JIS A 4201:2003 are still effective and applicable. It is regulated that the lightning protection system complying with JIS A 4201:1992 be compatible with the external lightning protection system complying with JIS A 4201:2003. Because of above-mentioned reasons, the similarity of the existing steel towers in Indonesia and from an economical point of view, JIS A 4201:1992 was applied in the design works in the Phase I Project.

However, in each version of JIS A 4201, the philosophy for determination of the protection area by the lightning rods is different. If JIS A 4201:2003 is applied, the radar scanner antennae and parabola antennae for multiplex communication links may not be covered by the existing lightning rod. In addtion, JIS A 4201:2003 has been introduced a concept that a lightning protection system is designed according to protection level. Thunderstorming days per year is one of the parameters to determine the protection level for the design. From this point of view, improvement of lightning rods by applying JIS A 4201:2003 is studied.

(5) Additional Measures III (Improvement of Earth-termination System)

The earth-termination system is to be strengthened considering the improvement to avoid partial voltage increase. An equi-potential earthing sytem is to be considered.

1) Earth-Termination System

Plate or rod (vertical) are used in the existing earth electrodes to reduce earth resistance as much as possible to avoid an increase in the earth-termination voltage when a thunderbolt occurs. The resistance values are sufficiently low and they satisfy the requirements of JIS A 4201:1992 at all sites. It should be noted, in JIS A 4201:2003 A-Type and B-Type earth electrodes are specified. Generally speaking, A-Type electrodes are good for small-scale building facilities and B-Type electrodes are sufficient for large-scale building facilities; however, the type selection is a designer's decision. If the earth resistance is zero, damages may not happen; however, such conditions do not exist, but equipotential bonding is effective to reduce the risk of damage. In this point of view, to improve equipotental state of the existing earth electrodes, B-Type earth electrodes (ring earth and/or mesh earth electrodes) are considered.

2) Earth-terminaltion of electrical cables outside of the building

The radar wave guide, other signal and electrical cables are connected to the earth electrodes inside of the building facilities in the existing system. However, in order to prevent lightning surge invasions to inside the building through these lines, direct bonding of the lines outside of the building with the above-mentioned improved earth-terminatioin system is considered.

3) Earth-termination of cable ladder

Electrical and signal cables are installed along the steel cable laddar equipped inside the building. To ensure the reduction of surge invasion to the equipment through these cables and ladders, bonding between the cable ladder and an improved earth-termination system are considered.

In addition to this, installation of a copper bus-bar (grounding-bus) is considered on the inside surface of the wall to minimize the grounding distance of each piece of equipment inside the building.

4) Earth-termination of fuel supply pipeline

Fuel supply pipelines are electronically connected to generator body and equipment inside the building. Therefore, lightning surges may invade through the pipelines. From this point of view, a earth-termination system for fuel supply pipelines is considered.

(6) Additional Measures IV (Relocation of Equipment/Apparatus)

Meteorlogical sensors at the top of the steel towers in Tg. Beratki and Hiyu Kecil were damaged. Simlarly, GPS antennae for the AIS base station system installed at the middle part of the towers in VTS Center, Tg. Berakit and Hiyu Kecil were also damaged. To reduce the risk against the lightning damage of this equipment/appartus, installed positions are to be changed to a position where the functions can be maintained but the risk of damage can be reduced.

(7) Additional Measures V (Introduction of Dissipasion Array System)

The effectiveness and appropriateness of introducing a dissipation array system with the air-termination system are studied.

3-2-2 Study on Risk Reductions

(1) Comparison Study of the Alternative Plans

For the Additional Measures I to V including repair works as mentioned above, items considering cost effectiveness are studied by comparing three (3) alternative plans. Table 3-1 shows the outline of the comparative study. “Plan A” is the case conducting all of the above measures I to V. Details are described later; however, the dissipation array system in Additional Measures V is not proposed in the final recommendation plan since (i) the system is expensive, (ii) heavy maintenance is necessary and (iii) protection effectiveness against lightning strikes can be obtained by the measures without this system. “Plan B” is the plan to take Additional Measures I to IV without V (dissipation array system) from the above-mentioned standpoint. “Plan B” is excellent from a technical viewpoint; however, high expenses are required to conduct this plan. To reduce the cost, items that can be omitted from “Plan B” are carefully and briefly examined from a technical point of view. “Plan C” is an alternative plan which has reduced several items to preserve the performance of the protection against thunderbolts, much the same as “Plan B.”

(2) Comparison of "Plan B” and “Plan C”

Protection performance against thunderbolts is highly dependent on the functions for not only the protection devices such as SPDs and isolation transformers, but also lightning rods, down-conductors and earth terminal systems. Mutual functioning of these devices and systems is fundamentally necessary for the protection. Therefore, it is necessary that the Additional Measures I to IV shall be applied considering the well-balanced functions. On the other hand, “Plan B,” which includes all of the recommended items Additional Measures I to IV, is expensive; therefore, items that can be deleted in “Plan B” are briefly studied and technically evaluated in order to reduce the cost without increasing the risk of damage from thunderbolts.

Details are as follows.

1) Additional Measures I (SPDs, Isolation transformers)

a. Isolation transformers are to be installed for electrical power supply cable lines for all sites; however, the transformers are expensive. Therefore, SPDs are to be selected in lieu of isolation transformers except for Hiyu Kecil where the power supply lines lay on the ground because underground installation is not possible due to the rocky ground conditions.

b. Only SPDs will be applied against surge invasions along the power supply lines in Batu Ampar. Based on the field survey, direct lightning to the air-terminal may occur, however, it is expected that damages due to the direct lightning strikes to the steel tower of the VTS system may not occur because there are many steel towers that are higher than the steel tower of the VTS Center building.

2) Additional Measures II (Air-termination system)

These facilities are necessary and no components can be omitted. At Batu Ampar, risk of equipment damage due to direct ligntning may be low, however, improvement of air-terminal is necessary because on the field survey, deformation and burned trace were found at the top of the air-terminal.

3) Additional Measures III (Earth-termination system)

a. To extend a wire for the earth-termination system to the sea in Hiyu Kecil, at the beginning, use of titanium materials for all segments was considered in order to avoid corrosion. However, the material cost is very expensive, so parts using titanium are minimized.

b. There are no items that can be reduced in other components.

4) Additional Measures IV (Relocation of the apparatus)

No items can be reduced.

The comparison results based on the above-mentioned items 1) to 4) are as shown in Table 3-1. Items to be conducted are “◎” and “○” marks in the table.

“Plan B” includes all items that are expected to have excellent effects and are indicated as ◎ marked parts except for Additional Measures V. “Plan C” includes the ◎ mark and ○ parts. ○ parts means some items are reduced from ◎ in Plan B, considering that they are still at a recommendable level for lightning protection.

Table3-1 Comparison Study for Three Alternative Plans (Repair and Additional Measures)

Measures					Plan A				Plan B				Plan C (Recommended)				Remarks
No.	Measures	Contents		Expected Effects	Batu Ampar (B.A)	Tanjung Berakit (T.B)	Hiyu Kecil (H.K)	Takong Kecil (T.K)	Batu Ampar (B.A)	Tanjung Berakit (T.B)	Hiyu Kecil (H.K)	Takong Kecil (T.K)	Batu Ampar (B.A)	Tanjung Berakit (T.B)	Hiyu Kecil (H.K)	Takong Kecil (T.K)	
1	Repair Works	Restoration of damaged equipment	Site Survey Procurement Adjustment of Damaged Equipment Total System Tuning	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	Repair items are same in all plan
2	Additional Measures I	Improvement of SPD and Isolated-Transformer	Installation of SPD and Isolated-Transformer between the Electrical Power Supply, Data Communication Lines	◎	◎	◎	◎	◎	◎	◎	◎	◎			◎		Installation lines of isolated transformer are selected since the trans is expensive. Installation lines are limited only for power supply cable in Batu Ampar
			Installation of SPD only for the Electrical Power Supply Lines	○									○				
			Installation of Islated-Transformer only for the Lines of the VTS Equipment	○										○		○	
3	Additional Measures II	Improvement of Air Terminal System	Designed by Protection Level 1 Air-Terminal System and Down-Conductor Improvement	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	
4	Additional Measures III	Improvement of Earth-Termination System	Installation of Ring Earth Electrode (by copper wire) (Ring Earth Electrode by Titanium Belt in Hiyu Kecil)	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎		◎	Titanium belt is expensive therefore, installation locations are selected in Hiyu Kecil.
			Partial application of Titanium Belt Electrode in Hiyu Kecil	○											○		
			Installation of Ring Earth Electrodes in the Equipment Building (by Copper Flat Bar)	◎	–	◎	◎	◎	–	◎	◎	◎	–	◎	◎	◎	
			In-door and Out-door Ring Earth Electrods Bonding	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	
			Installation of Earth-Terminal for Fuel Supply Pipeline	◎			◎	◎			◎	◎				◎	
5	Additional Measures IV	Relocation of Damaged Equipment	Relocation of Meteorological Observation Sensor Equipment and GPS Antenna for AIS Base Station System	◎	◎	◎	◎	–	◎	◎	◎	–	◎	◎	◎	-	
6	Additional Measures V	Introduction of Dissipation Array System	Introduction of Dissipation Array System	◎	◎	◎	◎	◎									
Cost for Measures (Thousand Yen)			Cost for Measures per Site (Thousand Yen)		50,460	77,818	93,789	76,051	20,460	47,818	63,789	46,051	18,147	35,204	54,823	33,437	
			Total Cost for Measures (Thousand Yen)		298,118				178,118				141,611				
			Rate against Plan B per Site (%)		246.6	162.7	147.0	165.1	100.0	100.0	100.0	100.0	88.7	73.6	85.9	72.6	
			Rate against Plan B in Total (%)		167.4				100.0				79.5				

Note: ◎: Excellent, ○: Very Good (Recommendable)

(3) Study on the Cost and its Effectiveness

Approximate costs of the above-mentioined Plans (A, B and C) are as shown in Table 3-2. Repair costs, which are not included in any additional measures, are about 42 million yen. The costs for additional measures of "Plan B" and "Plan C" are about 136 million yen and 99 million yen respectively. These amounts are almost the same as two (2) to three (3) times the repair cost of similar damage at this moment.

Table3-2 Cost Comparison for Plan A, B and C

No.	Measures	Items to be Improved	Expected Effects	Cost (1,000 Yen) Plan A	Plan B	Plan C (Recommend)
1	Repair	Repair/replace damaged parts	Restoration	42,426 (◎)	42,426 (◎)	42,426 (◎)
2	Additional Measures I	Improvement of SPDs and isolation-transformers	To increase surge protection abilitiy	61,975 (◎)	61,975 (◎)	34,434 (○)
3	Additional Measures II	Improvement of air-termination system	To increase protection area by air terminal	32,935 (◎)	32,935 (◎)	32,935 (◎)
4	Additional Measures III	Improvement of earth-termination system	To avoid electrical potential difference	38,307 (◎)	38,307 (◎)	29,341 (○)
5	Additional Measures IV	Relocation of the apparatus	To avoid direct lightning strike to the apparatus	2,475 (◎)	2,475 (◎)	2,475 (◎)
6	Additional Measures V	Introduction of dissipation array system	To avoid direct lightning	120,000 (◎)	Excluded	Excluded
			Cost for additional measures	255,692 (◎)	135,692 (◎)	99,185 (○)
			Total Cost	298,118 (◎)	178,118 (◎)	141,611 (○)

Note: ( ) on right side of the cost means effectiveness of measures. ◎ : Excellent, ○ : Very Good (Recommendable)

(4) Expected cost for future damages

Based on the field survey, if only the repair works are conducted, it is expected that similar damage/troubles of the VTS sytem may occur due to thunderbolts one (1) or two (2) times every year. If repair works are conducted per damage incident, about 40 million yen (4 billion Rupiah) may be necessary for the restoration works every time.

(5) Risk reduction by additional measures and its cost effectiveness

100% avoidance of lightning damage is not technically possible. Estimating the probability and frequency of damage is also difficult. However, based on this study, risks against lightning damage may be sufficiently reduced by conducting the additional measures. Considering VTS operations for the next 5 to 10 years, the current cost of repair and additional measures plus the O & M cost during this period may be cheaper than the restoration cost that may be necessary for the next 5 to 10 years if only repair works are conducted at this moment.

As mentioned above, Plan C omits several items in Plan B for cost-saving purposes but reserving as much as possible the performance of lightning protection in Plan B. Therefore, Plan C is being recommended as a result of this study. Further details of Plan C are described in the Basic Plan below.

3-2-3 Basic Plan

Based on the discussions in 3-1-1 and 3-1-2, the basic plan is to be established. For the Additional Measures I to V, the results of the cost effectiveness study will be described. According to the study results and considerations on the protection performance against lightning, it is recommended that all of the items with repair works shall be conducted. However, as the costs for these measures are quite expensive, componets to be included are carefully selected to minimize the cost while maintaining protection performance as much as possible.

(1) Repair of the Damaged Equipment

Restoration of damaged equipment and/or apparatus at VTS Center and other sensor stations is performed by replacing the damaged boards with new ones.

1) Restoration of damaged equipment in VTS Center

In VTS Center, automatic switchers of the backup generator and automatic fuel supply pumps are damaged. Restoration of these functions is conducted by replacing the damaged circuit boards in the generator room on the first floor in the center building.

2) Restoration of damaged equipment at other sensor stations

The radar system, AIS base station equipment, meteorological observation devices and other apparatus are to be restored by replacing the damaged circuit boards with new ones. Original functions are to be maintained by tuning the overall system after tuning each piece of equipment when the new boards have been installed.

Repair of air-conditioners is recommended to be conducted by local engineering companies who have knowledge about the equipment and its functions.

Based on the above, the following are the repair items of each site.

a. Repair items in Tanjung Berakit

i. Replacement of damaged PCBs of radar system
ii. Replacement of damaged PCBs of AIS base station devices
iii. Replacement of damaged PCBs of meteorological observation devices
iv. Equipment tuning and overall system tuning of the VTS system
v. Repair of air-conditioning system

b. Repair items in Hiyu Kecil

i. Replacement of damaged PCBs of radar system
ii. Replacement of damaged PCBs of AIS base station devices
iii. Replacement of damaged PCBs of meteorological observation devices
iv. Repair of multi-plex communication link units
v. Replacement of damaged PCBs in UPS unit
vi. Repair of lightning apparatus and its control boards for aviation obstruction lights
vii. Equipment tuning and overall system tuning of the VTS system
viii. Repair of air-conditioning system

c. Takong Kecil

i. Replacement of damaged PCBs of radar system
ii. Replacement of damaged PCBs of CCTV system
iii. Equipment tuning and overall system tuning of the VTS system
iv. Repair of air-conditioning system

Based on the above-mentioned considerations, restoration/repair plan of damaged equipment at each site is as shown in Table 3-7 to Table 3-10 including equipment specifications to be used for restoration/repair works in “3-2-4 Basic Design and Equipment Specifications”.

(2) Additional Measures I (Improvement of SPDs and isolation transformers)

According to the actual damage conditions and thunderstorm occurrences that were clarified by the field survey works, modification of surge protection devices (SPDs) and isolation transformers of the existing system and additional installations of these devices in effective positions against the lightning strikes are conducted.

In addition to this, cables are modified to magnetic shield type cables in order to avoid invasion of lightning surges to the equipment.

Furhtermore, because surge protection devices must be replaced periodically according to the actual conditions of lightning attacks, surge counters are to be installed for all sites. By using the surge counters, it is hopeful that actual lightning conditions can be clarified in the future. One unit of the counter is installed at the steel tower leg and an additional unit is installed near the earth terminal inside the buildings, in the operation room on the 4^{th} floor in VTS Center and in equipment buildings for other sites.

By installing the surge counters inside and outside of each building, it will be possible to observe and compare the number of occurances of lightning surges inside and outside of the buildings in the future. In addition, the effectiveness of the improved system designed by these survey works can be evaluated.

Further details of the additional measures are as follows:

1) Additional installation of SPDs

Every part and/or module of equipment generally has withstand voltage. In case certain surges invaded certain parts and/or modules, and if such invaded voltage is lower than the withstand voltage, these parts and/or modules are safe against such surge invasions. Because of this, some locations where the effect of lightning surges would be small, SPDs have not been installed in existing system.

However, based on actual damaged conditions, it was found that some damages are induced by reduction of withstand voltage due to surge invasions. Since occurrence of thunderstorms are expected about 120 days per year, surge invasion frequencies could be higher than expected and the parts and/or modules of equipment might have faced unexpected heavy conditions.

Considering these conditions, additional SPDs will be installed.

2) Modifications of Existing SPD Specifications

a. Replacement by the SPDs of more durable type

Similarly, frequency of surge invasions may be higher than expected. Therefore, more durable SPDs will be selected and installed.

b. Replacement by the SPDs for higher protection level

Parts and/or modules are damaged if invaded surge voltage is higher than the withstand voltage. To be protected by the SPDs, residual voltage after the SPD functioned shall be lower than the withstand voltage of the parts and/or modules.

On the other hand, SPD does not function in case of small surge invasions; in such a case, such small surges are invaded to the parts and/or modules passing through the SPDs. Thefore, surges level, which is not functioned SPDs shall be lower than the withstand voltage of the parts and/or modules to be protected (protection coordination shall be satisfied).

For protection against the lightning over-voltage by SPD, both of the above-mentioned conditions (protection coordination) shall be satisfied. Considering the actual damages, more better SPDs will be selected and insltalled.

3) Improvement following protection device modifications

By adopting additional measures IV, some devices such as meteorological observation sensor and CCTV camera on the top of the steel tower will be relocated to other sufficient positions. In order to prevent surge invasions in these relocated devices, installation of SPDs will be conducted accordingly.

4) Insulation by isolation transformer

Isolation transformer is generally expensive and sufficient space is necessary for its installation. This is the negative impact of the isolation transformer. However, considering surge protection against small surges, reliability of the isolation transformer is higher than SPDs. Therefore, isolation transformers will be installed in electrical power supply lines where surge invasions are expected.

5) Installation of surge counter

To conduct quantitative survey for the lighting conditions and occurrences of surge invasions to the system, surge counters are installed.

6) Isolation of tension member of optical cable

According to the field survey, the tension members of optical cables are fused. Evidence of sparks was found at the cable-fixing plate and in the LAN cable beside the optical cables. The sparks may have occurred due to lightning surge invasion through tension members of the optical cable when the lightning strikes hit the steel tower. Tension members cannot be isolated from the optical cable, however, isolation treatment is conducted at the tension member ends to avoid surge invasions.

7) Strengthen of earth bonding

For enhancement of the above-mentioned additional measures, direct and minimum distance bonding are conducted between each equipment and grounding system by conducted as Additional Measures III.

According to the above-mentioned considerations, the basic plan for Additional Measures I for each site is shown in the following Tables 3-3 to 3-6. To make a basic plan, some of the reasons in the above-cited item 1) to 7) are considered. The reasons applied to establish basic planning of the Additional Measures I are presented in the column “Reasons to Take Measures” in Tables 3-3 to 3-6. Equipment to be used and its specifications are determined based on these basic plans presented in Tables 3.7 to 3.10 in 3-2-4 “Basic Design and Equipment Specifications”. Item numbers in Tables 3.7 to 3.10 are linked to the item numbers in Tables 3.3 to 3.6. Therefore, relations between the basic plan and equipment to be used and its specifications can be shown in these item numbers.

Table3-3 Plan of Additional Measures I for Batu Ampar VTS Center (Improvement of SPDs and Isolation Transformers)

No.	Position	Equipment (Objectives)	System	Performance	Outlines of Additional Measures I	Reasons to Take Measures
B1, B2	Tower Top	Performance Monitor	Comm.	For communication	One new SPD box is installed. Power source is fed from Radar Antenna connection box.	1)
B3, B4	Tower Top	Radar Antenna	Power	For power supply	Addition of AC/DC power unit	3),1)
B5	Tower Leg	Lightning surge counter	—	—	The lightning surge counter is installed at the base of the tower to monitor the number of lightning strikes at the site.	5)
B6	Operation Room (4F)	Terminal Box (TB7)	Comm.	For communication	SPD installed at TB7 is substituted with a communication use one.	2)
B7	Operation Room	Terminal Box (K2,3)	Comm.	For communication	Two SPD are installed on K2 and K3 respectively.	1)
B8	Operation Room	Terminal Box (Near grounding terminal)	—	—	One set of surge counter system is newly installed inside terminal box	5)
B9	Power Room (1F)	ATFS-2	Power	For power supply system	SPD is installed on main power lines of ATFS-2 control panel.	1)

Table3-4 Plan of Additional Measures I for Tanjung Berakit (Improvement of SPDs and Isolation Transformers)

No.	Position	Equipment (Objectives)	System	Performance	Outlines of Additional Measures I	Reasons to Take Measures
B1 B2	Tower Top	Performance Monitor	Comm.	For communication	One new SPD box is installed. Power source is fed from Radar Antenna connection box.	1)
B3 B4	Tower Top	Radar Antenna	Power	For power supply system	Addition of AC/DC power unit	3),1)
B5	Tower Leg	Lightning surge counter	—	—	The lightning surge counter is installed at the base of the tower to monitor the number of lightning strikes at the site.	5)
B6 B7	Tower Top	Radar Antenna (SPD Box-1)	Power	For power supply	One set of isolation transformer and SPD is installed in PDB-1.	1),4)
B8 B9	Equipment Room	Terminal Box (SPDBox 2)	Power	For power supply	One set of SPD and isolation transformer is installed in Terminal Box. Power supply (+12V model) to Radar Antenna is substituted with 220Vac model.	1),4)
B10	Equipment Room	Terminal Box (TB7)	Comm..	For communication	SPD installed at TB7 is substituted with a communication use one.	2)
B11	Equipment Room	Terminal Box (K2,3)	Comm..	For communication	Two SPD are installed on K2 and K3 respectively.	1)
B12	Equipment Room	Terminal Box (Near grounding terminal)	—	—	One set of Surge counter system is newly installed inside terminal box	5)
B13	Equipment Room	Obstacle Light	Power	For power supply	SPD is installed on main power line of the control box for obstacle light.	1)
B14 B15	Generator Room	Automatic Exchanger	Comm..	For communication	SPD is installed on input and output terminals of DC-DC power unit.	1)
B16	Generator Room	Automatic Exchanger	Power	For power supply	SPDs are installed additionally at battery terminals of engine generator.	1)
B17	Power Room	Strengthen of earth bonding	—	—	Direct and minimum distance bonding are conducted between each equipment and grounding system which are conducted by additional measure III.	7)
B18	Equipment Room	Strengthen of earth bonding	—	—	Ditto as above	7)

Table3-5 Plan of Additional Measures I for Hiyu Kecil (Improvement of SPDs and Isolation Transformers)

No.	Position	Equipment (Objectives)	System	Performance	Outlines of Additional Measures I	Reasons to Take Measures
B1 B2	Tower Top	Performance Monitor	Comm.	For communication	One new SPD box is installed. Power source is fed from Radar Antenna connection box.	1)
B3 B4	Tower Top	Radar Antenna	Power	For power supply	Addition of AC/DC power unit	3),1)
B5	Tower Leg	Lightning surge counter	—	—	The lightning surge counter is installed at the base of the tower to monitor the number of lightning strikes at the site.	5)
B6 B7	Tower Top	Radar Antenna (SPD Box-1)	Power	For power supply	Isolation transformer with SPD is installed in Terminal Box and Radar Antenna.	1),4)
B8 B9	Equipment Room	Terminal Box (SPDBox 2)	Power	For power supply	SPD and isolation transformer are installed in Terminal Box. Power supply (+12V model) to Radar Antenna is substituted with 220Vac model.	1),4)
B10	Equipment Room	Terminal Box (TB7)	Comm.	For communication	SPD installed at TB7 is substituted with a communication use one.	2)
B11	Equipment Room	Terminal Box(K2,3)	Comm.	For communication	Two SPD are installed on K2 and K3 respectively.	1)
B12	Equipment Room	Terminal Box (Near grounding terminal)	—	—	Surge counter system is newly installed inside terminal box	5)
B13	Equipment Room	Obstacle Light	Power	For power supply	SPD is installed on main power line of the control box for obstacle light.	1)
B14 B15	Generator Room	Automatic Exchanger	Power	For power supply	SPD is installed on input and output terminals of DC-DC power unit.	1)
B16	Generator Room	Automatic Exchanger	Power	For power supply	Installation of additional SPD at terminal of generator battery	1)
B17	Fuel Tank	Fuel Transfer Pump	Power	For power supply	One SPD box is newly installed in fuel transfer pump controller.	1)
B18 B19	Generator Room	PDB-1	Power	For power supply	One set of isolation transformer and SPD is installed	1),4)
B20	Generator Room	PDB-1 (Interface NQD-2324)	Power	For power supply	One set of isolation transformer is installed	1),4)
B21	Generator Room	PDB-1 (Interface NQD-2324)	Power	For power supply	SPD is installed in PDB-1.	1)
B22	Generator Room	PDB-1 (Interface NQD-2324)	Power	—	Isolation of tension member ends of optical cable.	6)
B23 B24	Power Room	PDB-2	Power	For power supply	One set of isolation transformer and SPD is installed in PDB-2.	1),4)
B25	Power Room	PDB-3	Power	For power supply	SPD is installed for main source power lines.	1)
B26	Power Room	PDB-4	Power	For power supply	SPD is installed for main source power lines.	1)
B27 B28	Power Room	PDB-4 (Interface)	Power	For power supply	One set of isolation transformer and SPD is installed	1),4)
B29	Power Room	PDB-4 (Interface)	Comm.	—	Isolation of tension member ends of optical cable.	6)
B30	Power Room	Strengthen of earth bonding	—	—	Direct and minimum distance bonding are conducted between each equipment and grounding system which are conducted by additional measure III.	7)
B31	Equipment Room	Strengthen of earth bonding	—	—	Ditto as above	7)

Table3-6 Plan of Additional Measures I for Takong Kecil (Improvement of SPDs and Isolation Transformers)

No.	Position	Equipment (Objectives)	System	Performance	Outlines of Additional Measures I	Reasons to Take Measures
B1 B2	Tower Top	Performance Monitor	Comm.	For communication	One new SPD box is installed. Power source is fed from Radar Antenna connection box.	1)
B3 B4	Tower Top	Radar Antenna	Power	For power supply system	Addition of AC/DC power unit	3),1)
B5	Tower Leg	Lightning surge counter	—	—	The lightning surge counter is installed at the base of the tower to monitor the number of lightning strikes at the site.	5)
B6 B7	Tower Top	Radar Antenna (SPD Box-1)	Power	For communication	Isolation transformer with SPD is installed in Terminal Box and Radar Antenna.	1),4)
B8 B9	Equipment Room	Terminal Box (SPDBox 2)	Power	For power supply	One set of SPD and isolation transformer is installed in Terminal Box. Power supply (+12V model) to Radar Antenna is substituted with 220Vac model.	1),4)
B10	Equipment Room	Terminal Box (TB7)	Comm.	For communication	SPD installed at TB7 is substituted with a communication use one.	2)
B11	Equipment Room	Terminal Box(K2,3)	Comm.	For communication	Two SPD are installed on K2 and K3 respectively.	1)
B12	Equipment Room	Terminal Box (Near grounding terminal)	—	—	One set of surge counter system is newly installed inside terminal box	5)
B13	Equipment Room	Obstacle Light	Power	For power supply	SPD is installed on main power line of the control box for obstacle light.	1)
B14 B15	Generator Room	Automatic Exchanger	Power	For power supply	SPD is installed on input and output terminals of DC-DC power unit.	1)
B16	Generator Room	Automatic Exchanger	Power	For power supply	Installation of additional SPD at terminal of generator battery	1)
B17	Fuel Tank	Fuel Transfer Pump	Power	For power supply	One SPD box is newly installed in fuel transfer pump controller.	1)
B18 B19 B20	Tower Top	CCTVCamera (SPD Box-3)	Comm.	For communication	One SPD box is newly installed to enhance anti-surge capacity for communication lines. One set of coaxial arrester is added. Two sets of isolation transformer are added.	1)
B21	Equipmetn Room	WEB Encoder (SPD Box-3)	Comm.	For communication	Additioinal SPDs are installed in the existing panel	1)
B22	Equipmetn Room	WEB Encoder (SPD Box-3)	Comm.	For LAN	Additional SPDs are insltalled in the existing panel.	1)
B23	Equipmetn Room	WEB Encoder (SPD Box-3)	Power	For power supply	Additional isolation trans is installed	1)
B24	Power Room	Strengthen of earth bonding	—	—	Direct and short distance bonding are conducted between each equipment and grounding system which are conducted by additional measure III are maintained directly and minimum distance.	7)
B25	Equipment Room	Strengthen of earth bonding	—	—	Ditto as above	7)

(3) Additional Measures II (Improvement of air-termination system)

The existing air-termination system in all sites is composed of one unit of lightning rod designed using the protection angle method based on JIS A4201:1992. However, all of the sites are located near the seashore, where thunderclouds often accumulate at low altitudes.

According to interviews during the field survey works, it can be judged that the number of annual thunderstorms exceeds 120 days. In this regard, to increase the protection area by air terminals, improvement of lightning rods is conducted in conformity with JIS A4201:2003.

1) Protection Level

Protection level is classified according to the Protection Efficiency (E) as shown in the table below.

Protection Level	Pretection Efficiency (E)
I＋Addition	0.98＜E
I	0.95＜E ≦0.98
II	0.90＜E ≦0.95
III	0.80＜E ≦0.90
IV	0＜E ≦0.80
Not Necessary	E ≦0

Protection Efficiency means the percentage of the protection probability against damage due to direct lightning strikes. For example, E = 0.90 means, there will be a 90% success rate for screening against the electric current due to lightning strikes but the system will fail 10% of the time. The degree of electric current due to lightning strikes is determined according to the protection level.

For the design of the lightning rod, the protection level has to be determined. According to the technical standards for building utilities design in Japan (Ministry of Land, Infrastructure, Transport and Tourism is editorial supervisor), protection efficiency and the protection level is estimated as follows.

a. Nd: Expected number of occurrences of thunderbolts in one year (time/year)

Nd is calculated by the following formula.
$Nd = Ng \times Ae \times Ce \times 10^{-6}$
Where;
Ng is ground lightning discharge density (time/km^2/year).
Since Td (annual thunderstorm days) is 120 days, Ng is computed by the following formula.
$Ng = 0.04 \times Td^{1.25} = 0.04 \times Td^{1.25} = 0.04 \times 120^{1.25} \fallingdotseq 15.9$
Ae is the equivalent area (m^2) that receives thunder.
Since the size of a building is L= 21 m and width (W= 15 m),
height (H = 63.5 + 6 = 69.5 m), Ae is computed by the following formula.
$Ae = L \times W + 6H \times (L + W) + 9 H^2 \pi$
$= 21 \times 15 + 6 \times 69.5 \times (21 + 15) + 9 \times 69.52 \times 3.14 \fallingdotseq 151{,}829.8$
Ce is an environmental application factor.
Considering environment to be "the isolated building which stands on the top of a hill," this is "2."

As mentioned above, Nd is calculated as follows.
$Nd = Ng \times Ae \times Ce \times 10^{-6} = 15.9 \times 151{,}829.8 \times 2 \times 10^{-6} \fallingdotseq 4.8$

b. Nc: Allowable number of occurrences of thunderbolts (times/year)

Nc is computed by the following formula.
$Nc = 1 / (K1 + A + B + C + D)$
Where;
- K1 : Correlation factor, set to 0.04
- A : Structural index, set to 5 (“fireproof structure”)
- B : Index about human injury, set to 20, (“a general and large-scale building with 60 m or higher)
- C : Index about business and environment to the surrounding area, set to 19 ("provision of continuous service is necessary, no influence to the surrounding area”)
- D : Index about the property losses, economical losses, set to 30, ("importance is high")

The above is substituted for the equation of the number Nc of assumed thunderbolts, and the following is obtained.
$Nc = 1/(K1+A+B+C+D) = 1/(0.04+5+20+10+30) \fallingdotseq 0.00083$

c. E: Protection Efficiency

E is calculated by the following formula
$E = 1 - Nc/Nd = 1 - 0.00083/4.8 \fallingdotseq 0.99999$

According to the above-mentioned estimation, protection efficiency, E, exceeds 0.98. Therefore, “Protection Level 1 + Addition” shall be adopted for the lightning protection improvement design.

2) Improvement of air-termination system

Protection area of the existing faculties by the air terminal is designed using the protection angle method by JIS A4201:1992. In JIS A 4201: 2003, three (3) alternative methods to determine the protection area by air terminals are listed, namely: the protection angle method, the mesh method and the rolling sphere method.

i. Protection angle method

Using JIS A4201:2003 with the protection level at “1 + Addition,” the protection angle of air terminal shall be considered to be 25 degrees from the 60 degrees at present. But, if the elevation of the rod installed is higher than 30 m, the protection angle method shall not be applied.

ii. Mesh method

This method is good for a box shape building because the building can be protected by a mesh covering, consisting of specified intervals of conductive wires. This method is not suitable for structures equipped with radar systems, because radar performance is influenced by wires.

iii. Rolling sphere method

The envelope curve on the surface of a sphere is made from the spherical rotation locus of the radius R, and the scope of protection is decided by distance from the height of a lightning rod and the starting point of a blow of thunder. This is the most suitable method for the lightning protection improvement design in this system.

Based on the above considerations, the rolling sphere method is applied for the improvement design of the lightning system. Since the protection level is "1 + Addition," the radius of the rolling sphere shall be 20 m. The outline of the improvement design for the air-termination system applied to the VTS Center and other sensor stations are as follows.

3) Improvement of air-termination system for Batu Ampar VTS Center

In addition to the existing terminal rods, three (3) sets of vertical and eight (8) sets of horizontal air terminals are installed at the top of the steel tower. An additional four (4) horizontal rods are installed at three (3) stages at the middle part of the steel tower. On the roof of the VTS Center building, vertical rods are also installed at four (4) corners. Two (2) down-conductors are also installed. Down-conductors from all of the air terminals are connected with three (3) down-conductors (one (1) existing and two (2) additional) to induce smooth discharge of lightning surges from the air terminals to the earth electrode.

4) Improvement of air-termination system for other sensor stations

Similarly, in addition to the existing terminal rod, three (3) sets of vertical and eight (8) sets of horizontal air terminals are installed at the top of the steel tower. An additional four (4) horizontal rods are installed. Four (4) stages of these horizontal rods are installed at Tg. Berakit, Three (3) stages at Takong Kecil and two (2) stages at Hiyu Kecil according to the tower height.

Two (2) down-conductors are also installed for a total of three (3) down-conductors (one (1) existing and two (2) additional). Down-conductors from all of the air terminals are connected with these three (3) down-conductors for smooth discharge of lightning surges from air terminals to the earth electrode.

(4) Additional Measures III (Improvement of earth-termination system)

An A-Type earth electrodes are adopted as the existing earth-termination system in all sites. According to the observation results, the earth resistances at all sites are sufficiently low and all the values satisfy the requirements of the standards and the technical specifications for the time of construction of the facilities. However, in addition to the low earth resistance, it is effective to avoid electrical potential difference due to a partial increase of the potential. To maintain an equi-potential state, B-Type earth electrodes are applied in the improvement.

A ring earth electrode with 60 mm^2 copper wires is installed at each building facility in Batu Ampar VTS Center, Tanjung Berakit and Takong Kecil. Down-conductors, which are connected to the air terminals and other wires for equipment earthing, are bonded with the ring earth electrode. To maintain the equi-potential bonding of the earth-termination system in each site, ring earth electrodes of all facilities are bonded by 60 mm^2 copper wires.

For Hiyu Kecil, a similar equi-potential bonded earth-termination system is provided. A ring earth electrode with 1 mm thickness and a 40 mm titanium belt is to be used for its anti-corrosive properties. Because of the rocky subsoil conditions, underground installation of the electrodes is not possible. The earth-terminal electrodes to be extended to the sea that are temporarily installed at present are to be improved for permanent structures.

In addition to the above-mentioned improvement, in order to prevent lightning surges invading the equipment inside the building through wave guide tubes, bonding between the wave guide and improved ring earth electrodes are treated outside of the building. Also, for the same purpose, the following improvements are conducted.

1) Earth-termination of cable ladder

For wiring of various cables such as power supply and signal transmissions inside the building, a steel cable ladder is installed on the wall. In order to reduce lightning surge invasions through these cables, the cable ladder and earth electrode is bonded. In addition to this, the bus-bar with copper bar material is installed along the surface of the wall to maintain the discharges of the lightning surges.

The above measures were conducted three (3) sites except in Batu Ampar. In Batu Ampar, the above-mentioned treatment is not considered except in bonding of earth electrodes outside and inside of the building since there is no damaged equipment due to direct lightning under the present earth terminal system.

2) Earth-termination of fuel supply pipeline

In Hiyu Kecil and Taknog Kecil, steel pipelines are installed from 1,000 liter capacity tank near the shore to 6,000 litter tank beside the generator house to facilitate fuel transport when fuel supply by ship is done every three (3) months. The fuel supply pipelines are extended from the 6,000 liter tank to engine generators in the generator house.

These pipelines for fuel transport and supply to the engine generators are electrically connected to the engine generator and equipment racks. Some influences by the lightning surges along the fuel supply pipelines may occur; therefore, earth-termination of the pipelines is conducted in this improvement.

(5) Additional Measures IV (Relocation of the apparatus on the steel tower)

Meteorological observation sensors at the top of the steel towers in Tanjung Berakit and Hiyu Kecil, GPS antennas for AIS base station system at the middle part of the steel towers in VTS Center, Tanjung Berakit and Hiyu Kecil are relocated. Newly installed locations for this equipment are selected to be in a position where (i) the damage risk against lightning is small and (ii) there is no influence on the functions of the equipment itself.

(6) Additional Measures V (Introduction of dissipation array system)

In MPA Singapore, a dissipation array system is used in combination with a mesh type earth-termination system and surge protection divices (SPDs). Earth resistance is maintained at lower than 1 ohm. With these lightning systems, no serious damage has occurred except for minor troubles in recent years.

According to the results and experience of MPA Singapore, the dissipation array system may be considered effective to avoid lightning strikes. However, the initial investment cost is very expensive, the price is 30 million yen per unit, and rather heavy periodical maintenance is necessary. Therefore, this system is not introduced in this improvement.

3-2-4 Basic Design and Equipment Specifications

According to the basic plan that was established in "3-2-3 Basic Plan", basic design and equipment specifications are provided for Batu Ampar VTS Center and other VTS sensor stations. Details of the basic design and technical specifications are as described per site in below. Equipment to be used and its technical specifications are presented in Table 3.7 to Tale 3.10. As mentioned in 3-2-3, item numbers in these tables are linked to the item numbers in Tables 3.3 to 3.6. Relations between the basic plan and equipment to be used and its technical specifications can be checked using these item numbers.

3-2-4-1 Batu Ampar VTS Center

Equipment specifications and basic design drawings needed for restoration of the damaged apparatus and Additional Measures I to IV for Batu Ampar VTS Center are listed in below.

(1) Specifications of Equipment

Equipment to be used and its technical specifications for:

a. Restoration of the damaged apparatus
b. Additional Measures I (Improvement of SPDs and Isolation Trransformers)
c. Additional Measures II (Improvement of Air-termination System)
d. Additional Measures III (Improvement of Earth-termination System) and
e. Additional Measures IV (Relocation of Equipment/Apparatus)

For Batu Ampar VTS Center, the specifications are summarized in Table 3-7.

(2) Basic Design Drawings

Basic design drawings for Batu Ampar VTS Center are as shown in below.

Figure 3-1	General Plan of Equipment Repair
Figure 3-2	General Plan of Improvement of SPDs and Isolation Transformers (Additional Measures I)
Figure 3-3	General Plan of Improvement of Air-termination System (Additional Meeasures II)
Figure 3-4	General Plan of Improvement of Earth-termination System (Additional Measures III)
Figure 3-5	General Plan of Relocation of Equipment/Apparatus (Additional Measures IV)

Table3-7 Equipment Specifications for Batu Ampar VTS Center

No.	Equipment Name	Insltalled Location	Equipment Specifications Name	Model	Maker	Q'ty
A	**Equipment Repair**					
A1.	Automatic Exchanger Panel for Commercial Line					
A1-1	Exchange Control Panel	GR	Exchange control unit	ATS.1.1	Schneider	1 set
A2.	Automatic Fuel Trnasfer					
A2-1	ATFS Panel	GR			Schneider	1 set
	Motor Panel	GR			Schneider	1 set
B	**Additional Measures I**					
B1	Performance Monitor	TT	SPD for Signal, 7 pins	CLP- NM	JRC	4sets
B2	Performance Monitor	TT	SPD Box		JRC	1set
B3	Radar Antenna	TT	AC/DC Power Unit	AC220V→DC12V	JRC	1set
B4	Radar Antenna	TT	SPD Box	For Outdoor	JRC	1set
B5	Lightning Surge Counter	TL	Lightning Surge Counter	LME-PK	JRC	1set
B6	Terminal Box (TB7)	OR	SPD, 7 pins	CLP-NM	JRC	4sets
B7	Terminal Box (K2,3)	OR	SPD for K2, 3 protection, 2 circuit	ZP-DC12V	JRC	2sets
B8	Lightning Surge Counter	OR	Lightning Surge Counter	SCAR11DL-1	JRC	1set
B9	ATFS-2	PR	SPD for main powerl ines, 3 ϕ 4", 380V	MZCR-400K3aRR	JRC	1set
C	**Additional Measure II**					
C1	Ligghtning System 1					3sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			1pc
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×2600		1pc
C2	Lightning System 2					8sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			1pc
			Mounting pole 1	STK400 Φ60.5×3.2×600		1pc
C3	Lightning System 3					12sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			1pc
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×4660		1pc

Note: TT:Tower Top, TL: Tower Leg, OR: Operation Room (4F), PR: Power Room (IF)

Table 3-7 Equipment Specifications for Batu Ampar VTS Center (Continue)

No.	Equipment Name	Insltalled Location	Equipment Specifications Name	Model	Maker	Q'ty
C4	Lightning System 4					4sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		10m
			Terminal			1pc
			Holding parts			1pc
			Mounting pole 1	STK400 Φ60.5×3.2×600		1oc
C5	Down Conductor					1set
	Per Unit		Ogre Twist line	60 sq		115m
			Bolt-connector	For 60 sq		62pcs
			Fixing materials for copper wire	For 60 sq		153pcs
			Crimped terminal	For 60 sq		27pcs
D	**Addional MeasuresIII**					
D1	Ring Earth System					1set
	Per Unit		Twisted annealed copper wire	60 sq		119m
			Grounding resistance reduction materials	M5C (25 kg/bag)		48bags
			Bolt-connector	For 60 sq		6pcs
D2	Connection of Outdoor and Indoor Grounding Wire					1set
	Per Unit		IV wire	60 sq（Green）		20m
			Connector Type-T	T-122		2pcs
			Cramped terminal Type-C	C2-60		2pcs
E	**Additional Measures IV**					
E1	Antenna Mounting Materials for AIS Transponder					2sets
	Per Unit		Angle Type-L	L660 (65×65×6)		1set
			U bolt	M10		2pcs
			V bolt	For angle of M16 L		2pcs

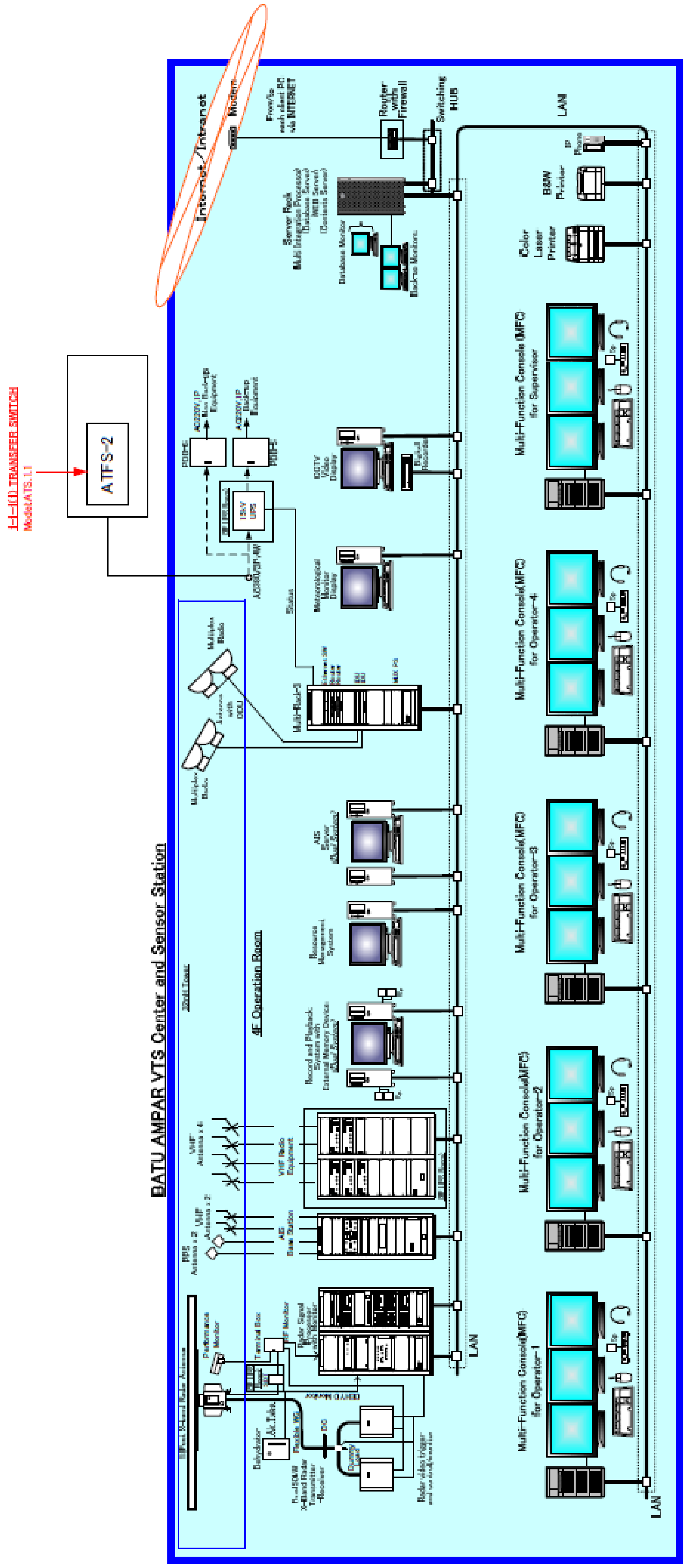


Figure 3-1 General Plan of Equipment Repair for Batu Ampar VTS Center

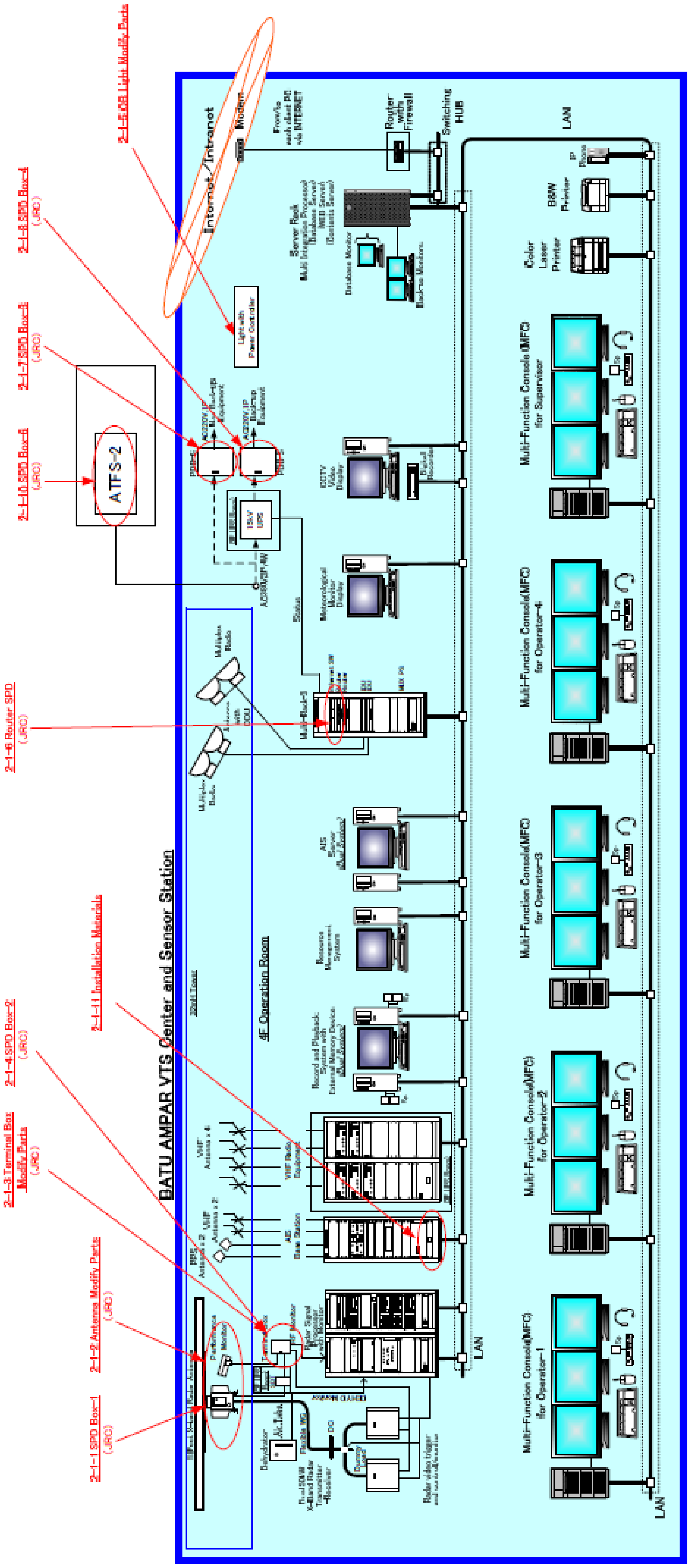


Figure 3-2 General Plan of Improvement of SPDs and Isolation Transformer
(Additional Measures I for Batu Ampar VTS Center)

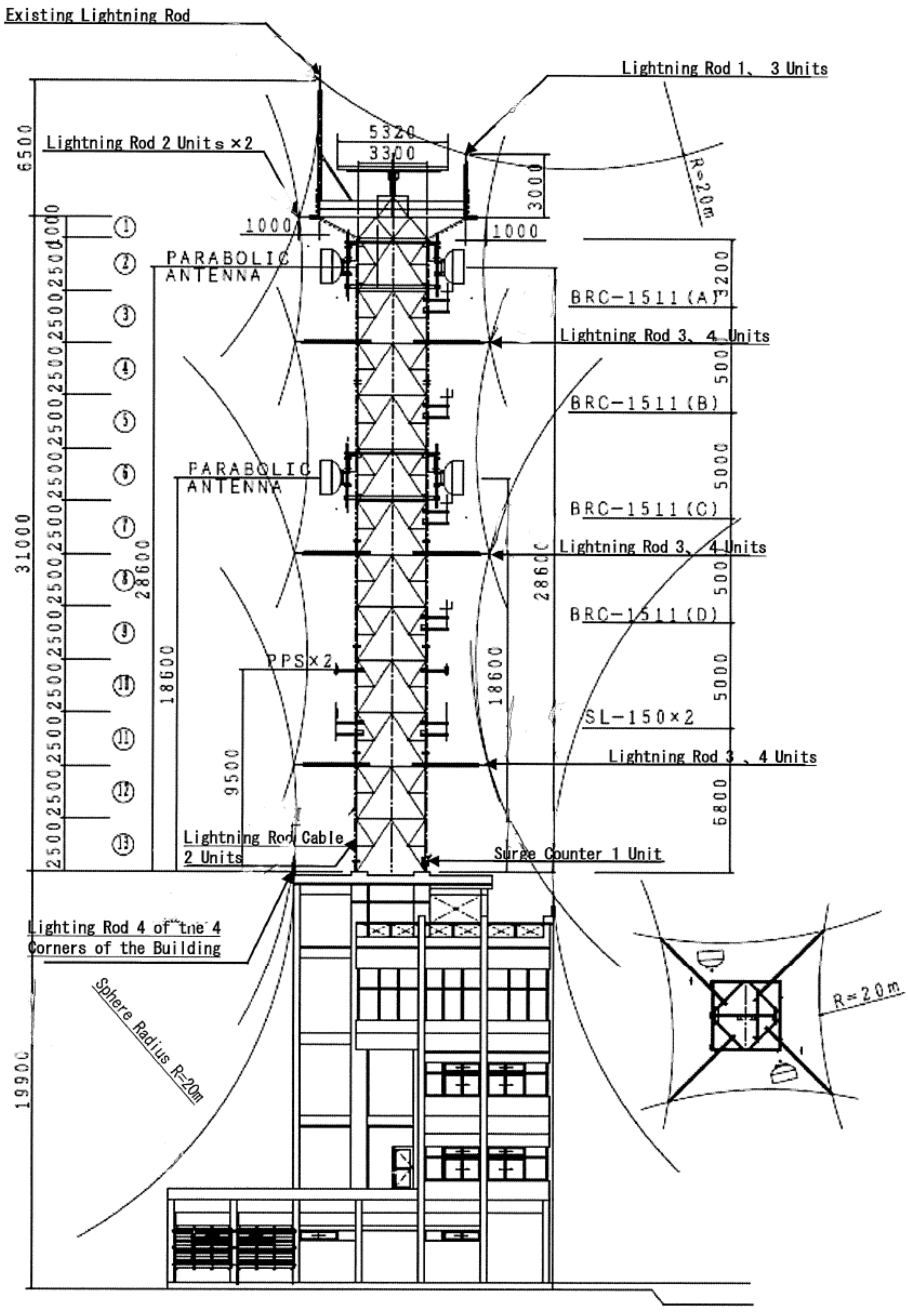


Figure 3-3 General Plan of Improvement of Air-termination System (Additional Measures II for Batu Ampar VTS Center)

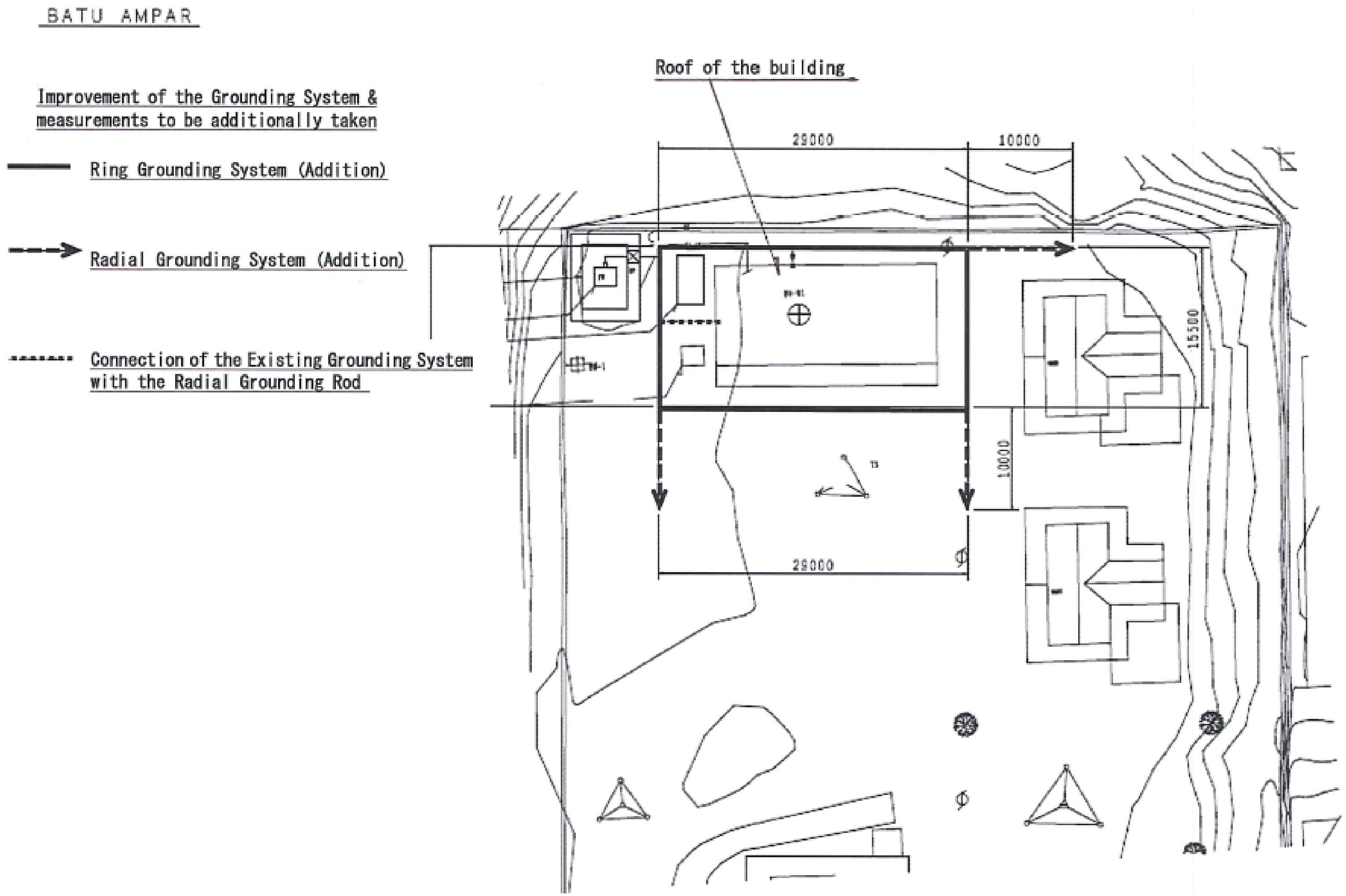


Figure 3-4 General Plan of Improvement of Earth-termination System (Additional Measures III for Batu Ampar VTS Center)

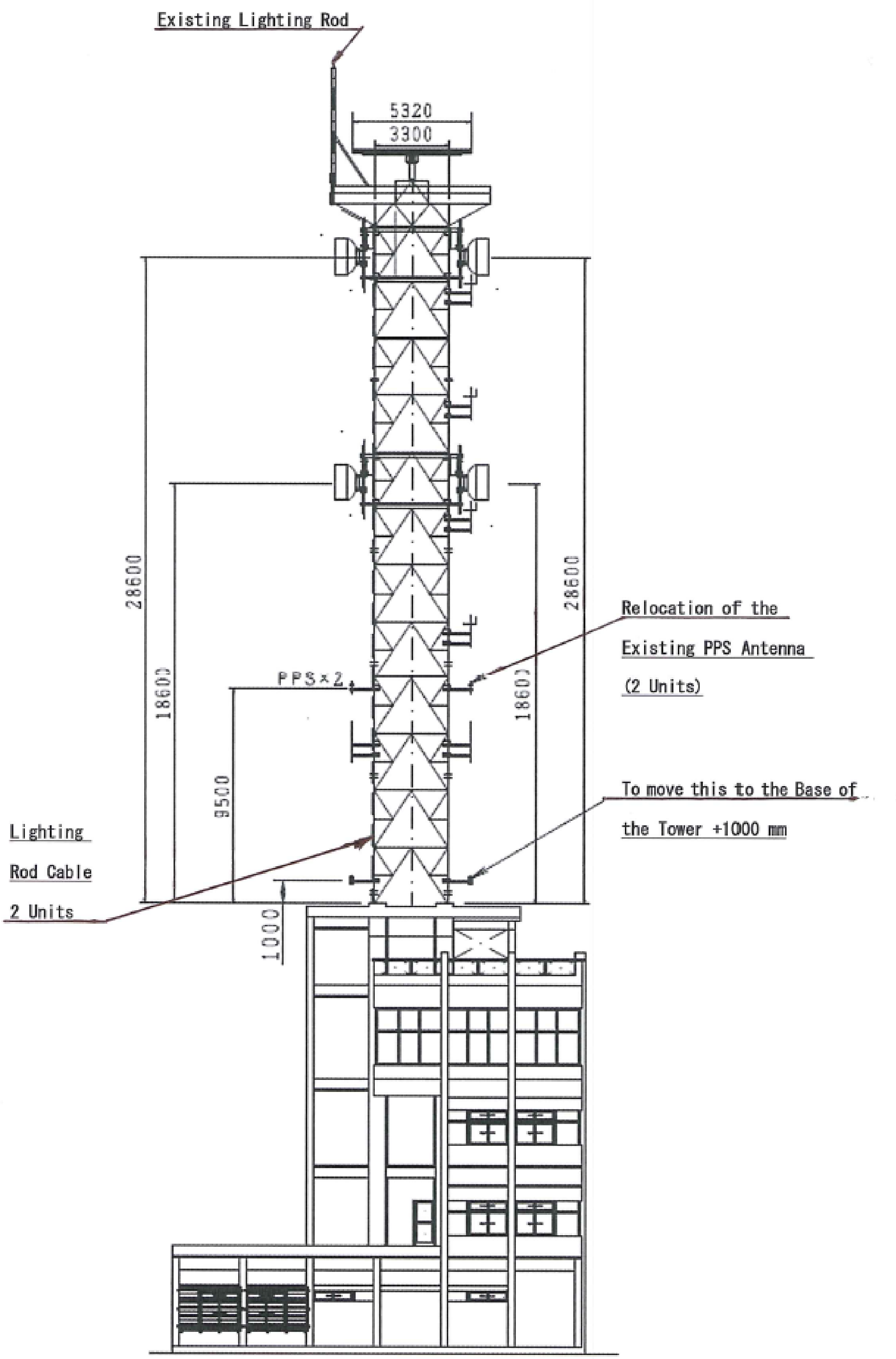


Figure 3-5 General Plan of Relocation of Equipment/Apparatus (Additional Measures IV for Batu Ampar VTS Center)

3-2-4-2 Tanjung Berakit

Equipment specifications and basic design drawings for restoration of the damaged apparatus and Additional Measures I to IV for Tanjung Berakit are shown below.

(1) Specifications of Equipment

Equipment to be used and its technical specifications for:

a. Restoration of the damaged apparatus
b. Additional Measures I (Improvement of SPDs and Isolation Transformeres)
c. Additional Measures II (Improvement of Air-termination System)
d. Additional Measures III (Improvement of Earth-termination System)
e. Additional Measures IV (Relocation of Equipment/Apparatus)

For Tanjung Berakit, the list is summarized in Table 3-8.

(2) Basic Design Drawings

Basic design drawings for Tanjung Berakit are shown below.

Figure 3-6	General Plan of Equipment Repair
Figure 3-7	General Plan of Improvement of SPDs and Isolation Transformers (Additional Measures I)
Figure 3-8	General Plan of Improvement of Air-termination System (Additional Measures II)
Figure 3-9	General Plan of Improvement of Earth-termination Sysmte (Additional Measures III
Figure 3-10	General Plan of Indoneer Ring Earth System (for all sites) (Additional Measures III)
Figure 3-11	General Plan of Relocation of Equipment/Apparatus (Additional Measures IV)

General plan of indoor ring earth system shown in Figure 3-10 is commonly applied for all sites except Batu Ampar VTS Center.

Table3-8 Equipment Specifications for Tanjung Berakit

No.	Equipment Name	Insltalled Location	Equipment Specifications Name	Model	Maker	Q'ty
A	**Equipment Repair**					
A1.	Radar System					
A1-1	18ft X-Band Radar Antenna	TT	ANT-OPT TX	CHU-59T	JRC	1set
A1-2	X-Band Radar TRX No.1	ER	DC PS Unit	CBD-1854	JRC	1set
A1-3	X-Band Radar TRX No.1	ER	T/R CONT	CMC-1205R	JRC	1set
A1-4	X-Band Radar TRX No.2	ER	DC PS Unit	CBD-1854	JRC	1set
A1-5	X-Band Radar TRX No.2	ER	T/R CONT	CMC-1205R	JRC	1set
A1-6	Terminal Box	ER	ANT-OPT RX	CHU-59R	JRC	1set
A1-7	Radar Signal Processor	ER	MPU Unit	CDJ-2408A	JRC	1set
A1-8	Radar Signal Processor	ER	Tracker-2 DC Power Unit	PCSA-37CP-X2S	JRC	1set
A1-9	Performance Monitor	TT	Performance Monitor	NJU-95	JRC	1set
A2.	AIS Base Station System					
A2-1	AIS Base Station	ER	AIS Transponder	NTE-182BC	JRC	2sets
A2-2	AIS Base Station	ER	AIS PP ANT		JRC	2sets
A3.	Meteorological Weather Monitoring System					
A3-1	Outdoor Box (for Weatehr Sensor Unit)	TT	SPD	SN-H2-H1	JRC	2sets
A3-2	Outdoor Box (for Weatehr Sensor Unit)	TT	SPD	CLP-H3cJK	JRC	3sets
A3-3	Outdoor Box (for Weatehr Sensor Unit)	TT	SPD	CLP-H3bJK	JRC	2sets
A3-4	Multi-Rack-1	ER	Digital Air Pressure Meter	PTB330	JRC	1set
A3-5	Multi-Rack-1	ER	Data Logger （for Weather Sensor）	CK-4100-J	JRC	1set
A4.	Air Conditioner					
A4-1	Air Conditioner	ER	Air Conditioner	FT35DVM/R35DV1	Daikin	1set
B	**Additional Measures I**					
B1	Performance Monitor	TT	SPD, 7 pins	CLP-NM	JRC	4sets
B2	Performance Monitor	TT	SPD Box		JRC	1set
B3	Radar Antenna	TT	AC/DC Power Unit	AC220V→DC12V	JRC	1set
B4	Radar Antenna	TT	SPD Box	For Outdoor	JRC	1set
B5	Lightning Surge Counter	TL	Lightning Surge Counter	LME-PK	JRC	1set
B6	Radar Antenna (SPD Box-1)	TT	Isolation Transformer	1 φ 2W220V,0.5kVA	JRC	1set
B7	Padar Antenna (SPD Box-1)	TT	SPD	1 φ , 2W 220V MZCR-200JK2ARR	JRC	1set
B8	Radar Antenna (SPD Box-2)	ER	Isolation Transformer	1 φ 2W220V,0.5kVA	JRC	1set
B9	Padar Antenna (SPD Box-2)	ER	SPD	1 φ , 2W 220V MZCR-200JK2ARR	JRC	1set
B10	Terminal Box (TB7)	ER	SPD, 7 pins	CLP-NM	JRC	4sets
B11	Terminal Box (K2,3)	ER	SPD, 2 circuits	P-DC12V	JRC	2sets
B12	Lightning Surge Counter (Inside of Terminal Box)	ER	Lightning Surge Counter	SCAR11DL-1	JRC	1set
B13	Obstacle Light	ER	SPD	1 φ 2W, 220V MZCR-200JK2ARR	JRC	1set
B14	Automatic Exchanger	GR	SPD	DC12V, ZP-DC12	JRC	2sets
B15	Automatic Exchanger	GR	SPD	DC24V, ZP-DC24	JRC	2sets
B16	Automatic Exchanger	GR	SPD	DC12V, ZP-DC12	JRC	4sets
B17	Strengthen of earth bonding	PR	Strengthen of earth bonding	40ｍ	JRC	1set
B18	Strengthen of earth bonding	ER	Ditto	40ｍ	JRC	1set

Note: TT:Tower Top, TL: Tower Leg, ER: Equipment Room, PR: Power Room, GR: Generator Room

Table 3-8 Equipment Specifications for Tanjung Berakit (Continue)

No.	Equipment Name	Insltalled Location	Equipment Specifications		Maker	Q'ty
			Name	Model		
C	**Additioinal Measures II**					
C1	Lightning System 1					3sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			1pc
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×2600		1pc
C2	Lightning System 2					8sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			1pc
			Mounting pole 1	STK400 Φ60.5×3.2×600		1pc
C3	Lightning System 3					4sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			2pcs
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×4660		1pc
C4	Lightning System 4					4sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60sq		2m
			Terminal			1pc
			Holding parts			2pcs
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×5240		1pc
C5	Lightning System 5					4sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			2pcs
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×6030		1pc

Table 3-8 Equipment Specifications for Tanjung Berakit (Continue)

No.	Equipment Name	Insltalled Location	Equipment Specifications Name	Model	Maker	Q'ty
C6	Lightning System 6					4sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			2pcs
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×6070		1pc
C7	Down Conductor					1set
	Per Unit		Ogre Twist line	60 sq		241m
			Bolt-connector	For 60 sq		64pcs
			Fixing materials for copper wire	For 60 sq		321pcs
			Crimped terminal	For 60 sq		27pcs
D	**Additional Measures III**					
D1	Ring Earth System (Outdoor)					1set
	Per Unit		Twisted annealed copper wire	60 sq		17m
			Grounding resistance reduction materials	M5C (25 kg)		95pcs
			Bolt-connector	For 60 sq		95pcs
D2	Ring Earth System (Indooer)					1set
	Per Unit		Flat bar of copper	t3×25×5000		17pcs
			Supporting materials for insulation	DB-50		95pcs
			Concrete Anchor	M8 SUS		95pcs
D3	Bonding between ring earth system of outdoor and indoor					1set
	Per Unit		IV wire	60 sq（Green）		120m
			Connector Type-T	T-122		19pcs
			Cramped terminal Type-C	C2-60		2pcs
E	**Additional Measures IV**					
E1	Antenna Mounting Materials for AIS Transponder					2sets
	Per Unit		Angle Type-L	L660 (65×65×6)		1pc
			U bolt	M10		2pcs
			V bolt	For angle of M16 L		2pcs
E2	Mounting Materials for Meteorological Sensor					1set
	Per Unit		Angle Type-L	L230 (240×260×6)		1oc
			V Bolt	For angle of M16 L		2pcs

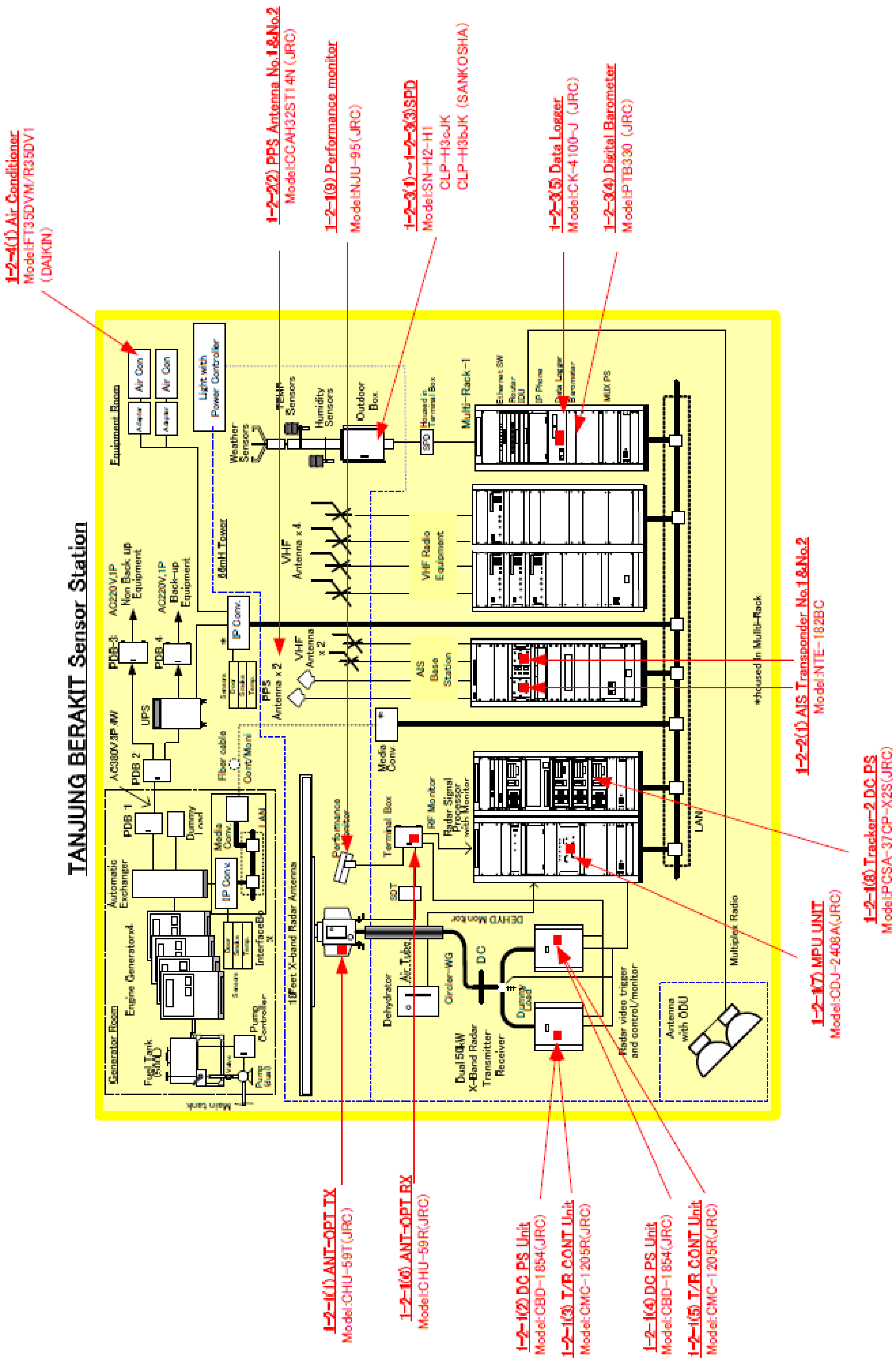


Figure 3-6 General Plan of Equipment Repair for Tanjung Berakit

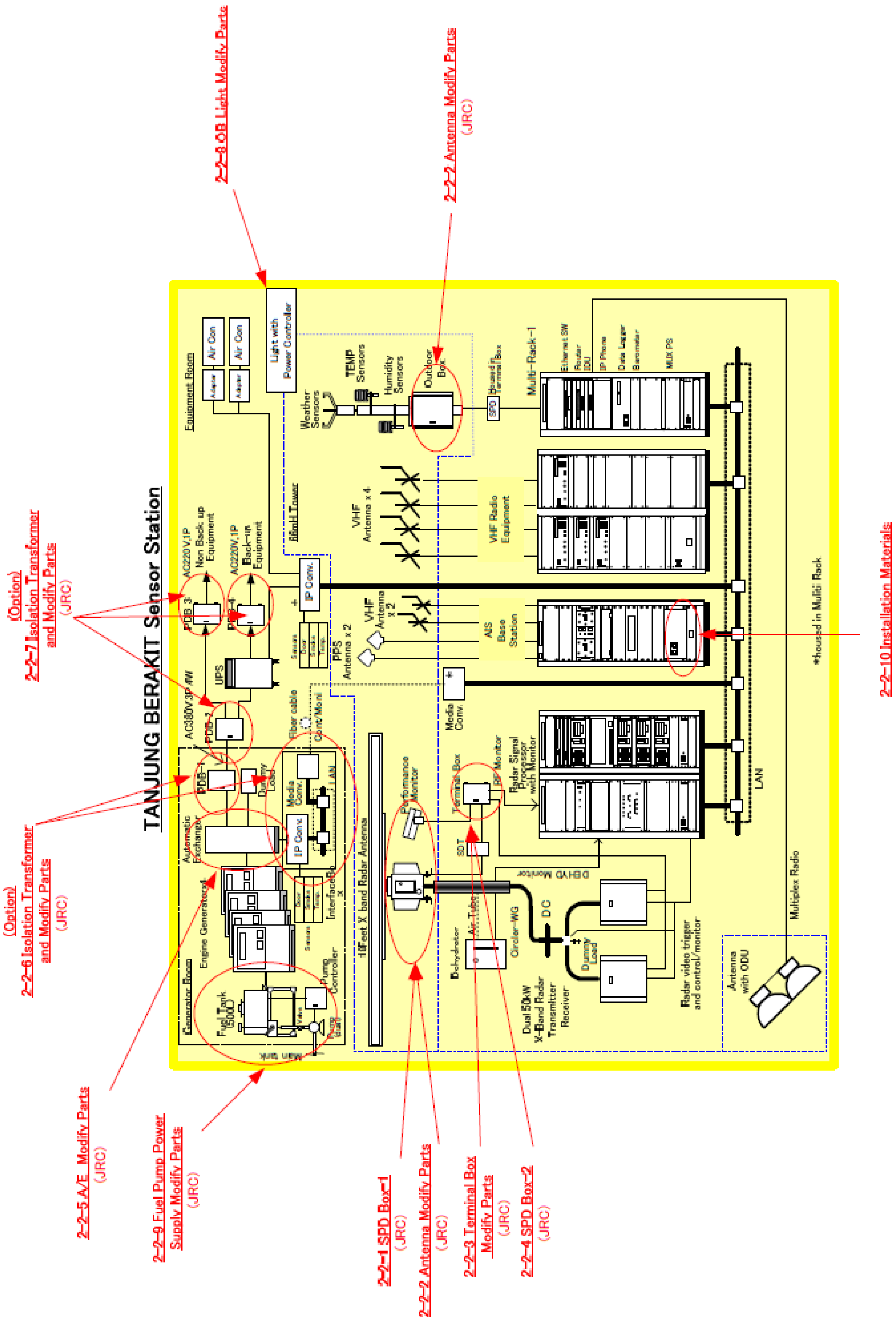


Figure 3-7 General Plan of Improvement of SPDs and Isolation Transformer (Additional Measures I for Tanjung Berakit)

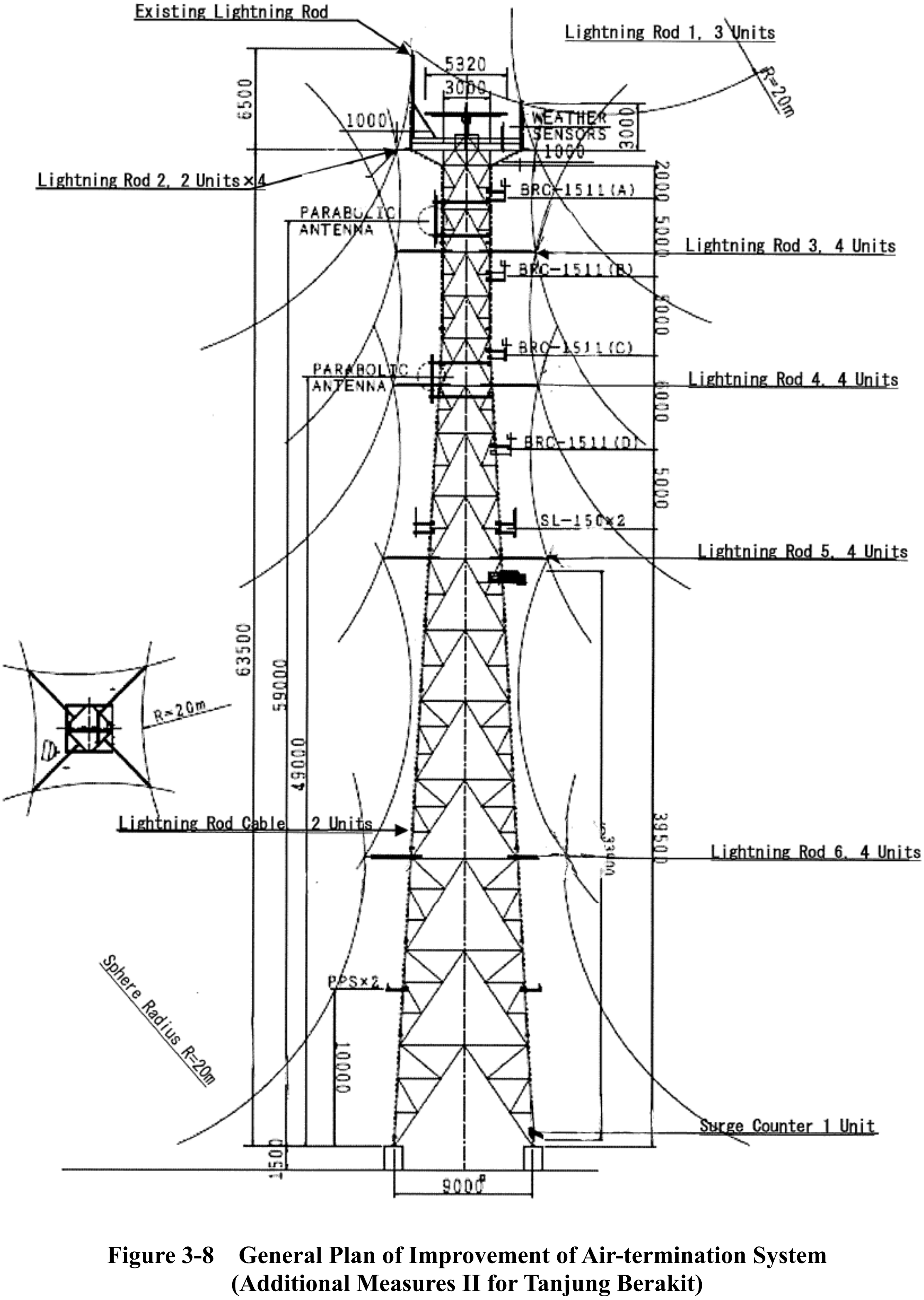


Figure 3-8 General Plan of Improvement of Air-termination System (Additional Measures II for Tanjung Berakit)

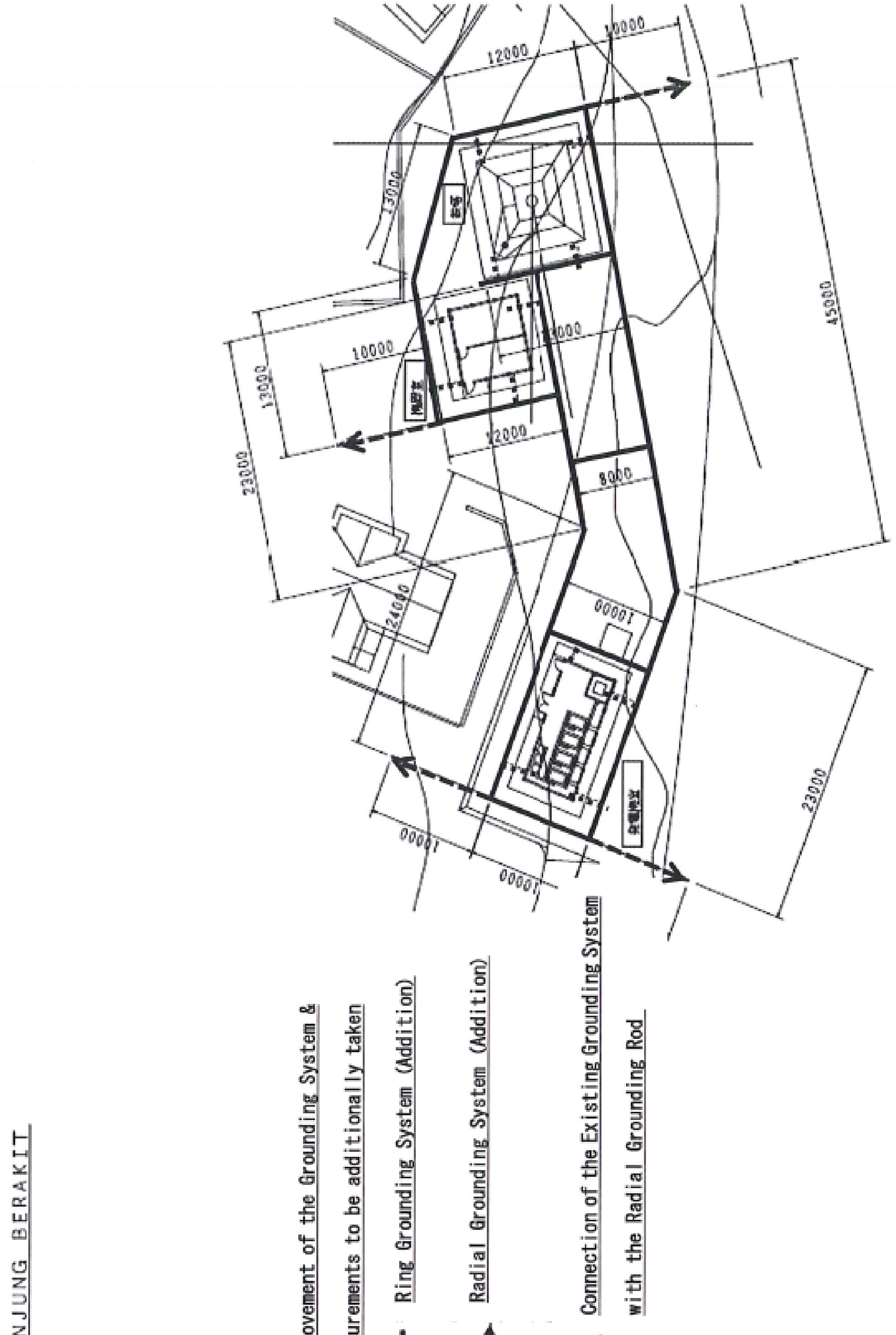


Figure 3-9 General Plan of Improvement of Earth-termination System (Additional Measures III for Tanjung Berakit)

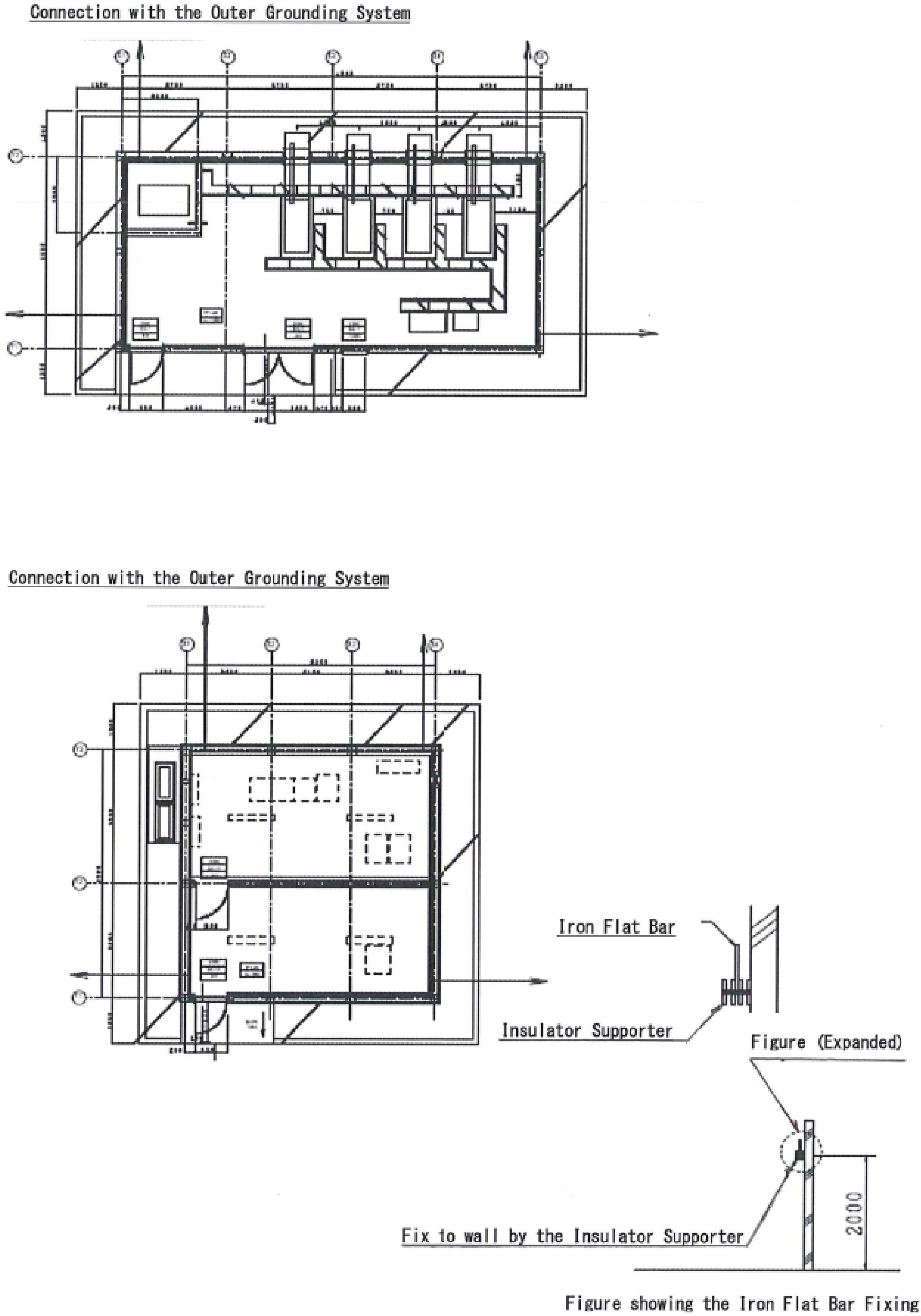


Figure 3-10 General Plan of Indoor Ring Earth System (for all sites) (Additional Measures III for Indoor System)

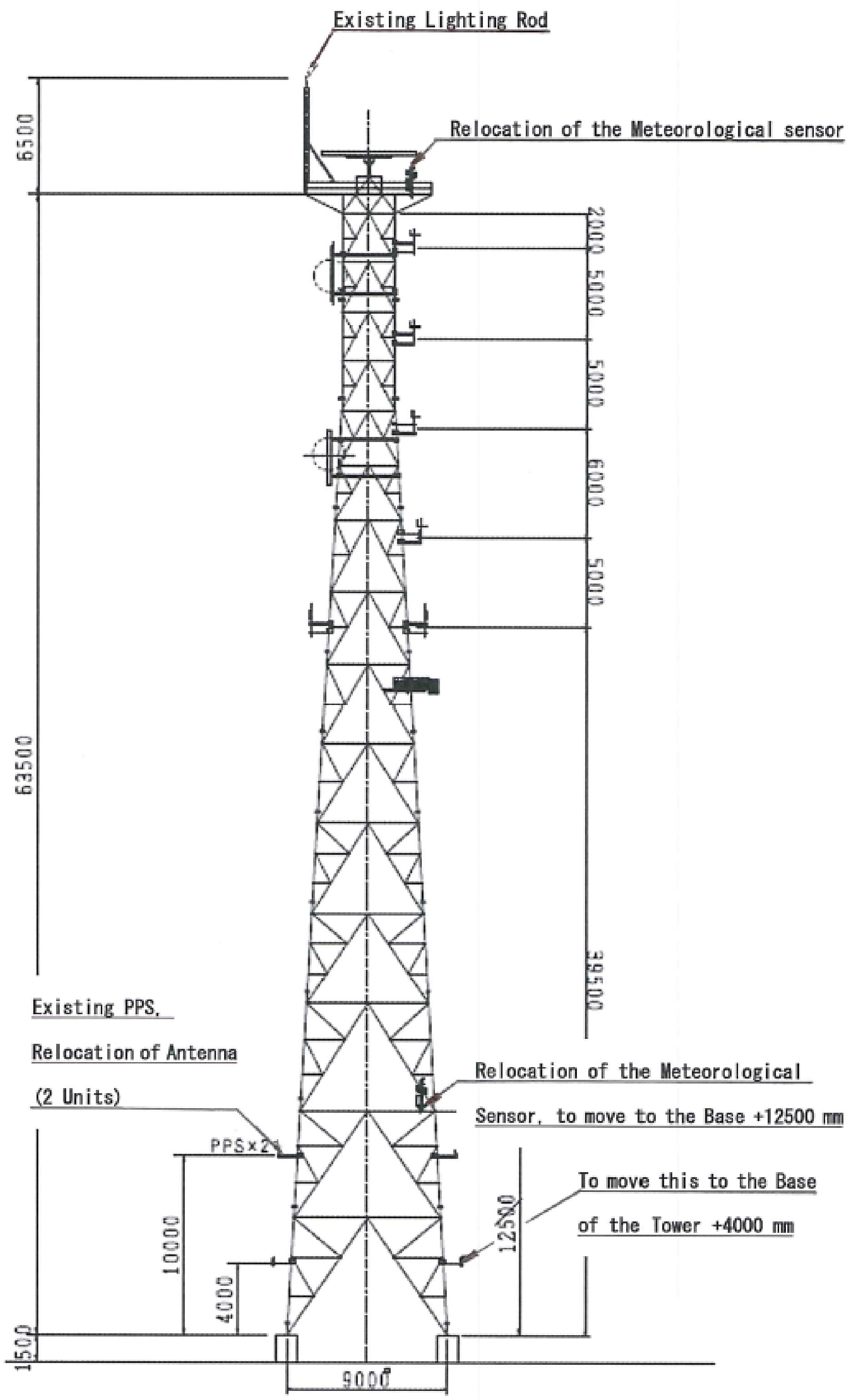


Figure 3-11 General Plan of Relocation of Equipment/Apparatus
(Additional Measures IV for Tanjung Berakit)

3-2-4-3 Hiyu Kecil

Equipment specifications and basic design drawings for restoration of the damaged apparatus and Additional Measures I to IV for Hiyu Kecil are shown below.

(1) Specifications of Equipment

Equipment to be used and their technical specifications for:

a. Restoration of the damaged apparatus
b. Additional Measures I (Improvement of SPDs and Isolation Transformers)
c. Additional Measures II (Improvement of Air-termination System)
d. Additional Measures III (Improvement of Earth-termination System)
e. Additional Measures IV (Relocation of Equipment/Apparatus)

for Hiyu Kecil, the list is summarized in Table 3-9.

(2) Basic Design Drawings

Basic design drawings for Hiyu Kecil are showin below.

Figure 3-12	General Plan of Equipment Repair
Figure 3-13	General Plan of Improvement of SPDs and Isolation Transformers (Additional Measures I)
Figure 3-14	General Plan of Improvement of Air-termination System (Additional Measures II)
Figure 3-15	General Plan of Improvement of Earth-termination Sysmte (Additional Measures III
Figure 3-16	General Plan of Relocation of Equipment/Apparatus (Additional Measures IV)

General plan of indoor ring earth system as described in Additional Measures III are given in Figure 3-10.

Table3-9 Equipment Specifications for Hiyu Kecil

No.	Equipment Name	Insltalled Location	Equipment Specifications Name	Model	Maker	Q'ty
A	**Repair Works**					
A1.	Radar System					
A1-1	18ft X-Band Radar Antenna	TT	ANT-OPT TX	CHU-59T	JRC	1set
A1-2	X-Band Radar TRX No.1	ER	DC PS Unit	CBD-1854	JRC	1set
A1-3	X-Band Radar TRX No.1	ER	T/R CONT	CMC-1205R	JRC	1set
A1-4	X-Band Radar TRX No.2	ER	DC PS Unit	CBD-1854	JRC	1set
A1-5	X-Band Radar TRX No.2	ER	T/R CONT	CMC-1205R	JRC	1set
A1-6	Terminal Box	ER	ANT-OPT RX	CHU-59R	JRC	1set
A1-7	Radar Signal Processor	ER	MPU Unit	CDJ-2408A	JRC	1set
A1-8	Performance Monitor	TT	Performance Monitor	NJU-95	JRC	1set
A2.	AIS Base Station System					
A2-1	AIS Base Station	ER	AIS Transponder	NTE-182BC	JRC	2sets
A3.	Meteorological Weather Monitoring System					
A3-1	Outdoor Box (for Weatehr Sensor Unit)	TT	SPD	SN-H2-H1	JRC	2sets
A3-2	Outdoor Box (for Weatehr Sensor Unit)	TT	SPD	CLP-H3cJK	JRC	3sets
A3-3	Outdoor Box (for Weatehr Sensor Unit)	TT	SPD	CLP-H3bJK	JRC	2sets
A3-4	Multi-Rack-1	ER	Data Logger (for Weather Sensor)	CK-4100-J	JRC	1set
A4.	Multiplex Radio Equipment					
A4-1	Multi-Rack-1	ER	IDU	MDP-34MB-28C-J	JRC	1set
A5.	UPS					
A5-1	Automatic Exchanger	PR	DC-CD UNIT	VTD24SC12-J	JRC	1set
A5-2	Interface Box	PR	Interface Box	NDC-1389	JRC	1set
A5-3	UPS	ER	Printed Board	PK-1229C-J	JRC	1set
A6.	Air Conditioner					
A6-1	Air Conditioner	ER	Air Conditioner	FT35DVM/ R35DV1	Daikin	1set
A7.	Obstruction Light					
A7-1	Obstacle Light	TT	Obstacle Light	XGP500 100-220Vac Type-A	Phillips	4sets
A7-2	Control Panel of Obstruction Light	ER	1.Photo-Electric Switch	200Vac, 6A Contact, 100-1000lux (LUMINA)	Phillips	1set
			2. Control Contactor (Relay)	25A 3P Coil220V (+INC+INO) (Schneider LC1-D09M7)	Phillips	1set
			3. Incoming Power Indicator LT	220Vac LED Type (Schneider Merin Gerin STI Series)	Phillips	1set
			4. Fuse	2A (X85AVB Series)	Phillips	2sets

Note: TT:Tower Top, TL: Tower Leg, ER: Equipment Room, PR: Power Room, GR: Generator Room, FT: Fuel Tank

Table 3-9 Equipment Specifications for Hiyu Kecil (Continue)

No.	Equipment Name	Insltalled Location	Equipment Specifications Name	Model	Maker	Q'ty
B	**Additional Measures I**					
B1	Performance Monitor	TT	SPD, 7 pins	CLP-NM	JRC	4sets
B2	Performance Monitor	TT	SPD Box		JRC	1set
B3	Radar Antenna	TT	AC/DC Power Unit	AC220V→DC12V	JRC	1set
B4	Radar Antenna	TT	SPD Box	Outdoor Type	JRC	1set
B5	Lightning Surbe Counter	TL	Lightning Surbe Counter	LME-PK	JRC	1set
B6	Padar Antenna (SPD Box-1)	TT	Isolation Transformer	1ϕ2W 220V, 0.5kVA	JRC	1set
B7	Radar Antenna (SPD Box-1)	TT	SPD	1ϕ2W 220V, MZCR-200JK2ARR	JRC	1set
B8	Terminal Box (SPD Box-2)	ER	Isolation Transformer	1φ2W 220V, 0.5kVA	JRC	1set
B9	Terminal Box (SPD Box-2)	ER	SPD	1ϕ2W 220V, MZCR-200JK2ARR	JRC	1set
B10	Terminal Box (TB7)	ER	SPD, 7 pins	CLP-NM	JRC	4sets
B11	Terminal Box (K2, 3)	ER	SPD, 2 circuits	ZP-DC12V	JRC	2sets
B12	Lightning Surge Counter (Near grounding terminal)	ER	Lightning Surge Counter	SCAR11DL-1	JRC	1set
B13	Obstacle Light	ER	SPD	1ϕ2W, 220V, MZCR-200JK2ARR	JRC	1set
B14	Automatic Exchanger	GR	SPD	DC12V, ZP-DC12	JRC	2sets
B15	Automatic Exchanger	GR	SPD	DC12V, ZP-DC24	JRC	2sets
B16	Automatic Exchanger	GR	SPD	DC12V, ZP-DC12	JRC	4sets
B17	Fuel Transfer Pump	FT	SPD Box	3ϕ4W, 380V, NZCR-400JK3ARR	JRC	1set
B18	PDB-1	GR	Isolation Transformer	3ϕ4W, 380V, 30kVA	JRC	1set
B19	PDB-1	GR	SPD	3ϕ4W, 380V, MZCR-400JK3ARR	JRC	1set
B20	PDB-1 (Interface NQD-2324)	GR	Isolation Transformer	1ϕ2W 220V, 2kVA	JRC	1set
B21	PDB-1 (Interface NQD-2324)	GR	SPD	1ϕ2W 220V, MZCR-200JK2ARR	JRC	1set
B22	PDB-1 (Interface NQD-2324)	GR	Optical Cable.	Isolation of tension member ends of optical cable.	JRC	1set
B23	PDB-2	PR	Isolation Transformer	3ϕ4W, 380V, 30kVA	JRC	1set
B24	PDB-2	PR	SPD	3ϕ4W, 380V, MZCR-400JK3ARR	JRC	1set
B25	PDB-3	PR	SPD	3ϕ4W, 380V、MZCR-400JK3ARR	JRC	1set
B26	PDB-4	PR	SPD	1ϕ2W 220V, MZCR-200JK2ARR	JRC	1set
B27	PDB-4 (Interface)	PR	Isolation Transformer	1ϕ2W 220V, 2kVA	JRC	1set
B28	PDB-4 (Interface)	PR	SPD	1ϕ2W 220V, MZCR-200JK2ARR	JRC	1set
B29	PDB (Interface)	PR	Optical Cable.	Isolation of tension member ends of optical cable.	JRC	1set
B30	Strengthen of earth bonding	PR	Strengthen of earth bonding	40m	JRC	1set
B31	Strengthen of earth bonding	ER	Strengthen of earth bonding	40m	JRC	1set

Note: TT:Tower Top, TL: Tower Leg, ER: Equipment Room, PR: Power Room, GR: Generator Room, FT: Fuel Tank

Table 3-9 Equipment Specifications for Hiyu Kecil (Continue)

No.	Equipment Name	Insltalled Location	Equipment Specifications Name	Model	Maker	Q'ty
C	**Additional MeasuresII**					
C1	Lightning System 1					3sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			1pc
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×2600		1pc
C2	Lightning System 2					8sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			1pc
			Mounting pole 1	STK400 Φ60.5×3.2×600		1pc
C3	Lighting System 3					4sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			2pcs
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×4660		1pc
C4	Lightning System 4					4sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			12pcs
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			2pcs
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×5240		1pc
C5	Down Conductor					1set
	Per Unit		Ogre Twist line	60 sq		118m
			Bolt-connector	For 60 sq		44pcs
			Fixing materials for copper wire	For 60 sq		157pcs
			Crimped terminal	For 60 sq		19pcs

Table 3-9 Equipment Specifications for Hiyu Kecil (Continue)

No.	Equipment Name	Insltalled Location	Equipment Specifications Name	Model	Maker	Q'ty
D	**Additional Measure III**					
D1	Ring earth system (Outdoor)					1set
	Per Unit		Titanium belt	w40×t1		160m
			Titanium nuts and bolts	M12×25		40pcs
			Twisted annealed copper wire	60 sq		410m
			Grounding resistance reduction materials	M1C (25 kg)		9bags
			〃	M5C (25 kg)		164bags
			Cement mortar	25 kg		260pcs
			Electrode for in-sea use			4pcs
D2	Ring Earth System (Indoor)					1 set
	Per Unit		Flat bar of copper	t3×25×5000		17pcs
			Supporting materials for insulation	DB-50		95pcs
			Concrete Anchor	M8 SUS		95pcs
D3	Bonding between ring earth system of outdoor and indoor					1set
	Per Unit		IV wire	60 sq（Green）		120m
			Connector Type-T	T-122		54pcs
			Cramped terminal Type-C	C2-60		2pcs
D4	Earth Termination of Fuel Supply Tank					1set
			IV wire	60 sq（Green）		120m
			Connector Type-T	T-122		24pcs
			Cramped terminal Type-C	C2-60		24pcs
E	**Additional Measures IV**					
E1	Antenna Mounting Materials for AIS Transponder					2sets
	Per Unit		Angle Type-L	L660 (65×65×6)		1pc
			U bolt	M10		2pcs
			V bolt	For angle of M16 L		2pcs
E2	Mounting Materials for Meteorological Sensor					1set
			Angle Type-L	L230 (240×260×6)		1pc
			V Bolt	For M16 L Angle		2pcs

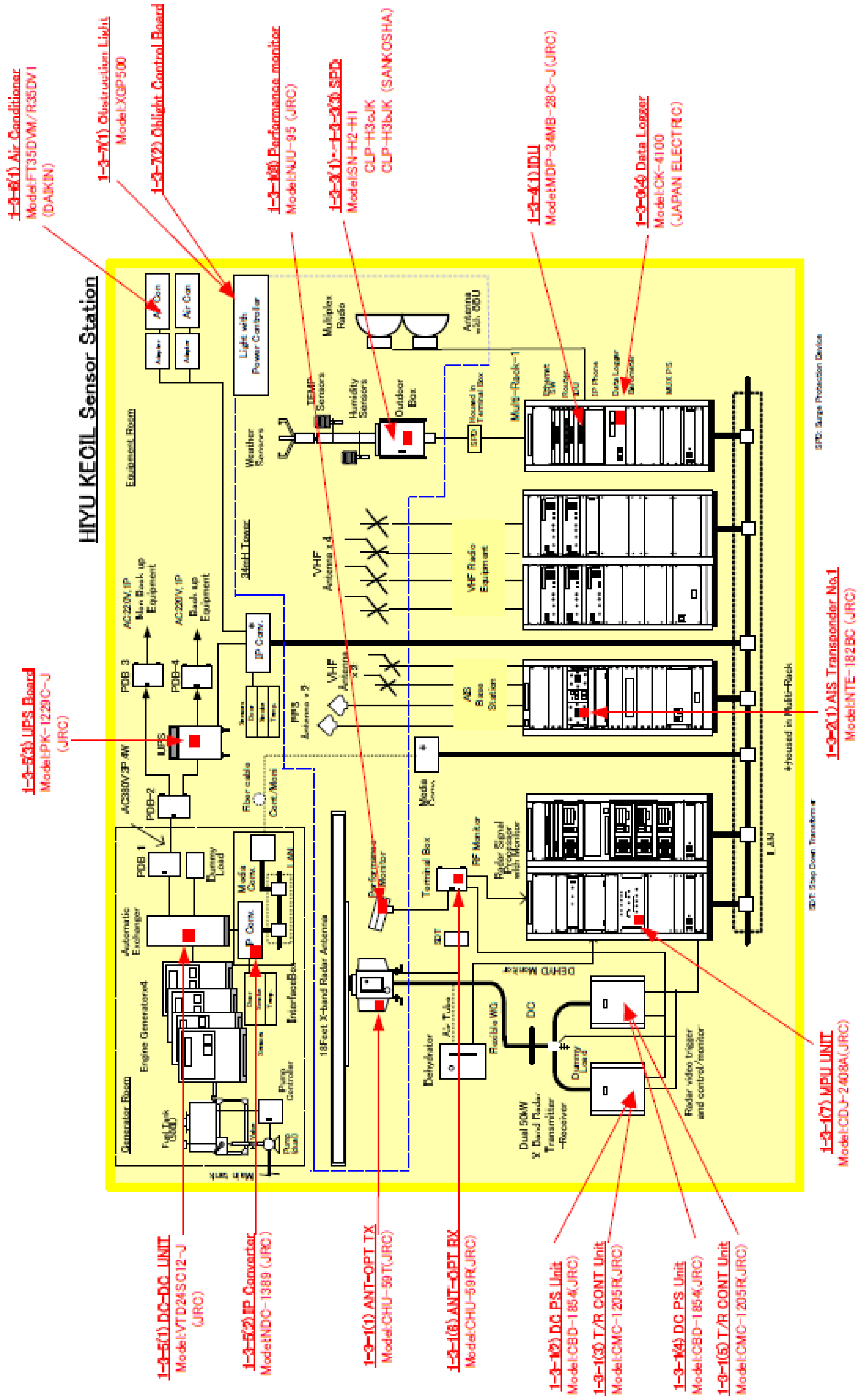


Figure 3-12 General Plan of Equipment Repair for Hiyu Kecil

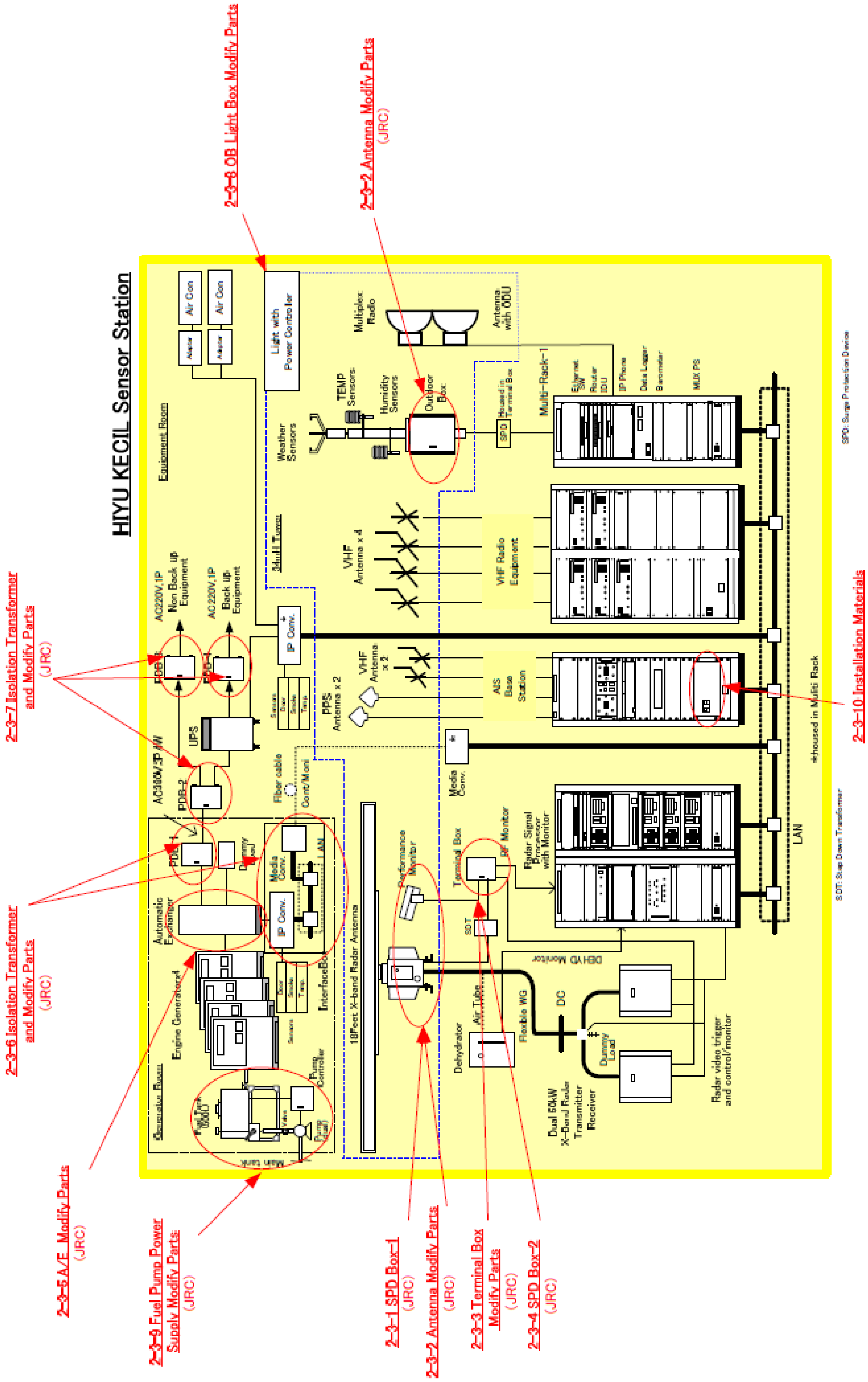


Figure 3-13 General Plan of Improvement of SPDs and Isolation Transfomer (Additional Measures I for Hiyu Kecil)

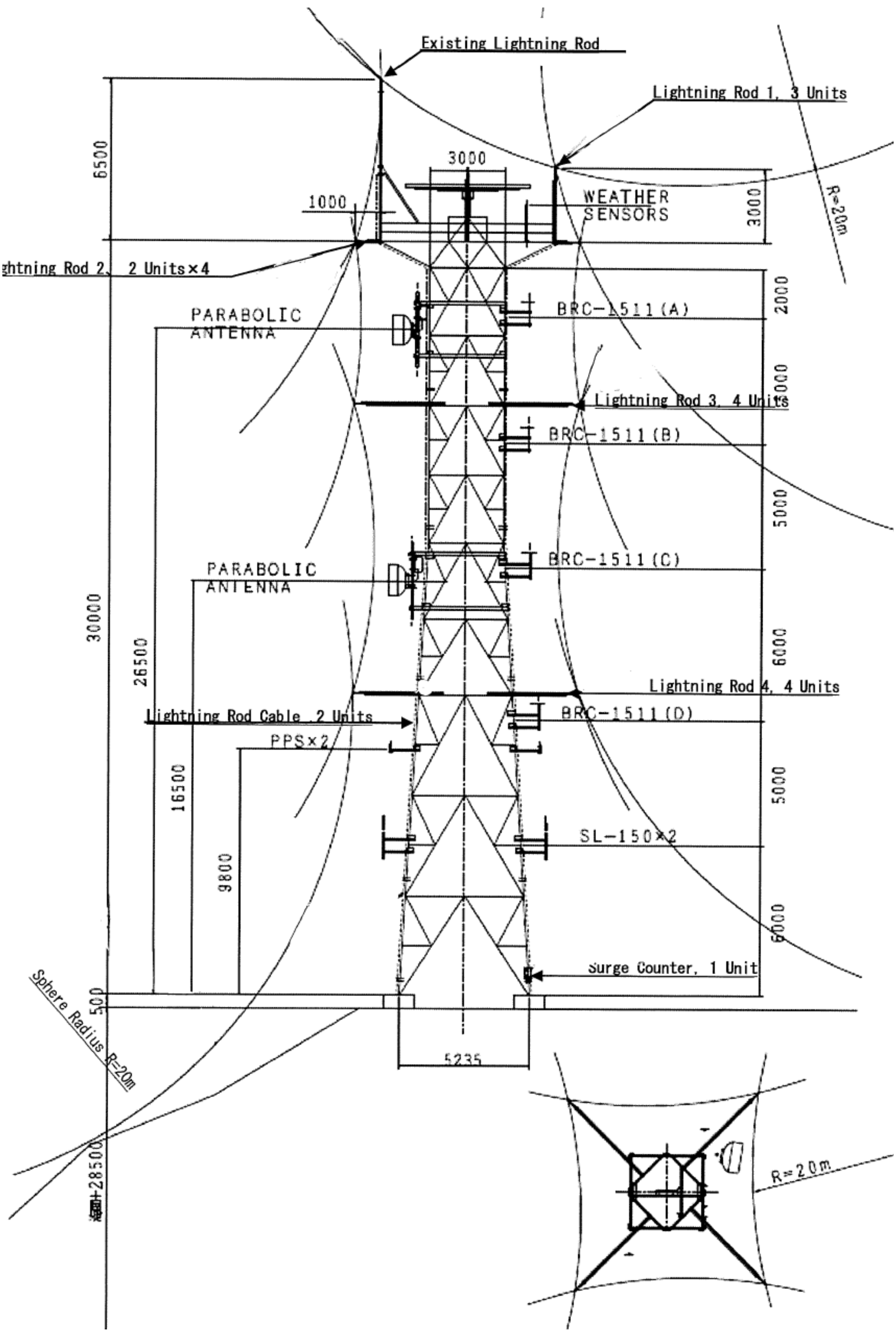


Figure 3-14 General Plan of Improvement of Air-termination System (Additional Measures II for Hiyu Kecil)

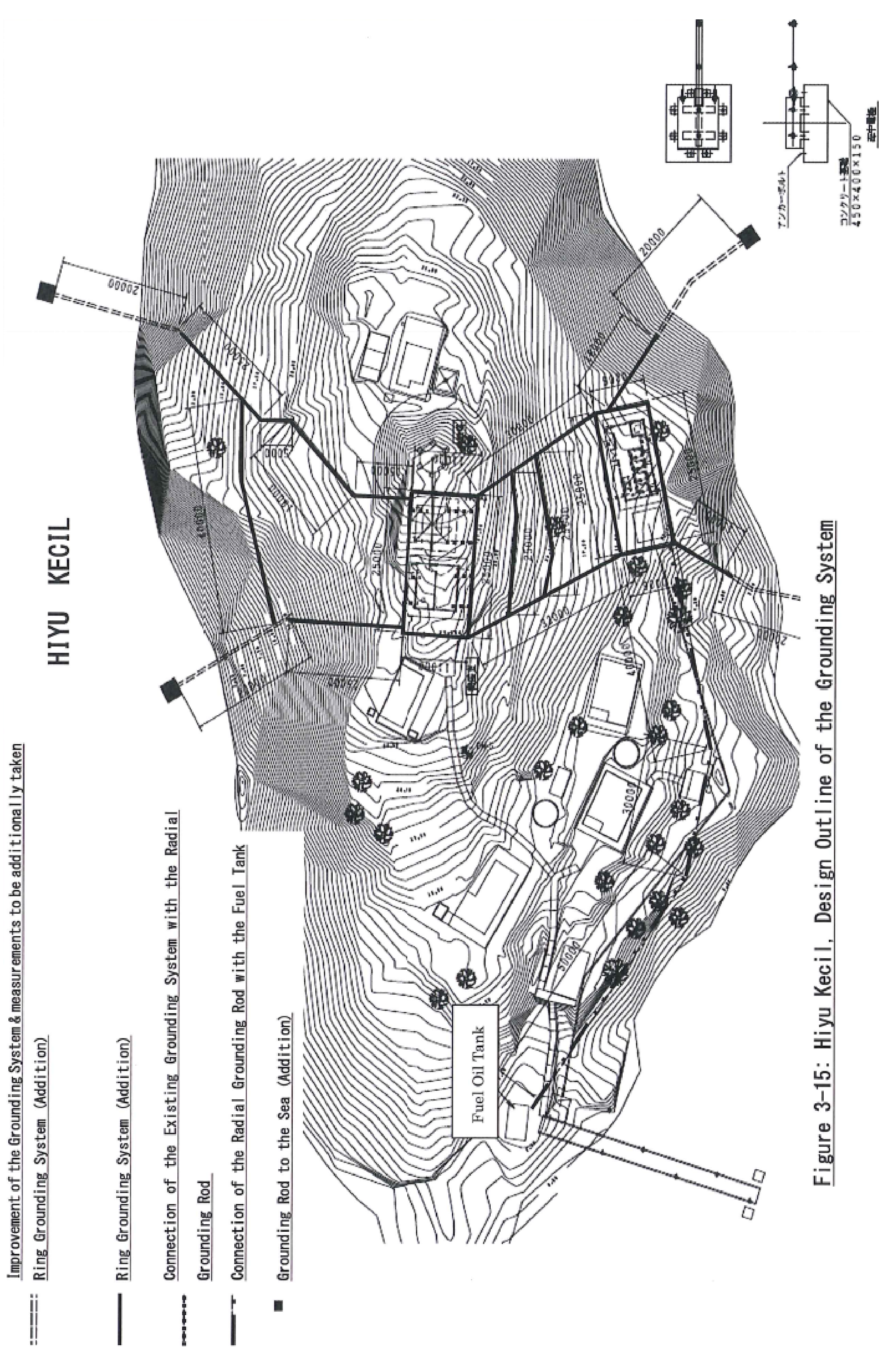


Figure 3-15 General Plan of Earth-termination System (Additional Measures III for Hiyu Kecil)

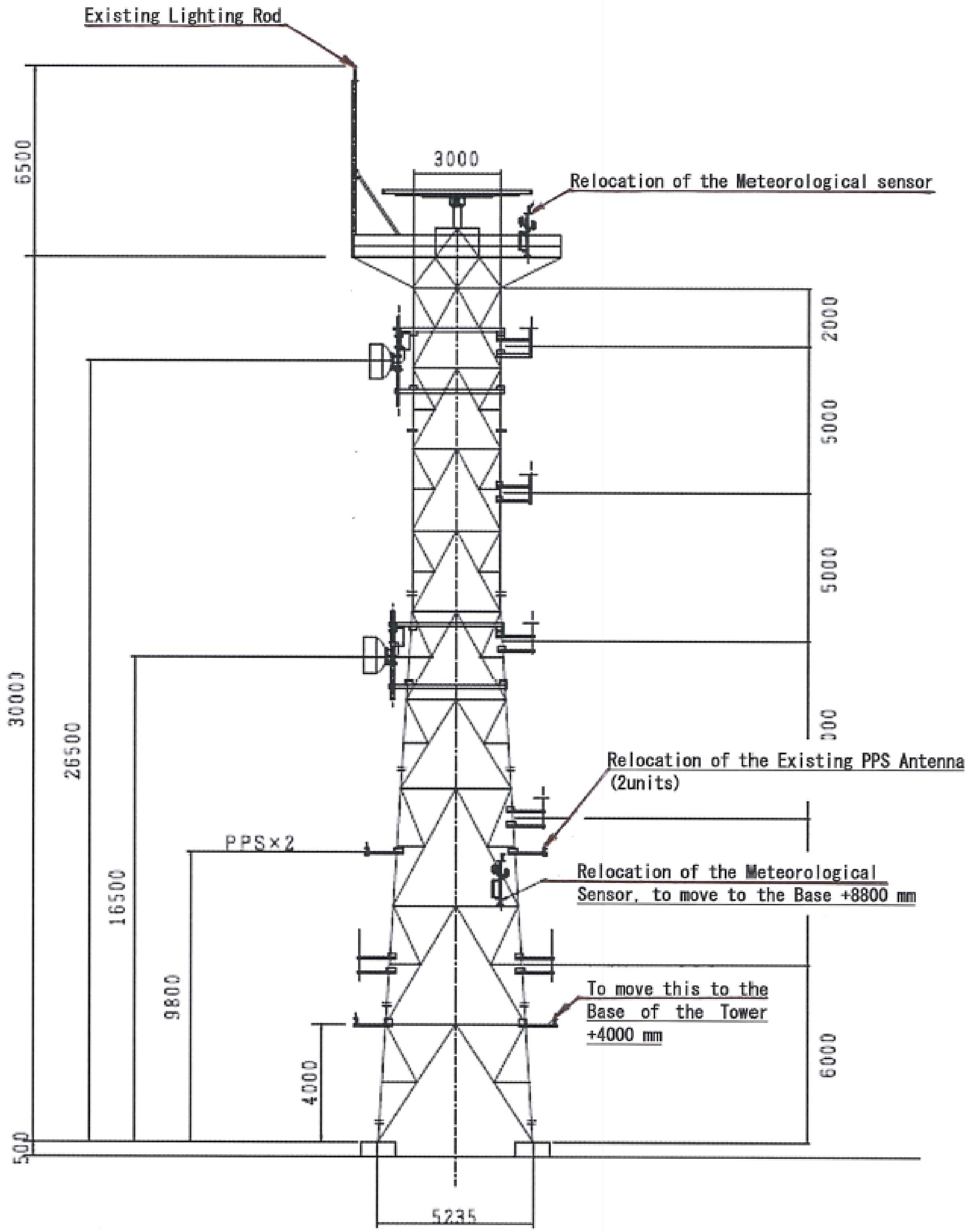


Figure 3-16 General Plan of Relocation of Equipment/Apparatus (Additional Measures IV for Hiyu Kecil)

3-2-4-4 Takong Kecil

Equipment specifications and basic design drawings for restoration of the damaged apparatus and Additional Measures I to IV for Takong Kecil are as shown in below. In Takong Kecil, there are no equipment/apparatus is necessary to relocate as specified in Additional Measures IV.

(1) Specifications of Equipment

Equipment to be used and its technical specifications for:

a. Restoration of the damaged apparatus

b. Additional Measures I (Improvement of SPDs and Isolation Transformers)

c. Additional Measures II (Improvement of Air-termination System)

d. Additional Measures III (Improvement of Earth-termination System)

For Takong Kecil, the list is summarized in Table 3-10.

(2) Basic Design Drawings

Basic design drawings for Takong Kecil are showin below.

Figure 3-17 General Plan of Equipment Repair
Figure 3-18 General Plan of Improvement of SPDs and Isolation Transformers (Additional Measures I)
Figure 3-19 General Plan of Improvement of Air-termination System (Additional Measures II)
Figure 3-20 General Plan of Improvement of Earth-termination System (Additional Measures III

General plan of indoor ring earth system as specified in Additional Measures III are shown in Figure 3-10.

Table3-10 Equipment Specifications for Takong Kecil

No.	Equipment Name	Insltalled Location	Equipment Specifications		Maker	Q'ty
			Name	Model		
A	**Equipment Repair**					
A1.	Radar System					
A1-1	18ft X-Band Radar Antenna	TT	ANT-OPT TX	CHU-59T	JRC	1set
A1-2	X-Band Radar TRX No.1	ER	DC PS Unit	CBD-1854	JRC	1set
A1-3	X-Band Radar TRX No.1	ER	T/R CONT	CMC-1205R	JRC	1set
A1-4	X-Band Radar TRX No.2	ER	DC PS Unit	CBD-1854	JRC	1set
A1-5	X-Band Radar TRX No.2	ER	T/R CONT	CMC-1205R	JRC	1set
A1-6	Terminal Box	ER	ANT-OPT RX	CHU-59R	JRC	1set
A1-7	Radar Signal Processor	ER	MPU Unit	CDJ-2408A	JRC	1set
A1-8	Performance Monitor	TT	Performance Monitor	NJU-95	JRC	1set
A2.	CCTV Camera System					
A2-1	CCTV Camera	TT	CCTV Camera	HC-240-J	JRC	1set
A2-2	CCTV Camera Controller	ER	MPU Unit	CDJ-2408A	JRC	1set
A2-3	WEB Encoder	ER	WEB Encoder	PT-IP150T	JRC	1set
A2-4	Multi Rack	ER	Serial IP Converter	SI-65-J	JRC	2sets
A3.	Air Conditioning System					
A3-1	Air Conditioner	ER	Air Conditioner	FT35DVM/R35DV1	Daikin	1set

Note: TT:Tower Top, TL: Tower Leg, ER: Equipment Room, PR: Power Room, GR: Generator Room, FT: Fuel Tank

Table 3-10 Equipment Specifications for Takong Kecil (Continue)

No.	Equipment Name	Insltalled Location	Equipment Specifications Name	Model	Maker	Q'ty
B	**Additional Measure I**					
B1	Performance Monitor	TT	SPD, 7 pins	CLP-NM	JRC	4sets
B2	Performance Monitor	TT	SPD Box		JRC	1set
B3	Radar Antenna	TT	AC/DC Power Unit	AC220V→DC12V	JRC	1set
B4	Radar Antenna	TT	SPD Box	Outdoor Type	JRC	1set
B5	Lightning Surge Counter	TL	Lightning Surge Counter	ME-PK	JRC	1set
B6	Radar Antenna (SPD Box-1)	TT	Isolation Transformer	1 φ 2W 220V, 0.5kVA	JRC	1sett
B7	Radar Antenna (SPD Box-1)	TT	SPD	1 φ 2W 220V, MZCR-200JK2ARR	JRC	1set
B8	Terminal Box (SPDBox 2)	ER	Isolation Transformer	1φ2W 220V, 0.5kVA	JRC	1set
B9	Terminal Box (SPDBox 2)	ER	SPD	1 φ 2W 220V, MZCR-200JK2ARR	JRC	1set
B10	Terminal Box (TB7)	ER	SPD, 7 pins	CLP-NM	JRC	4sets
B11	Terminal Box(K2,3)	ER	SPD, 2 circuits	ZP-DC12V	JRC	2sets
B12	Lightning Surge Counter (Near Grounding Terminal)	ER	Lightning Surge Counter	SCAR11DL-1	JRC	1set
B13	Obstacle Light	ER	SPD	1 φ 2W, 220V, MZCR-200JK2ARR	JRC	1set
B14	Automatic Exchanger	GR	SPD	DC12V, ZP-DC12	JRC	2sets
B15	Automatic Exchanger	GR	SPD	DC24V, ZP-DC24	JRC	2sets
B16	Automatic Exchanger	GR	SPD	DC12V, ZP-DC12	JRC	4sets
B17	Fuel Transfer Pump	FT	SPD Box	3 φ 4W, 380V, NZCR-400JK3ARR	JRC	1set
B18	CCTV Camera (SPD Box-3)	TT	SPD for RS422	ZP-H2-H1	JRC	2sets
B19	CCTV Camera (SPD Box-3)	TT	SPD:	CX-H-N	JRC	1set
B20	CCTV Camera (SPD Box-3)	TT	Isolation Transformer	1 φ 2W 220V, 0.5kVA	JRC	1set
B21	WEB Encoder (SPD Box-3)	ER	SPD for RS422	ZP-H2-H1	JRC	2sets
B22	WEB Encoder (SPD Box-3)	ER	SPD for LAN	RJ-45, LAN-1000IS	JRC	1set
B23	WEB Encoder (SPD Box-3)	ER	Isolation Transformer	1 φ 2W 220V, 0.5kVA	JRC	1set
B24	Strengthen of earth bonding	PR	Strengthen of earth bonding	40m	JRC	1set
B25	Strengthen of earth bonding	PR	Strengthen of earth bonding	40m	JRC	1set

Note: TT:Tower Top, TL: Tower Leg, ER: Equipment Room, PR: Power Room, GR: Generator Room, FT: Fuel Tank

Table 3-10 Equipment Specifications for Takong Kecil (Continue)

No.	Equipment Name	Insltalled Location	Equipment Specifications		Maker	Q'ty
			Name	Model		
C	**Additional Measures II**					
C1	Lighting System 1					3sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			1pc
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×2600		1pc
C2	Lightning System 2					8sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			1pc
			Mounting pole 1	STK400 Φ60.5×3.2×600		1oc
C3	Lightning System 3					4sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60sq		2m
			Terminal			1pc
			Holding parts			2pcs
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×4660		1pc
C4	Lightning System 4					4sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			2ocs
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×5240		1pc
C5	Lightning System 5					4sets
	Per Unit		Lightning Rod	Kokousyou-type LR-1		1pc
			Dai-Coupling			1pc
			Ogre Twist line	60 sq		2m
			Terminal			1pc
			Holding parts			2pcs
			Mounting pole 1	STK400 Φ60.5×3.2×100		1pc
			Mounting pole 2	STK400 Φ89.1×4.2×6030		1pc
C6	Down Conductor					1set
	Per Unit		Ogre Twist line	60 sq		170m
			Bolt-connector	For 60 sq		54pcs
			Fixing materials for copper wire	For 60 sq		226pcs
			Crimped terminal	For 60 sq		23pcs

Table 3-10 Equipment Specifications for Takong Kecil (Continue)

No.	Equipment Name	Insltalled Location	Equipment Specifications		Maker	Q'ty
			Name	Model		
D	**Additional Measures III**					
D1	Ring Earth System (Outdoor)					1set
	Per Unit		Twisted annealed copper wire	60 sq		227m
			Grounding resistance reduction materials	M5C (25 kg)		91bags
			Bolt-connector	For 60 sq		10pcs
D2	Ring Earth System (Indoor)					1set
	Per Unit		Flat bar of copper	t3×25×5000		17pcs
			Supporting materials for insulation	DB-50		95pcs
			Concrete Anchor	M8 SUS		95pcs
D3	Bonding between ring earth system of outdoor and indoor					1set
	Per Unit		IV wire	60 sq（Green）		120m
			Connector Type-T	T-122		18set
			Cramped terminal Type-C	C2-60		2sets
D4	Earth-Termination of Fuel Supply Tank					1set
	Per Unit		IV wire	60 sq（Green）		30m
			Cramped terminal	R60-8 with circle cap		6pcs
			Bolt-connector	For 60 sq		6pcs
E	**Additional Measures IV**					
	No measures					

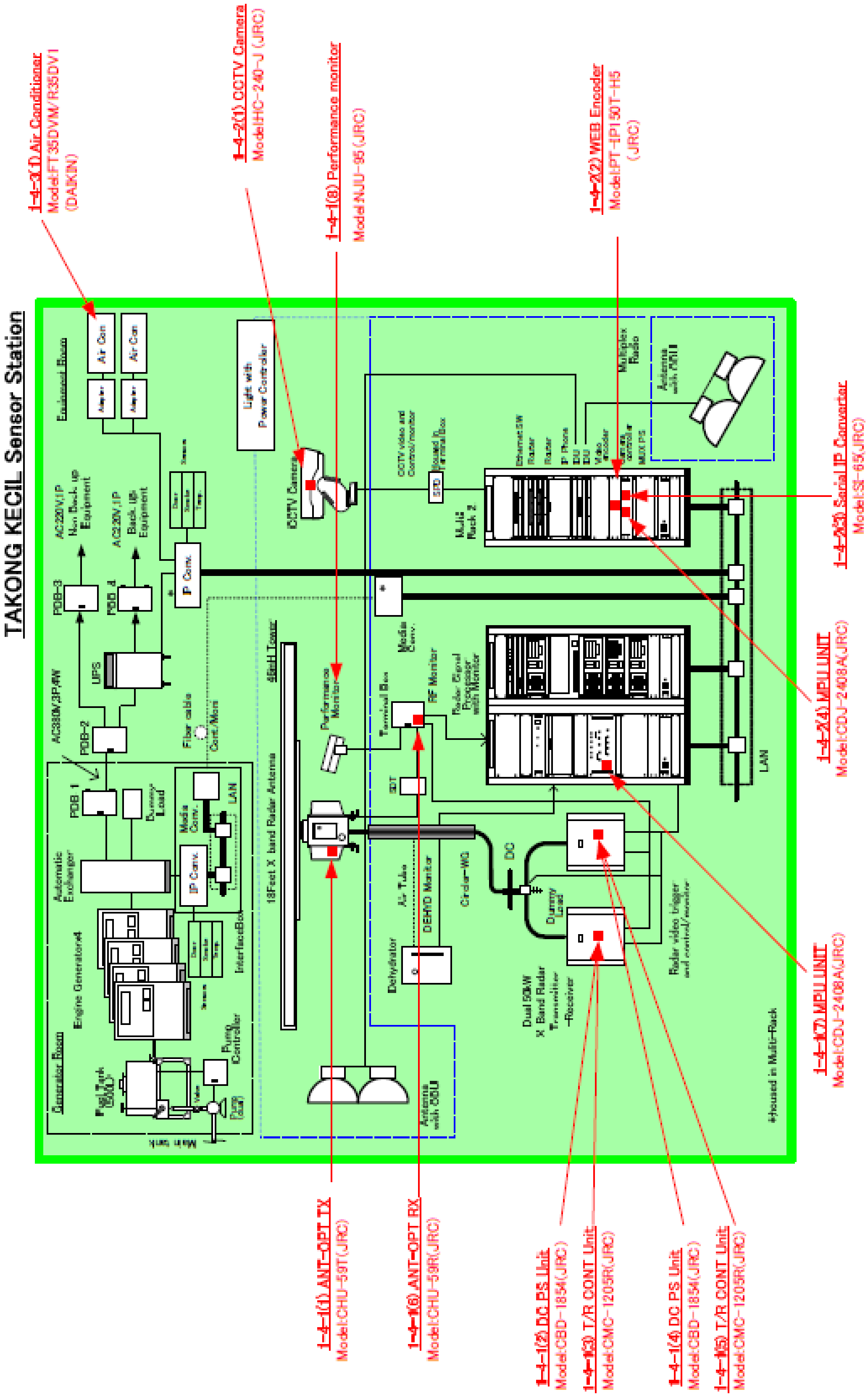


Figure 3-17 General Plan of Equipment Repair for Takong Kecil

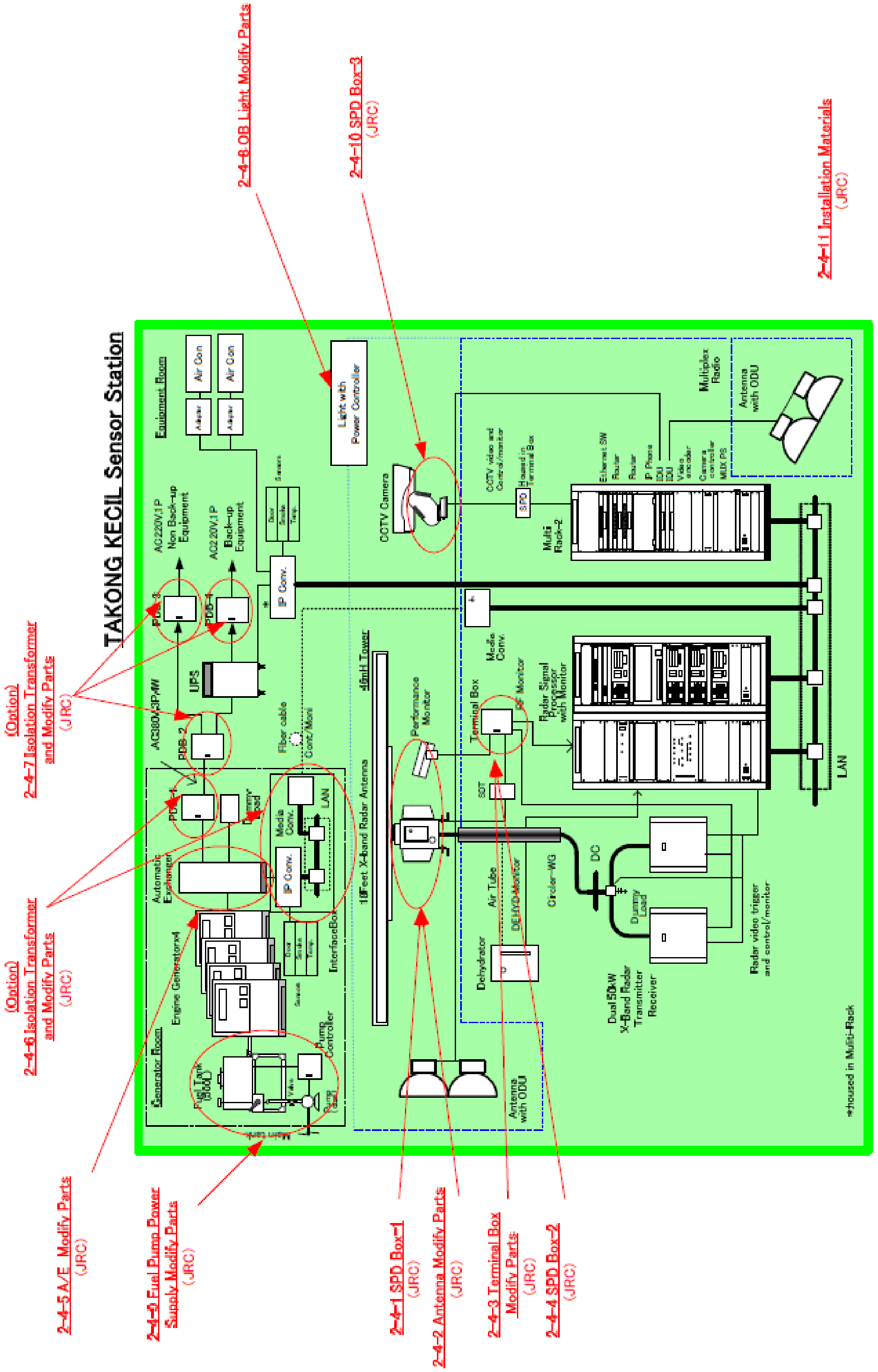


Figure 3-18 General Plan of Improvement of SPDs and Isolation Transformer (Additional Measures I for Takong Kecil)

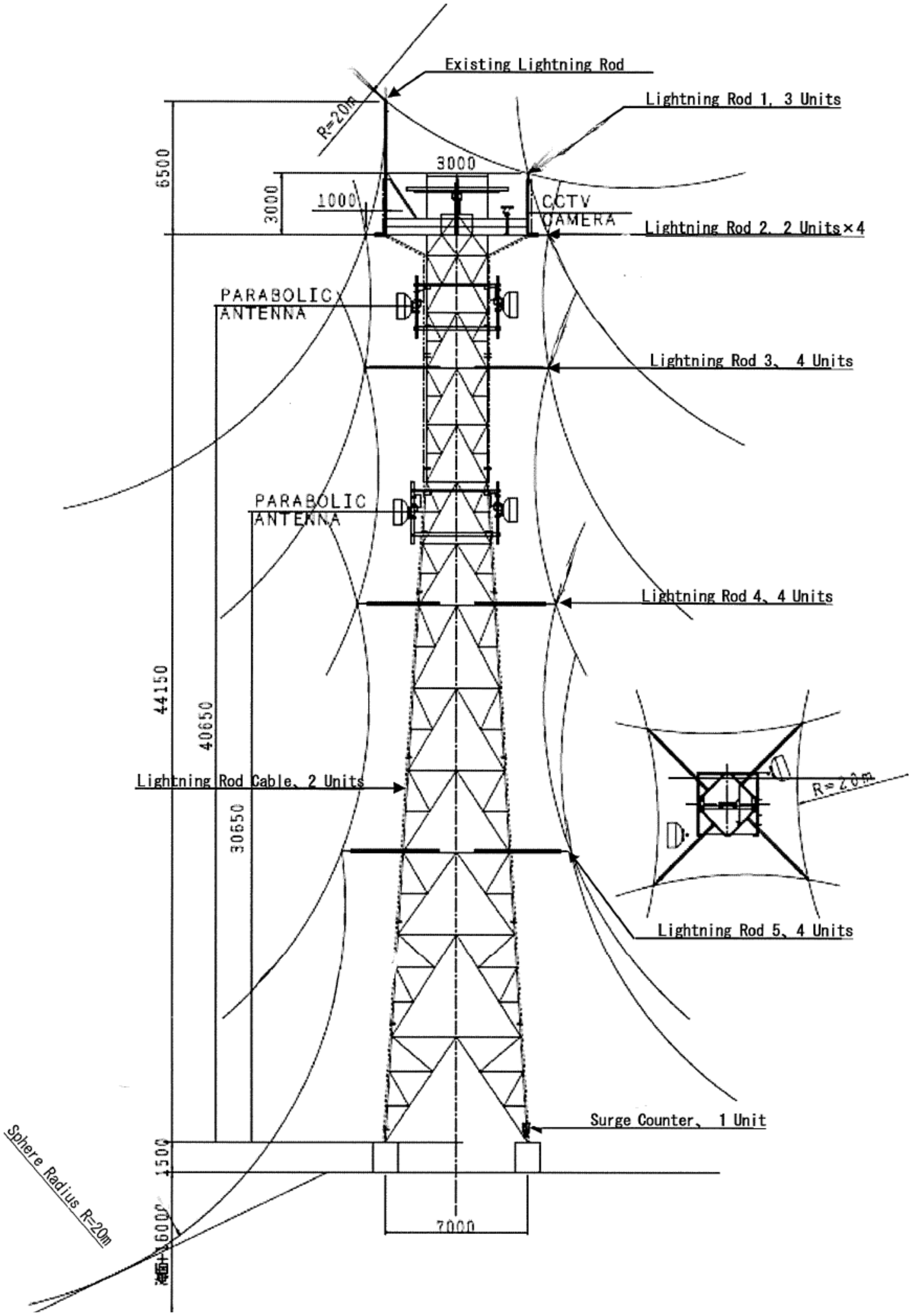


Figure 3-19 General Plan of Improvement of Air-termination System (Additional Measures II for Takong Kecil)

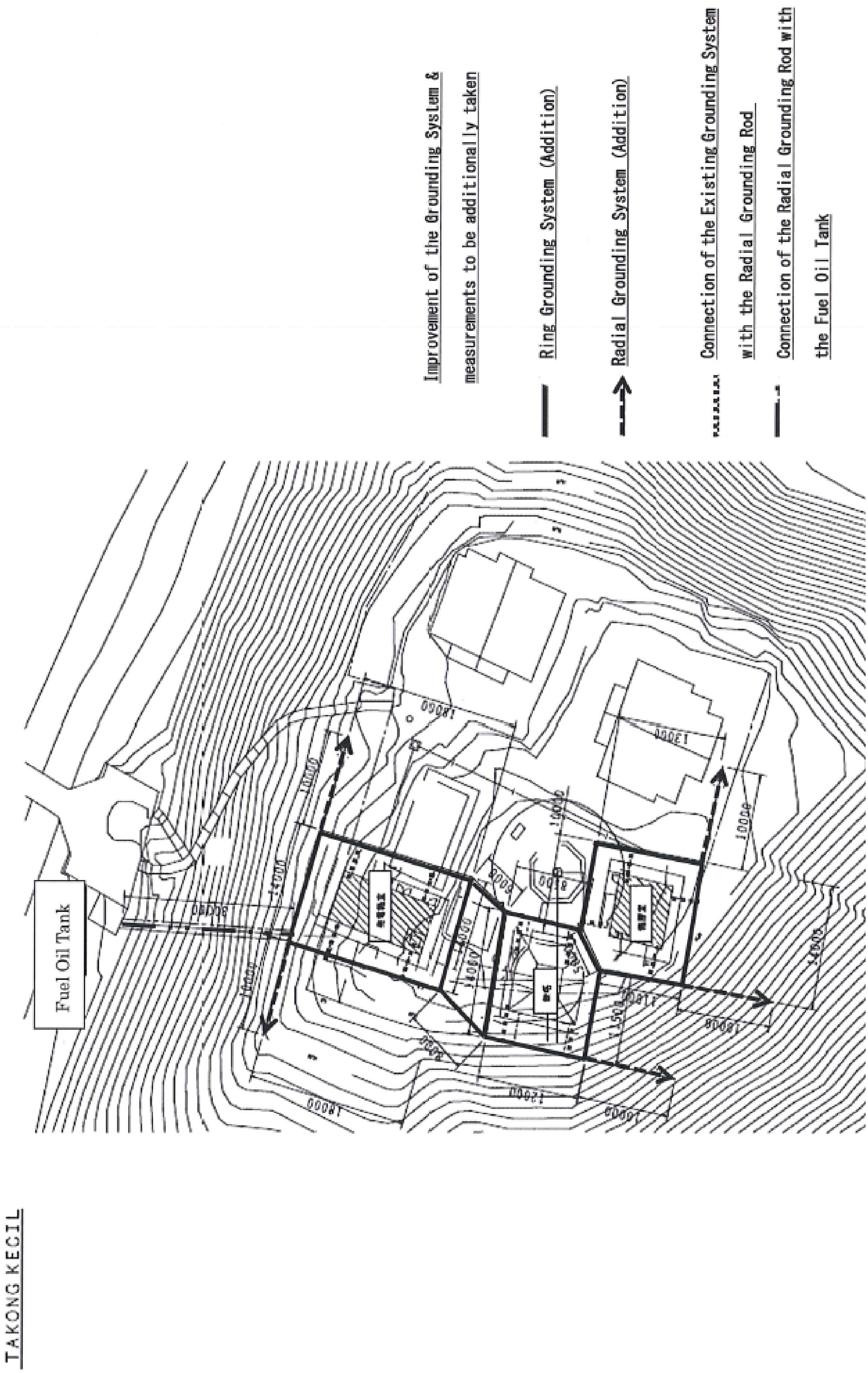


Figure 3-20 General Plan of Improvement of Earth-termination System (Additional Measures III for Takong Kecil)

Chapter 4 Cost for Repair and Additional Measures

4-1 Cost Estimation

The estimated cost for the recommended "Plan C" based on the study in Chapter 3 is as follows.

Table4-1 Cost for Measures (Plan C)

Site	Cost (Unit: 1,000 Yen)
Batu Ampar	18,147
Tg. Berakit	35,204
Hiyu Kecil	54,823
Takong Kecil	33,437
Total	141,611

Table4-2 Cost per Works (Plan C)

No.	Measures	Cost (Unit: 1,000 Yen)
1	Restoration Works	42,426
2	Additional Measures I	34,434
3	Additional Measures II	32,935
4	Additional Measures III	29,341
5	Additional MeasuresIV	2,475
Cost for Additional Measures		99,185
Total Cost		141,611

Details per site are as follows.

Table4-3 Cost for Measures for Batu Ampar VTS Center
(Unit: Thousand Yen)

<table>
<tr><th colspan="4">Repair and Additional Measures of Damaged Equipment</th><th rowspan="2">Q'ty</th><th rowspan="2">Cost</th><th rowspan="2">Remarks</th></tr>
<tr><th>No.</th><th>Measures</th><th colspan="2">Contents</th></tr>
<tr><td>1</td><td>Repair Works</td><td>Restoration of Damaged Equipment</td><td>Survey and Procurement
Adjustment of Damaged Equipment
Total System Tuning</td><td>1</td><td>4,057</td><td></td></tr>
<tr><td>2</td><td>Additional Measures I</td><td>Improvement of SPDs and Isolation Transformers</td><td>Installation of SPDs and Isolation Transformers between the Electrical Power Supply Line,
Installation of Surge Counter</td><td>1</td><td>3,181</td><td>Recom-mended</td></tr>
<tr><td>3</td><td>Additional Measures II</td><td>Improvement of Air Termination System</td><td>Air-Terminals and Down-Conductors Improvement</td><td>1</td><td>7,866</td><td></td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Additional Measures III</td><td rowspan="2">Improvement of Earth-Termination System</td><td>Ring Earth Electrodes (Outdoor) Improvement</td><td>1</td><td>2,271</td><td></td></tr>
<tr><td>Indoor and Outdoor Ring Earth Electrodes Bonding</td><td>1</td><td>193</td><td></td></tr>
<tr><td>5</td><td>Additional Measures IV</td><td>Relocation of Damaged Equipment</td><td>Relocation of PPS Antenna for AIS Base Station System</td><td>1</td><td>579</td><td></td></tr>
<tr><td colspan="4">Total</td><td></td><td>18,147</td><td></td></tr>
</table>

Table4-4 Cost for Measures for Tanjung Berakit

(Unit: Thousand Yen)

Repair and Additional Measures of Damaged Equipment				Q'ty	Cost	Remarks
No.	Measures	Contents				
1	Repair Works	Restoration of Damaged Equipment	Survey and Procurement Adjustment of Damaged Equipment Total System Tuning	1	11,987	
2	Additional Measures I	Improvement of SPDs and Isolation Transformers	Installation of SPDs and Isolation Transformers along the Power Supply Line (Isolation Transformers between Generator House and Equipment House are excluded)	1	5,577	Recom-mended
3	Additional Measures II	Improvement of Air Termination System	Air-Terminals and Down-Conductors Improvement	1	10,540	
4	Additional Measures III	Improvement of Earth-Termination System	Ring Earth Electrodes (Outdoor) Improvement	1	4,385	
			Ring Earth Electrodes (Inside) for Equipment Building and Generator House Improvement	1	1,228	
			Indoor and Outdoor ring Earth Electrodes Bonding	1	539	
5	Additional Measures IV	Relocation of Damaged Equipment	Relocation of PPS Antenna for AIS Base Station System and Meteorological Observation Equipment	1	948	
Total					35,204	

Table4-5 Cost for Measures for Hiyu Kecil

(Unit: Thousand Yen)

Repair and Additional Measure of Damaged Equipment				Q'ty	Cost	Remarks
No.	Measures	Contents				
1	Repair Works	Restoration of Damaged Equipment	Survey and Procurement Adjustment of Damaged Equipment Total System Tuning	1	14,168	
2	Additional Measures I	Improvement of SPDs and Isolation Transformers	Installation of SPDs and Isolation Transformers along the Power Supply Line (Isolation Transformers between Generator House and Equipment House are excluded)	1	18,914	
3	Additional Measures II	Improvement of Air Termination System	Air-Terminals and Down-Conductors Improvement	1	6,127	
4	Additional Measures III	Improvement of Earth-Termination System	Improvement of Ring Earth Electrodes (Outdoor) by Titanium Belt (partially) Improvement of Fuel Supply Pile Earth-Termination	1	12,627	Recom-mended
			Ring Earth Electrodes (Inside) for Equipment Building and Generator House Improvement	1	1,228	
			Indoor and Outdoor Ring Earth Electrodes Bonding	1	811	
5	Additional Measures IV	Relocation of Damaged Equipment	Relocation of PPS Antenna for AIS Base Station System and Meteorological Observation Equipment	1	948	
Total					54,823	

Table 4-6 Cost for Measures for Takong Kecil

(Unit: Thousand Yen)

Repair and Additional Measures of Damaged Equipment				Q'ty	Cost	Remarks
No.	Measures	Contents				
1	Repair Works	Restoration of Damaged Equipment	Survey and Procurement Adjustment of Damaged Equipment Total System Tuning	1	12,214	
2	Additional Measures I	Improvement of SPDs and Isolation Transformers	Installation of SPDs and Isolation Transformers along the Power Supply Line (Isolation Transformers between Generator House and Equipment House are excluded)	1	6,762	Recom-mended
3	Additional Measures II	Improvement of Air Termination System	Air-Terminals and Down-Conductors Improvement	1	8,402	
4	Additional Measures III	Improvement of Earth-Termination System	Ring Earth Electrodes (Outdoor) Improvement	1	4,294	
			Ring Earth Electrodes (Inside) for Equipment Building and Generator House Improvement	1	1,228	
			Indoor and Outdoor Ring Earth Electrodes Bonding	1	537	
Total					33,437	

4-2 Study on Implementation Priorritization

All of the proposed additional measures are recommended to be conduct together with the repair works of the damaged equipment. However, since estimated cost for this recommendation is rather high, the repair and additional measures may be conducted in several stages. From this standpoint, a study on implementation prioritization has been conducted. Following is the summary of the study, including technical recommendations if the works to be performed wil be done in several stages.

4-2-1 Basic Principles from the Technical Point of View

If the implementation works will be conducted in several stages, the following matters have to be considered.

1) It is highly recommended to conduct both the repair works and additional measures completely for each stage. There is a high risk of repeated damage if the repair works will be done without executing any additional measures.

2) Additional measures I to IV are necessary to increase performance for lightning protection. These measures will work effectively through "mutual functioning". Therefore, it is necessary to perform these additional measures simultaneously. It is not recommended to conduct each measure independently.

4-2-2 Considerations and Plans

(1) Basic Considerations in Implementation Prioritization

Plans for implementation prioritization have been studedid based on the recommended Plan C which is summarized in Chapter 3. Basic considerations for the prioritization are as follows.

1) The most recommended implementation program is to execute all the measures without any division.

2) At Batu Ampar VTS Center, there are many steel towers that are higher than the tower of the VTS system. Therefore, there is risk (low level but not negligible) that direct lightning may struck the VTS system steel tower. Considering this measures in item I to protect lightning surge invasion against thunderbolt near the site are more important than the other countermeasures for items II to IV, which may not be considered high priority for this stage.

3) For Batu Ampar VTS Center and the three (3) sensor stations, it is necessary to conduct all the proposed additional measures, items I to IV, together with repair works. Therefore, if implementation in several stages will be considered, it is highly recommended that the works be done per site. It is not recommended gradual implementation of items I to IV divided as a component.

4) Although the four (4) sensor stations are all important technically perspective. Takong Kecil sensor station that function not only the VTS sensor station but also as a repeater station for data transmission to/from Hiyu Kecil is the most critical. If Takong Kecil has some trouble and cannot transmit data, there is a risk of equivalent damage to the other sensor stations, even if the Hiyu Kecil station is functioning normally. Therefore, the execution of repair and additional measures for Takong Kecil shall be highly prioritized higher than those for Hiyu Kecil.

5) Hiyu Kecil is the site where damage often occurs first. It is recommended to give sufficient attention to this site at the earliest possible stage considering its rocky ground conditions and other unique natural features.

6) Tanjung Berakit sensor station is very critical since its monitoring area is the entrance to the straits. However, the site (Tanjung Berakit) is located on a land area whereas Hiyu Kecil and Takong Kecil stations are located on isolated islands in the ocean and it is accecible by car. Therefore execution works are easier than those for Hiyu Kecil and Takong Kecil.

(2) Prioritized Implementation Plans

Based on the above-mentioned considerations, following are five (5) planned alternative implementation programs. Components of these plans are shown in Table 4-8.

1) Plan 1: All to be done in one stage

From the technical point of view, this plan is the most recommended. All of the repair works and additional measures shall be completed in one stage.

2) Plan 2: No implementation (low priority) of additional rmeasures II to IV in Batu Ampar in "Plan 1".

As stated previously, considering the low-risk condition against direct lighting strike of the Batu Ampar VTS system facilities, especially the steel tower, executing additional rmeasures for these parts is low priority in this plan.

3) Plan 3: No implementation (low priority) of additional rmeasures described as items II to IV, in Tanjung Berakit in "Plan 2".

This is an altenative plan to exclude additional rmeasures items II to IV in Tanjung. Berakit due to cost difference. Excluded parts of items II to IV shall be conducted at the same time with the other works.

4) Plan 4: No implementation (low priority) of all works for Tanjung Berakit in “Plan 2”.

All works for Tanjung Berakit is excluded from the “Plan 2”. The repair works in Tanjung Berakit will not be conducted because without the implementation of any additional measures, there will be high risk of damage due to lightning.

(3) Estimated Costs for Implementation Plans

Estimated costs for plans studied in the above are as summarized in Table 4-7 in below.

Table 4-7 Estimated Costs of Prioritized Implementation Plans

Plan	Contents	Cost (Thousand Yen)
1	All in one execution plan	141,611
2	Low prioritized of additional measures II to IV in Batu Ampar VTS Center in “Plan 1”	130,702
3	Low rioritized of additional measures II to IV in Tg. Berakit in “Plan 2”	113,062
4	Low prioritized of all works in Tg. Berakit in “Plan 2”.	95,498

Table 4-8 Implementation Plans (Study on Implementation Priority)

Measures					Plan 1 (Basic)				Plan 2				Plan 3				Plan 4			
No.	Measures		Contents	Expected Effects	B.A	T.B	H.K	T.K	B.A	T.B	H.K	T.K	B.A	T.B	H.K	T.K	B.A	T.B	H.K	T.K
1	Repair Works	Restoration of damaged equipment	Site Survey Procurement Adjustment of Damaged Equipment Total System Tuning	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
2	Additional Measures I	Improvement of SPD and Isolated-Transformer	Installation of SPD and Isolated-Transformer between the Electrical Power Supply, Data Communication Lines	◎			◎				◎				◎				◎	
			Installation of SPD only for the Electrical Power Supply Lines	○	○				○				○				○			
			Installation of Isolated-Transformer only for the Lines of the VTS Equipment	○		○		○		○		○		○		○		○		○
3	Additional Measures II	Improvement of Air Terminal System	Designed by Protection Level 1 Air-Terminal System and Down-Conductor Improvement	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
4	Additional Measures III	Improvement of Earth-Termination System	Installation of Ring Earth Electrode (by copper wire) (Ring Earth Electrode by Titanium Belt in Hiyu Kecil)	◎	◎	◎		◎	◎	◎		◎	◎	◎		◎	◎	◎		◎
			Partial application of Titanium Belt Electrode in Hiyu Kecil	○			○				○				○				○	
			Installation of Ring Earth Electrodes in the Equipment Building (by Copper Flat Bar)	◎	–	◎	◎	◎	–	◎	◎	◎	–	◎	◎	◎	–	◎	◎	◎
			In-door and Out-door Ring Earth Electrodes Bonding	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
			Installation of Earth-Terminal for Fuel Supply Pipeline	◎				◎				◎				◎				◎
5	Additional Measures IV	Relocation of Damaged Equipment	Relocation of Meteorological Observation Sensor Equipment and GPS Antenna for AIS Base Station System	◎	◎	◎	◎	–	◎	◎	◎	–	◎	◎	◎	–	◎	◎	◎	–
6	Additional Measures V	Introduction of Dissipation Array System	Introduction of Dissipation Array System	◎																
Cost for Measures (Thousand Yen)			Cost for Measures per Site (Thousand Yen)		18,147	35,204	54,823	33,437	7,238	35,204	54,823	33,437	7,238	17,564	54,823	33,437	7,238	0	54,823	33,437
			Total Cost for Measures (Thousand Yen)		141,611				130,702				113,062				95,498			
			Rate against Plan B per Site (%)		100.0	100.0	100.0	100.0	39.9	100.0	100.0	100.0	39.9	49.9	100.0	100.0	39.9	0.0	100.0	100.0
			Rate against Plan B in Total (%)		100.0				92.3				79.8				67.4			

Chapter 5 Recommendations for Implementation Works

5-1 Recommendations for Materials, Parts, Apparatus/Equipment Procurement

The necessary parts for the repair works shall be the same as those utilized for the existing system. In the Phase 1 Project, almost all of the equipment parts were procured from Japan. Technically, it is highly recommended that all parts to be used for the same purpose be procured from the same source. Parts and modules used for radar, AIS and other systems are circuit boards composed of many parts and such boards were produced “made to order” or by “special order”, since they are not commercially available in the market. Because of such circumstances, repair and restoration works will be contracted only to specified suppliers.

For Additional Measures I, necessary parts and modules include modifications of circuits and/or modules. Therefore similar to repair and restoration works, procurement for these parts and modules have to be made only to specified suppliers.

For Additional Measures II to IV, to minimize the risk of future damage by lightning strikes ensure the quality of the equipment and parts, consistency of the existing system and its improvement, reliability of the functional combination of lightning rods, down-conductor, earthing system, SPD and isolated transformer and other related parts. It is highly recommended to contract the work fully (or as “one lot”) to the supplier who conducts repair and/or restoration works and Additional Measures I.

5-2 Recommendations for Implementations

(1) Advice for Implementation Works by Stages

1) Plan 1 is the highly recommended plan since functions at each site are the part of the VTS system and the system will work as one system mutually supported by each function.

2) Because the restoration and improvement plans are included four (4) additional measures to reduce risk of future damage due to lighting. Measures to risk may not be effective if restoration works are conducted without implementation of any additional measures. Therefore, it is necessary that the restoration and improvement works shall be conducted compeletely for one stage.

3) If implementation works are to be conducted according to the prioritaization plan, works shall be executed per site. The works shall not be divided on a per additional measure. i.e., additional measure 1 for all sites, then additional measure II for all sites, etc. This is because the risk of lightning damage can be reduced only if all additional measures I to IV will be completely executed as one stage.

(2) Recommendations for Execution Works

When performing the field works related to Additional Measures I, it is recommended to conduct the works under the supervision of the supplier’s engineer who is knowledgeable about the overall design concept of the VTS system, components, function and performance of the equipment. In this work, it is not only replacement of the damaged parts, but also some modifications of the existing equipment are necessary. The works must be performed very carefully in order not to damage the existing system.

For the field works of Additional Measures II to IV, the execution of works will only be effective if equipment quality is ensured, consistence of existing system and improved parts, and there is reliability of functional combinations of the equipment and facilities. In this regard, it is also recommended that the works be under the supervision of the supplier's engineer who can manage the overall system of both the VTS equipment and building facilities.

Air conditioner repair works for the three sites, except Batu Ampar, is recommended to be undertaken by an Indonesian engineering firm who knows how the units function and local conditioins.

Chapter 6 Appendices

6-1 Member List of the Survey Team

(1) Field Survey in Indonesia (From December 3 to 19, 2012)

Mr. Masahiko KOSHIMIZU	Chief Consultant / VTS Planning Specialist	Oriental Consultants Co., Ltd.
Mr. Hidetoshi ITO	VTS Lightning Protection Specialist	Japan Aids to Navigation Association (Sankosha Corporation)
Mr. Setsuo AKAISHI	VTS Equipment Specialist 1	Japan Aids to Navigation Association
Mr. Yoku SANTO	VTS Equipment Specialist 2 / Procurement and Cost Estimation Specialist	Japan Aids to Navigation Association

(2) Draft Explanation (From March 4 to 8, 2013)

Mr. Masahiko KOSHIMIZU	Chief Consultant / VTS Planning Specialist	Oriental Consultants Co., Ltd.
Mr. Hidetoshi ITO	VTS Lightning Protection Specialist	Japan Aids to Navigation Association (Sankosha Corporation)

6-2 Survey Schedule

(1) Field Survey in Indonesia (December 3 to 19, 2012)

No.	Date		Chief Consultant/ VTS Planner	VTS Equipment Specialist 1	VTS Lightning Protection Specialist	VTS Equipment Specialist 2/ Procurement and Cost Estimation Specialist
			Masahiko Koshimizu	Setsuo Akaishi	Hidetoshi Ito	Yoku Santo
1	12/3	Mon.	Narita --> Jakarta by JL. 725 (11:20 NRT - 17:20 CGK)			
2	12/4	Tue.	9:00 JICA Indonesia Office, 11:00 Embassy of Japan, 13:00 DGST			
3	12/5	Wed.	Discussion with DGST			Survey for Insurance
4	12/6	Thr.	Jakarta -> Batam by GA 152 (09:20 CGK - 11:00 BTH), Survey of Batu Ampar VTS Center			
5	12/7	Fri.	Batam ---> Tg. Pinang, Discussion at Navigation District Tg. Pinang ----> Tg. Pinang			
6	12/8	Sat.	Tg. Pinang ---> Tg. Berakit, Survey of Tg. Berakit VTS Sensor Station ----> Tg. Pinang			
7	12/9	Sun.	Batam -->Jakarta by GA155 16:30BTM - 18:10 JKT	Tg. Pinang ---> Batu Ampar, Internal Discussions and Documentation		
8	12/10	Mon.	Meeting with JICA for Phase 2	Batu Ampar ---> Hiyu Kecil, Survey of Hiyu Kecil VTS Sensor Station ----> Tg. Balai Karimun		
9	12/11	Tue.	Meeting with DGST, JKT->Batam by GA154 14:05JKT - 15:45 BTM	Tg. Balai Karimun ----> Survey of Hiyu Kecil VTS Sensor Station, Hiyu Kecil ---> Tg. Balai Karimun		
10	12/12	Wed.	Tg. Balai Karimun ----> Survey at Takong Kecil VTS Sensor Station ----> Batu Ampar			
11	12/13	Thr.	Batu Ampar ----> Survey at Takong Kecil VTS Sensor Station, Takong Kecil ---> Batu Ampar			
12	12/14	Fri.	Survey of Batu Ampar VTS Center, Batu Ampar -> Jakarta by GA 155 (16:30 BTH - 18:10 JKT)			Survey of Batu Ampar VTS Center
13	12/15	Sat.	Internal Discussions and Documentation			Documentation
14	12/16	Sun.	Internal Discussions and Documentation			Documentation, Batam ---> Singapore
15	12/17	Mon.	Discussion with DGST			Survey of Singapore Port
16	12/18	Tue.	9:00 DGST, 13:00 JICA Indonesia Office, 15:00 EOJ, Leave from Jakarta (22:30)			Survey of Singapore Port, Leave from Singapore (01:55)
17	12/19	Wed.	Arrive at Narita (07:15) by JL 726			(09:30) by JL 710

(2) Draft Explanation (from March 4 to 8, 2013)

No.	Date		Chief Consultant/ VTS Planner	VTS Lightning Protection Specialist
			Masahiko Koshimizu	Hidetoshi Ito
1	3/4	Mon.	Narita --> Jakarta by JL. 725 (11:20 NRT - 17:20 CGK)	
2	3/5	Tue.	9:00 JICA Indonesia Office, 13:30 Explanation of the Draft Report and Discussion with DGST	
3	3/6	Wed.	8:00 Coutecy Call to Director of Navigation, Discussion with DGST	
4	3/7	Thr.	10:00 JICA Indonesia Office, 11:30 DGST JICA Expert, 15:00 EOJ, Leave from Jakarta by JL 726 (22:05)	
5	3/8	Fri.	Arrive at Narita (7:15)	

6-3 List of Concerned Parties in Indonesia

Directorate General of Sea Transportation (DGST)

Ir. A. Tonny Budiono, MM	Director of Navigation (Authorized Budget User of VTS Phase 2 Project)
Ir. M. Ali Malawat	Head of Sub-Directorate of Maritime Telecommunication
Mr. Kardiawan Sudarno	Authorized Commitment Officer of VTS Phase 2 Project
Drs. Tofan Rindoyo	Head of Section of Operation Sub-Directorate of Marine Telecommunication
Mr. Heri Supriyadi	Staff of Section of Equipment and Maintenance
Mr. Wisnu Panca Perbaya	Ditto
Mr. Rizki Cahyadi	Ditto
Mr. Tony Rafiq	Ditto
Mr. Fathan Muta'ali	Ditto
Ms. Caroline Veronica	Ditto
Mr. Ryuji Nishibun	JICA Expert on Maritime Safety and Security
Mr. Akira Ubukata	Ditto

District Navigation in Tanjung Pinang Office

Capt. Herman Pattiasina	Head of Operation Division
Mr. Maryanto	Staff of District Navigation in Tanjung Pinang Office
Mr. Sumber Yanto	Ditto

Coastal Radio Station in Batu Ampar

Mr. Sudiantoro	Chief of Coastal Radio Station (CRS)
Mr. Yanto Maryanto	Staff of CRS
Mr. Taufik	Ditto
Mr. Efriadi	Ditto

Embassy of Japan

Mr. Kenji Kamite	First Secretary

JICA Indonesia Office

Mr. Hajime Higuchi	Representative
Ms. Sulistyo Wardani	Program Officer for Infrastructure

6-4 Meeting Records

(1) Attendants List for Meeting on December 4, 2012 (Inception Report Explanation)

AGENDA : Meeting with JICA Team for Lighting Damage of VTS

DAY / DATE : Tuesday, 4th December 2012

TIME : 13.00-15.00 WIB

NO	NAME	ORGANIZATION	SIGNATURE
1	TONNY BUDIONO	DIR. NAVIGASI	
2	TOPAN R	DGST	
3	Kardiawan .S	DGST	
4	Heri Supriyadi	—	
5	Tony Rafia	-11-	
6	NISHIBUN RYUJI	JICA	
7	UBUKATA Akira	JICA	生方
8	SANTO YOKU	JANA	山家
9	ITO HIDETOSHI	SANKOSHA	伊藤
10	MASAHIKO KOSHIMIZU	ORIENTAL CONSULTANTS	
11	SETSUO AKAISHI	JANA	赤石
12	WHISNU	DGST	
13			

(2) Attendants List for Meeting on Mach 5, 2013 (Draft Explanation)

DAFTAR HADIR

Rapat Intern Report " Lightning Protection" Untuk Desain Survey VTS

Ruang Rapat Bima Sakti
Jakarta, 5 Maret 2013

No	Nama	Unit	Tanda Tangan
1			1
2	M. Ali Malawat	Head of Subdit	2
3	Masahiko Koshimizu	Oriental Consul.	3
4	Hidehiroshi Ito	Sankosha	4
5	UBUKATA AKIRA	JICA	5 生方 章
6	NISHIBUN RYUJI	JICA	西分 6 亮二
7	TOFAN R. PANDOYO	DGST	7
8	Fathan Muta'ali	DGST	8
9	Caroline Veronica	DGST	9
10	Tomy Rafia	DGST	10
11	Higuchi Hajime	JICA Indonesia Office	11
12			12
13			13
14			14
15			15
16			16
17			17
18			18
19			19
20			20
21			21
22			22