添付資料－2　技術移転セミナー

技術移転セミナー

1.　セミナー実施項目

技術移転セミナーに関しては、カウンターパート側から既に具体的な以下の 3 項目の要求があげられており、具体的内容について第 1 次現地調査時にカウンターパートと協議、合意した。また、これに沿った技術移転をスラバヤの PJB 本社でカウンターパートに対して第 2 回ワークショップと同時期に 2 日間行った。

① 信頼度向上のための絶縁設計・耐雷耐塩設計を含む送変電設備設計
② 電圧調整手法、系統保護
③ 設備保全技術を含む送変電設備の高度化・効率化

2.　セミナー日程

<u>Technology Transfer Program (Draft) 1st Day</u>

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

Time	Content	Presenter
10:00 - 10:20	Coffee Time	
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
09:10 - 11:10	Technology Transfer : System Operation	Mr. Koyama
11:10 - 11:40	Question and Answer	
11:40 - 11:50	Questionnaire to Audience	
11:50 - 12:00	Closing Speech by JICA	Mr. Yamaoka
12:00 - 13:00	Lunch	

3. セミナー実施内容

実施項目を表 1 に示す。

表 1 技術移転セミナー実施内容

1. **技術移転セミナー実施内容案(送変電)**

1.1 送変電絶縁設計

1) **過電圧の種類および想定値**
- 外雷：雷サージ
- 内雷：開閉サージ、持続性過電圧

2) **がいし個数の決定**
- がいし個数の決定方法

3) **耐雷設計（避雷針、架空地線、接地抵抗低減）**
- 架空地線遮蔽角の低減、架空地線の複線化、接地抵抗の低減、不平衡絶縁

4) **耐汚損設計**
- 汚損区分（じんあい／塩害地区）と塩分付着密度
- がいしの汚損閃絡特性
- 塩じん害対策

5) **送電線と変電所との絶縁協調**
- 第 1 鉄塔の絶縁強度の決定

6) **避雷器設置位置と変電所の絶縁協調**

- 変電所における避雷器の適正配置

1.2　送変電設備の高度化･効率化技術

1)　GIS 設備（変電所の縮小化）

- コンパクト化による変電所面積の縮小、メンテナンスの減少

2)　変電機器の保全評価

- 保全評価アルゴリズムや取替判定の考え方

3)　監視制御システムの高度化

- ＬＡＮ型監視制御の概要

4)　低風圧電線ならびに大容量電線

- 風圧減少による鉄塔重量の低減、大容量電線の概要

5)　避雷装置

- 送電用アレスタ、続流遮断型アークホーン等の送電線雷事故低減装置

2　技術セミナー実施内容案（系統運用）

1)　関西電力における大規模停電事故の紹介

- 御母衣事故、阪神大震災、大飯幹線／第二大飯幹線事故

2)　事故波及防止リレー

- 保護リレーの分類（事故波及防止、事故除去など）
- 事故波及防止リレーの目的

3)　電圧運用方法

- 電圧運用方法の分類（タップ調整、調相設備運用など）

4)　調相設備

- 調相設備の分類（SC、ShR、SVG など）、調相設備計画、運用

5)　直流設備

- 紀北変換所直流設備の紹介

6)　揚水発電所

- 系統運用上の位置づけ

7)　系統解析

- 系統解析手法
- 解析用データ整備手法

8)　水系運用

- 支援システムを用いた水系運用

4.　技術移転セミナー状況

技術移転プレゼンテーション終了時に今回の技術移転内容について実施したアンケート結果では、セミナー満足度（今回のセミナーに満足したかとの問いに対する YES の回答割合）および業務貢献度（今回のセミナーが業務に役立つかとの問いに対する YES の回答割合）が、1 日目、2 日目とも 83%～95%の高い評価を得ており、今回のセミナーがカウンターパートにとって有益となるよう技術移転の項目であり、かつ、業務の改善に貢献できる有益な内容であったといえる。

Topics in the seminar	Substation and Transmission (1st day)	System Operation (2nd day)
セミナー満足度	83% (29/35)	95% (22/23)
業務貢献度	91% (31/35)	91% (21/23)

また、セミナー理解度については、50%以上の理解度を示す割合が、1 日目で 89%、2 日目で 91%となり、短期間で高度な内容でありながら、多数の技術者の理解が得られ非常に有効なプレゼンテーションであったといえる。

Topics in the Seminar	Substation and Transmission	System Operation
Date	1st day 2008/8/27	2nd day 2008/8/28
80 ~ 100 % understood	6	3
50 ~80 % understood	25	18
0~50 % understood	4	2
Number of collected questionnaires	35	23

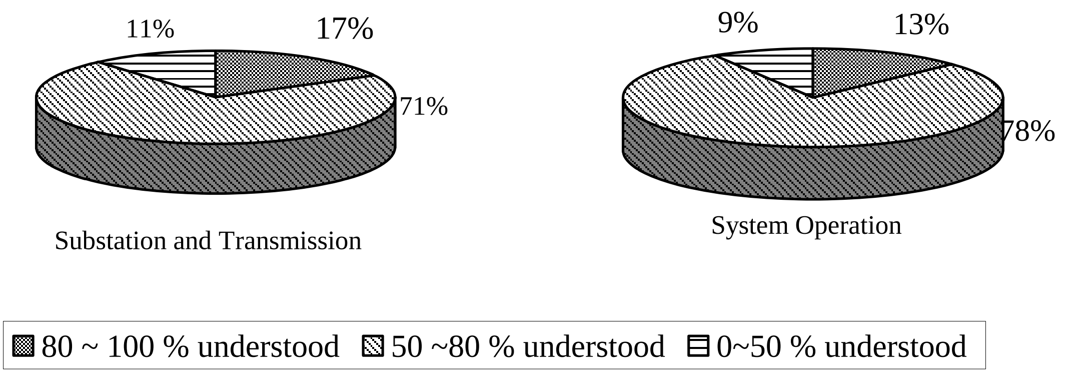

表 2（1/2） 技術移転実施後のアンケート調査結果（1 日目：2008.8.27）

Questionnaire Survey on Technology Transfer Seminar relating to Substation, Transmission on August 27 at PJB Head Office			
2. Technology Transfer related to Substation and Transmission			
2.1	Topics in the Seminar		
	Are you satisfied with the topics presented in the Seminar?	Yes (**29**)	No (**6**)
	If your answer is "No", what kind of topics do you expect?		
	Reactive power planning and Voltage control		
2.2	Understanding of topics		
	Do you understand the contents presented in the Seminar? Please tell us the degree of understanding.		
	80 ~ 100 % understood (**6**)	50 ~80 % understood (**25**)	0~50 % understood (**4**)
2.3	Contribution toward your work		
	Is this seminar useful for your work?	Yes (**31**)	No (**3**)

表 2（2/2） 技術移転実施後のアンケート調査結果（2 日目：2008.8.28）

Questionnaire Survey on Technology Transfer Seminar relating to Substation, Transmission on August 28 at PJB Head Office			
2. Technology Transfer related to System Operation			
2.1	Topics in the Seminar		
	Are you satisfied with the topics presented in the Seminar?	Yes (**22**)	No (**1**)
2.2	Understanding of topics		
	Do you understand the contents presented in the Seminar? Please tell us the degree of understanding.		
	80 ~ 100 % understood (**3**)	50 ~80 % understood (**18**)	0~50 % understood (**2**)
2.3	Contribution toward your work		
	Is this seminar useful for your work?	Yes (**21**)	No (**2**)

5.　技術移転セミナー状況写真

1．セミナー会場(PJB 本社)

2．技術移転セミナー（8/27）

3．技術移転セミナー（8/27）

4．技術移転セミナー（8/27）

5．技術移転セミナー（8/28）

6．技術移転セミナー（8/28）

6. 出席者リスト

(a) 出席者リスト(8/27)

Attendant List [1 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" — JICA

Date: August.27, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
1	T. MATSUNO	JICA	JICA	[illegible]
2	Y. NAKAJIMA	JICA	JICA	[illegible]
3	Y. TANAKA	JICA	JICA	[illegible]
4	S. Yamaoka	Team Leader	JICA	[illegible]
5	H. Yamada	JICA	JICA	[illegible]
6	T. Kishishita	JICA	JICA	[illegible]
7	K. Manabe	JICA	JICA	[illegible]
8	T. OHWADA	JICA	JICA	[illegible]
9	M. NISHIDA	JICA	JICA	[illegible]
10	Y. MATSUDA	JICA	JICA	[illegible]

Attendant List [1 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" — JICA

Date: August.27, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
1	Y. Koyama	JICA	JICA	[illegible]
2	Y. Maruoka	JICA	JICA	[illegible]

Attendant List [3 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" — PLN

Date: August.27, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
1	Sairin	Rensis	PLN Pusat	[illegible]
2	ERWIN MIRZA	[illegible]	PLN P3T	[illegible]
3	SURYO ISKANDAR	RENSIS	P3T	[illegible]

Attendant List [1 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" — PJB

Date: August.27, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
1	Gunawan S	AHL	PJB JB	[illegible]
2	AHMAD YUSUF S		PJB JB	[illegible]
3	MUNAWAR		PJB JB	[illegible]
4	Teguh Brit		PJB JB	[illegible]
5	Aziz		PJB JB	[illegible]
6	SUTRISNO S		PJB JB	[illegible]
7	CHAIRUL ANAM		PJB . JB . KJB	[illegible]
8	SUCI ROSITAWATI		PJB JB RJTB	[illegible]
9	Ajeng Welly		PJB JB	[illegible]
10	[illegible]		—	[illegible]
11	krisna		PJB JB	[illegible]
12	DJOKO MULYADI		PJB JB	[illegible]

Attendant List [1 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA"

PJB JP

Date: August.27, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature	
1	[illegible] P	[illegible] Operator	PT PJB UP PAITON		✓
2	T. E. HAPSARA	"	"		
3	[illegible]	Pantjm PJB UP Paiton	PT. PJB UP PTN		
4	Nisawan W W	PJB UP Brn	PT PJB UP Brantas		
5	Farid WF	PJB UP Brantas	PT PJB UP Brantas		
6	SUYANTO		PT PJB UP Brantas		✓
7	ARIF WAHYU [illegible]	PT PJB	SO ROP		
8	Bb Tjahjono	PJB UPMKK	UPMKK		✓
9	Thomui Haposan	PJB MTW	MTW		
10	Nyoman Awatara	PJB ROP	ROP		
11	Mulyono Rosta	Sardiaw	PJB		
12	W. ~~[illegible]~~ Priyadi	PJB UPHB	PJB		
13	S. HARYANTO	PJB-SDK	PJB-RST		
14	Bernadus S.	PJB Manager	PJB - KO		
15	Rudy. Firmansyah	UPHB/MBR	—		
16	Didik M	CIRATA	—		
17	Harry Santoso	enjinering	UP. Cirata		✓
18	Kurniawan E W	Eng	—		
19	Teguh Widowo	MTEK	PJB Kantor Pst		
20	Bayu A S	ROP	ROP		

Attendant List [2 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA"

PJB. JP

Date: August.27, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature	
1	Wimk Sudiyanto	G. Mani.	UBP PT. Gratiyon		
2	ARY CAHYONO	Mage	UBP Muara Grati		✓
3	Tirtuq Budihartono	Ops	— " —		
4	MUHAMMAD MAUDUDIN	Operasi	— " —		
5	Aryanti	VPE	H.O		
6	[illegible]	[illegible]	PJB		
7	TOTOT S	[illegible]	[illegible]		
8	PUTRI YUNITASARI	TIME KEEPER	PJB		
9	Sarita Wardani	secretary	PJB		
10	Teguh C	SD UMUM	PJB		
11	Duvall	PR	—		
12	HARRY PRIJONO	SDMUM	PJB		
13	BUDI UTOMO	SDKM	PJB		
14	SUHUD	Sekuriti	PJB		
15	M. Ujfir a	SD Umum	PJB		
16	Dadang W	—	—		

Attendant List [1 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA"

JP. PJB

Date: August.27, 2008 Place: PJB HEAD OFFICE

21	Name	Position	Unit &Organization	Signature
22	Restina	ROP	ROP	
23	Andi P		UPHT	
24	Sukardi		UPHT	
25	Raditya KA		UPHT	
26	Ahmad Fajar R		UP Eng	
27	Retno Handayani	SDME	SDME	
28	Denik P. P.		SDME	
29	Hepi	ME	SDME	
30	Mulis	•	UP GRSIK	
31	DEDY. M	EM	UP GRESIK	
32	T. GUNAWAN	RENDAL OP	UP GRESIK	
33	Setyono W	Rawat.	—	
34	I Dyana Ngurah	Staf	SJN	
35	Vivi Agus	Maintenance	PT. UP USPI GP	
36	Bambang Setiawan	Enjiniring	PT. PJB UP. Muara Tawar	
37	Yan Suprayogi	Rendal Har	UP. MTW	
38	RIJAIFUL ABAS	PJB	PJB	
99	DODI	SPTI	SPTI	
20	NANIK KW	Staff	KW	
40	[illegible]	PJB	PJB	

(b) 出席者リスト(8/28)

Attendant List [1 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" — JICA

Date: August.28, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
1.	S. Yamaoka	Team Leader	JICA	[illegible]
2.	H. Yamada	JICA	JICA	[illegible]
3.	Y. NAKAJIMA	〃	〃	[illegible]
4.	T. MATSUNO	〃	〃	[illegible]
5.	Y. Matsuda	〃	〃	[illegible]
6.	Y. TANAKA	〃	〃	[illegible]
7.	T. OHWADA	JICA	JICA	[illegible]
8.	K. Manabe	JICA	〃	[illegible]
9.	Y. Maruoka	JICA	JICA	丸岡
10.	M. NISHIDA	JICA	JICA	[illegible]

Attendant List [2 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" — JICA

Date: August.28, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
1.	Y. Koyama	JICA	JICA	[illegible]
2.	T. Kishishita	JICA	JICA	[illegible]

Attendant List [1 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" — PJB

Date: August.28, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
1	Ahmad [illegible]		PJB JB	[illegible]
2	Ajeng Welly		— 〃 —	[illegible]
3.	Munawar		PJB TB	[illegible]
4.	Teguh [illegible]		PJB JB	[illegible]
5.	Choirul Anam		PJB. JB	[illegible]
6	Erima		PJB JB	[illegible]

Attendant List [1 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" — PJB

Date: August.28, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
1.	IWAN AGUNG	M.	UP BRS	[illegible]
2.	RACHMAT HIDAYAT	M	UP CIRATA	[illegible]
3.	Adi Firmanto		SDTEK	[illegible]
4.	MIFTAHUL J		UP MTW	[illegible]
5.	Rudy. T		UPHB	[illegible]
6.	SUTOMO		UPHT	[illegible]
7.	Raditya KA		UPHT	[illegible]
8.	Adi Setyawan		UPHT	[illegible]
9.	Irwan Supangkat	VPE	VP Eng	[illegible]
10.	Paminto A.B	M UPGRK	PJB	[illegible]
11.	Rachmanul I.	up Gresik	PJB	[illegible]
12.	[illegible]		MN KPI	[illegible]
13.	Martiko B		PT PJB	[illegible]
14.	Tedjo Lelono	MTEK	PT PJB	[illegible]
15.	A. DJATI R	UP PTN	UP PTN	[illegible]
16.	ARIF WAHYU A	SD POP	PJB	[illegible]
17.	Wisnoe Satrijono	SD Keu	PJB	[illegible]
18.	WAHYUDI	SD POP	PJB	
19.	ACHMAD RIANTO	SD UMUM	PJB	
20.	M. JUPRI	SD UMUM	PJB	

Attendant List [2 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" PJB

Date: August.28, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
21	Sitta	BHCU	PJB	
22	Paramita Purwaanti	LAB	PJB	
23	Pinoji Astuti	—	—	
24	Elisia Nigma	SD KM	PJB	
25	Rohib N.	—	—	
26	Wisnoe Satrijono	SDKOM	SDKOM	
27	DODI	SDTI	SDTI	
28	NANIK KD	SD KKU		
29	Ali Basono	PJB	PJB	
30	TOTOT-S	Admin/PJB	PJB	
31	PUTRI YUNIATTIASARI	TIME KEEPER	PJB	
32	Durall	PR	—	
33	Santika I	Security	[illegible]	
34	Teguh S.	SD UMUM		
35	HARRY PRIJONO	SDMUM	PJA	
36	BUDI UTOMO	SDKM	PJB	
37	SUTTUD	SEKURITI	PJB	
38	Windarto	SDMUM	PJB	
39	M. Jafri A	SD UMUM	PJB	
40	Rahayu KA	Rendal	UPHT	

Attendant List [2 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" PJB

Date: August.28, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
1	Danni Yanuar	UP MKG	PJB	
2	Anti [illegible]	MPUT	PJB	
3	Dadang W	—	—	
4	Sukanti	TEPHT	PJB	
5	Hepi		SDMR	
6	Nyoman Awatan	ROP	Rop	
7	Ratna Handayani		SD MME	
8	Danik	ME		
9	DADANG K	MOPRA	PJB – PSKEU	

Attendant List [2 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" PJB

Date: August.28, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
1	Sugiyanto	Pembina	PJB UP PTN	
2	ARIF WAHYU AB	PT PJB	PT PJB	
3	Bambang Setiawan	PT PJB	UP Muara Tawar	
4	Yan Suprayogi	PT. PJB	UP. Muara Tawar	
5	Kurniawan E.W	PT. PJB	Cirata	
6	Farid WF	PT. PJB	UP Brantas	
7	Didik M	ENG.	UP CIRATA	
8	Harry Santoso	Eng.	UP. Cirata	
9	Faisal R	UP Paiton		
10	I.B. Hapsara	PC	UP Paiton	
11	Mulyono Rosita	SAT INEAT	PJB	
12	Sb Tjahjono	Mpu KK	MPHKK	
13	Heri S	VPE	PJB	
14	Ahmad Fajar R	VPE	PJB KP	
15	Thamrin Hapsoro	Eng	PJB MPV	
16	Hariyati	KM	PJB KP	
17	Rausa Sangsthito A	COMPU	PJB KP	
18	Aryanti	VPE	H.O	
19	Dian A	KM	PT PJB KP	
20	SJAIFUL ANAS	PJB	PJB	

Attendant List [3 /]

Title of Meeting: TECHNOLOGY TRANSFER SEMINAR OF "THE STUDY ON OPTIMAL ELECTRIC DEVELOPMENT IN JAVA-MADURA-BALI IN THE REPUBLIC OF INDONESIA" IP

Date: August.28, 2008 Place: PJB HEAD OFFICE

	Name	Position	Unit &Organization	Signature
1	Heru Mugi Santoso	Maintenance	PT. IP UBPPGT	
2	Mirik Wiryadi	E. Mgr	G.[illegible]	
3	G. Rully Triwandoyo	Manager	PT PJB UPHT	
4	M. IMADUDDIN	Operation	PT IP UBPPGT	
5	ARY CAHYONO B.J	OPERATION	—	
6	Tuhan B	OPS	PT IP	

技術移転セミナー時 配布資料

1. Design of Transmission Line and Substation
2. Advanced and Efficient Technologies of Transmission and Substation Equipment
3. System Operation (Voltage Control and System Protection)

TECHNOLOGY TRANSFER SEMINAR

OF

THE STUDY ON

OPTIMAL ELECTRIC POWER DEVELOPMENT

IN JAVA-MADURA-BALI

IN THE REPUBLIC OF INDONESIA

AUGUST 27, 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	

1. DESIGN OF TRANSMISSION LINE AND SUBSTATION

SPEAKER: MR. MARUOKA YOSHIO,

MR. MANABE KAZUHIRO,

KANSAI ELECTRIC POWER CO., Inc.

1. Design of Transmission Line and Substation

Technical Transfer Seminar

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

August 2008
NEWJEC Inc.
The Kansai Electric Power Co., Inc.

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1. Design of Transmission Line and Substation

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1-0. Introduction

Outline

- Component of Overhead Transmission Line
- Concept of Insulation
- Insulation Material

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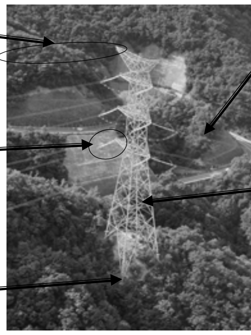
Component of Overhead Transmission Line

Overhead Ground Wire
To protect conductors from direct lightning

Insulator
To insulate conductors from tower

Foundation



Conductor
To flow electricity
Cf) ACSR, HDCC etc

Tower
To support conductors

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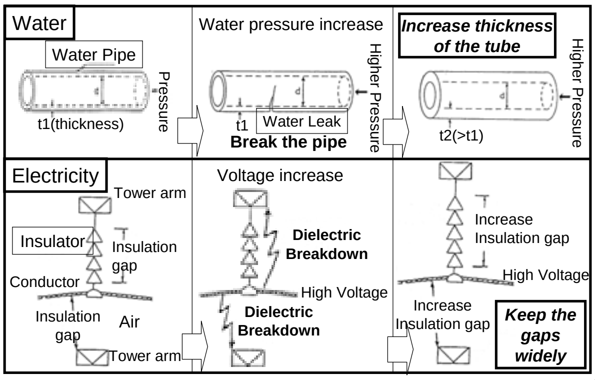
Concept of Insulation

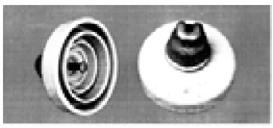


Insulation Material

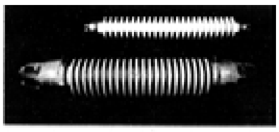
Form	Insulator Material	Place to Use	Dielectric Breakdown Strength	Comparison of Strength
Gas	**Air**	■**Overhead Transmission** ■**Bus of Circuit Breaker**	**21 kV/cm**	**1.0 (Base)**
	SF6	■**GIS & GIL**	380 kV/cm	18.1
Liquid	**Electrical Insulating oil**	■**Transformer** ■**Circuit Breaker** ■OF cable	78 kV/2.5mm	14.9
Solid	**Insulator (Alumina porcelain)**	■**Overhead Transmission** ■**Bushing** ■Pothead of Cable	**10 kV/mm**	**4.8**
	Paper (Craft Paper)	■OF Cable	30 kV/mm (Oil filled paper)	14.3
	Cross-linked Polyethylene	■CV Cable	38 kV/mm	18.1
	Vinyl Chloride	■Wiring (Inside & Outside)	20 kV/mm	9.5

Insulation Material

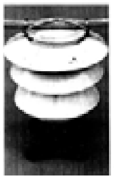
Suspension Insulator



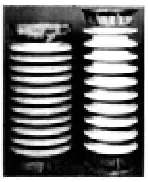
Long Rod Insulator



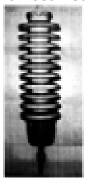
Pin Insulator



Station Post Insulator



Line Post Insulator



Insulation Material

Insulator classified by material

Material		Characteristics
Porcelain	Crystobarite porcelain	■Weakness to thermal shock, not used at new lines
	Alumina porcelain	■**Improved mechanical strength of crystobarite porcelain**
Glass	Soda-lime	■More vulnerable than porcelain insulator
Synthetic resin	Epoxy resin	■Used indoor only
	Polymer	■**Good anti-pollution characteristics, but possibility of brittle fracture of FRP core**

⇨ *Alumina porcelain* is generally used as insulation material of electricity equipments in Japan

1. Design of Transmission Line and Substation

1-1. Classification of the overvoltages and overview of design against them

Outline

- **Basis of Insulation Design**
- **External Overvoltage**
- **Internal Overvoltage**
- **Summary**

1. Design of Transmission Line and Substation

Basis of Insulation Design

Not only normal voltage but also external and internal overvoltages should be considered in the insulation design of the transmission line.

1	[Against the external overvoltage (Lightning)] it is necessary to reduce the damage through the combination of system protection method and by protection designs for lightning*
2	[Against the internal overvoltage] it is necessary to extremely reduce the probability of flashover.

*Protection designs for lightning include:
• adoption of proper insulation method
• installation of overhead ground wire
• reduction of grounding resistance   etc.

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External Overvoltage

The biggest external overvoltage is lightning surge.

Type	Source of generation	Characteristics
Lightning Surge	It is generated by direct lightning on conductor or by back flashover caused by lightning at overhead ground wire	Time order is several micro seconds. Magnitude of surge varies, and sometimes exceeds 2,000 kV.

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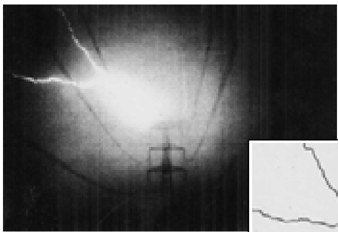
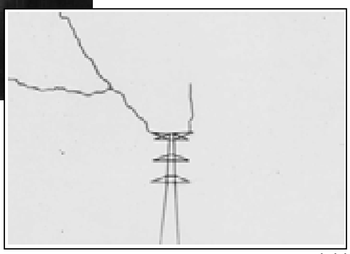
External Overvoltage

Photos of Lightning

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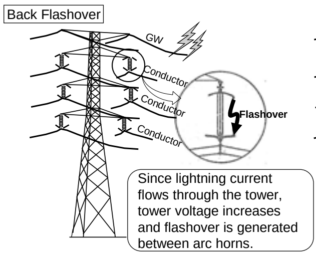
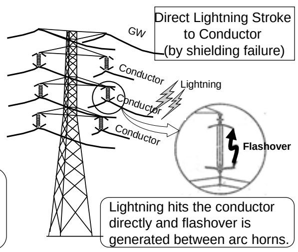
External Overvoltage





	Back Flashover	Direct Lightning Stroke
Parts to be Hit by Lightning	Tower or Overhead Ground Wire	Conductor
Frequency of Lightning	Many	Few
Direction of Lightning Current	Tower → Conductor	Conductor → Tower
Strength of Lightning Current	Weak	Strong
Damage of Equipment	Small	Large

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Internal Overvoltage

There are two types of overvoltages which is generated inside electricity equipment.

Type	Source of generation	Characteristics
Switching Surge	It is generated when a circuit breaker is opened or closed.	Time order is several hundred micro seconds. In 500 kV transmission line, magnitude is about 2 times larger than normal line-to-ground voltage.
Sustained Overvoltage	It is generated at sound phases when single line-to-ground fault occurs.	Magnitude is about 1.2-1.3 times larger (in direct grounding system) and about $\sqrt{3}$ times larger (in resistance grounding or ungrounded system) than normal line-to-ground voltage respectively.

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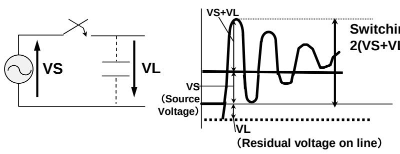
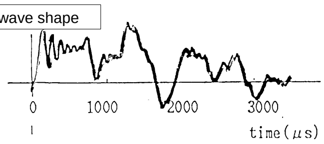
Internal Overvoltage ; Switching Surge

Overvoltage is generated when a circuit breaker is opened or closed.



In general, the switching surge voltage is shown as follows:
K(VS+VL) -VL

Example of wave shape



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Internal Overvoltage ; Switching Surge

- Switching surge is 2.0 – 4.0 times larger than the crest value of normal voltage
- Magnitude depends on grounding method

Grounding method	Non-grounding	Resistance reactor	Direct grounding	Direct grounding
Nominal voltage [kV]	22, 33	66, 77, 154	275	500
Switching surge ratio	x 4.0	x 3.3	x 2.8	x 2.0

[Switching Surge Voltage]

= [Highest Allowable Voltage of IEC; *Um*] * ($\sqrt{2}$ / $\sqrt{3}$) * [Switching Surge Ratio]

= [Crest Value of Highest Allowable Voltage to Ground] * [Switching Surge Ratio]

Um = [Nominal Voltage *V*] × (12 / 11)

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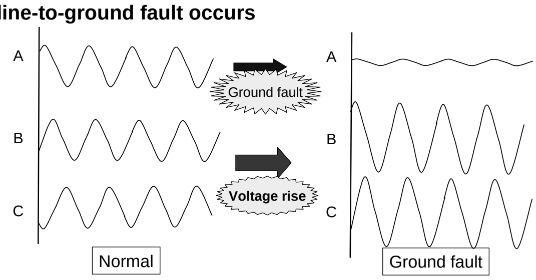
Internal Overvoltage; Sustained Overvoltage

- Sustained overvoltage is generated when single line-to-ground fault occurs



Voltages of 3 phases are almost equivalent

Voltage of grounding phase is almost zero. Voltages of sound phases rise.

1-19

Internal Overvoltage; Sustained Overvoltage

- Sustained overvoltage is 1.3 – $\sqrt{3}$ times larger than the highest allowable voltage
- Magnitude depends on grounding method

Grounding method	Non-grounding	Resistance reactor	Direct grounding
Nominal voltage [kV]	22, 33	66, 77, 154	275, 500
Overvoltage ratio	$\times\sqrt{3}$	$\times\sqrt{3}$	x1.3

[Sustained Overvoltage]

= [Highest Allowable Voltage] * (1/ $\sqrt{3}$) * [Overvoltage Ratio]

[Highest Allowable Voltage] = [Nominal Voltage *V*] × (11.5 / 11)

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Internal Overvoltage

<Switching surge overvoltage >

Nominal voltage *V* [kV]	22	33	66	77	154	275	500	Notes
Highest allowable voltage *Um* [kV]	24	36	72	84	168	300	525	$V\times\frac{12}{11}$
Crest value of highest allowable voltage to ground [kV]	19.6	29.4	58.8	68.6	137	245	429	$Um\times\frac{\sqrt{2}}{\sqrt{3}}$
Switching surge ratio *n*	4.0	4.0	3.3	3.3	3.3	2.8	2.0	
Switching surge voltage [kV]	78.4	117.6	194	226	452	686	858	$Um\times\frac{\sqrt{2}}{\sqrt{3}}\times n$

<Sustained overvoltage>

Nominal voltage *V* [kV]	22	33	66	77	154	275	500	Notes
Highest allowable voltage [kV]	23	35	69	81	161	288	525	$V\times\frac{11.5}{11}$
Overvoltage ratio *n*	$\sqrt{3}$	$\sqrt{3}$	$\sqrt{3}$	$\sqrt{3}$	$\sqrt{3}$	1.3	1.3	
Sustained overvoltage [kV]	23	35	69	81	161	216	394	$V\times\frac{11.5}{11}\times\frac{n}{\sqrt{3}}$

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Summary

- External and internal overvoltages shall be considered for insulation design.
- The biggest external overvoltage is lightning surge.
- The internal overvoltage includes; swicthing surge and sustained overvoltage. These values are estimated by setting the overvoltage ratio.

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1. Design of Transmission Line and Substation

1-0. Introduction

1-1. Classification of the overvoltages and overview of design against them

1-2. Determination of the number of insulators

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1-6. Insulation design in substations with surge arresters

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1-2. Determination of the Number of Insulators

Outline

- Determination of the Number of Insulators
- Required Number of Insulators against Switching Surge
- Application of Arc Horn
- Summary

Determination of the Number of Insulators

The number of insulators determined by switching surge

The number of insulators determined by sustained overvoltage

To select the bigger number

In general, the number determined by switching surge is bigger than that by sustained overvoltage.

Determination of the number of insulator

The actual determined number of insulators depends on arc horn gap and pollution withstand voltage.

Required Number of Insulators against Switching Surge

(250mm suspension insulator, Non-polluted area)

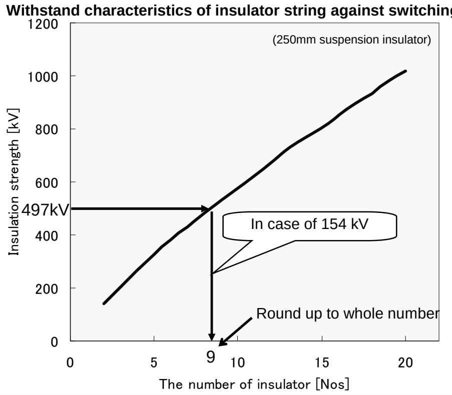
Nominal voltage *V*[kV]	22	33	66	77	154	275	500	Notes
Highest allowable voltage *Um* [kV]	24	36	72	84	168	300	525	$V\times\frac{12}{11}$
Crest value of highest allowable voltage to ground [kV]	19.6	29.4	58.8	68.6	137	245	429	$Um\times\frac{\sqrt{2}}{\sqrt{3}}$
Switching surge ratio *n*	4.0	4.0	3.3	3.3	3.3	2.8	2.0	
Switching surge voltage [kV]	78.4	117.6	194	226	452	686	858	$Um\times\frac{\sqrt{2}}{\sqrt{3}}\times n$
Reduction coefficient of insulation *k*	1.1	1.1	1.1	1.1	1.1	1.1	1.1	*
Required insulation strength of insulator [kV]	86	129	213	249	497	755	944	$Um\times\frac{\sqrt{2}}{\sqrt{3}}\times n\times k$
Required number of insulators**	**2**	**2**	**4**	**4**	**9**	**14**	**19**	From the graph of next page

*Reduction coefficient of insulation: revised coefficient in consideration with insulation reduction of insulator string by difference of the sea level and climate condition

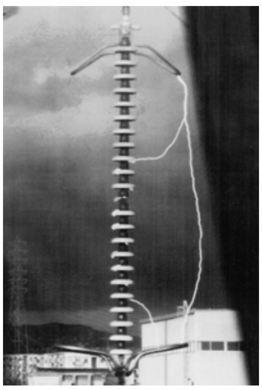
**In Japan generally, added one more insulator for maintenance

Required Number of Insulators against Switching Surge

Withstand characteristics of insulator string against switching surge



Application of Arc Horn



Function of the Arc Horn

1. Protection of Insulator

Arc horn does not permit flashover on the surface of insulators against;
•lightning stroke, or
•pollution of insulators
in order to avoid the rupture of insulator

2. Corona Shield

Arc horn shields corona which is generated from insulator or fitting

Application of Arc Horn ; Horn Gap

Flashover must not be permitted between arc horns when expected internal overvoltages (such as switching surge and sustained overvoltage) are generated

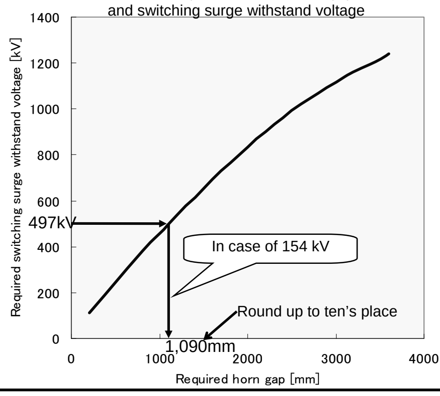
Minimum horn gap is determined by the internal overvoltages.
(In general, it is determined by switching surge withstand voltage characteristics)

Minimum arc horn gap (Required arc horn gap against switching surge)

Nominal voltage *V* [kV]	22	33	66	77	154	275	500	Notes
Highest allowable voltage *Um* [kV]	24	36	72	84	168	300	525	$V\times\frac{12}{11}$
Required switching surge withstand voltage [kV]	86	129	213	249	497	755	944	
Required gap L [mm]	170	250	430	510	1,090	1,770	2,400	From the graph of next page

Application of Arc Horn ; Horn Gap

Relationship between the horn gap and switching surge withstand voltage

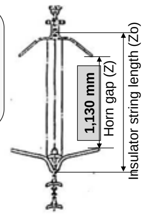


1-30

Application of Arc Horn ; Horn Gap

Required number of insulator for internal overvoltages and minimum gap between arc horn should be checked, and the number of insulator and arc horn gap are revised and used.

Z/Zo (Z: horn gap, Zo: insulator string length) should be adjusted as about 75 - 85 %



Standard number of insulators and arc horn gaps

Nominal voltage [kV]	22, 33	66, 77	154	275	500
Number of insulators	4	6	10	16	29
Insulator string length [mm]*	584	876	1,460	2,336	4,234
Horn gap [mm]	**450**	**650**	**1,130**	**1,970**	**3,200**
Z/Zo [%]	77.0	74.1	77.4	84.3	75.6

*Insulator string length [mm] = Height of 254mm Insulator (146 [mm]) × Number of insulators

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Summary

•The number of insulators is determined by internal overvoltages. In general, it is determined by switching surge.

• Arc horn is the important device in terms of insulation and corona.

•Practical arc horn gap and the number of insulators should be mutually adjusted.

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1. Design of Transmission Line and Substation

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1-3. Protection Design against Pollution

Outline

- **Basic philosophy of Japanese Utility**
- **Classification of Pollution Level**
- **The Number of Insulator determined by Pollution**
  - **Japanese Situation**
  - **Conforming to IEC**
- **Anti-Pollution Insulator**
- **Summary**

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Basic Philosophy of Japanese Utility

The number of insulators should be determined based on not only internal overvoltages and horn gap, but also required anti-pollution characteristics

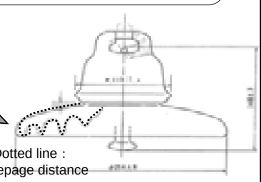
Basic concept of the management of pollution

・To increase creepage distance

・To implement insulator washing (up to 154 kV line)

It is necessary to control pollution properly by both of above.

Flashover voltage of the insulator relates to the length along the insulator porcelain surface, which is creepage distance.



1-35

Classification of Pollution Level ; Japanese Situation

In Japan, each power utilities set the pollution condition originally because climate conditions are peculiar to each area.

The way of applied distance **(taking concept of KANSAI as example)**

It should be applied in consideration of circumstances of each region
In general, the application is as follows:
○the Pacific side : Classification of the distance to the typhoon
○the Japan sea side : Classification of the distance to the seasonal wind

Classification of the pollution and the distance from the sea

Classification of pollution		No pollution	A	B	C	D	E
Estimated maximum salt deposit density [mg/cm²]		No pollution	0.063	0.125	0.25	0.5	1.0
Distance from the coast [km]	Against typhoon	More than 30	20-30	10-20	3-10	0-3	exposed to sea water directly
	Against seasonal wind	More than 20	10-20	3-10	1-3	0-1	

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The Number of Insulator determined by Pollution

Target Value of Withstand Voltage

Up to 154kV

Considering the maximum value of the normal phase-to-ground voltage

Target withstand voltage is set on the assumption that insulator washing is implemented.

(Temporary overvoltage on sound phase is not considered when single line-to-ground fault occurs)

$$Vm = \frac{1.15}{1.1} \times \frac{1}{\sqrt{3}} \times V$$

Vm : Target withstand voltage（kV）
V : Nominal voltage（kV）

275kV and above (Direct grounding system)

Considering temporary overvoltage on sound phase when ground fault occurs

(Meeting a demand for high reliability and considering difficulty of insulator washing during maintenance period)

$$Vm = \frac{1.15}{1.1} \times \frac{1}{\sqrt{3}} \times V \times k$$

Vm : Target withstand voltage （kV）
V : Nominal voltage（kV）
k : Increase ratio of sound phase voltage
（Area considered koniology: *1.3、
Area by salt protection design: *1.2）

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The Number of Insulator determined by Pollution

Required number of 250 mm suspension insulator (Criteria of KANSAI as example)

Classification of pollution		No pollution	A	B	C	D	E
Assumed highest salt density [mg/cm²]		No pollution	0.063	0.125	0.25	0.5	1.0
Distance from the sea coast [km]	Against typhoon	Over 30	20～30	10～20	3～10	0～3	exposed to sea water directly
	Against seasonal wind	Over 20	10～20	3～10	1～3	0～1	
154kV	Target withstand voltage [kV]	93.1*1					
	Designed withstand voltage [kV/Nos]	13.7	9.5	8.2	7.1	6.3	5.8
	Required number [Nos]	**7 (10)**	**10**	**12**	**14**	**15**	**17**
500kV	Target withstand voltage [kV]	394*2	364*3				
	Designed withstand voltage [kV/Nos]	13.7	9.5	8.2	7.1	6.3	5.8
	Required number [Nos]	**29**	**39**	**45**	**52**	**58**	**63**

（ ）is the number determined by the arc horn designing

***1** $154 \times \frac{1.15}{1.1} \times \frac{1}{\sqrt{3}} = 93.1$ ***2** $500 \times \frac{1.15}{1.1} \times \frac{1}{\sqrt{3}} \times 1.3 = 394$ ***3** $500 \times \frac{1.15}{1.1} \times \frac{1}{\sqrt{3}} \times 1.2 = 364$

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Classification of Pollution Level ; Conforming to IEC 60815

From IEC60815

Pollution level	Examples of typical environments
I – Light	■Areas without industries and with low density of houses equipped with heating plants ■Areas with low density of industries or houses but subjected to frequent winds and/or rainfall ■Agricultural areas / Mountainous areas All these areas shall be situated at least 10 km to 20 km from the sea and shall not be exposed to winds directly from the sea
II – Medium	■Areas with industries not producing particularly polluting smoke and/or with average density of houses equipped with heating plants ■Areas with high density of houses and/or industries but subjected to frequent winds and/or rainfall ■Areas exposed to wind from the sea but not too close to the coast (at least several kilometers distant)
III – Heavy	■Areas with high density of industries and suburbs of large cities with high density of heating plants producing pollution ■Areas close to the sea or in any case exposed to relatively strong winds
IV – Very heavy	■Areas generally of moderate extent, subjected to conductive dusts and to industrial smoke producing particularly thick conductive deposits ■Areas generally of moderate extent, very close to the coast and exposed to sea-spray or to very strong and polluting winds from the sea ■Desert areas, characterized by no rain for long periods, exposed to strong winds carrying sand and salt, and subjected to regular condensation

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The Number of Insulator ; Conforming to IEC 60815

Pollution characteristics for every pollution level of IEC 60815

Pollution level		Very Light*	I – Light	II – Medium	III – Heavy	IV – Very heavy
Minimum nominal specific creepage distance [mm/kV]		12 -	16	20	25	31
Salt Deposit Density [mg/cm²]		-	0.03 to 0.06	0.10 to 0.20	0.30 to 0.60	-
Distance from Sea Coast		-	10 to 20 km	Several km	Close to the sea	Very close the sea coast
Number of insulators** (250mm suspension)	150 kV	7 -	9	12	15	18
	500 kV	12 -	29	36	45	56

*In very lightly polluted areas, specific nominal creepage distance lower than 16 mm/kV can be used depending on service experience. 12mm/kV seems to be a lower limit

**[Number of insulators]
= [Minimum nominal specific creepage distance] x [highest phase-to-phase voltage] / [Creepage distance per insulator] (292mm)

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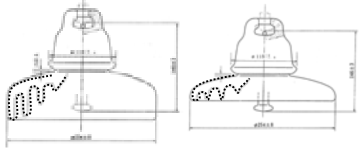
Anti-Pollution Insulator

1. Fog Type Insulator

High anti-pollution characteristics because creepage distance is longer than that of conventional suspension insulator

(fog type insulator) （suspension insulator）



Type of insulator	Ratio of Salt deposit density	Ratio of Withstand voltage
250 mm suspension	1.00	1.00
280 mm suspension	0.80	1.15
320 mm suspension	0.75	1.30
250 mm fog type	0.80	1.30
320 mm fog type	0.70	1.50

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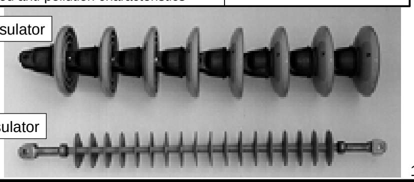
Anti-Pollution Insulator

2. Polymer Insulator
•Polymer insulator has already installed as practical use in Europe Continent or US.
•In Japan, some companies has installed, but other companies has carried out field examination.

Characteristics of polymer and porcelain insulators

Material	Advantage	Disadvantage
Porcelain	■Even if a piece of insulator breaks, it doesn't affect insulator string	■Not good anti-pollution characteristics than polymer ■Heavy weight
Polymer	■Light weight ■Good anti-pollution characteristics	■Possibility of brittle fracture of FRP core



Porcelain Insulator

Polymer Insulator

1-42

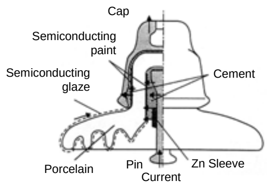
Anti-Pollution Insulator

3. Semiconducting Glazed Insulator

•The surface resistance is 10 – 20Mohm
(That of conventional insulator is 2,000Mohm and above.)

•Voltage distributed insulator string is almost uniform (does not concentrate as such a conventional insulator)

•Surface current of 0.5-1 A always flows, and it is not easy to generate partial arc because of heat generation effect



•Special attention shall be paid because accidents of insulator breakage installed at heavy polluted area (e.g. area exposed sea water directly) have been reported.

1-43

Summary

•Japanese power utilities have their own criteria against pollution in consideration of the climate situations in their area.

•Against pollution, their countermeasures are to increase the number of insulators and to wash the insulators.

•Anti-pollution insulators include; fog type insulator, polymer insulator and semiconducting glazed insulator.

1-44

1. Design of Transmission Line and Substation

1-45

1-4. Protection Design against Lightning Surge

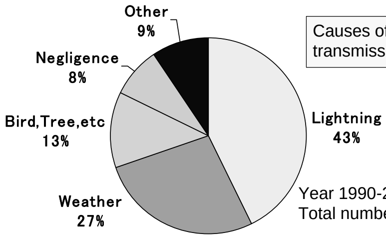
Outline

- **Trip Rate of Overhead Transmission Line in Japan**
- **(1) Reduction of shield angle**
- **(2) Multiple ground wire**
- **(3) Reduction of grounding resistance**
- **(4) Differential and high insulation**
- **(5) Lightning protection device**
- **Summary**

1-46

Trip Rate of Overhead Transmission Line in Japan

The major causes of electrical faults are due to lighting.



Causes of supply interruption on transmission lines

Year 1990-2000
Total number 4049 cases

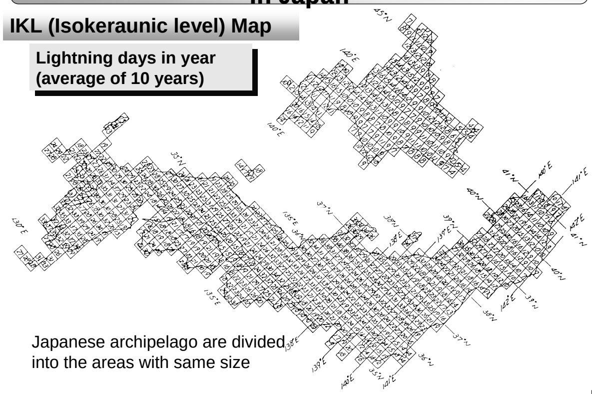
In Japan, high quality of electricity is required. Therefore, countermeasure to lightning problem is important issue for power utilities.

1-47

Trip Rate of Overhead Transmission Line in Japan

IKL (Isokeraunic level) Map

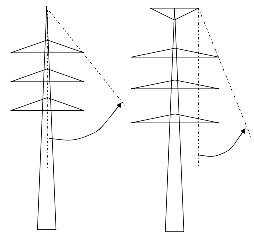
Lightning days in year (average of 10 years)



Japanese archipelago are divided into the areas with same size

1-48

(1) Reduction of Shield Angle



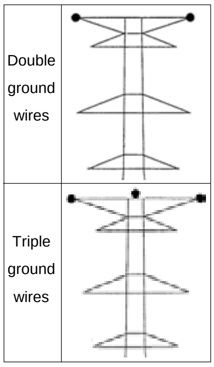
Example of Shield Angle

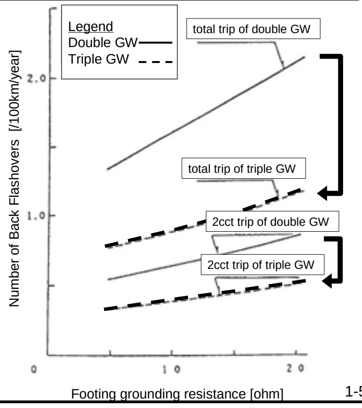
Voltage	Shield Angle
Up to 33kV	45 degree
77kV	35 degree
154kV	13 degree
275kV and above	0 degree

The number of direct lightning stroke on conductors is reduced by reduction of shield angle.

1-49

(2) Multiple Ground Wire



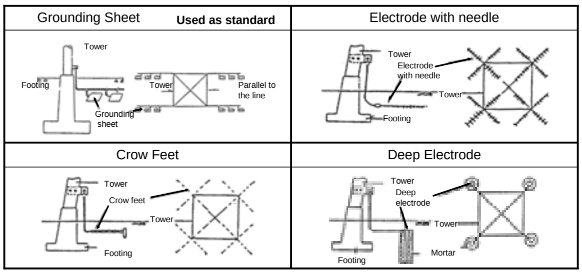


1-50

(3) Reduction of Grounding Resistance

In order to reduce the flashover fault, it is necessary to reduce the footing tower resistance

In Japanese regulation, tower grounding resistance is provided as up to 100 ohm

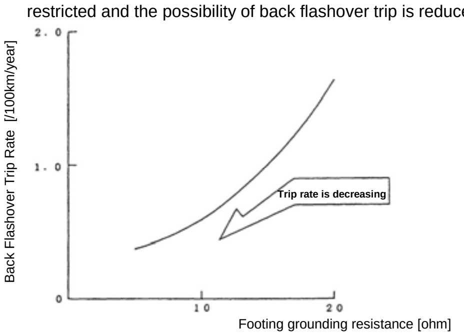


1-51

(3) Reduction of Grounding Resistance

Effect of the reduction of back flashover trip rate by the reduction of grounding resistance

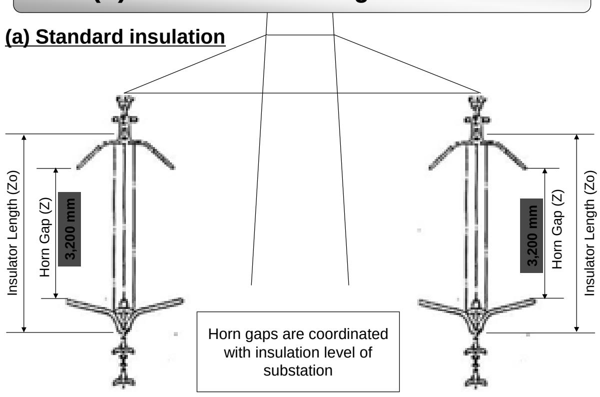
If grounding resistance is low, the rise tower voltage could be restricted and the possibility of back flashover trip is reduced.



1-52

(4) Differential and High Insulation

(a) Standard insulation

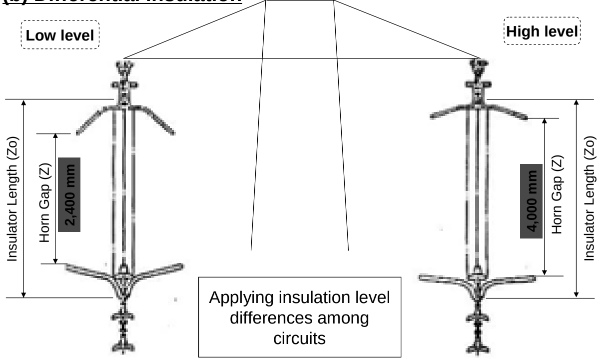


(in case of 500kV as example)

1-53

(4) Differential and High Insulation

(b) Differential insulation

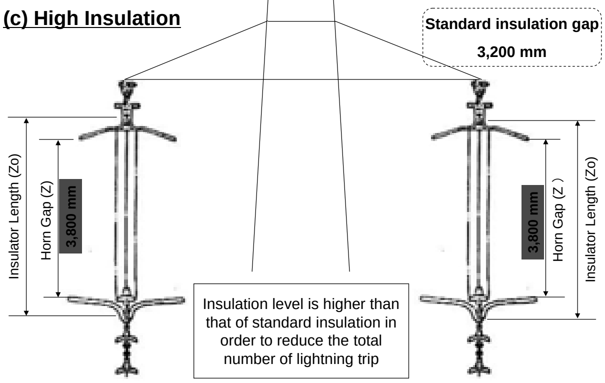


(in case of 500kV as example)

1-54

(4) Differential and High Insulation

(c) High Insulation

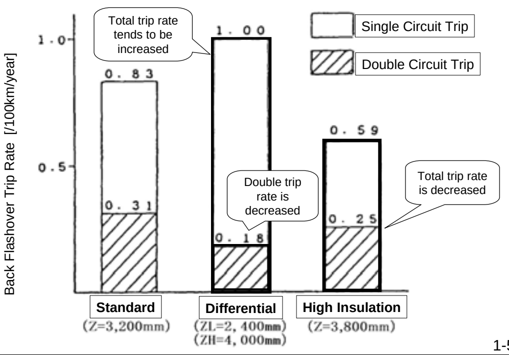


(in case of 500kV as example)

1-55

(4) Differential and High Insulation

Lightning trip rate (back flashover) in each insulation method



1-56

(5) Lightning Protection Device

Line arresters and Compact-type arresters

Line arresters (traditional type)

Applicable voltage : Up to 500kV

High performance but expensive

Compact-type arresters

Applicable voltage : Up to 275kV

Better cost-performance

1-57

(5) Lightning Protection Device

ACTIVE HORN (New type of lightning protection device)

Cutting-edge lightning protection device

・**Inexpensive (about 30% of compact-type arrester)**

・Easy-installation and easy-handling

1-58

Summary

- Countermeasures against lightning include;
  - Reduction of shield angle
  - Multiple ground wire
  - Reduction of grounding resistance
  - Differential and high insulation
  - Lightning protection device
- When we apply these methods to the line, we have to consider lightning rate, importance of line and cost etc, and decide the methods and the areas where they are applied.

1-59

1. Design of Transmission Line and Substation

1-60

1-5. Insulation coordination among substation and transmission line

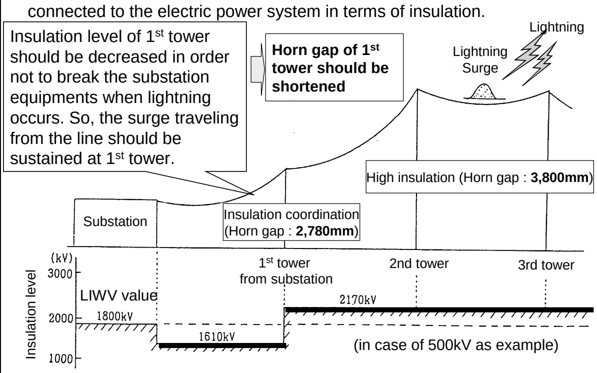
Outline

- **Insulation Coordination**
- **Summary**

1-61

Insulation Coordination

Transmission line should be designed in coordination with equipments connected to the electric power system in terms of insulation.



Summary

•In order not to break the substation equipment by lightning to the transmission line, the insulation level of 1st tower should be lower than that of substation equipment.

1-63

1. Design of Transmission Line and Substation

1-64

1-6. Insulation design in substations with surge arresters

Outline

(1) Overvoltage affecting substation

(2) Substation insulation design items

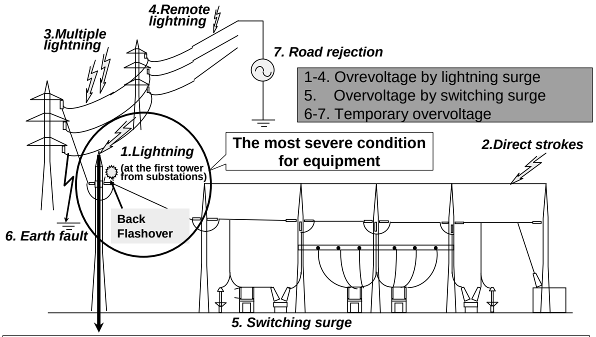
(3) Insulation design process

(4) Arresters layout

(5) Summary

1-65

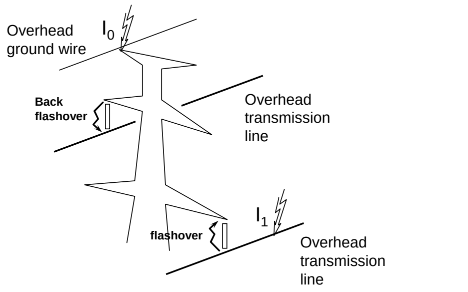
Overvoltage affecting substations



The factors of overvoltage affecting substations are shown in this figure.
The most severe condition for equipment is back flashover at the first tower from substations.

1-66

Lightning surge affecting substation



Since lightning current I_0 flows through the towers to the ground, tower voltage is increased and back flashover occurs between arcing horns.

1-67

Overvoltage by surge in power system

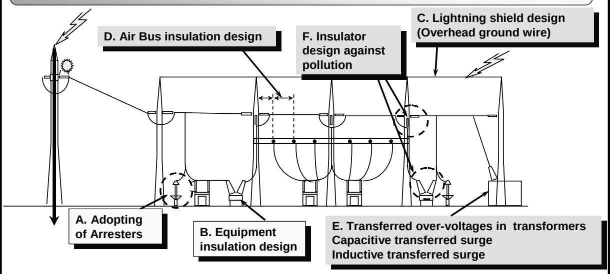
Classification	type	Occurring factor	aspect
Overvoltage by surge	Lightning overvoltage	Overvoltage by Direct strokes to the phase conductors or by back flashovers.	Duration of overvoltage is usually a few micro second. The severe case is back flashover at the first tower from substations.
	Circuit breaker switching overvoltage	Overvoltages due to CB switching operations	Duration of over-voltage is usually a few hundred micro second. When CBs are closed, overvoltage of CB switching operation is severe. However, overvoltage is suppressed because of closing resistance installed in CB.
	Disconnecter Switching overvoltage	Overvoltage due to Disconnector switching operations (with restrike)	Waveform of overvoltage is close to lightning surge rather than switching surge. Although analysed values are relatively large, they are still smaller than lightning overvoltage.

Insulation level (LIWV) of substation equipment is decided by lightning overvoltage level.

LIWV (Lightning impulse withstand voltage)

1-68

Substation insulation design items



[A,B] : After layout and the characteristics of the lightning arresters are determined [A], insulation design of equipment can be decided [B].

[C] : Overhead ground wire in substation is designed in order to avoid direct stroke.
[D] : Air insulation distance is decided by higher value of LIWV or SIWV.
[E] : Design of neutral arresters and secondary arresters in transformers are decided.
[F] : Insulator design against pollution is designed by overvoltage due to earth fault.

SIWV (Switching impulse withstand voltage) PFWV (Power frequency withstand voltage)

1-69

Insulation design process

Insulation design considering LIWV of equipment

- Consideration of substation equipment layout →
- 1. Arrester layout design and selection of arrester rated voltage and protection level
  2. Setting of LIWV targets of equipment →
- 1. EMTP Analysis: Calculation of LIWV overvoltage level
  2. Cost estimation: Total cost including the number of arresters and equipment with reduced LIWV should be considered.
- NG → back to arrester layout design; Good →
- 1. Decision of Arrester and layout design of all equipment
  2. Decision of LIWV of equipment

Decision of LIWV of equipment leads insulation design as below.

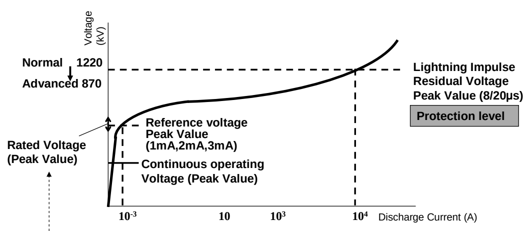
Insulation design of equipment, insulators and buses

LIWV, SIWV, PFWV →	Decision of withstand voltage of each equipment for factory tests
LIWV, SIWV →	Decision of insulation distance for air insulated buses
PFWV →	Decision of insulator design against pollution

1-70

Rated voltage and protection level of surge arresters

Residual voltage – discharge current curve of arresters



Arresters : Metal-oxide surge arresters without gaps

Rated voltage (route mean square)
= overvoltage multiple by earth fault x margin x (nominal voltage x 1.2 / 1.1) / $\sqrt{3}$

1-71

Rated voltage and protection level of surge arresters

Nominal Voltage	Rated Voltage	Protection level Normal Arrester residual voltage	 Advanced Arrester residual voltage
500kV	420kV	1220kV	870kV
275kV	266kV	851kV	600kV
154kV	196kV	627kV	533kV
77kV	98kV	314kV	267kV

Residual voltages are cut about 30% (500kV, 275kV)

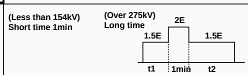
In general, construction cost is reduced from 2 to 3% due to reduction of insulation level of the equipment

1-72

Classification of insulation level of equipment

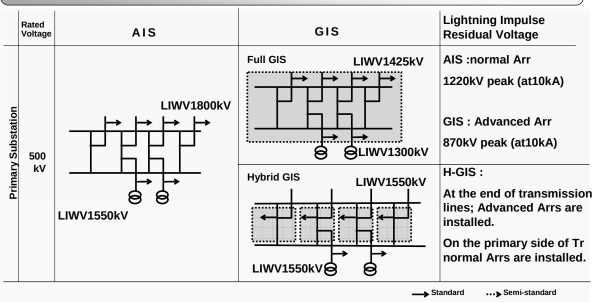
	Lightning impulse withstand voltage (LIWV) Advanced arrester	 Normal arrester	Power frequency withstand voltage (PFWV)
77kV		400kV	160kV
154kV		750kV	325kV
275kV	950kV	1050kV	250kV-330kV-250kV
500kV	1300kV 1425kV	1550kV 1800kV	475kV-635kV-475kV

If insulation level LIWV of equipment is decided, SIWV and PFWV of equipment are decided according to Japanese standard.



1-73

Layout of arresters

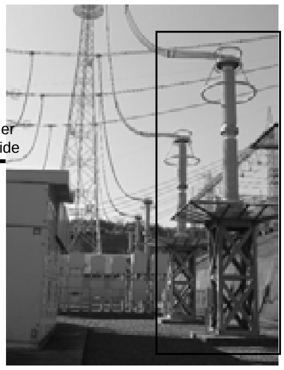


[AIS], [GIS] :
Arresters are installed at the end of transmission lines and the primary side of transformers because high reliability is required for 500kV substations.

1-74

500kV arresters installation experience

500kV transformer primary side



Installed 500kV arresters on the primary side of 500kV transformer [Insulator type arrester, Normal type]

1-75

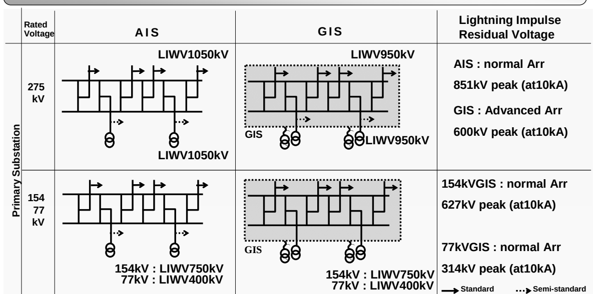
500kV arresters installation experience

500kV outgoing side

Installed 500kV arresters at the end of transmission line [Tank type arrester, Advanced type]

1-76

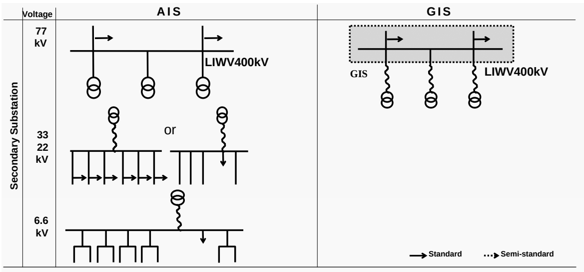
Layout of arresters



[AIS] : Arresters are installed at the end of transmission lines because circuit breakers on feeder must be protected from overvoltage. Arresters will be installed to the primary side of transformers if necessary as the result of EMTP analysis.
[GIS] : Arresters are only installed at the end of transmission lines, because buses of substations are compact.

1-77

Layout of arresters

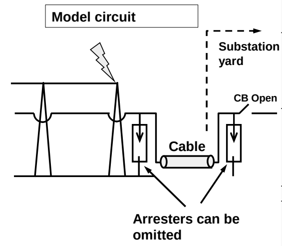


[AIS] : 77kV arresters are installed at the end of transmission lines because circuit breakers on feeder must be protected from overvoltage. Arresters less than 33kV are installed on buses in case that all outgoing lines are power cables.
[GIS] : Arresters are only installed at the end of transmission lines because buses are compact.

1-78

Arrester layout design for substations with power cable

Model circuit



If cable length is longer than the length in this table, arresters can be omitted.
With regard to OF cable, the length is shorter than that of CV cable.

Voltage [kV]	Cable type	Cable route	LIWV [kV]	Cable length [m]
66	CV-T 3×100mm²	duct	350	8000
	CV-T 3×250mm²			3700
	CV 1×600mm²			2500
	CV 1×2000mm²			1600
	OF 1×2000mm²			220
77	CVT 3×100mm²		350	6300
	CVT 3×250mm²			3000
	CV 1×600mm²			2000
	CV 1×2000mm²			950
	OF 1×2000mm²			160
110	CV 1×600mm²		550	6000
154	CV 1×600mm²		750	2300
	CV 1×2000mm²			1900
	CV 1×2000mm²	cave		2100
	OFAZV1×2000mm²	duct		550
187	CAZV 1×1400mm²			2700
	CAZV 1×2000mm²			2600
220	OFAZV1×1500mm²		900	850
275	CAZV 1× 600mm²	duct	1050	7050
	CAZV 1×2000mm²	cave		2400
	CAZV 1×2500mm²	duct		3800
500	CAZV 1×2500mm²		1425	3800

1-79

Summary

1. Insulation design of equipment
   - The most severe condition for equipment is back flashover at the first tower from substation.
   - Insulation level (LIWV) of substation equipment is decided by lightning overvoltage level.
   - If LIWV insulation level of equipment is decided, SIWV and PFWV of equipment is decided according to Japanese standard.
2. Layout of Arresters
   - Arresters more than 77kV are installed at the end of transmission lines.
   - 500kV arresters are installed on the primary side of transformers.
3. Construction cost
   - Total cost shall be calculated considering the number of arresters and equipment with reduced LIWV.

1-80