2. ADVANCED AND EFFICIENT TECHNOLOGIES OF TRANSMISSION AND SUBSTATION EQUIPMENT

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KANSAI ELECTRIC POWER CO., Inc.

2. Advanced and Efficient Technologies of Transmission and Substation Equipment

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- **2-1. Gas Insulated Switchgear (GIS)**
- **2-2. Life assessment of substation equipment**
- **2-3. Advanced monitoring and control system**
- **2-4. Conductor with reduced wind load and conductor with bulk capacity**
- **2-5. Lightning protection devices for transmission line**

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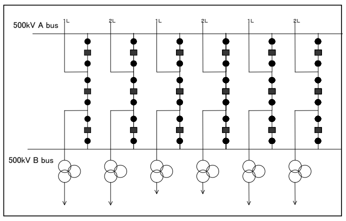
2-1. Gas Insulated Switchgear (GIS)

Outline

(1) Comparison of site area between GIS and AIS
(2) Transition of GIS
(3) Examples of the application of GIS
(4) Comparison of construction cost between GIS and AIS
(5) Comparison of maintenance cost between GIS and AIS
(6) Summary

Comparison of site area between GIS and AIS (500kV)

500kV Main circuit single line diagram in KANSAI



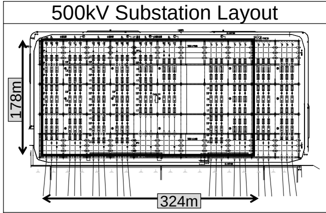
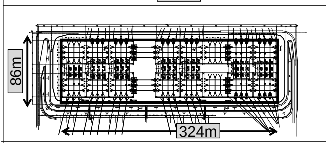
Bus system : 1.5 CB system

- **Circuit breaker**
- **Disconnecting switch**

Type of Substation

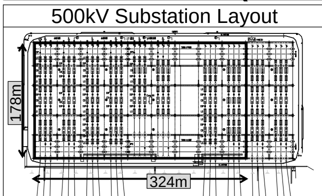
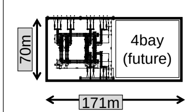
500kV AIS : Air insulated substation
500kV GIS : Gas insulated substation
Hybrid GIS : Switchgears are gas insulated. Buses are air insulated. It is called Hybrid type because of two insulation type.
Full GIS : Switchgears and buses are gas insulated.

Comparison of site area between GIS and AIS (500kV)

500kV Substation Layout	Substation Type
	AIS : Air Insulated Substation **Area : 100%** (500kV 9bays)
	Hybrid GIS : Switchgears are gas insulated. Buses are air insulated. **Area : 48%** (500kV 9bays)

➢ **Hybrid GIS area is as small as 48% of AIS area.**

Comparison of site area between GIS and AIS (500kV)

500kV Substation Layout	Substation Type
	AIS **Area : 100%** (500kV 9bays)
	Full GIS : Buses and switchgears are gas insulated. Outgoing lines are overhead lines. **Area : 21%** (500kV 9bays)

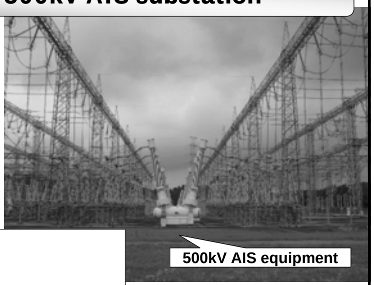
➢ Full GIS area is as small as 21% of AIS area.

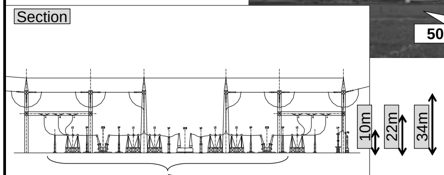
2. Advanced and Efficient Technologies of Transmission and Substation Equipment

Example of 500kV AIS substation

500kV Air insulated substation

Switchgears and buses are air insulated.





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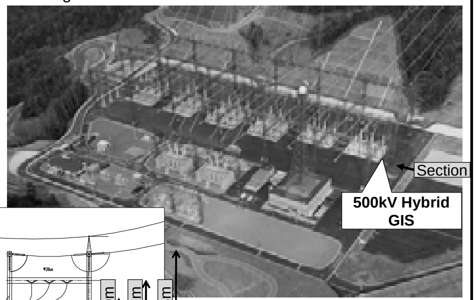
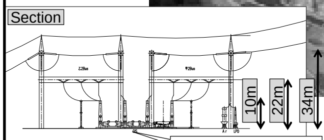
Example of 500kV Hybrid GIS substation

500kV Hybrid GIS

Switchgears are SF6 gas insulated. Buses are air insulated.





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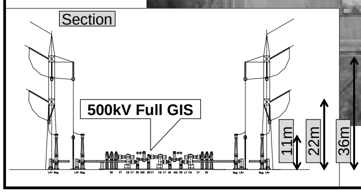
Example of 500kV Full-GIS substation

500kV Full GIS

Switchgears and buses are SF6 gas insulated.



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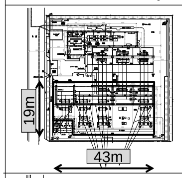
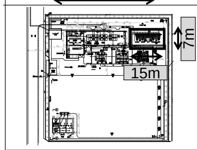
Comparison of site area between GIS and AIS (77kV)

77kV Substation Layout	Substation Type	
	AIS Area : 100%	**[Layout of substation]** **77kV 4Lines** **77/6.6kV Transformers 3units**
	GIS (advanced complex type) Area : 13.5%	

➢ **GIS area is as small as 13.5% of AIS area.**

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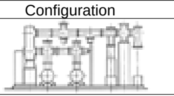
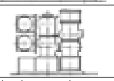
Transition of GIS design (77kV)

Type and date	Configuration	SF6 amount	Installation area
Single phase enclosure type (1965-)		100% (250kg)	100%
Three phase enclosure type (1975-)		90% (225kg)	102%
Complex type (1985-)		60% (150kg)	64%
Advanced complex type (current type)		40% (100kg)	27%

1. GIS has changed from single phase enclosure type to three phase enclosure type, and to complex type, because advanced analysis technologies have been developed and insulation design has been improved.
2. Therefore, both installation area and SF6 gas amount are reduced greatly. Installation area of advanced complex type is as small as 27% of single phase enclosure type.

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Transition of GIS design (500kV)

Type	Number of breaks	SF6 amount	Installation area
Double pressure type	4 breaks	100% (1700kg)	100%
Single pressure type (current type)	2 breaks	51% (870kg)	91%

1. 500kV CBs have been changed from double pressure type to single pressure type, because arc extinguish chambers are improved.
2. Therefore, both installation area and SF6 gas amount are reduced. Especially, SF6 gas amount of single pressure type is about half of double pressure type.

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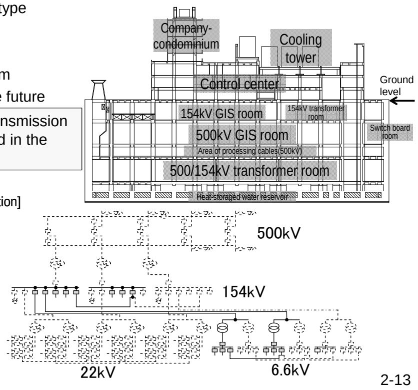
2. Advanced and Efficient Technologies of Transmission and Substation Equipment

GIS experience 1 (underground substation)

-Completely underground type
-Composite building
  -Control center
  -Company-condominium
-Designed for 500kV in the future

In the future, 500kV transmission lines will be constructed in the center of Osaka city.

-Current equipment
  [Uehonmachi substation]
  154kV 4 Lines
  154/6.6kV Transformer 2 units
-Future equipment
  500kV 6bays
  154kV 9 lines
  500/154kV Transformer 3 units
  154/22kV Transformer 3 units
  154/6.6kV Transformer 3units



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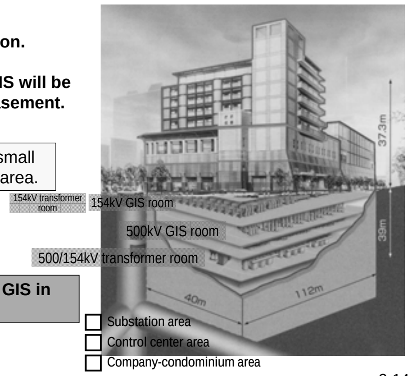
GIS experience 1 (underground substation)

This is a view of the underground substation.

In the future, 500kV GIS will be installed on the 2nd basement.

500kV GIS area is as small as 7.5% of 500kV AIS area.

It is efficient to install GIS in such an urban area.



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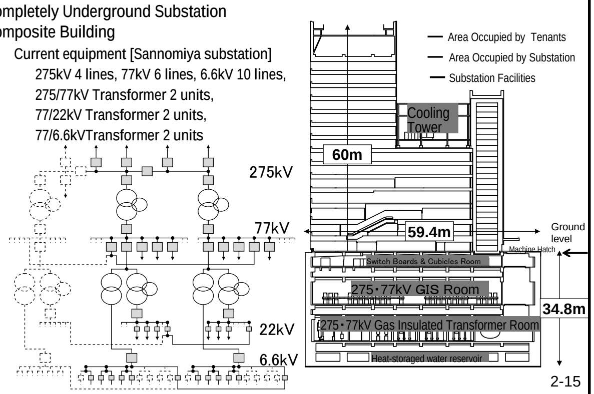
GIS experience 2 (underground substation)

Completely Underground Substation
Composite Building
  Current equipment [Sannomiya substation]
    275kV 4 lines, 77kV 6 lines, 6.6kV 10 lines,
    275/77kV Transformer 2 units,
    77/22kV Transformer 2 units,
    77/6.6kVTransformer 2 units



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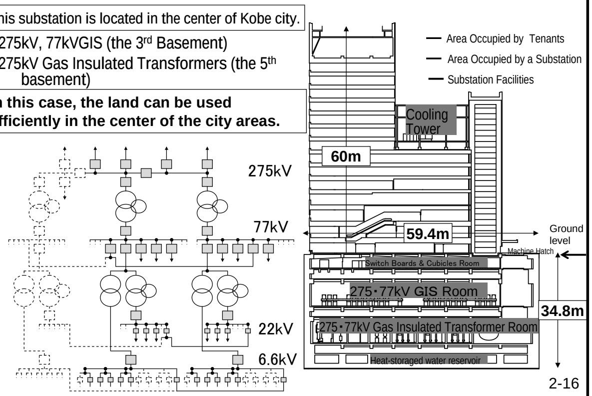
GIS experience 2 (underground substation)

This substation is located in the center of Kobe city.

275kV, 77kVGIS (the 3rd Basement)
275kV Gas Insulated Transformers (the 5th basement)

In this case, the land can be used efficiently in the center of the city areas.



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GIS experience (underground substation)

・Completely Underground Type
・Composite Building

The land is used effectively.

・ Adoption of GIS and Gas Insulated Transformers
- Compact
- Light-weight
- Oil-Free (Non-flammability)

Construction cost of the building is reduced.

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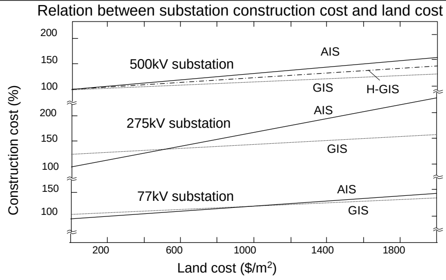
Comparison of construction cost between GIS and AIS

Relation between substation construction cost and land cost



In all voltage class substations, if land cost is much higher than equipment cost, construction cost of GIS substation is lower than that of AIS substation.
Especially, in the center of the city where land cost is high, GIS substation has advantage.

Substation type should be selected in consideration with total construction cost.

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Comparison of maintenance cost between GIS and AIS

		GIS		AIS	
	Inspection Item / Type of inspection	Regular (every 6yrs)	Internal (every 18yrs)	Regular (every 6yrs)	Internal (every 18yrs)
Circuit breaker	Bushing	-	-	Required	Required
	Operation Mechanism, Linkage, Control Circuit	Required	Required	Required	Required
	Contact	-	Required	-	Required
	Operation Test, Pressure Meter Test, Insulation Resistance measurement etc.	Required	Required	Required	Required
	Inspection Cost	86% (Compare to AIS Regular Inspection)	98% (Compare to AIS Internal Inspection)	100% (Base)	100% (Base)

GIS maintenance cost is lower than AIS maintenance cost.
- Vehicles for high lift work for the maintenance of bushing or insulator aren't required.
- GIS Parts insulated by SF6 gas are enclosed in tank. Therefore they aren't polluted.

The views of inspection period will be presented in the next section "Life assessment".

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Summary (GIS)

Advantages of GIS are;

1. Reduction of site area and land cost

Adoption of GIS is effective in the reduction of land cost and ground making cost.

2. Reduction of maintenance cost

Adoption of GIS can reduce maintenance cost, because GIS parts insulated by SF6 gas are not polluted and maintenance cost for bushing isn't needed.

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2. Advanced and Efficient Technologies of Transmission and Substation Equipment

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2-2. Life assessment of substation equipment

Contents

1. Outline

2. Condition Based Maintenance for Substation Equipment
- **(1) Transformers**
- **(2) Circuit Breaker**

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Contents

1. Outline

2. Condition Based Maintenance for Substation Equipment
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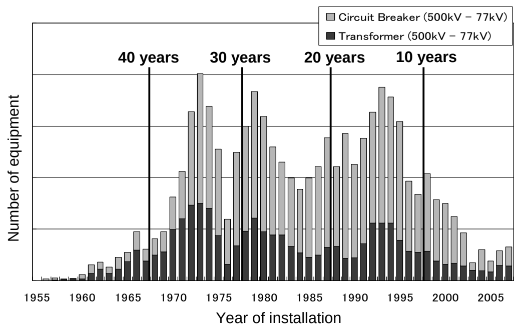
Profile of the age of assets



The number of old equipment is increasing.
High reliability and effective use of equipment is required.

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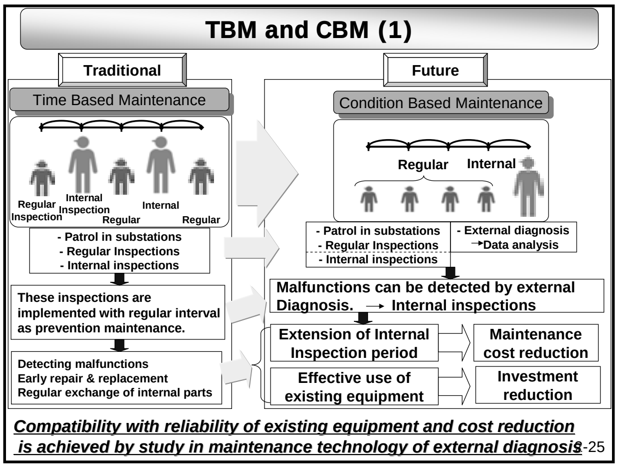
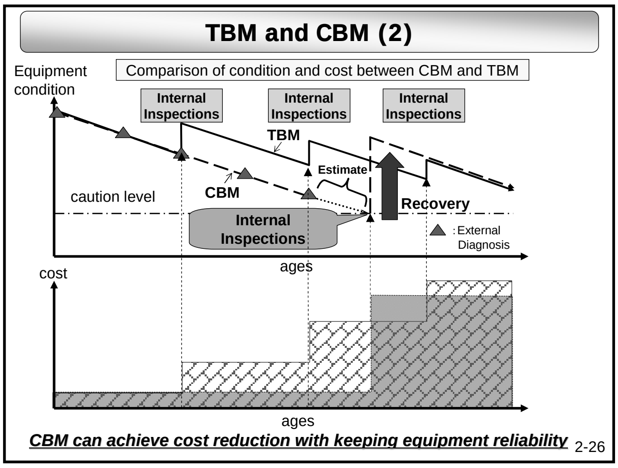
2. Advanced and Efficient Technologies of Transmission and Substation Equipment





Contents

1. Outline

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   (1) Transformers
   (2) Circuit Breakers

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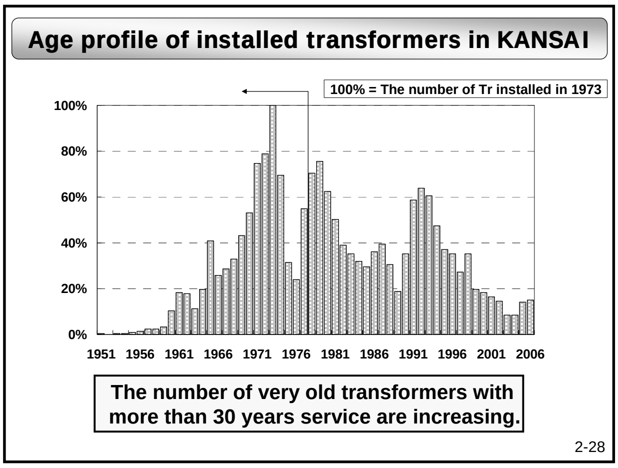
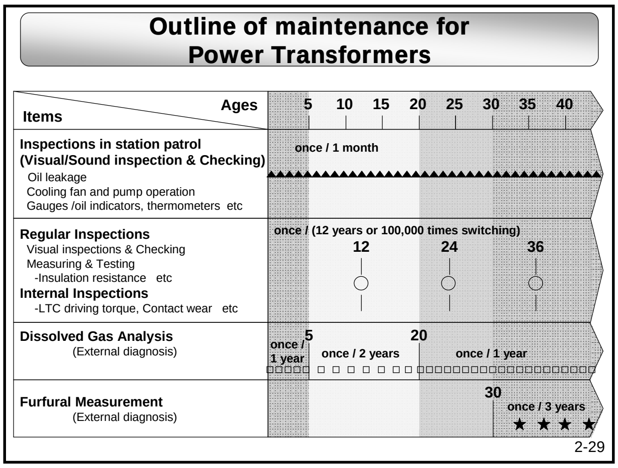
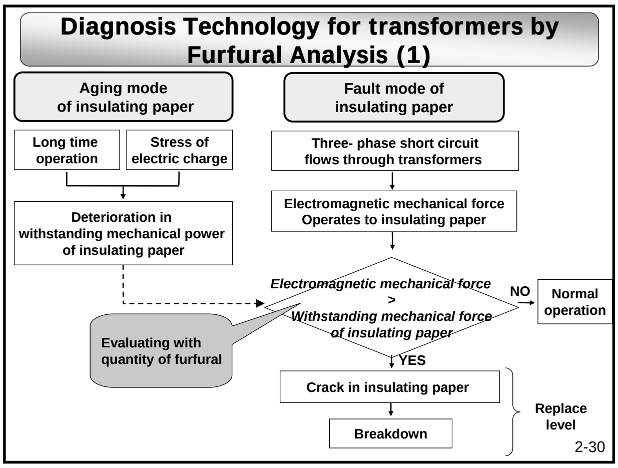


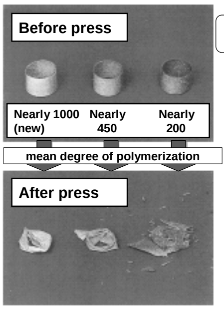




2. Advanced and Efficient Technologies of Transmission and Substation Equipment

Diagnosis Technology for Transformers by Furfural Analysis (2)

◆Furfural Analysis



Heat, oxygen or water inside the transformers

Reducing degree of polymerization of insulating paper
Generating furfural in insulating oil

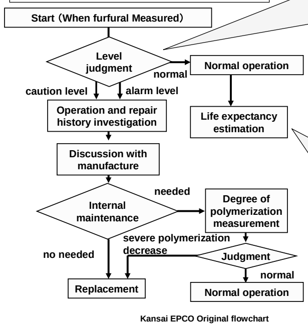
Mechanical strength of insulating paper is weaken

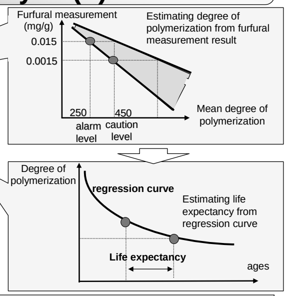
Serious Accident caused by insulating paper broken **due to mechanical force induced by short circuit current through windings**

◆**Expects Lifetime of Transformers from the viewpoint of mechanical lifetime of insulating paper**

Diagnosis Technology for Transformers by Furfural Analysis (3)

◆Furfural Analysis flow





◆**Useful for estimating residual life of transformer and deciding how to take care of aged transformers**

Contents

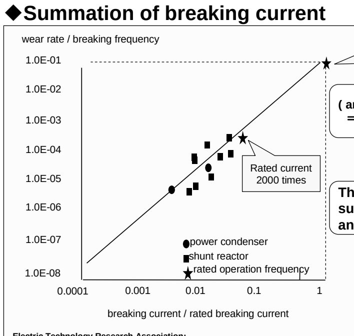
Outline of maintenance for SF_6 Gas circuit Breakers

Items \ Ages	5	10	15	20	25	30	35	40
Inspections in station patrol (Visual/Sound inspection & Checking) Operating mechanism Gauges/gas pressure Switching indicators etc	once / 1 month							
Regular Inspections Visual inspections & Checking Measuring & Testing -Insulation resistance -Main contact resistance -Operating stroke, travel, time -Partial discharge etc (External inspections)	once / 6 years: 6, 12, 18, 24, 30, 36							
Internal Inspections Measuring & Testing -Arcing contact condition, wear, length -Main contact position etc	once / 18 years or when necessary: 18 ★, 36 ★							

Detecting malfunctions or Summation of breaking current

Diagnosis Technology for Circuit Breakers by Contact Wear Estimation (1)

◆Summation of breaking current



Electric Technology Research Association:
"The specifications and maintenance standards for Gas Insulated Circuit Breakers", Electric. Technology Research, Vol 52, No. 1, (1996, 11).

(arc contact wear)
$= \Sigma$ constant x (breaking current) ^{K}

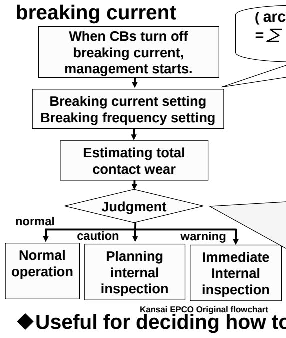
There is a correlation between summation of breaking current and contact wear.

◆**Decides internal inspection timing from the viewpoint of contact wear**

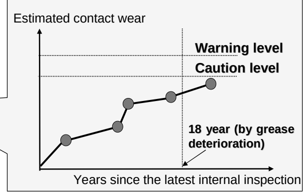
Diagnosis Technology for Circuit Breakers by Contact Wear Estimation (2)

◆Estimation of contact wear by the summation of breaking current

(arc contact wear)
$= \Sigma$ (breaking current / rated breaking current) ^{K}
=10 (upper limit) K=1.6



Deciding internal inspection timing judging from estimated contact wear and years passed



◆**Useful for deciding how to take care of aged gas circuit breakers**

2. Advanced and Efficient Technologies of Transmission and Substation Equipment

Summary

➢ ***Condition Based Maintenance Strategies Based on Equipment Conditions***
- *Coped with aged equipment increase*
- *Compatibility with reliability and cost reduction*
- *Furfural analysis for transformers*
- *Contact wear for circuit breakers*

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2. Advanced and Efficient Technologies of Transmission and Substation Equipment

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2-3. Advanced Monitoring and Control System

Outline

(1) Present conditions and background
(2) Transition of Monitoring and Control System
(3) Benefits of advanced LAN System
(4) Reliability of monitoring and control system
(5) Characteristics of monitoring and control system
(6) Replacement cost
(7) Challenges of the system
(8) Summary

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Present condition and background

1. **Many substations less than 275kV are monitored and controlled from a load dispatching control center.**
2. **Almost all 500kV substations are manned.**
3. **Some monitoring and control systems of 500kV substations are outdated.**
4. **Replacement of such system is planned in the near future.**
5. **LAN system is adopted for new system.**
6. **Unattended operation of 500kV substation is planned after replacement.**

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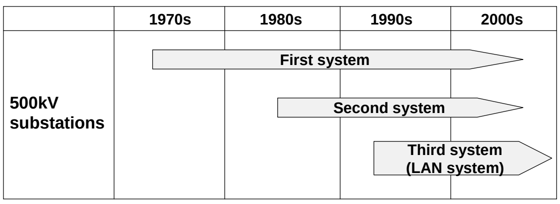
Transition of Monitoring and Control system(1)



From 1970s, the first system has been operated.
From 1980s, the second system has been operated.
From 1990s, the third system with optical LAN has been operated.

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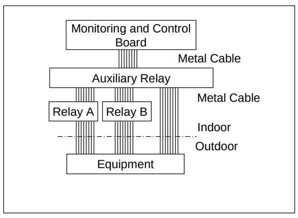
Transition of Monitoring and Control system(2)

The first system



1. The amount of information is the least in the three systems.
   For example, failure indicator is limited to minimum.
2. All control cables are metallic.

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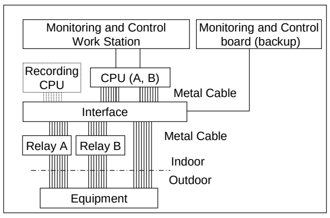
2. Advanced and Efficient Technologies of Transmission and Substation Equipment

Transition of Monitoring and Control system(3)

The second system



1. The amount of information was increased comparing to the first system.
2. Two CPU systems are installed.

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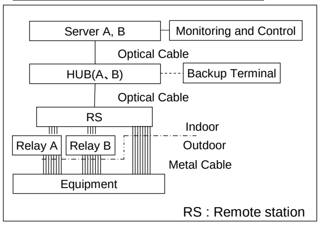
Transition of Monitoring and Control system(4)

Advanced system (LAN system)



1. This system can handle more information.
   In the future, modification for unattended operation is easier and its cost is lower than the second system. [Benefits of adopting this system]
2. This system is designed with high reliability. [Reliability of this system]
3. Servers have data recording function. The function is needed in only manned substation. [Functions of this system]
4. Construction cost can be reduced, because control cables are reduced by using optical cables. [Replacement cost of this system]

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Benefits of advanced LAN system

Advanced monitoring and control system can treat much information.
↓
Conditions of unattended substations can be grasped exactly.
↓
Unattended substations can be treated as same as manned substations.
↓
It is possible to expand to unattended operation in 500kV substations.

Experience and plan in KANSAI

All 275kV substations with LAN system were unattended.
↓
LAN system has been introduced to 500kV substations one after another.
↓
500kV substations are planned to be unattended in the future.

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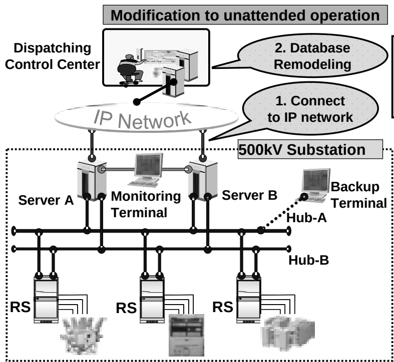
Benefits of advanced LAN system

Modification to unattended operation



In this system, modification for unattended operation is easier and its cost is lower than the second system.

The second system needs to be equipped with tele-control board and connected with metallic cables.
↓
Adoption of unattended operations can reduce operators.

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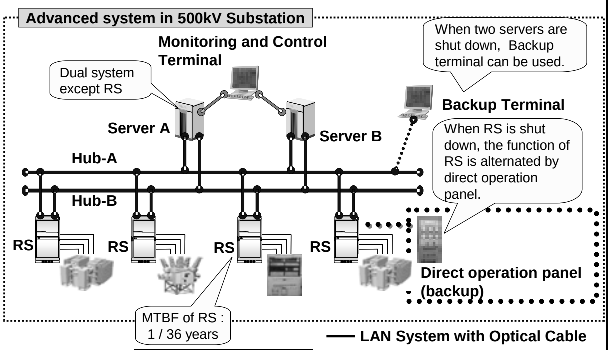
Reliability of monitoring and control system



MTBF : mean time between failure

— LAN System with Optical Cable
— Metallic Cable
RS: Remote Station

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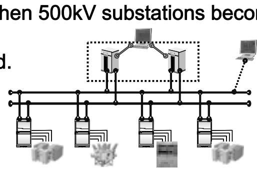
Characteristics of monitoring and control system with LAN

Fundamental Function of Server

Server Reliability
- ➢ **Each of Server and HUB is dual system for redundancy.**
- ➢ **Even though two severs are shut down, we can operate equipment by using Backup Terminal connected to HUB.**

Server Functions
- ➢ Direct control is possible by operators at 500kV Substations.
- ➢ Remote control is possible when 500kV substations become unattended in the future.
- ➢ Various data can be recorded.

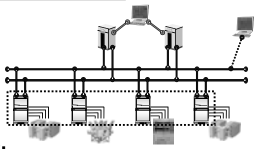


2-48

2. Advanced and Efficient Technologies of Transmission and Substation Equipment

Characteristics of monitoring and control system with LAN

Fundamental Function of Remote Station



RS Reliability
- ➢ RS is single system.
- ➢ RS is installed for each CB.
- ➢ In case RS is shut down, equipment can be operated using direct operation panel with local mode.

RS Functions
- ➢ Control signals are transmitted from RSs to equipment through O/E converter.
- ➢ Conditions of equipment are transmitted from RSs to server through E/O converter.

2-49

Replacement cost of monitoring and control system with LAN

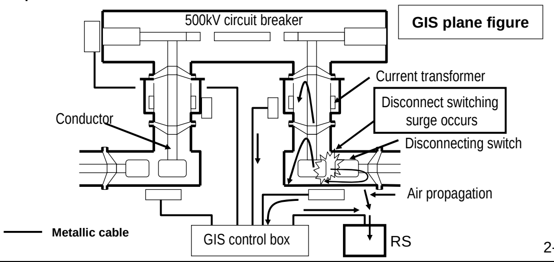
	The second system	Advanced system
Cable rack install	1%	1%
Building Expansion	14%	0%
Cable	10%	9%
Monitoring System	105%	90%
Total Cost	130%	100%

When advanced system is adopted, replacement cost can be reduced from the following point of view.
- ➢ It isn't necessary to expand building.
  (New monitoring and control system doesn't need large space.)
- ➢ Metallic Control Cables are decreased by using Optical Cables.
- ➢ The cost of monitoring system itself is lower than that of the second system.

2-50

Challenges of monitoring and control system

In order to avoid malfunction of outdoor RS, surge level was investigated.
- ➢ If RSs are installed near outdoor equipment, switching surge, static induction and electromagnetic wave noise, etc may cause wrong operation.
- ➢ In the future, it is better to install RSs outdoor because the amount of metallic control cables can be reduced significantly.
- ➢ Therefore, RS was investigated with regard to characteristics of withstand surge in field test for one year.
- ➢ According to the study, surge voltage for the test of RS is decided to be rectangular impulse of 4kV.



2-51

Summary

1. By the adoption of advanced LAN system, replacement cost can be reduced.
   - Expansion of existing building isn't needed.
   - The amount of control cables gets smaller.
   - The cost of the LAN system itself is lower than that of the second system.
2. By the adoption of 500kV unattended substations, the number of operators can be reduced.
   - Advanced LAN system can treat much information.
   - Conditions of unattended substations can be grasped exactly.
   - Unattended operation can be realized at 500kV substations.
3. Surge level of outdoor RS was investigated and surge voltage for the test was determined.

2-52

2. Advanced and Efficient Technologies of Transmission and Substation Equipment

- 2-1. Gas Insulated Switchgear (GIS)
- 2-2. Life assessment of substation equipment
- 2-3. Advanced monitoring and control system
- 2-4. Conductor with bulk capacity and Conductor with reduced wind load
- 2-5. Lightning protection devices for transmission line

2-53

2-4. Conductor with bulk capacity and conductor with reduced wind load

Outline

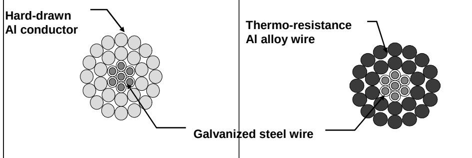
- ♦ Conventional Conductors
- ♦ Low-sag Up-rating Conductor (conductor with bulk capacity)
  - (1) Gap Conductor (GTACSR)
  - (2) Invar Conductor (ZTACIR)
- ♦ Conductor with Reduced Wind Load

2-54

2. Advanced and Efficient Technologies of Transmission and Substation Equipment

♦ Conventional Conductors

・ACSR and TACSR are generally used as conductors of overhead transmission line

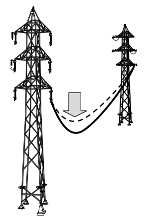
	ACSR Al Conductors Steel-Reinforced	TACSR Thermo-Resistance Al Alloy Wires
Cross-sectional view		
Continuous allowable temperature	90 deg. C →	150 deg. C

Maximum allowable current increases by temperature rise

Al: Aluminum

2-55

♦ Low-sag Up-rating Conductor



Background

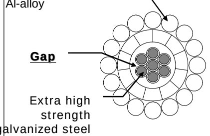
Conductor generates much heat as current flow increases
↓
Sag increases by thermal expansion of conductor
↓
Necessity of the taller tower
↓
Cost increase
↓
It had been desired to develop the conductor having lower sag and upper rating characteristics simultaneously

2-56

♦ (1) Gap Conductor (GTACSR)

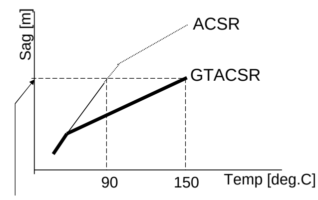
GTACSR;
Gap Type Thermal Resistant Aluminum Alloy Conductors, Steel Reinforced

Cross-sectional view



GTACSR 240mm²

Characteristic Curve of Sag



Sag at continuous allowable temperature

2-57

♦ (1) Gap Conductor (GTACSR)

Principle of up-rating:
Using thermo-resistance aluminum alloy conductor

Principle of low-sag:
Relaxation of stress of aluminum wire by the gap

⇨ •Continuous allowable temperature:
150 deg. C
•Current capacity:
1.6 times larger than that of ACSR with same size

Ease or difficulty of stringing work:
Special attention shall be paid to the tension of aluminum and steel wire respectively ⇨ Necessity of the special technical stringing method

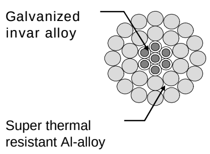
2-58

♦ (2) Invar Conductor (ZTACIR)

ZTACIR
(Super-Thermo Resistant Aluminum Alloy Conductors, Galvanized Invar Reinforced)

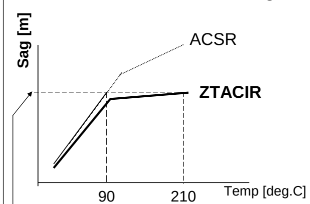
"Invar" is an abbreviation of "invariable"

Cross-sectional view



Co-efficient of thermal linear expansion
Steel: 11.5×10^{-6} (1/deg.C)
Invar: **3.6×10^{-6}** (1/deg.C)

Characteristic Curve of Sag



Sag at continuous allowable temperature

2-59

♦ (2) Invar Conductor (ZTACIR)

Principle of up-rating:
Using super thermal resistant alloy

Principle of low-sag:
Using invar wire, which has 1/3 thermal expansion of conventional steel

⇨ •Continuous allowable temperature:
210 deg. C
•Current capacity:
2.0 times larger than that of ACSR with same size

Ease or difficulty of stringing work:
•Stringing method is same as that of conventional ACSR ⇨ Easy stringing

2-60

2. Advanced and Efficient Technologies of Transmission and Substation Equipment

♦ Low-sag Up-rating Conductor

Characteristics of each conductor
(Conductor size is corresponding to 410mm²)

Designation	Continuous allowable temperature [deg.C]	Continuous allowable current [A]	Current ratio	Sag [m]	Difference from ASCR sag [m]
ACSR	90	829	1.0 (Base)	8.9	–
TACSR	150	1,323	1.6	11.2	+2.3
GTACSR	**150**	**1,323**	**1.6**	**9.1**	**+0.2**
ZTACIR	**210**	**1,675**	**2.0**	**8.9**	**0.0**

Condition of sag calculation :
Maximum working tension is 500kN, Span Length is 300m, At continuous allowable temperature

⇨ Low-sag up-rating conductors can upgrade the current capacity of existing lines without constructing new lines or modifying existing towers

♦ Low-sag Up-rating Conductor

Flow chart of conductor selection

Decision of planning power capacity

Measures with new line
・Adoption of thermo-resistant aluminum alloy wire
・Adoption of bundled conductor

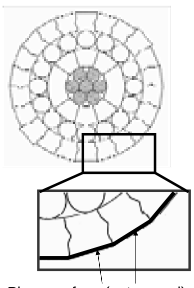
Measures with existing line
・**Replacement with low-sag up-rating conductor**
・Reconstruction or modification of existing tower

Select the most suitable measure from economical and environmental point of view

♦ Conductor with Reduced Wind Load

PLY（PoLYgon）type conductor with reduced wind load

Cross-sectional view



Plane surface (not curved)

Characteristics:
・Possible to reduce the wind pressure by polygon surface

・Conductor size：
(Equivalent to ACSR 240mm²-810mm²)

Size	Designation	Cross section
240mm²	PLY240	17-sided polygon
330〃	PLY330	20-sided
410〃	PLY410	20-sided
610〃	PLY610	22-sided
810〃	PLY810	22-sided

→possible to adopt to every voltage level

・String method is same as that of conventional ACSR

♦ Conductor with Reduced Wind Load

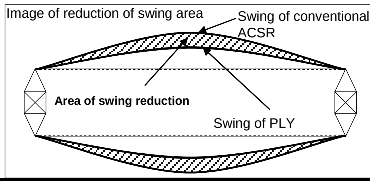
Effect of the reduction of wind load and conductor swing

Designation	Drag co-efficient* C_D	Reduction ratio of swing area [%] (in model case)
PLY240	**0.85**	**15**
PLY330	**0.80**	**22**
PLY410	**0.80**	**14**
PLY610	**0.80**	**26**
PLY810	**0.80**	**18**

Effect of the reduction of wind load
15% - 20%

Effect of the reduction of conductor swing (Swing area)
14% -26%

Image of reduction of swing area



*Drag co-efficient (C_D) is used in calculation of average wind pressure and average conductor swing. C_D of ACSR is 1.0

(Reduction ratio of swing area)
$$= 1 - \frac{\text{Swing area of PLY}}{\text{Swing area of ACSR}}$$

♦ Conductor with Reduced Wind Load

- Effects by the reduction of wind load (design load)

•When it is adopted to new line,
<u>construction cost will be reduced.</u>
(It is possible to use slenderer tower steel)

•When it is adopted to existing line,
<u>tower strength will be increased relatively.</u>

- Effect by the reduction of conductor swing

<u>Reduction of Right Of Way (ROW)</u>

(Additional effect)
- Effect by the low-sag characteristic
<u>Reduction of tower height</u>
(in comparison with conventional ACSR with same size in same temperature)

♦ Summary

•Low-sag up-rating conductor includes; Gap conductor and Invar conductor. They can upgrade the capacity of existing lines without constructing new lines or modifying existing towers.

•Conductor with reduced wind load has some effects; reduction of construction cost, increase of the strength of existing tower and reduction of ROW.

2. Advanced and Efficient Technologies of Transmission and Substation Equipment

2. Advanced and Efficient Technologies of Transmission and Substation Equipment

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2-5. Lightning protection devices for transmission line

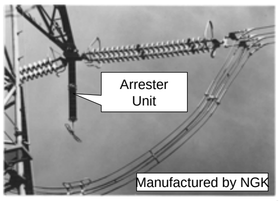
Outline

- ♦ **Line Arresters**
  - ♦ **Normal Type**
  - ♦ **Compact Type**
- ♦ **Active Horn (A new type of arc horn)**
- ♦ **Comparison of Line Arrester and Active Horn**

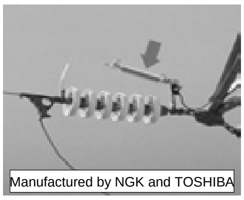
2-68

♦Line Arresters

Line Arrester (Normal Type)



Line Arrester (Compact Type)



Shut-down principle is same as that of normal type

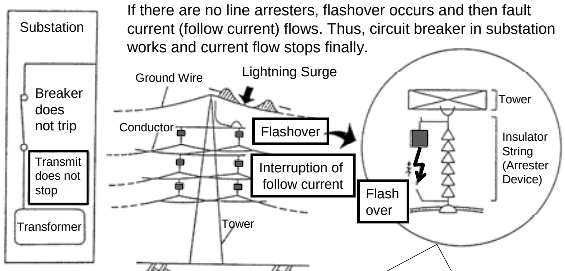
By the non-linear characteristics of zinc oxide (ZnO) element contained in arrester units, voltage rise between arc horns and flashover is prevented when lightning occurs.

2-69

♦Line Arresters

Function of Line Arrester

If there are no line arresters, flashover occurs and then fault current (follow current) flows. Thus, circuit breaker in substation works and current flow stops finally.

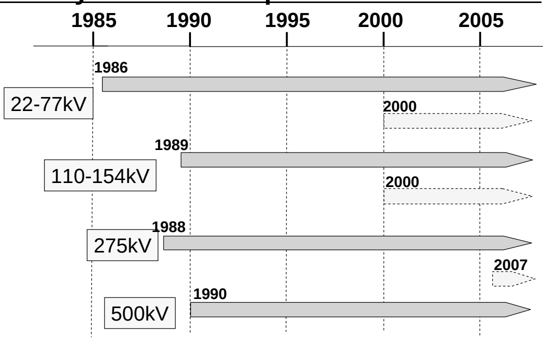


If there are line arresters, fault current is restricted and extinguished in a short time. Thus, power current flow continues without tripping.

2-70

♦Line Arresters

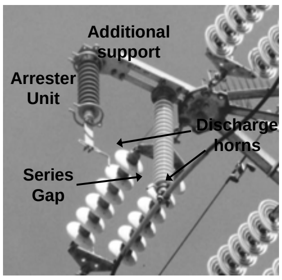
History of the development of line arrester



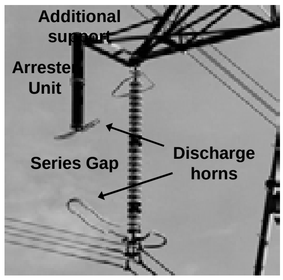
2-71

♦Line Arresters ; Normal Type

Application of Line Arresters to Tower



77kV System



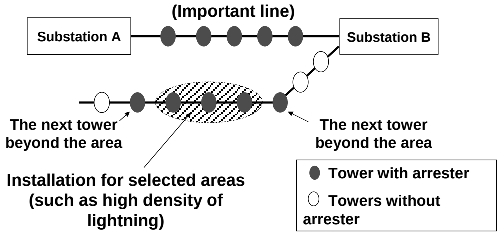
500kV System

2-72

2. Advanced and Efficient Technologies of Transmission and Substation Equipment

♦Line Arresters ; Normal Type

Application Method in Power System



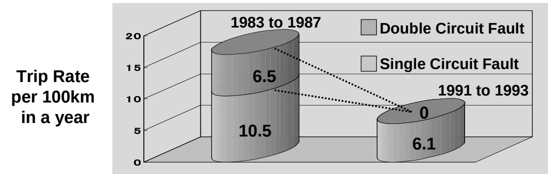
The towers where line arresters to be installed shall be selected in consideration with frequency of faults due to lightning, installation cost, importance of the line, etc.

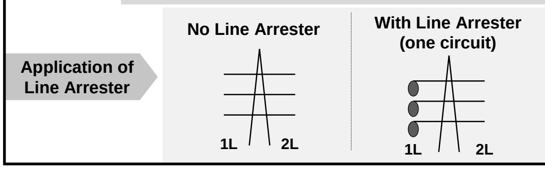
2-73

♦Line Arresters ; Normal Type

Field observation of the Line arrester

Trip rate of some 77kV lines was investigated before and after the installation of the line arresters

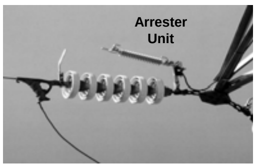


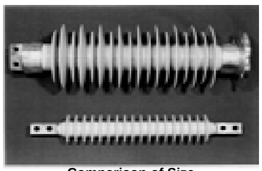


2-74

♦Line Arresters ; Compact Type

Operating Duty	Limited Discharge Capacity for Shielded Systems	
Arrester Unit	Very Compact & Light Weight ⇨	Easier Handling
Mounting Method	Replacement of Existing Arc Horn ⇨	Drastic Improvement of Installation Work





Comparison of Size

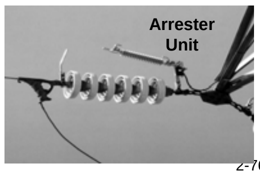
2-75

♦Line Arresters ; Compact Type

Field observation of compact type arrester

	Without arrester	With compact-type arrester
Fault on 1 circuit	9	5
Fault on 2 circuit	3	0
Total	12	5

Compact-type arrester is also effective as well as normal type line arrester



2-76

♦Active Horn (A New Type of Arc Horn)

Development of new protection device

Although line arrester, including compact type, has high performance against lightning problem, the problem remains that installation cost of these devices are expensive.

⬇

The development of more low-cost type of lightning protection device which has moderate performance has been desired.

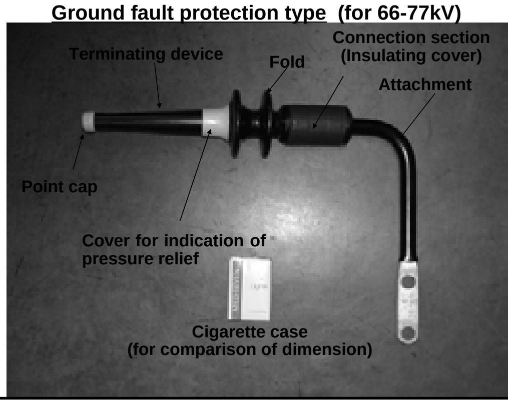
⬇

In Japan, new type of arching horn with lightning protection capability has been developed and installed in transmission line.

2-77

♦Active Horn (A New Type of Arc Horn)

Ground fault protection type (for 66-77kV)



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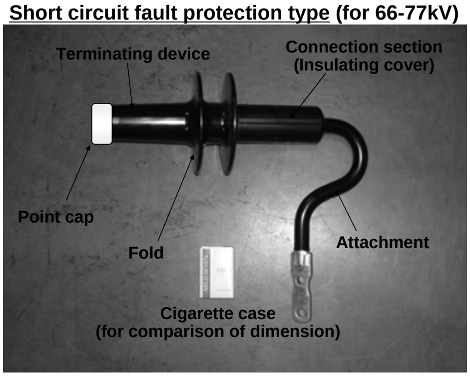
2. Advanced and Efficient Technologies of Transmission and Substation Equipment

♦Active Horn (A New Type of Arc Horn)

Short circuit fault protection type (for 66-77kV)

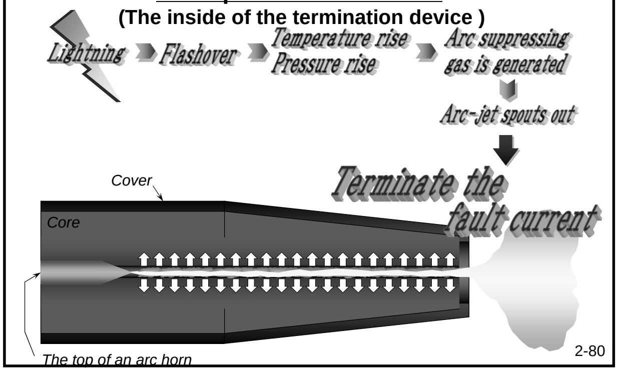


2-79

♦Active Horn (A New Type of Arc Horn)

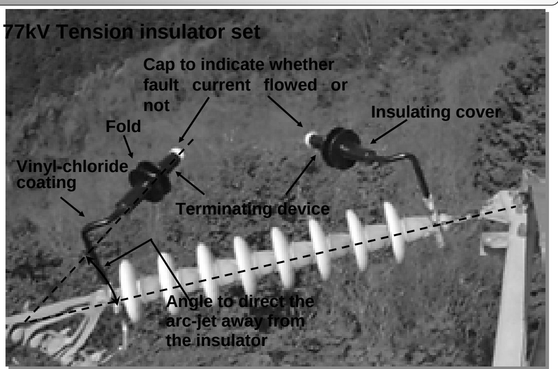
Principle of a termination

(The inside of the termination device)



2-80

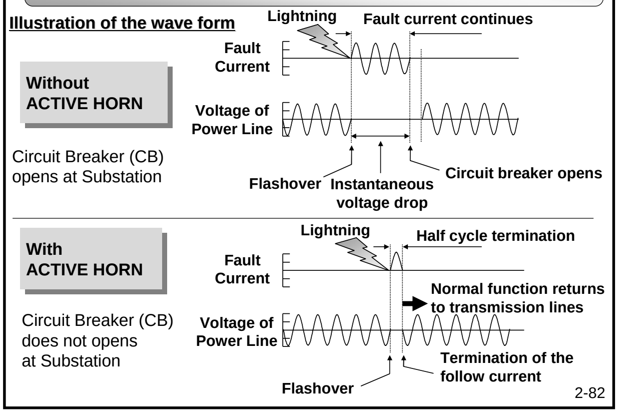
♦Active Horn (A New Type of Arc Horn)



ACTHIVE HORN is easily attached on insulator set as same as normal arching horn.

2-81

♦Active Horn (A New Type of Arc Horn)



2-82

♦Active Horn (A New Type of Arc Horn)

Advantage

- **Reduction of installation cost (Very cheap compared to line arrester)**
- **Light weight and compact**
- **Easy handling and installation**
- **No concern for lightning current**
- **Effective against bird contact** (because of its insulation characteristic)

Disadvantage

- **Limitation on the number of operation frequency**
  - It works at least 5 times (as termination follow current within 1 cycle)
  - After the limitation , it works as normal arching horn
- **Follow current runs until the termination completion**
  - Coordination with trip out relay in S/S is necessary
- **Limitation on applicability**
  - not applicable where short circuit current is more than 10kA (for 77kV short circuit protection type)

2-83

♦Comparison between Line Arrester and Active Horn

Item	Line arrester		Active horn	
	Normal type	Compact type	For short circuit	For ground fault
Operation principle	**Non linear characteristics of zinc-oxide element**		**Generation of arc-suppressing gas**	
Follow current	**Less than 1A**		**Depend on power system**	
Termination capability	**Short circuit fault & Ground fault**			**Ground fault**
Operation frequency	**No limitation**		**More than 5 times**	
Short circuit current of the installed line	**No limitation**		**Less than 10kA**	**-**
Maximum discharge current of lightning	**Exists**		**No limitation**	
Applicable voltage	**Up to 500kV**	**Up to 275kV**	**Up to 77kV**	**Up to 154kV**
Applicable area	**All area**	**Except polluted area**	**All area**	**All area**
Probability of fault prevention	**About 99%**	**About 95%**	**50 – 100%**	**About 50%**
Cost	**Expensive**	**Not expensive**	**Low cost**	**Very low cost**

2. Advanced and Efficient Technologies of Transmission and Substation Equipment

♦Summary

In Japan, following devices are widely installed as a lightning protection device.

•Line arrester (normal type), for preventing trip out with high reliability.

•The compact type line arrester; for reducing the installation cost of the normal type arresters.

•A new design of arcing horn, which is called “active horn”; as a cheap lightning protection device.

2-85

TECHNOLOGY TRANSFER SEMINAR

OF

THE STUDY ON

OPTIMAL ELECTRIC POWER DEVELOPMENT

IN JAVA-MADURA-BALI

IN THE REPUBLIC OF INDONESIA

AUGUST 28, 2008

AT

PJB HEAD OFFICE

PRESENTED BY

JICA STUDY TEAM

The Study on Optimal Electric Power Development in Java-Madura-Bali in the Republic of Indonesia

Technology Transfer Program (Draft) 1st Day

Date :	27 August 2008 at 10:00 AM.
Place:	PJB Head Office
Subject:	Technology Transfer (Substation and Transmission)

Time	Content	Presenter
10:00 - 10:10	Opening Speech by PLN	
10:10 - 10:20	Opening Speech by JICA Study Team	Mr. Yamaoka
10:20 - 12:00	Technology Transfer "Design of Transmission and Substation"	Mr. Manabe Mr. Maruoka
12:00 - 12:30	Question and Answer	
12:30 - 13:30	Lunch	
13:30 - 15:00	Technology Transfer "Advanced and efficient technologies of Transmission and Substation equipment"	Mr. Manabe Mr. Maruoka
15:00 - 15:20	Question and Answer	
15:20 - 15:30	Questionnaire to Audience	

Technology Transfer Program (Draft) 2nd Day

Date :	28 August 2008 at 9:00 AM.
Place:	PJB Head Office
Subject:	Technology Transfer (System Operation)

Time	Content	Presenter
09:00 - 09:05	Opening Speech by JICA Study Team	Mr. Yamaoka
09:05 - 11:00	Technology Transfer : System Operation	Mr. Kishishita
11:00 - 11:40	Question and Answer	
11:40 - 11:50	Questionnaire to Audience	
11:50 - 12:00	Closing Speech by PLN	
12:00 - 13:00	Lunch	