Substation Design

Quantum Power Group

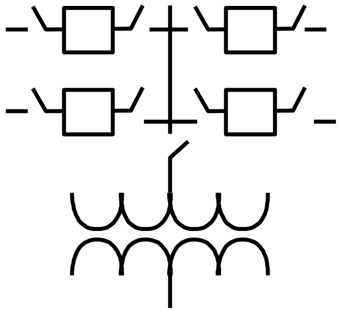
Bus Configurations and Arrangement

- Types of Bus Configurations
- Types of Substations Construction

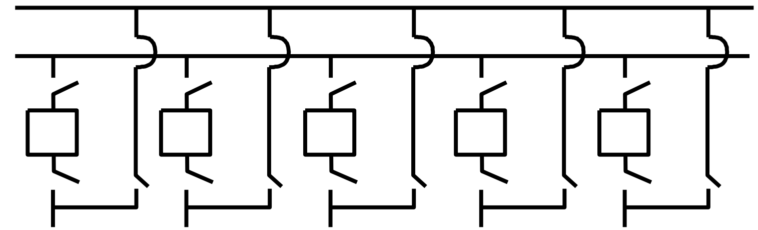
Typical Bus Configurations

- Radial Bus
- Sectionalized Radial Bus
- Main and Transfer
- Single Breaker Double Bus
- Ring Bus
- Breaker and One Half
- Double Breaker Double Bus

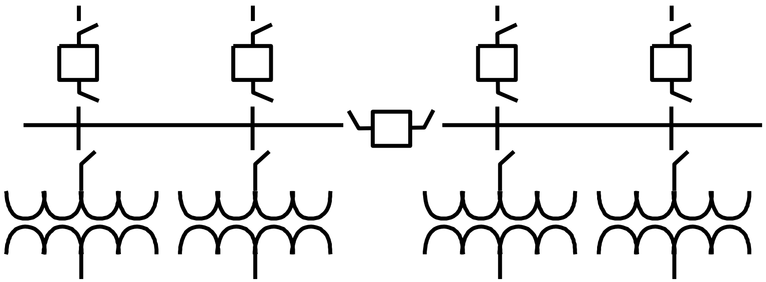
Typical Bus Configurations



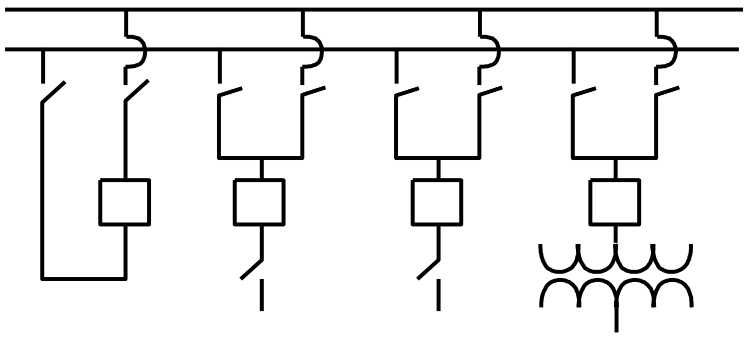
Typical Radial Bus



Typical Main and Transfer Bus

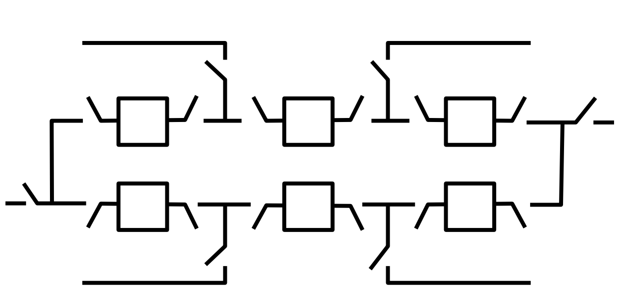


Typical Split Bus Radial

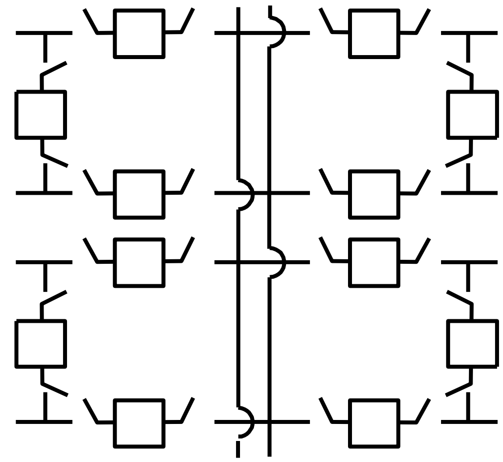


Typical Single Breaker, Double Bus

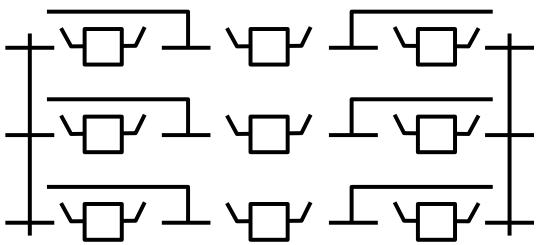
Typical Bus Configurations



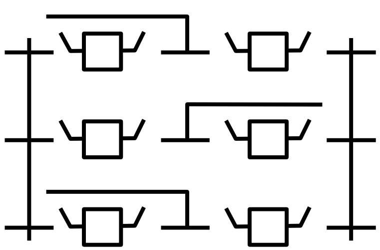
Typical Ring Bus



Typical Breaker & One Half
(Folded)



Typical Breaker & One Half
(Conventional)

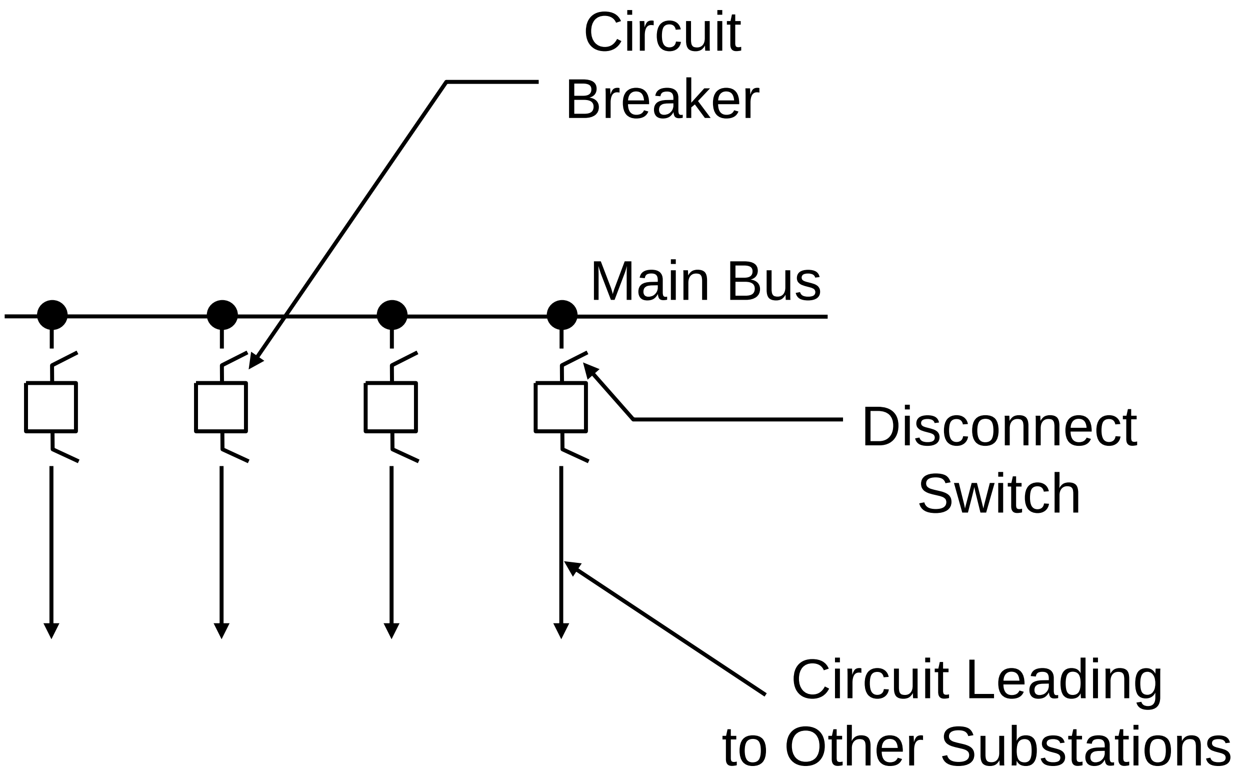


Typical Double Breaker, Double Bus

Criteria for Selection

- Reliability
- Maintainability
- Flexibility of Operation
- Cost

Radial Bus



Circuit
Breaker
Main Bus
Disconnect
Switch
Circuit Leading
to Other Substations

Radial Bus Substations

Advantages and Disadvantages

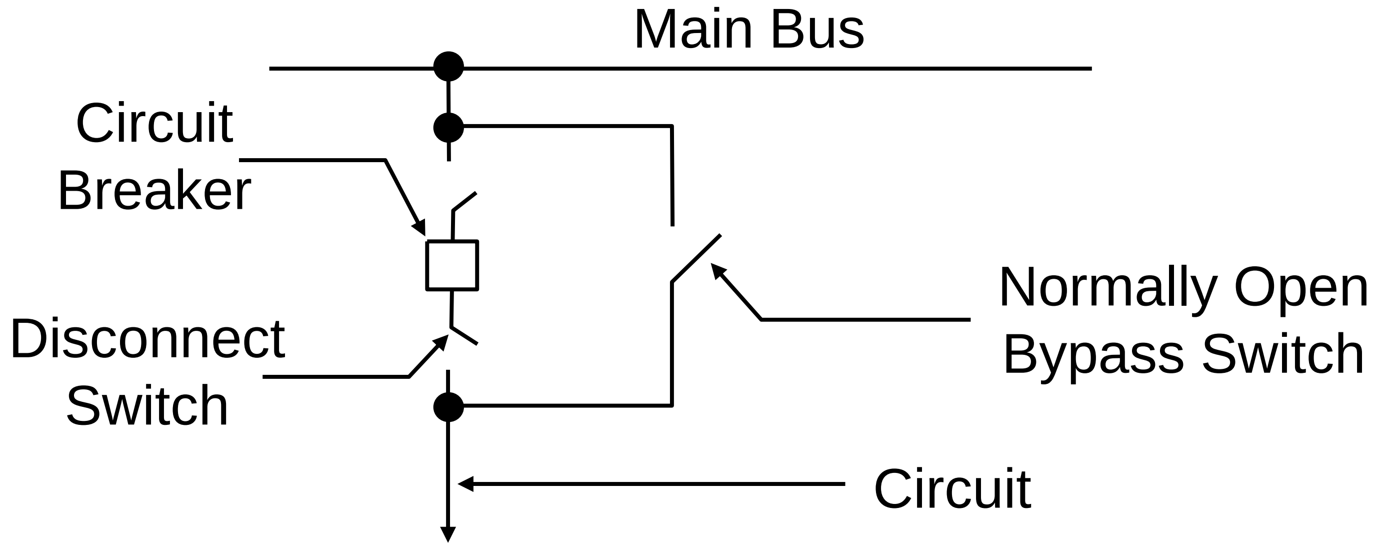
Advantages:

- Lowest Cost
- Small Land Area Required
- Easy to Expand
- Simple to Operate
- Simple Protective Relaying

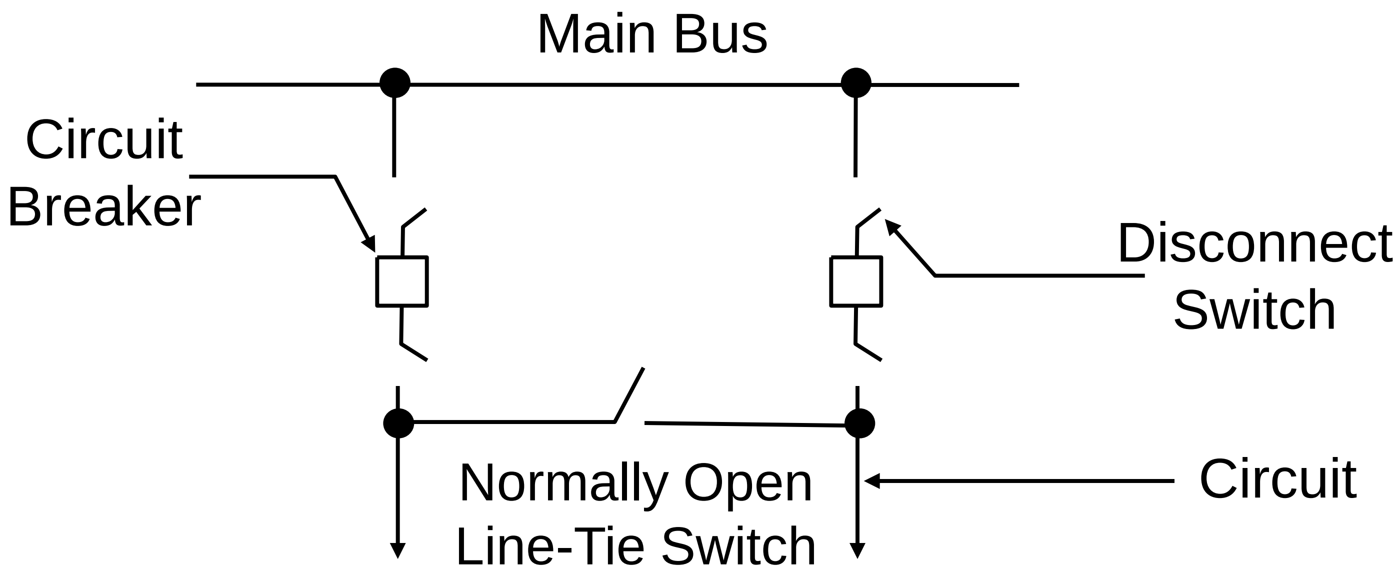
Disadvantages:

- Low Reliability
- Low Flexibility of Operation for Maintenance
- Bus Faults and Failure of a Breaker Requires the Substation be Removed from Service

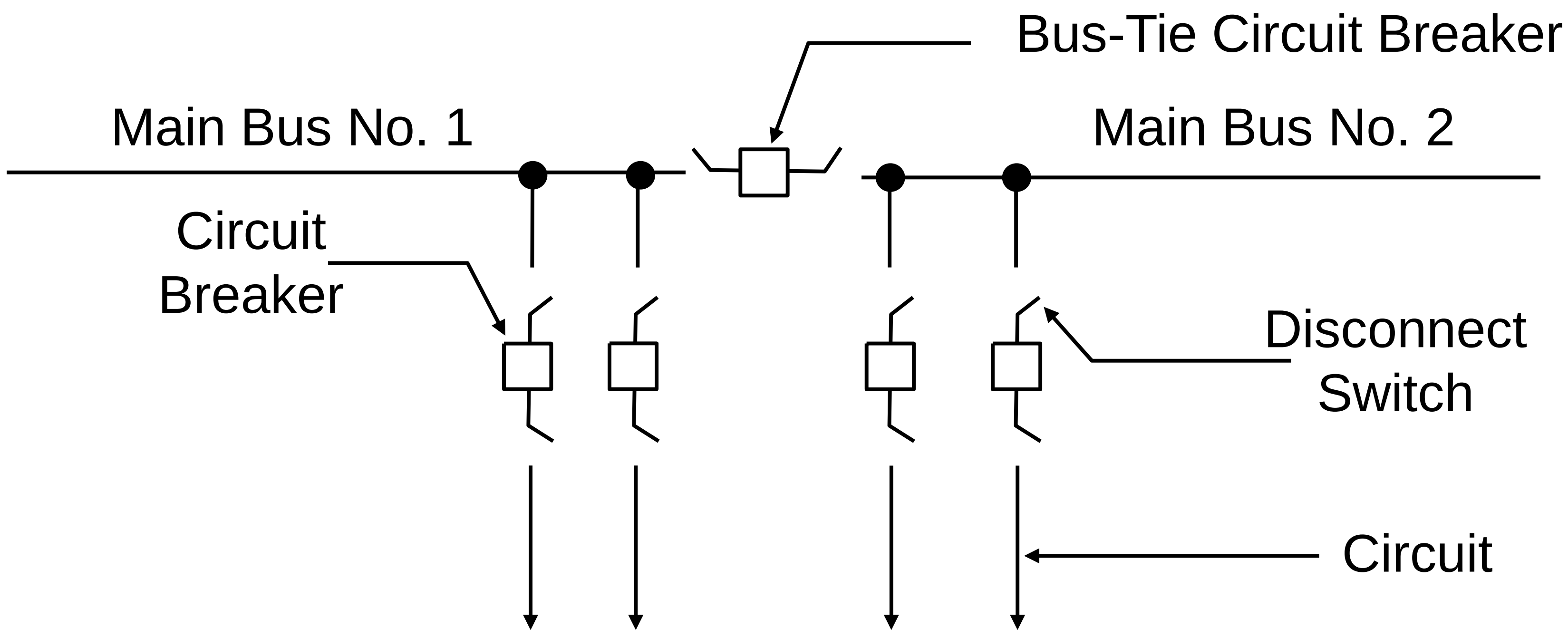
Breaker Bypass Switch



Line Tie Switch



Sectionalized Radial Bus



Sectionalized Radial Bus Substations

Advantages and Disadvantages

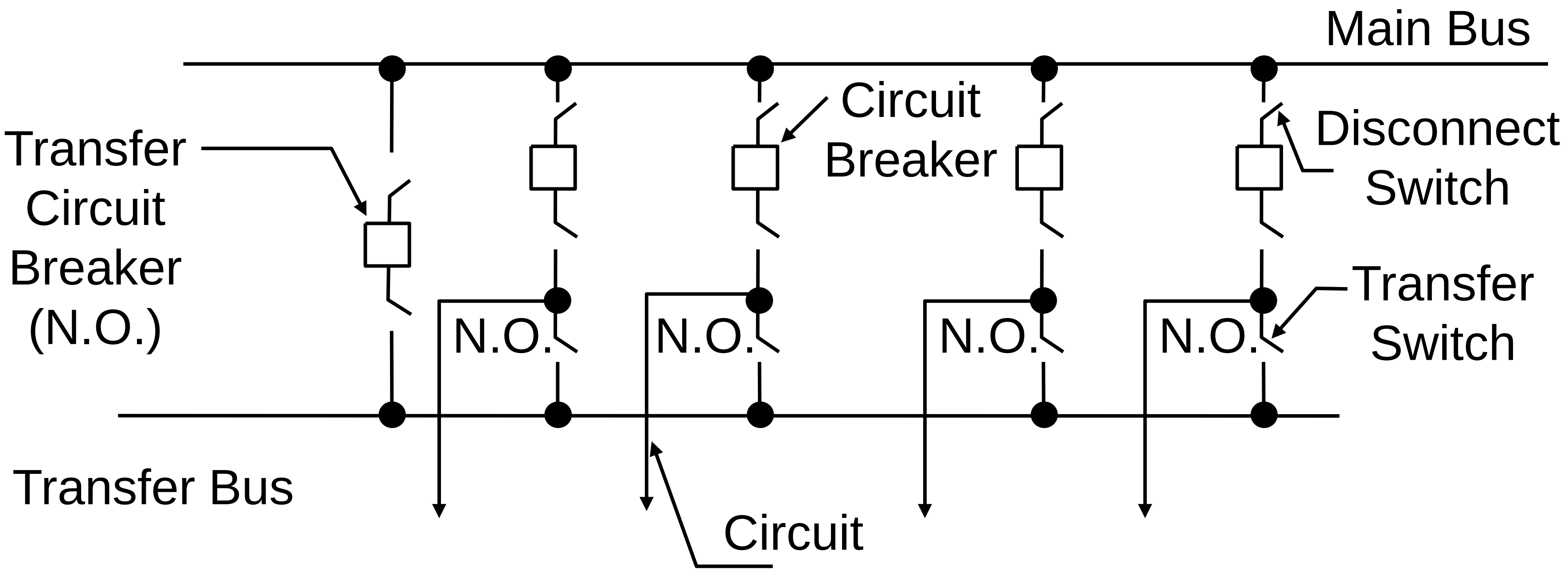
Advantages:

- Small Land Area Required
- Increased Reliability Over Radial Bus
- Increased Flexibility of Operation Over Radial Bus
- Easy to Expand

Disadvantages:

- Increased Cost Over Radial Bus
- Increased Complexity of Operation Over Radial Bus
- Increased Complexity of Protective Relaying Over Radial Bus

Main and Transfer Bus



Main and Transfer Bus Substations

Advantages and Disadvantages

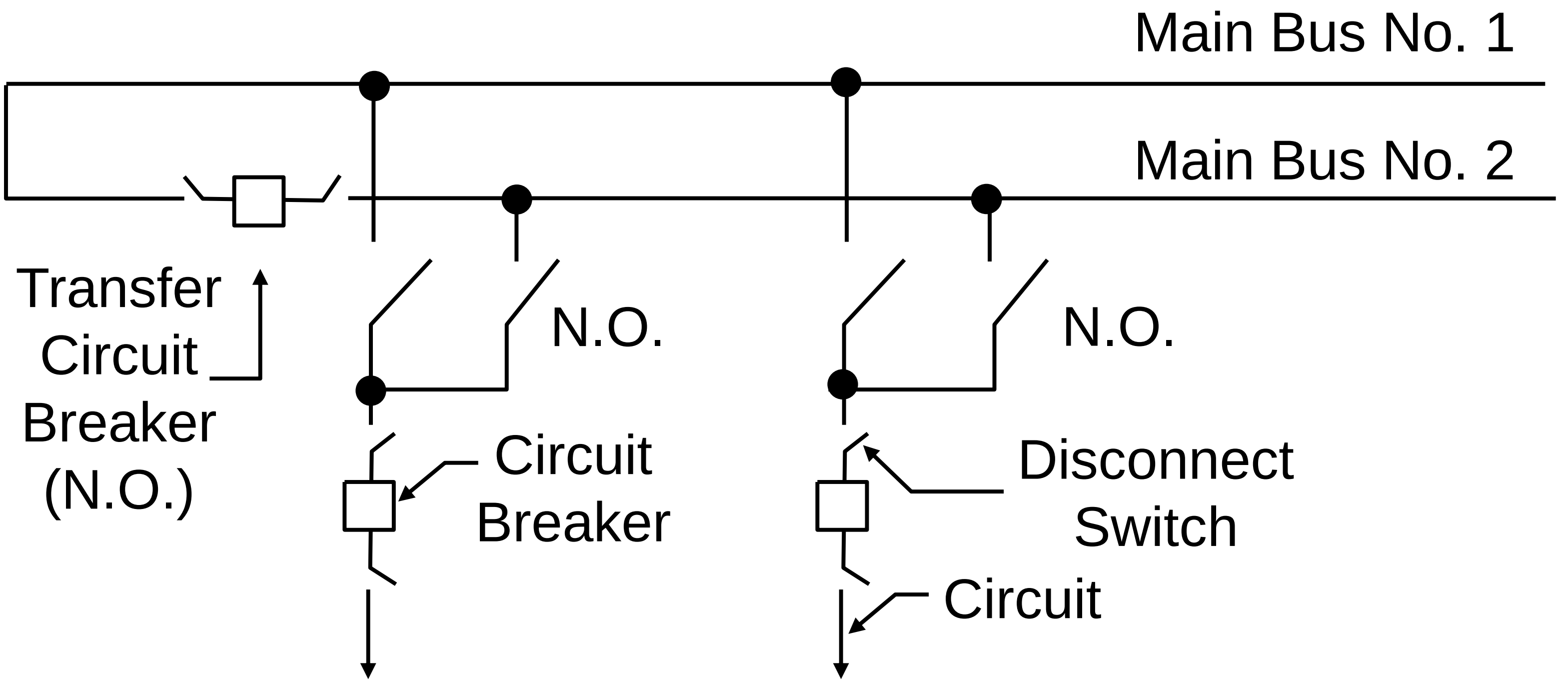
Advantages:

- Small Land Area Required
- Easy to Expand
- Increased Flexibility of Operation Over Radial Bus
- Any Breaker Can Be Removed from Service Without an Outage

Disadvantages:

- Increased Cost Over Radial Bus
- Increased Complexity of Operation Over Radial Bus
- Increased Complexity of Protective Relaying Over Radial Bus
- Low Reliability

Single Breaker Double Bus



Single Breaker Double Bus

Advantages and Disadvantages

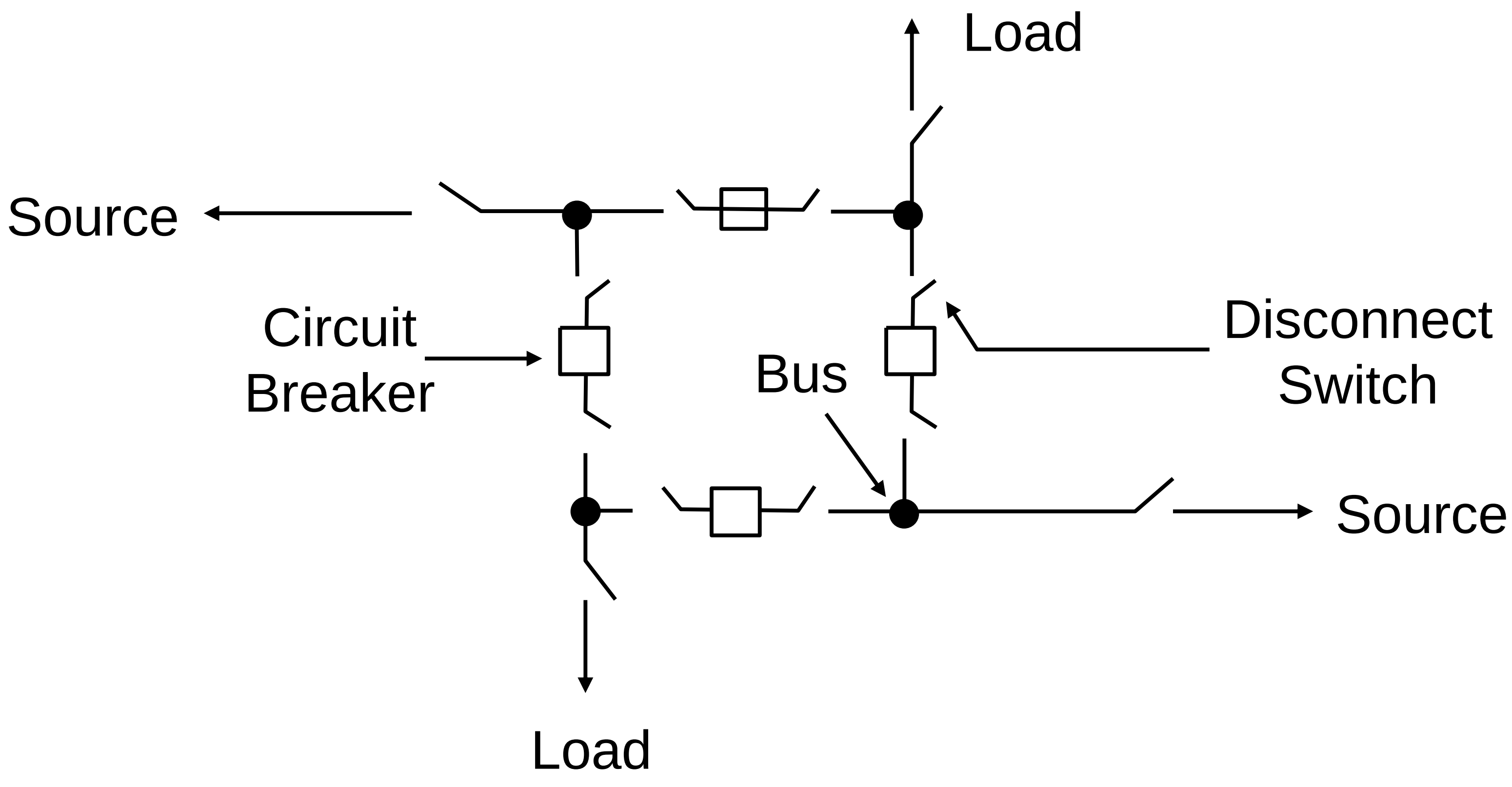
Advantages:

- Increased Reliability Over Radial Bus
- Increased Flexibility of Operation Over Radial Bus
- Easy to Expand

Disadvantages:

- Increased Cost Over Radial Bus
- Increased Complexity of Protective Relaying Over Radial Bus
- Switching of Current Transformer Secondary Circuits

Ring Bus (Four Position)



Ring Bus

Advantages and Disadvantages

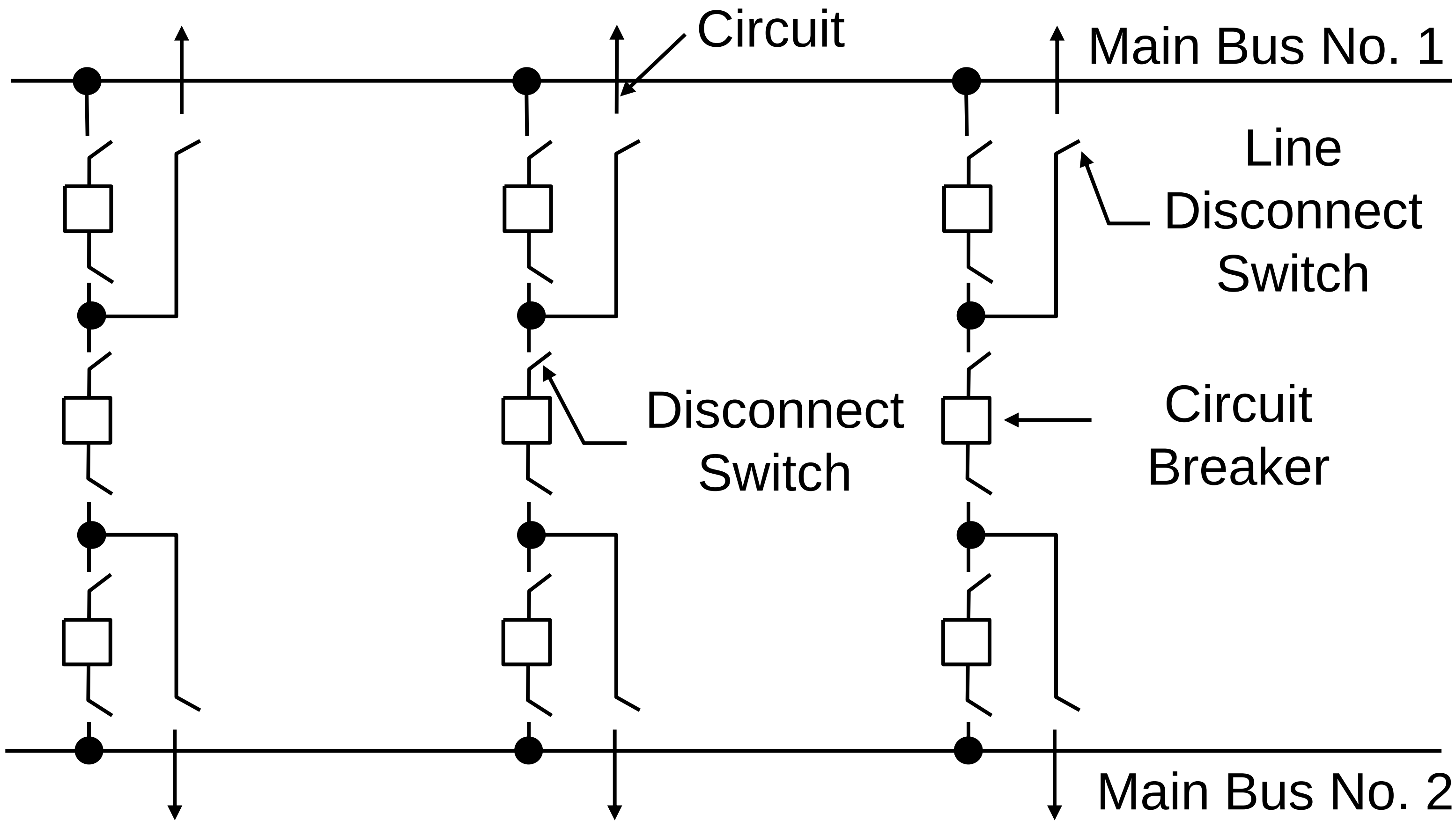
Advantages:

- High Reliability
- Flexibility of Operation
- Low Cost
- Any Breaker Can Be Removed from Service Without Outage
- Expandable to Breaker and One Half Configuration

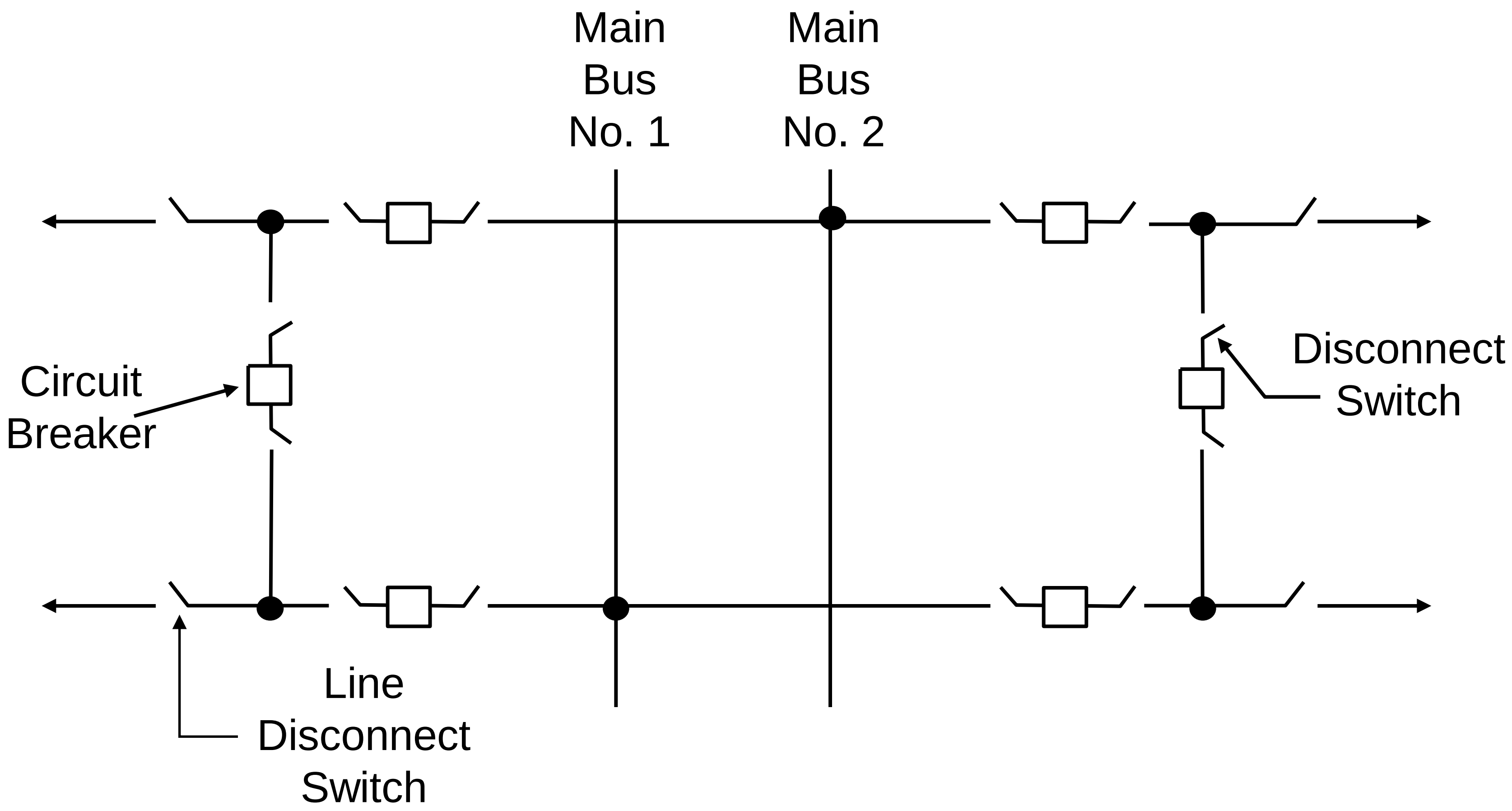
Disadvantages:

- Complex Protective Relaying and Control
- Failed Breaker During Fault Causes Outage of One Additional Circuit

Breaker and One Half



Inverted (Folded) Breaker and One Half



Breaker and One Half Substations

Advantages and Disadvantages

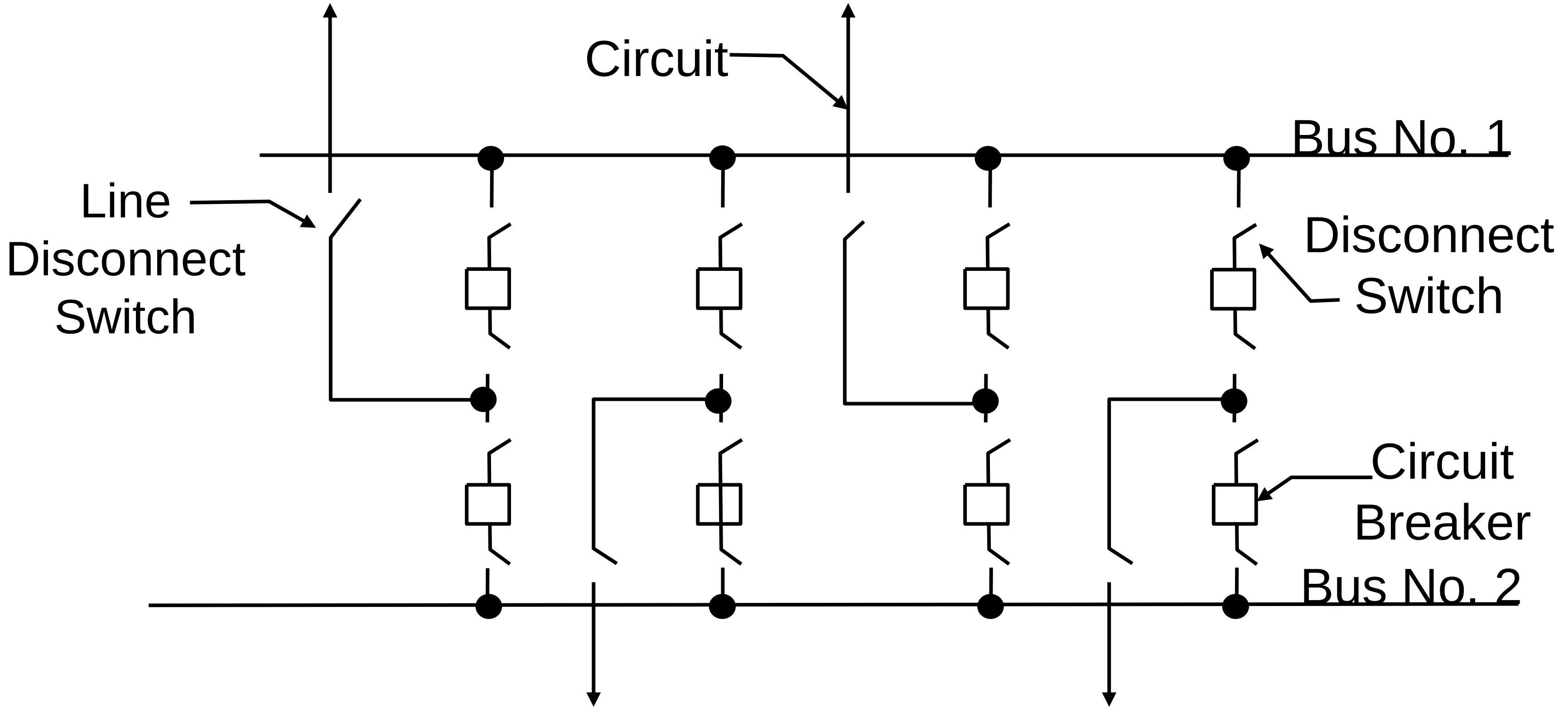
Advantages:

- Very High Reliability
- Very Flexible Operation
- Any Breaker Can Be Removed from Service Without an Outage
- Easy to Expand

Disadvantages:

- Large Land Area Required
- High Cost
- Complex Protective Relaying and Control

Double Breaker Double Bus



Double Breaker Double Bus Substations

Advantages and Disadvantages

Advantages:

- Very High Reliability
- Very Flexible Operation
- Any Breaker Can Be Removed from Service for Maintenance Without an Outage
- Easy to Expand

Disadvantages:

- High Cost
- Large Land Area Required
- Complex Protective Relaying and Control

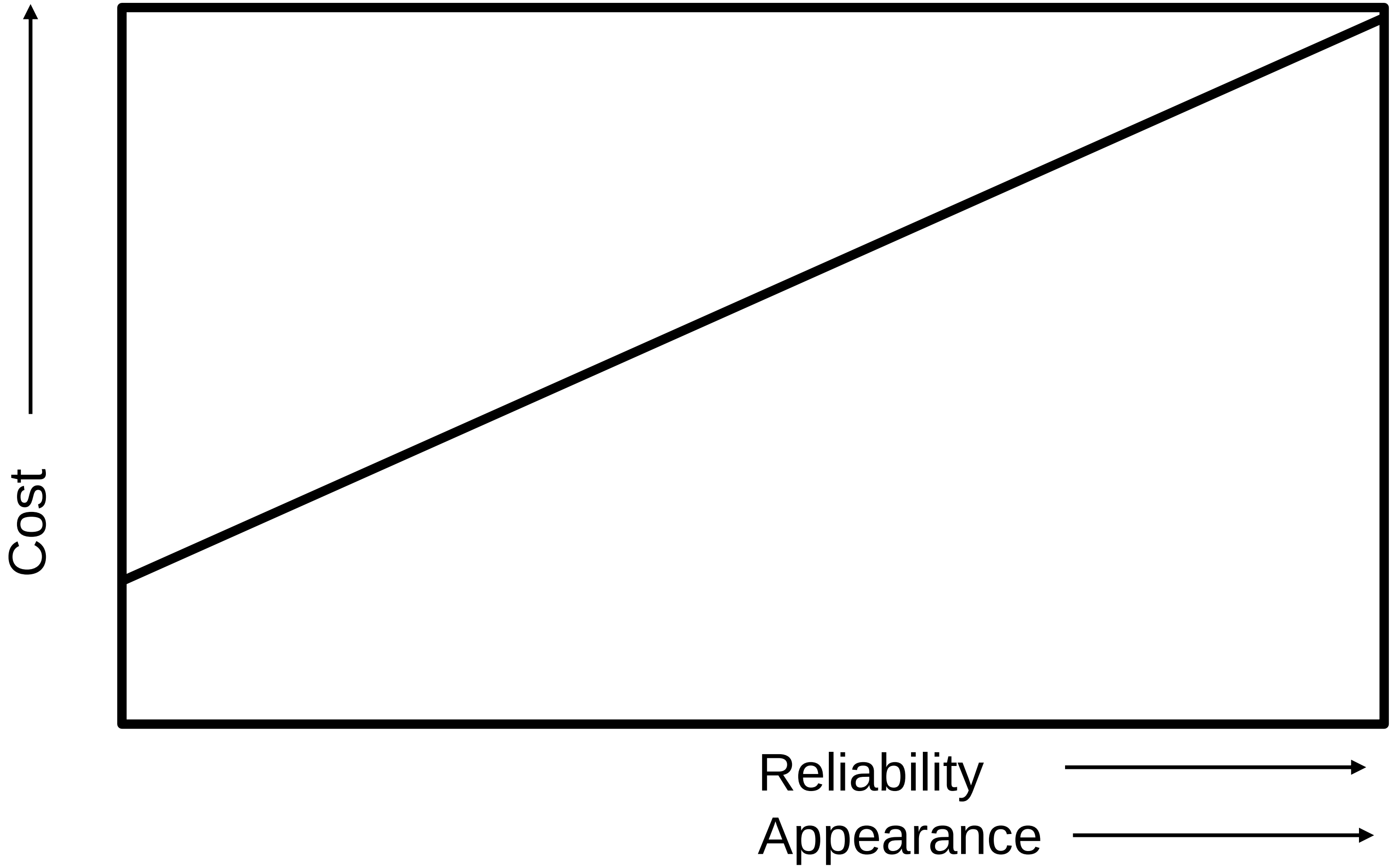
Comparison of Types of Bus Configuration

	Approximate per Unit Cost	Reliability
Radial	1.00	6
Sectionalized Radial	1.17	5
Main and Transfer	1.20	4
Single Breaker Double Bus	1.20	4
Ring Bus	1.25	3
Breaker and One Half		
Conventional	1.45	2
Folded	1.48	2
Double Breaker Double Bus	1.75	1

Types of Construction

- Box Structure
- Low Profile
  - Rigid Bus
  - Strain Bus
- Gas Insulated

Reliability and Appearance Versus Cost of Substation



Clearances – Spacing bus

Standardized USA AC Substation Voltages

Nominal kV-rms	Maximum kV-rms
13.8	15.5
23.5	25.8
34.5	38.0
46	48.3
69	72.5
115	121
138	145
161	169
230	242
345	362
500	550
765	800

Substation Insulation

- Self-Restoring (Bus Insulation)
  - Air
  - Porcelain
- Non-Self-Restoring (Equipment Insulation)
  - Mineral Oil
  - Polyethylene
  - Kraft/Oil Paper
  - SF_6 Gas

Insulators

- Post and Suspension
- Porcelain and Composites
- Specification
  - Creep (Leakage) Distance
  - Air Gap (Dry Arcing) Distance
  - 60 Hz Flashover (Dry and Wet)
  - Mechanical Strength
  - Impulse (BIL)

Definitions

- BIL - Basic Impulse Insulation Level
  - Conventional BIL
    - Certain No. of Test Waves - No Failure
    - Non-Self-Restoring Insulation Rated This Way
  - Statistical BIL
    - 90% Probability of Withstand When Tested
    - Applicable to Self-Restoring Insulation Only
- BSL - Basic Switching Impulse Insulation Level
  - Conventional BSL
  - Statistical BSL

External Insulation BIL (Lightning Impulse Withstand) Ratings for Maximum System Voltage

Rated Maximum Voltage (kV rms)	Rated Insulator Withstand Voltage, 1.2 x 50 μs Wave (kV Crest)
8.25	95
15.5	110
25.8	150
38.0	200
48.3	250
72.5	350
121	550
145	650
169	750
242	900
242	1,050

EHV Preferred BILs/BSLs

Maximum System Voltage V_m (rms) (kV)	Base for per Unit Values $V_m \frac{\sqrt{2}}{\sqrt{3}}$ (crest)	BSL (p.u.)	BSL (kV)		BIL (kV)
					825
362	296	2.53	750		900
		2.79	825	*	1,050
		3.04	900		1,175
		3.55	1,050		1,300
550	449	2.17	975		1,175
		2.34	1,050		1,300
		2.62	1,175	*	1,425
		2.90	1,300		1,550
		3.17	1,425		1,675
					1,800
800	653	1.99	1,300		1,675
		2.18	1,425		1,800
		2.37	1,500	*	1,925
		2.57	1,675		2,050
					2,175
					2,300
1,200	980	‡	‡		‡

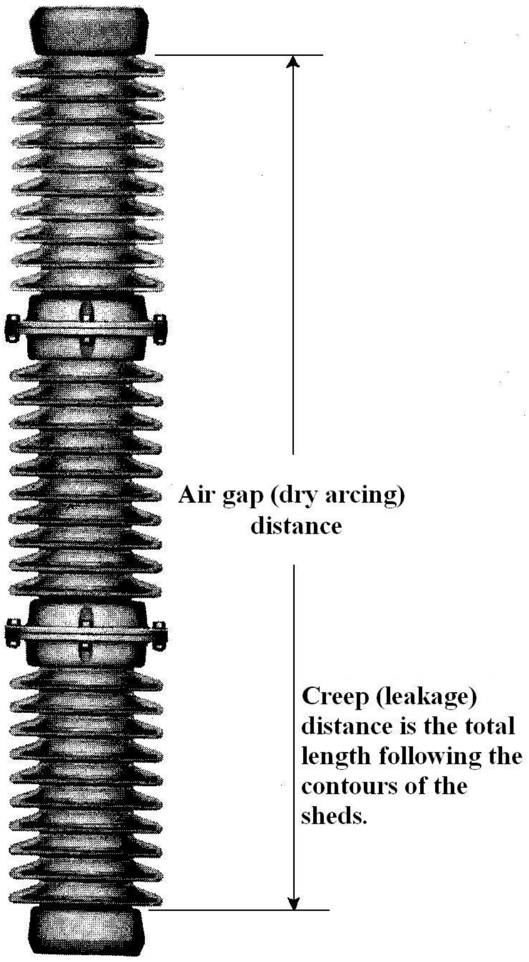
* Various Values of BIL and BSL May Be Used in Combination as Appropriate to Specific Apparatus or System Elements

‡ These Values Are Not Presently Specified

Altitude Correction Factors

Elevation		Correction
Feet	Meters	Factor
3,300	1,000	1.00
4,000	1,200	1.02
5,000	1,500	1.05
6,000	1,800	1.09
7,000	2,100	1.12
8,000	2,400	1.16
9,000	2,700	1.21
10,000	3,000	1.25
12,000	3,600	1.33
14,000	4,200	1.43
16,000	4,800	1.54
18,000	5,400	1.64
20,000	6,000	1.79

Insulator Definitions



Surface Leakage Current Increases With. . .

- Increased Voltage
- Degree and Type of Contamination
- Insulator Surface Characteristics
- Humidity

Suggested Leakage Distance for Contaminated Areas

Contamination Level	Equivalent Amount of NaCl mg/cm^2	Leakage Distance in./kV L - G
Very Light	0.0 - 0.03	About 1.0
Light	0.03 - 0.06	1.0 - 1.25
Moderate	0.06 - 0.1	1.5 - 1.75
Heavy	0.1 - 0.25	2.0 - 2.50

* From REA Bulletin 1724E-200

Minimum Quantity of Suspension Insulators

Nominal System Phase-to-Phase Voltage kV	BIL kV	Minimum Quantity of Suspension Insulators *
14.4	110	2
23	150	2
34.5	200	3
46	250	4
69	350	5
115	550	8
138	650	9
161	750	10
230	900	12
230	1,050	14

* For Standard 14.6 x 25.4 Centimeter (5-3/4 x 10 inch) Suspension Insulators

Substation Clearances

TABLE 1. MINIMUM ALLOWABLE SUBSTATION SPACINGS AND CLEARANCES

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
				Disconnecting Switches C_L to C_L Phase Spacing							
System Voltage kV	Maximum Rated Voltage kV	BIL kV	Minimum Metal-to-Metal Phase Spacing in.	Vertical and Double Side Break in.	Single Side Break in.	All Horn Gap in.	Ground Clearance Minimum in.	Ground Clearance Recommended in.	Minimum OH Cond Clearance To Grade ft	Minimum Clearance to Unguarded Parts Vertical ft-in.	Minimum Clearance to Unguarded Parts Horizontal ft-in.
14.4	15.5	110	12	24	30	36	7	10	9	9-0	3-6
23	25.8	150	15	30	36	48	10	14	10	9-3	3-9
34.5	38	200	18	36	48	60	13	18	10	9-6	4-0
46	48.3	250	21	48	60	72	17	22	10	9-10	4-4
69	72.5	350	31	60	72	84	25	30	11	10-5	4-11
115	121	550	53	84	108	120	42	45	12	11-7	6-1
138	145	650	63	96	132	144	50	54	13	12-2	6-8
161	169	750	72	108	156	168	58	62	14	12-10	7-4
230	242	900	89	132	192	192	71	80	15	14-10	9-4
230	242	1,050	105	156	216	216	83	92	16	--	--
345	362	1,050	105	156	216	216	84	92	18	15-6	10-0
345	362	1,300	119	174	--	240	104	106	18	17-2	11-8
500	550	1,550	--	--	--	--	124	128	--	18-10	13-4
500	550	1,800	--	--	--	--	144	152	--	20-6	15-0
765	800	2,050	--	--	--	--	166	182	--	22-5	16-11
1,100	1,200	--	--	--	--	--	--	--	--	--	--

Notes:

1. The values in Columns 2 through 7 for systems up to 345 kV are taken from ANSI C37.32, Table 5. The values in Columns 2 and 3 for systems above 345 kV are taken from ANSI C92.2.

2. The values in Columns 8 and 10 and the BIL for 800 kV maximum rated voltage (Column 3) are taken from NEMA SG6, Table 1. NEMA SG6 has been rescinded but these values are considered the best available.

3. The values in Columns 11 and 12 are taken from ANSI C2 (NESC), Table 124-1.

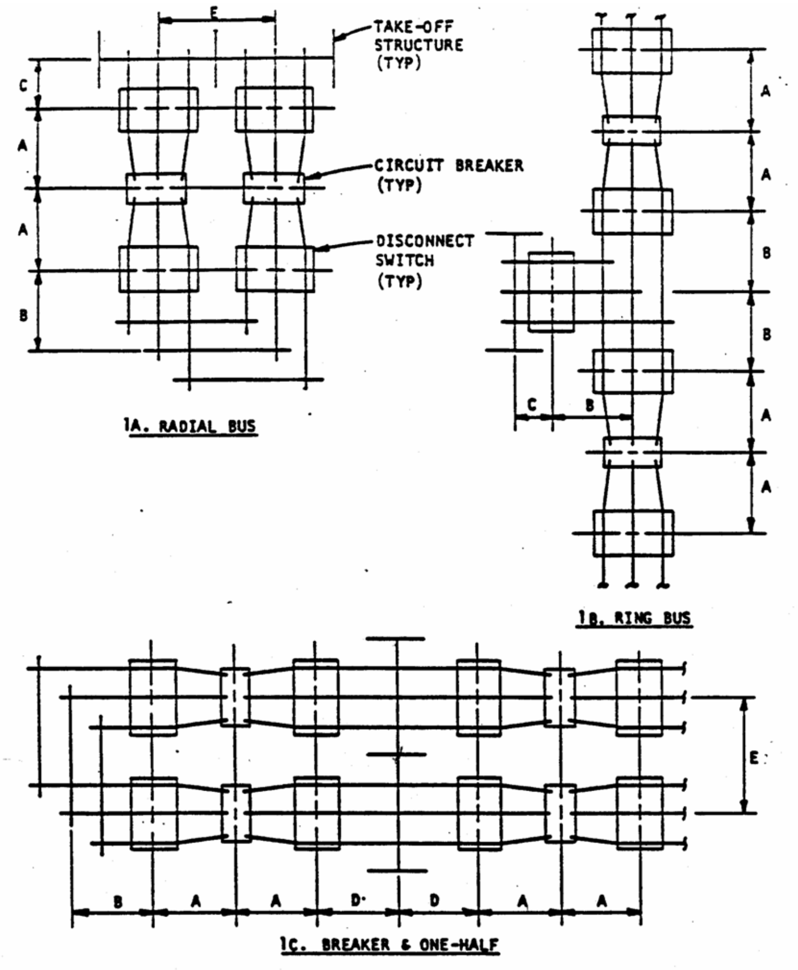
4. The values in Column 9 are the heights of station post insulators as given in NEMA Standard HV-1 and its proposed changes, and/or the Lapp Insulator Catalog.

Typical Substation Spacings

System Voltage kV	Rated Voltage kV	BIL kV	Bus Separation and Clearance: Horizontal ℄ to ℄ Phase Spacing ft	Height Above Grade: Low Bus ft	Height Above Grade: High Bus ft	Equipment and Structure Separation: A** ft	B** ft	C ft	D** ft	E ft
69	72.5	350	5	14	17.5	10	12	10	--	24
115	121	550	7	14	19	12	16	10	15	28
138	145	650	8	16	22	14	18	12	18	30
161	169	750	9	17	24	15	23	12	23	36
230	242	900	11	18	26	17	25	17	25	45
230	242	1,050	13	20	30	23	30	21	30	55
345	362	1,050	13	20	30	23	30	21	30	55
345	362	1,300	14.5	22	34	30	35	25	35	64
500	550	1,550	20	24	40	35	40	30	40	72
500	550	1,800	25	30	50	40	45	35	45	80
765	800	2,050	30	35	60	45	50	40	50	90

** Dimensions A, B, and D May Be Reduced if "Vee" Type Switches Are Used

Typical Substation Spacings



Larger Spacings Sometimes Required

- Short Circuit
- Equipment Projections
- Grounding Switches
- Switching Surge Requirements for EHV

Bus Design

Design Informational Sources

- REA Bulletin 65-1
- ANSI Std. C119.4
- IEEE Std. 605
- Aluminum Association, Aluminum Electrical Conductor Handbook, Third Edition, 1989

Advantages of Rigid Bus

- Smaller Phase Spacing
- Lower Profile
- Smaller Structures
- Better Appearance
- Higher Ampacity

Advantages of Strain Bus

- Smaller Footprint
- Minimizes Short Circuit Effect
- Well Suited for Long Spans

Conductor Materials - Rigid / Flexible

- Aluminum
- Copper

Copper Advantages

- 60% to 145% Higher Volume Conductivity
- Higher Modulus of Elasticity/Less Creep

Aluminum Advantages

- Higher Yield Strength
- Lower Weight
- Lower Cost

Rigid Bus Conductor Alloys

Allowable Stress

Alloy	Elastic Limit	Minimum Yield (F_A)	Modulus of Elasticity (E)	Conductivity (IACS)
	psi	psi	psi	Percent
Aluminum 6061-6	29,500	35,000*	10×10^6	43.0
Aluminum 6063-T6	20,500	25,000*	10×10^6	53.0
Aluminum 6101-T6	20,500	25,000*	10×10^6	55.0
Aluminum 6101-T61	11,000	15,000*	10×10^6	57.0
Copper No. 110 Hard Drawn	--	11,000**	16×10^6	98.0

*With 0.2 Percent Offset Per ASTM-8241
**With 0.5 Percent Offset Per ASTM-8188

Conductor Ampacity

- Conductor Material
- Climatic Conditions
- Conductor Temperature Rise
- Altitude

Aluminum Tubular Bus

6063-T6 Alloy

Size in.	OD in.	ID in.	Weight lb/ft	Ampacity Outdoor* Temp Rise Above 40 C 30 C	40 C	50 C	Indoor** Temp Rise Above 40 C 30 C	40 C	50 C
Schedule 40									
1/2	0.84	0.622	0.294	416	493	562	292	346	394
3/4	1.05	0.824	0.391	517	612	698	369	437	498
1	1.315	1.049	0.581	681	807	920	493	584	666
1-1/2	1.90	1.610	0.940	984	1,165	1,329	731	866	987
2	2.375	2.067	1.264	1,234	1,462	1,667	930	1,101	1,256
2-1/2	2.875	2.469	2.004	1,663	1,970	2,246	1,267	1,501	1,711
3	3.50	3.068	2.621	2,040	2,416	2,755	1,573	1,863	2,124
3-1/2	4.00	3.548	3.151	2,347	2,780	3,170	1,824	2,160	2,463
4	4.50	4.026	3.733	2,664	3,155	3,598	2,085	2,469	2,816
4-1/2	5.001	4.507	4.337	2,984	3,534	4,030	2,349	2,782	3,172
5	5.563	5.047	5.057	3,348	3,965	4,521	2,652	3,141	3,582
6	6.625	6.065	6.564	4,064	4,813	5,488	3,249	3,848	4,388
Schedule 80									
1/2	0.84	0.546	0.376	470	567	635	330	391	446
3/4	1.05	0.742	0.510	590	699	797	421	499	569
1	1.315	0.957	0.751	774	917	1,045	561	664	758
1-1/2	1.90	1.50	1.256	1,137	1,347	1,536	844	1,000	1,140
2	2.375	1.939	1.737	1,446	1,713	1,953	1,089	1,290	1,471
2-1/2	2.875	2.323	2.650	1,907	2,259	2,575	1,454	1,722	1,964
3	3.50	2.90	3.547	2,363	2,799	3,191	1,823	2,159	2,462
3-1/2	4.00	3.364	4.326	2,735	3,239	2,694	2,127	2,519	2,873
4	4.50	3.826	5.183	3,118	3,693	4,211	2,441	2,891	3,297
4-1/2	5.001	4.291	6.092	3,505	4,151	4,734	2,762	3,271	3,730
5	5.563	4.183	7.188	3,949	4,677	5,333	3,130	3,707	4,227
6	6.625	5.761	9.884	4,891	5,793	6,605	3,916	4,638	5,289

Frequency = 60 Hertz

*2 FPS Crosswind, Emissivity = 0.5
**Still, But Unconfined Air, Emissivity = 0.35

Copper Tubular Bus

Size	OD	ID	Weight	Ampacity					
				Outdoor*			Indoor**		
				Temp Rise Above 40 C			Temp Rise Above 40 C		
in.	in.	in.	lb/ft	30 C	40 C	50 C	30 C	40 C	50 C
Standard Pipe Sizes (SPS) --Schedule 40									
1/2	0.84	0.625	0.956	550	620	985	433	508	572
3/4	1.05	0.882	1.30	680	775	860	545	645	730
1	1.315	1.062	1.83	860	985	1,090	705	835	945
1-1/2	1.90	1.60	3.19	1,285	1,460	1,620	1,065	1,275	1,440
2	2.375	2.062	4.21	1,585	1,800	2,000	1,345	1,600	1,800
2-1/2	2.875	2.50	6.12	2,010	2,300	2,550	1,760	2,050	2,350
3	3.50	3.062	8.72	2,560	2,900	3,260	2,240	2,650	3,000
3-1/2	4.00	3.50	11.38	3,040	3,500	3,900	2,650	3,200	3,650
4	4.50	4.00	12.90	3,400	3,850	4.350	2,970	3,550	4,050
4-1/2	5.00	4.50	14.42	3,700	4,300	4,750	3,100	3,800	4,400
5	5.563	5.043	16.21	4,100	4,700	5,300	3,425	4,100	4,900
6	6.625	6.125	19.35	4,750	5,400	6,000	4,150	4,800	5,700
Extra Heavy Pipe Sizes (EXPS) - Schedule 80									
1/2	0.84	0542	1.25	620	710	785	490	585	660
3/4	1.05	0736	1.70	770	885	980	615	735	835
1	1.315	0951	2.50	1,010	1,150	1,270	818	980	1,105
1-1/2	1.90	1.494	4.18	1,460	1,670	1,850	1,210	1,440	1,650
2	2.375	1.933	5.78	1,850	2,100	2,350	1,560	1,850	2,100
2-1/2	2.875	1.315	8.82	2,390	2,750	3,050	2,050	2,450	2,800
3	3.50	2.892	11.79	3,000	3,400	3,750	2,580	3,050	3,500
3-1/2	4.00	3.358	14.34	3,410	3,900	4,300	2,980	3,550	4,050
4	4.50	3.818	17.22	3,880	4,400	4,900	3,400	4,050	4,650
4-1/2	5.00	4.25	21.05	4,300	4,860	5,410	3,600	4,290	4,810
5	5.563	4.813	23.62	4,700	5,340	5,910	4,000	4,760	5,460
6	6.625	5.751	32.83	5,400	6,120	6,800	4,800	5,710	6,550

Frequency = 60 Hertz

*2 FPS Crosswind, Emissivity = 0.5
**Still, But Unconfined Air, Emissivity = 0.5

Corona Free Conductor Sizes

Voltage kV	Cable	Tubing inches
15	No. 2AWG	1/2
34.5	No. 1/0 AWG	1/2
69	No. 1/0 AWG	1/2
115	No. 4/0 AWG	1/2
230	750 MCM	1-1/2
345	-	2
500	-	4

Rigid Bus Design

- Pinned Versus Fixed
- Slip, Rigid and Expansion
- Splicing
- Bending

Bus Thermal Expansion

Change in Length

$$\Delta L = \alpha L_i \; (T_i - T_f)$$

Where

ΔL = Change in Span Length, in.

α = Coefficient of Thermal Expansion, 1/°C

T_i = Initial Installation Temperature, °C

T_f = Final Temperature, °C

L_i = Span Length at the Initial Temperature, in.

Bus Expansion

- Temperature Range
  Low: -30 C (-20 F)
  High: 70 C (160 F)
- Aluminum Bus - 100-Foot Span
  L = 2-3/4 Inches

Bus Thermal Expansion

Force at Bus End

$$F_{TE} = AE \frac{\Delta L}{L_i} = AE \, \alpha \, (T_i - T_f)$$

Where

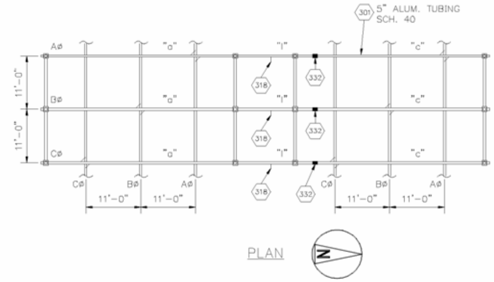
F_{TE} = Thermal Force, lb

A = Cross Sectional Area of the Conductor, sq. in.

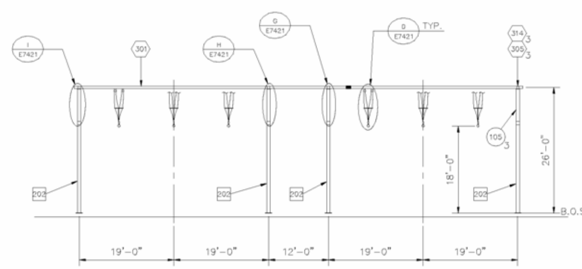
E = Modulus of Elasticity, lb/sq in.

Coefficient of Thermal Expansion

	Coefficient of Thermal Expansion α	
	in./in./°C	in./in./°F
Aluminum	2.30×10^{-5}	1.28×10^{-5}
Copper	1.69×10^{-5}	9.4×10^{-5}



PLAN



ELEVATION
SECTION 6
SEE DWG E7400
SCALE: 1"=10'-0"

NOTES:
1. SEE GENERAL NOTES ON DRAWING CPPA-E7400.

REFERENCE DRAWINGS:

CPPA-E7400 — 230KV SUNRISE SUBSTATION SITE ELECTRICAL PLAN

NO	DATE	REVISIONS AND RECORD OF ISSUE	DRN	DES	CHK	PDE	APP
2	07-01-2001	CONFORMED TO CONSTRUCTION RECORD	IWH	EPC	JTH	RWC	RWC
1	12-21-2000	ISSUED FOR CONSTRUCTION	IWH	EPC	JTH	RWC	RWC
0	10-02-2000	ISSUED FOR CEC REVIEW	IWH	EPC	JTH	RWC	RWC

1"=10'

BLACK & VEATCH CONSTRUCTION, INC.

ENGINEER EPC DRAWN IWH
CHECKED JTH DATE 11-24-1999

SUNRISE POWER CO.
SUNRISE POWER PROJECT
FELLOWS, CALIFORNIA

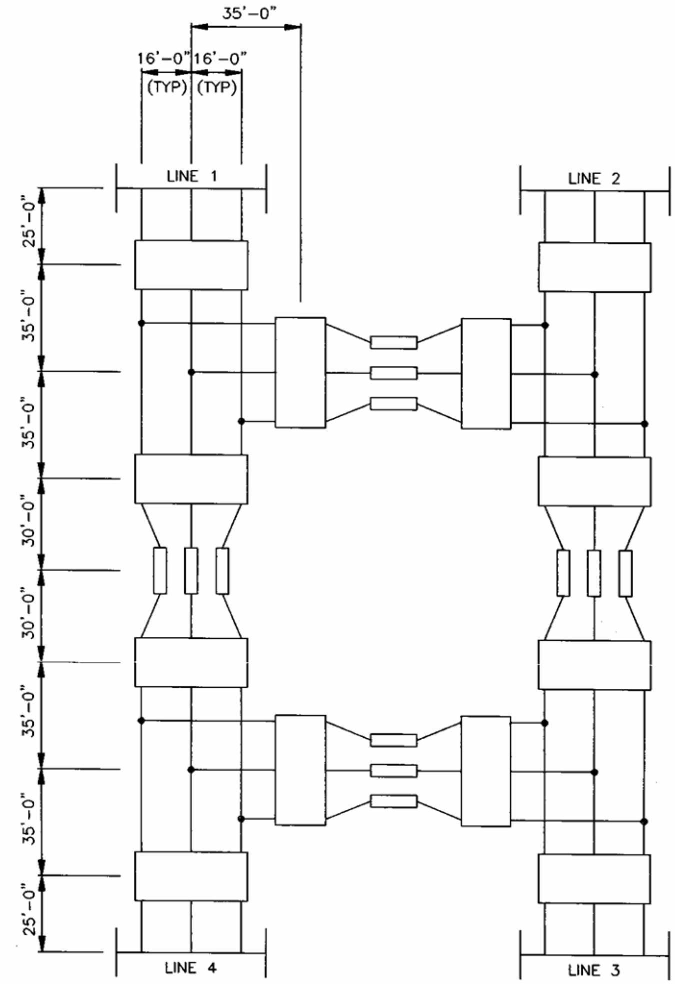
ELECTRICAL SECTION 6

PROJECT / DRAWING NUMBER: 99498-CPPA-E7413 REV 2

CODE
AREA

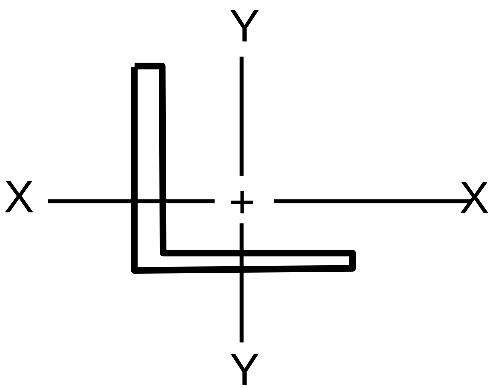
ACAD 15 1=1 D1
IWH AAAPL005 6/5/01

Rigid Bus Arrangement-Example

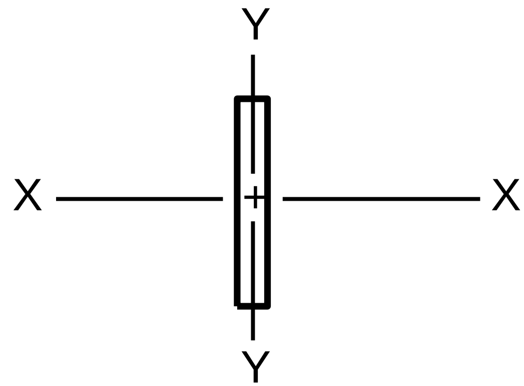


345 kV Ring Bus
1300 kV BIL
Continuous Bus Rating, 2000A

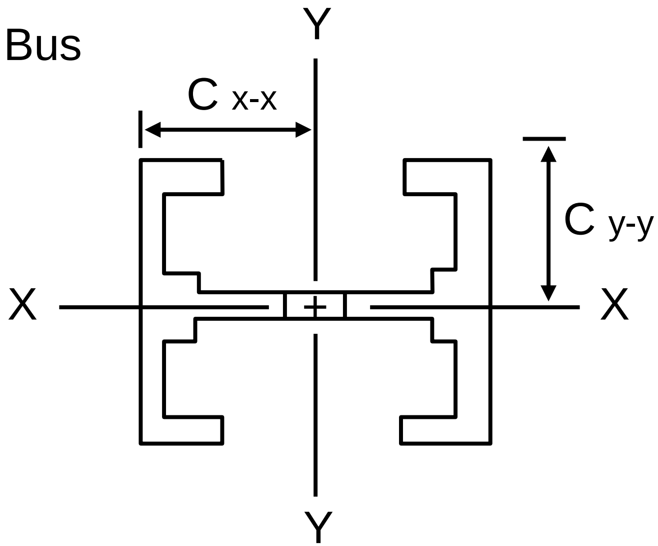
Rigid Bus Shapes



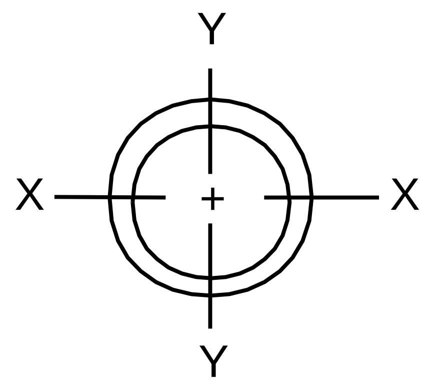
Angle Bus



Rectangular Bar

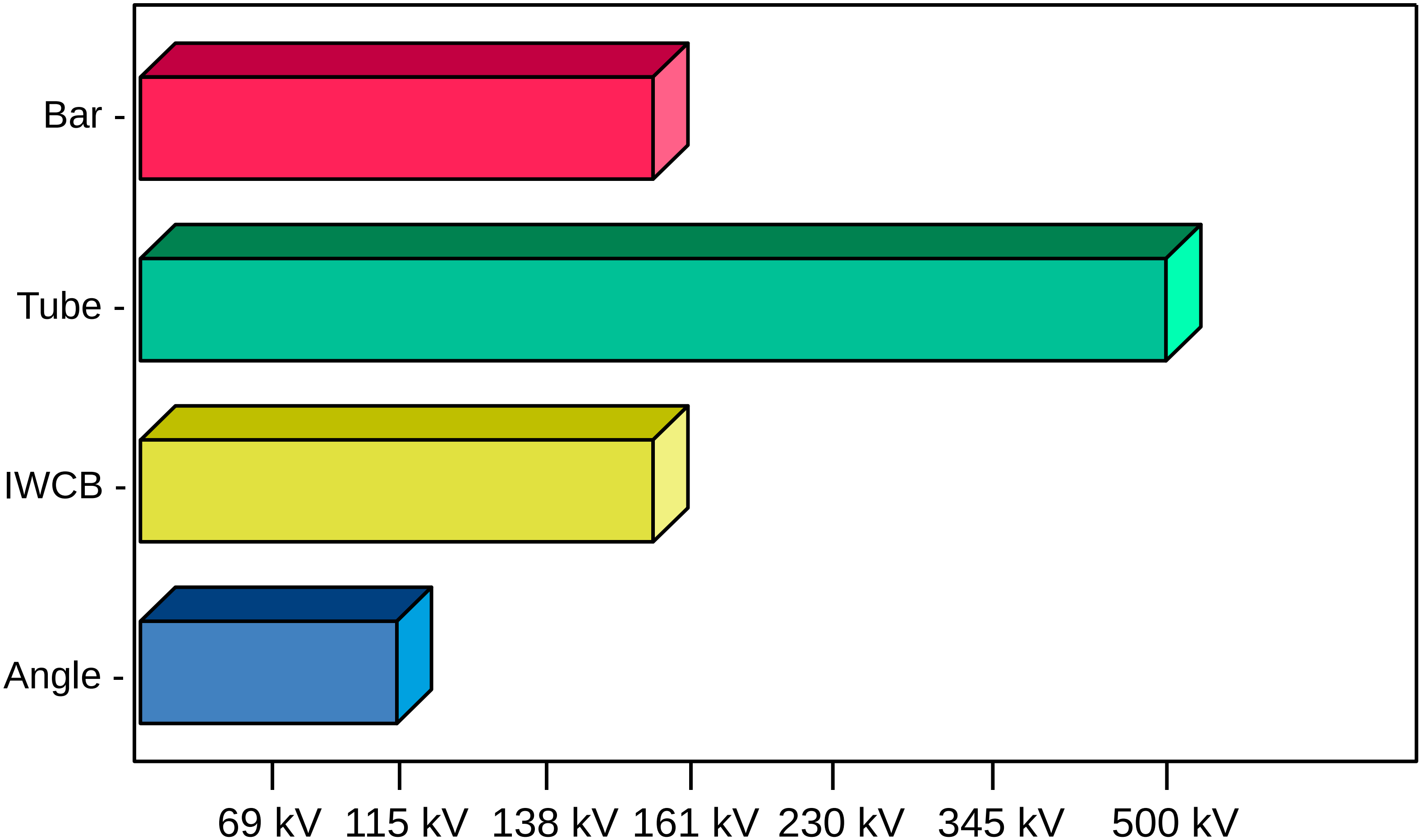


Aluminum Integral Web Channel Bus



Tubular Bus

Rigid Bus Usage



Rigid Bus Design Procedure

- Establish Criteria
- Select Material, Shape and Size
- Select Insulator
- Develop Load Cases
- Calculate Bus Forces
- Calculate Maximum Allowable Spans
  - Deflection
  - Fiber Stress
  - Insulator Strength
- Compare to Actual Switchyard Arrangement

Rigid Bus Design

Establish Criteria

- Voltage and BIL
- Three-Phase Fault Current
- Maximum Continuous Current
- Phase Spacing
- Site Conditions
  - Altitude
  - Wind
  - Ice
  - Seismic
  - Environmental Contamination
- Switchyard Layout

Rigid Bus Design

Select Bus Material, Shape and Size

- Aluminum or Copper
- Tube, Bar, IWCB or Angle
- Size Based on
  - Ampacity Required
  - Span Length
  - Voltage (Corona)
- Determine Need for Damping
  - Natural Frequency/Aeolian Vibration
  - Horizontal Spans Longer Than 15 Feet

Typical Rigid Bus Load Cases

- Case 1, Simultaneous Application of
  - Radial Ice
  - 50-Year Extreme Wind
  - Short Circuit
- Case 2, Simultaneous Application of
  - No Radial Ice
  - 100-Year Extreme Wind
  - Short Circuit
- Case 3 (Seismic), Simultaneous Application of
  - No Radial Ice
  - No Wind
  - Short Circuit
  - Seismic
- Calculate Bus and Insulator Forces for Each Load Case

Calculate Bus Forces (IEEE 605)

- Vertical
  - Per Unit Weights
  - Concentrated Loads
- Horizontal
  - Short Circuit
  - Wind
- Seismic

Calculate Maximum Allowable Spans

- Based on Vertical Deflection
- Based on Fiber Stress
- Based on Insulator Strength

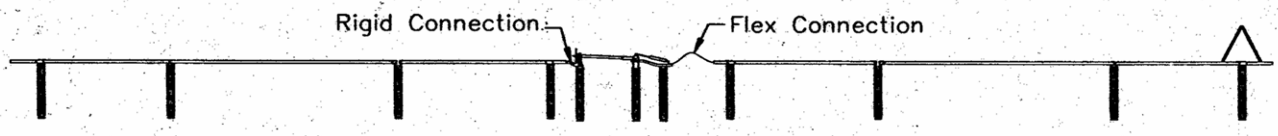
Effective Bus Span Lengths

Based on Insulator Cantilever Strength

- Bus Forces Transmitted to Insulator
- Forces on Insulator
- Insulator Mounting
- Insulator Overload Factors

BUS SPAN DESIGN
APPLICATION GUIDE

Max Fiber Stress:	$\frac{1}{8} \times \frac{wL_1^2}{S}$	$\frac{1}{8} \times \frac{wL_2^2}{S}$	$\frac{1}{8} \times \frac{wL_3^2}{S}$	$\frac{1}{8} \times \frac{wL_4^2}{S}$	$\frac{1}{8} \times \frac{wL_5^2}{S}$	$\frac{1}{8} \times \frac{wL_6^2}{S}$	(Note 1)
Max Deflection:	$\frac{1}{185} \times \frac{wL_1^4}{EI}$	$\frac{1}{185} \times \frac{wL_2^4}{EI}$	$\frac{1}{185} \times \frac{wL_3^4}{EI}$	$\frac{5}{384} \times \frac{wL_4^4}{EI}$	$\frac{1}{185} \times \frac{wL_5^4}{EI}$	$\frac{1}{185} \times \frac{wL_6^4}{EI}$	(Note 1)
Span Length:	L_1	L_2	L_3	L_4	L_5	L_6	



Bus Connection:	RG	SL	EX	RG	RG	EX	SL	RG
End Condition:	P	F	P	F	P	P	F	P/F (Note 1)
Support Reaction: (Effective Span)	$\frac{3}{8}L_1$	$\frac{5}{8}L_1 + \frac{5}{8}L_2$	$\frac{3}{8}L_2 + \frac{3}{8}L_3$	$\frac{5}{8}L_3$	$\frac{1}{2}L_4$	$\frac{1}{2}L_4 + \frac{3}{8}L_5$	$\frac{5}{8}L_5 + \frac{1}{2}L_6$	$\frac{1}{2}L_6$ (Note 1)

Legend:

w = Load in pounds per foot
L_i = Span length in feet
S = Section modulus of bus
E = Modulus of elasticity of bus section
I = Moment of inertia of bus section

RG = Rigid bus connection
SL = Slip bus connection
EX = Expansion bus connection

P = Pinned support condition
F = Fixed support condition

Notes:

1. The end condition for A-frames at the end of a bus section may behave as somewhere between a FIXED and a PINNED condition. Therefore, a conservative check would be to model as FIXED to determine the support reaction (as shown above), and PINNED to determine max deflection and max fiber stress (as shown above).

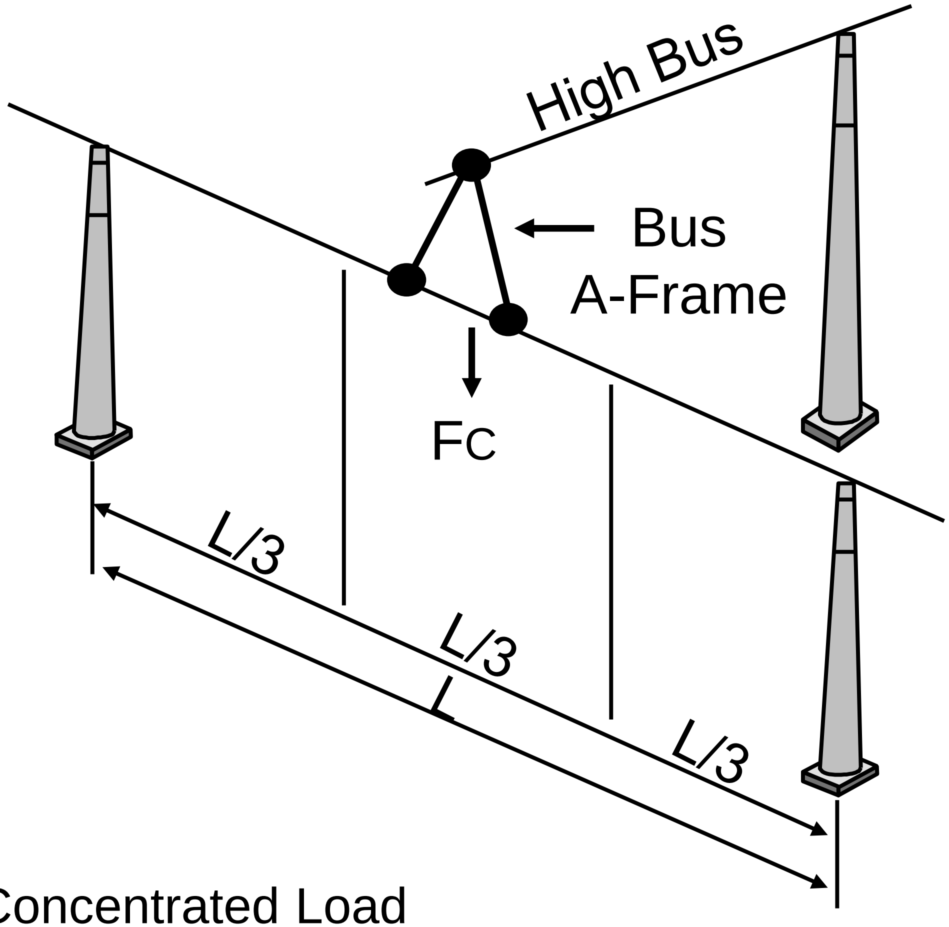
Compare Actual to Maximum Allowable Spans

- Increase Bus Size
- Shorten Span by Rearranging or Adding Bus Supports
- Change End Conditions by Relocating Expansion Fittings
- If Based on Fiber Stress, Increase Phase-to-Phase Spacing to Decrease Short Circuit Forces
- Change Bus Material, Alloy or Shape

Spans Containing Concentrated Loads

- Jumpers to CCVTs, PTs & LAs Can Be Ignored
- Analyzed for Vertical Deflection
- Simplified Methods Used

Concentrated Load



F_C = Concentrated Load
= 1/2 (High Bus Span Weight) + Bus A-Frame Weight

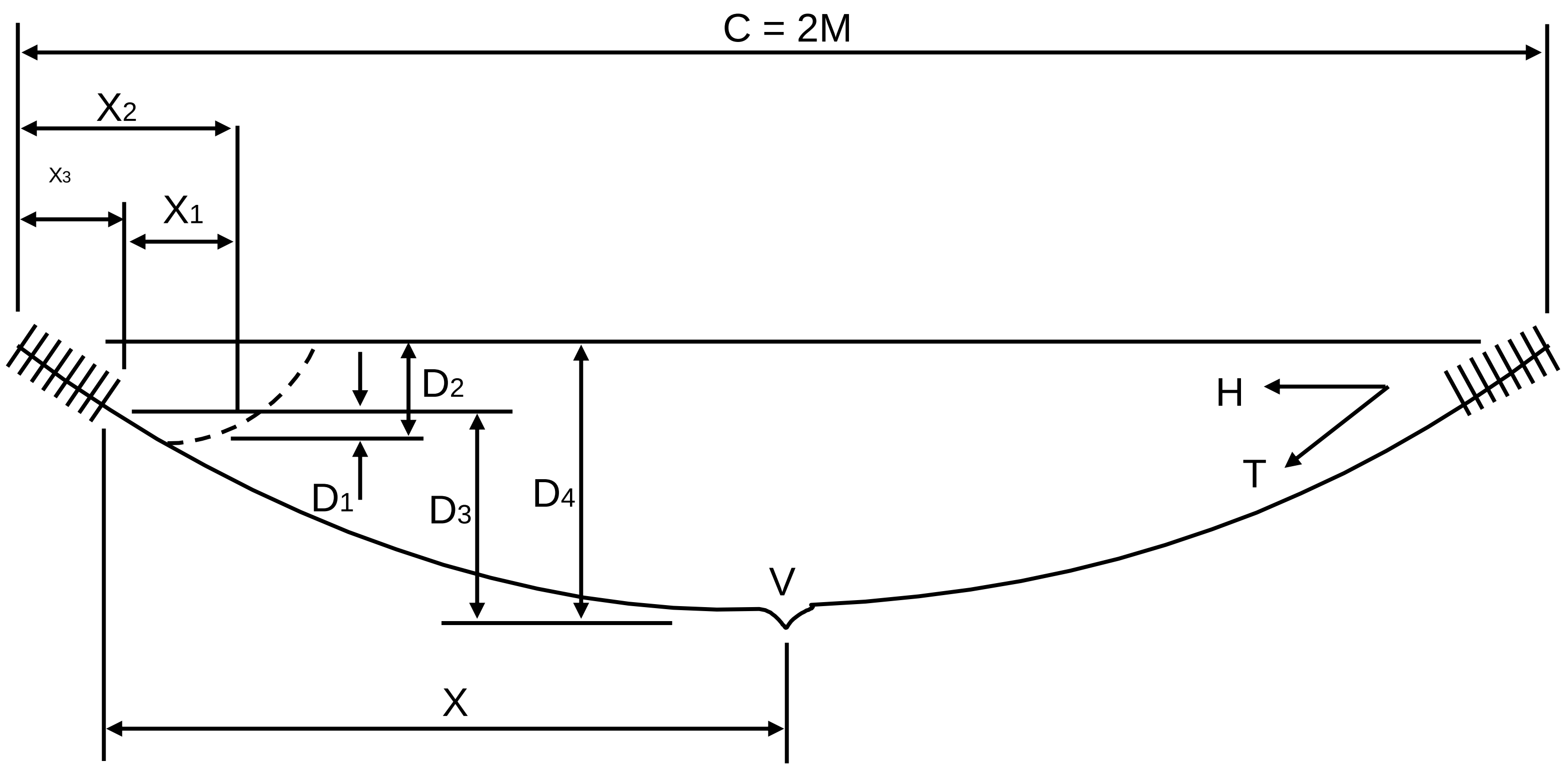
Strain Bus Design

Strain Bus Design

- Suspension Insulator Effect
- Span Length versus Sag
- Tap Loads

Strain Bus Design Procedure

- Select Conductor Material and Size
- Determine Spacings and Clearances
- Select Suspension Insulator Quantity
- Determine Bus Conductor Loading
- Calculate Conductor Sag
- Determine Insulator Effect on Conductor Sag
- Adjust Design as Required
- Prepare Stringing Sag/Tension Charts


C = 2M
X2
X3
X1
D2
D4
D1
D3
H
T
V
X

Observations

- Tensions of Some Conditions Increase, Which the Structure Must Support
- Sags of Some Conditions Increase, Which Must be Examined for Electrical Clearance Requirements

Substation Connectors

Connector Materials

- Aluminum
- Copper
- Bronze

Types of Connectors

- Welded
  - Weldments
  - Exothermic
- Compression
- Bolted

Types of Connectors

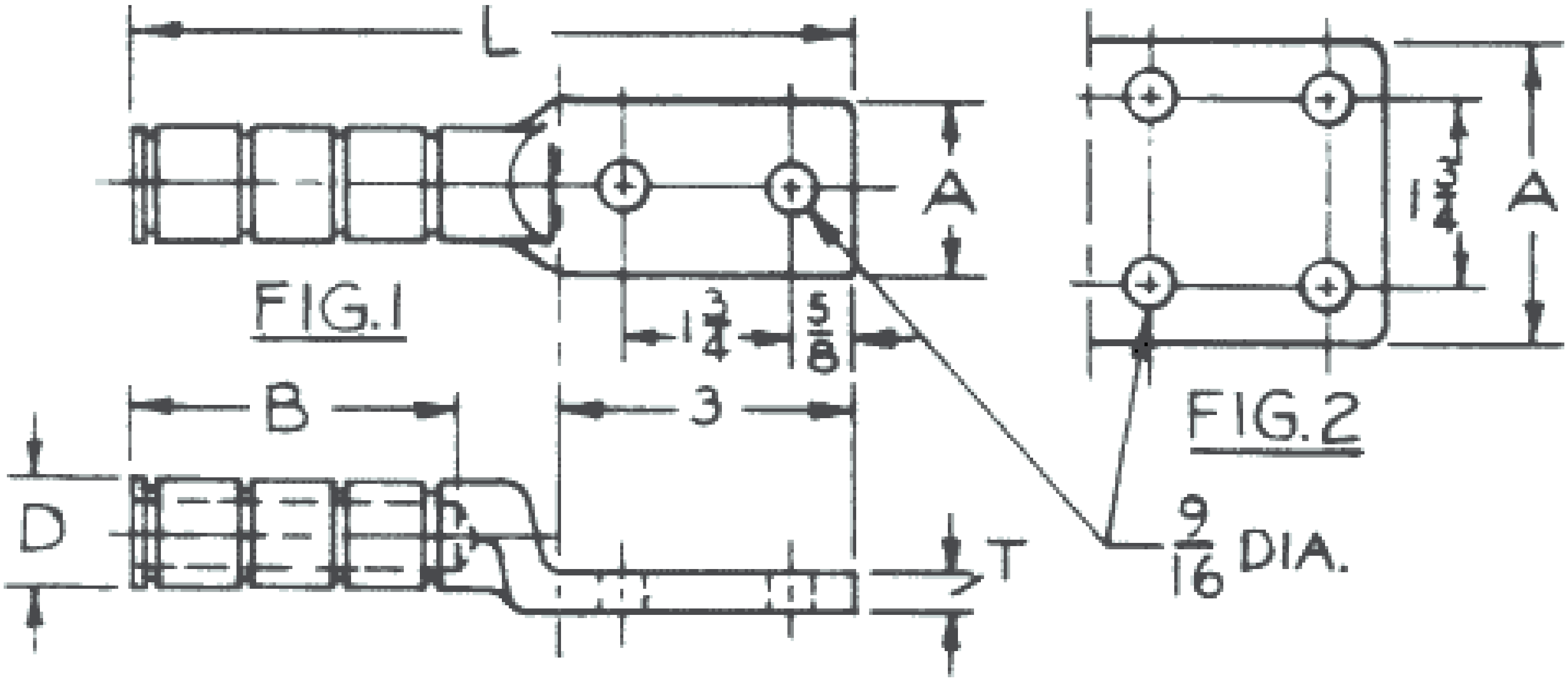


FIG.1

FIG.2

Pad Connections

1. Clean Surface
2. Electrical Joint Compound
    a. Grit or No Grit
3. Allow for Temperature Expansion
    a. SS Bolts & Belleville Washers
    b. Aluminum Bolts
4. Maximize Pressure

Clean Surface

Aluminum Corrosion is Almost Instantaneous

Wire Brush and Coat with Electrical Joint Compound

Wire Brush Through Joint Compound

Electrical Joint Compound

Conducting Air Tight Compound

Temperature Resistant

No Grit for Flat Surfaces

Grit for Cables

Temperature Expansion

Aluminum Bolts

Stainless Steel Bolts

Flat Washers vs. Belleville Washers

Maximize Pad Pressure

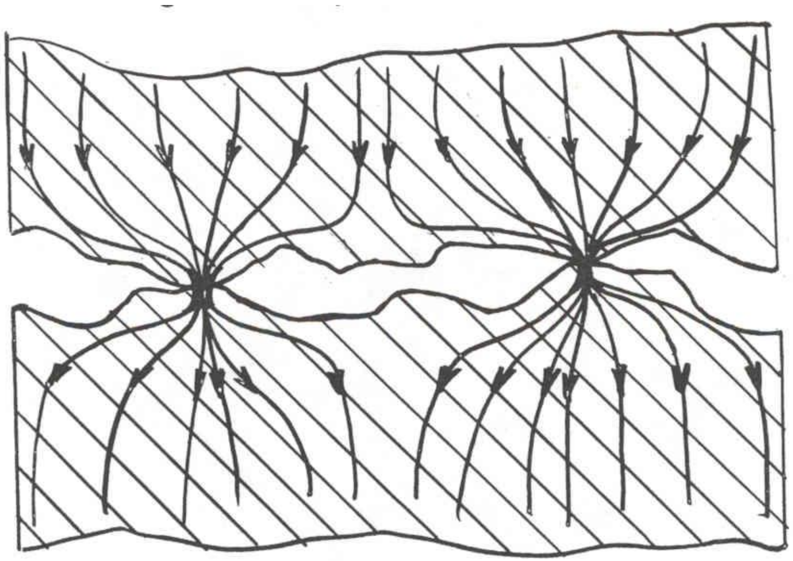
Contact Resistance is Proportional to Pressure

Current Carrying Capacity

vs.

Contact Resistance

Current Constriction at Contact Points



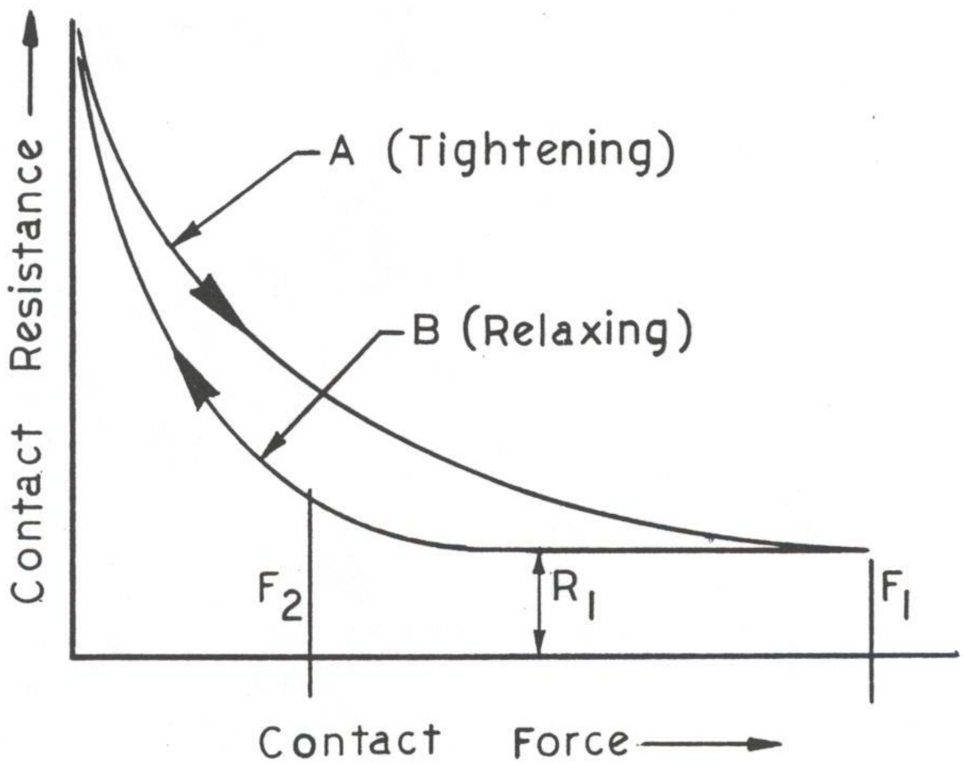
Increasing the pressure increases the number of contact points

Aluminum Creep

Pressure Reduces by 20% within 24 Hours

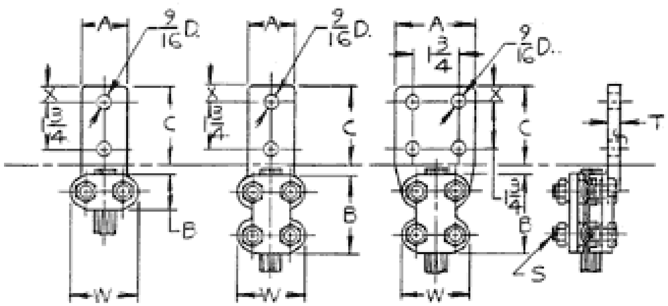
Use Flat Washers under Belleville Washers

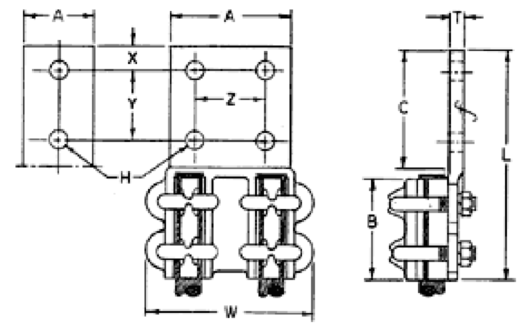
Relaxation of Pressure Due to Creep

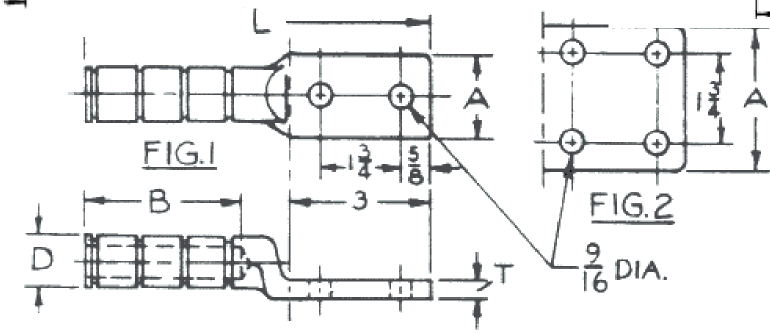


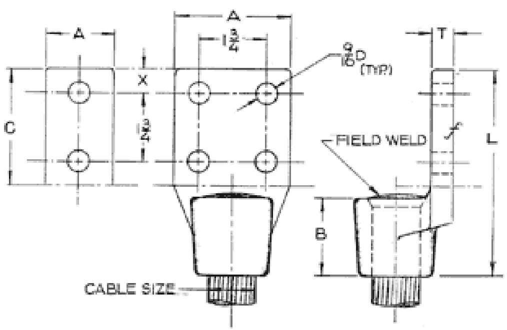
After initial tightening, the contact resistance does not reduce in proportion to the pressure

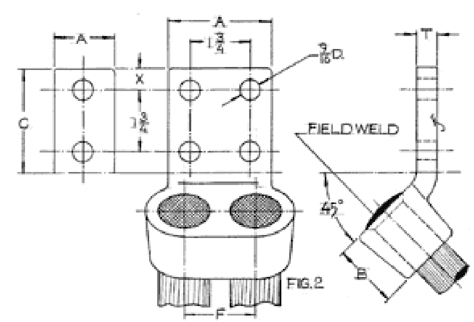
Cable to 4-hole Pad Connection









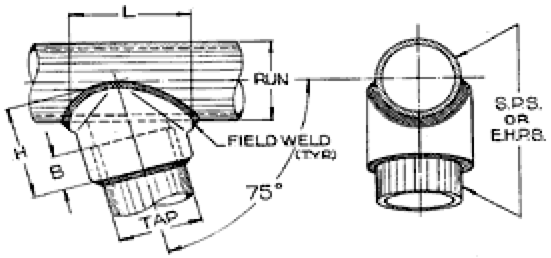


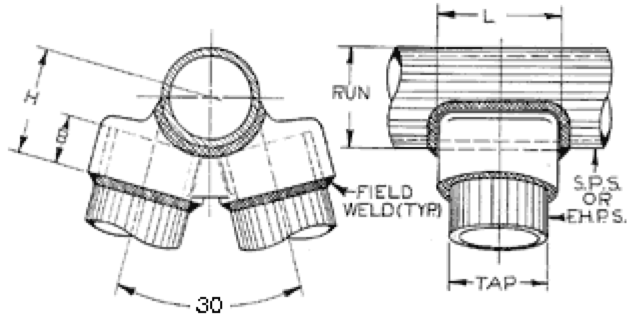
Bolted vs. Compression

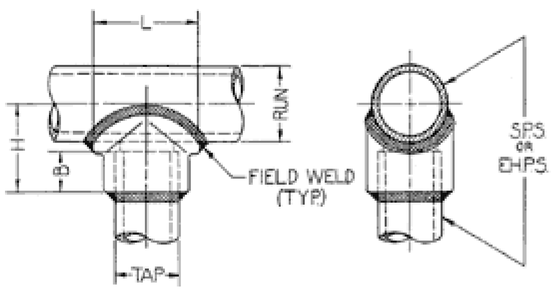
Oxygen Cell or Crevice Corrosion

Temperature Cycling

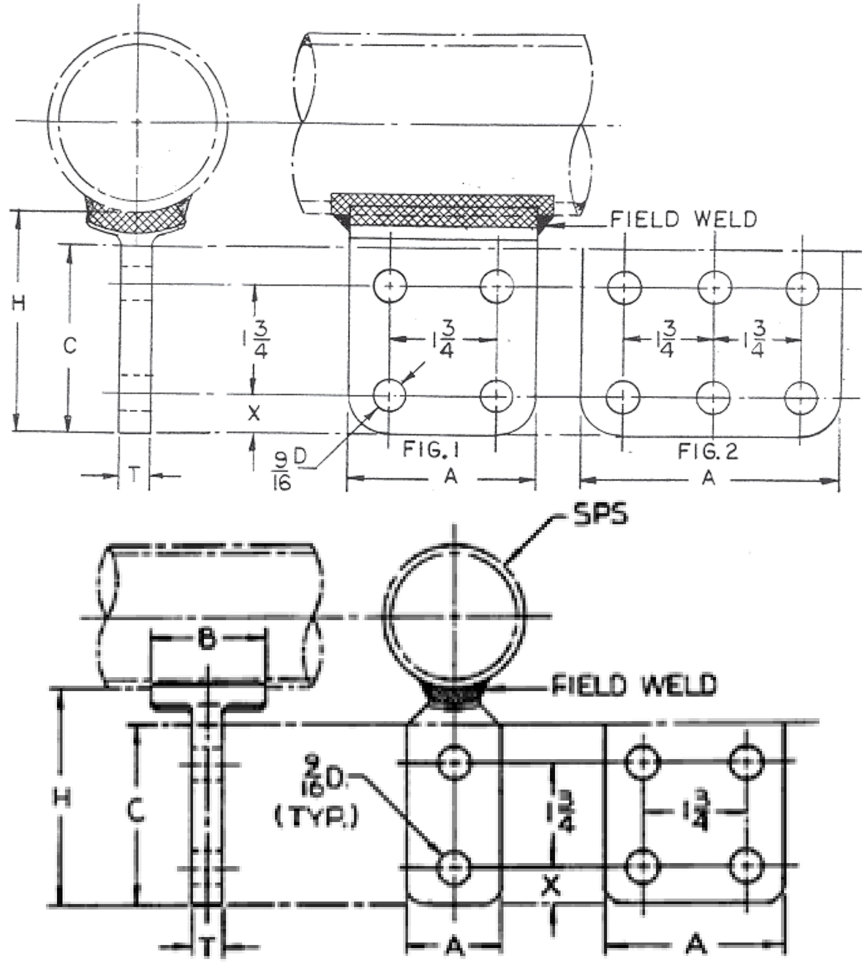
Welded Fittings



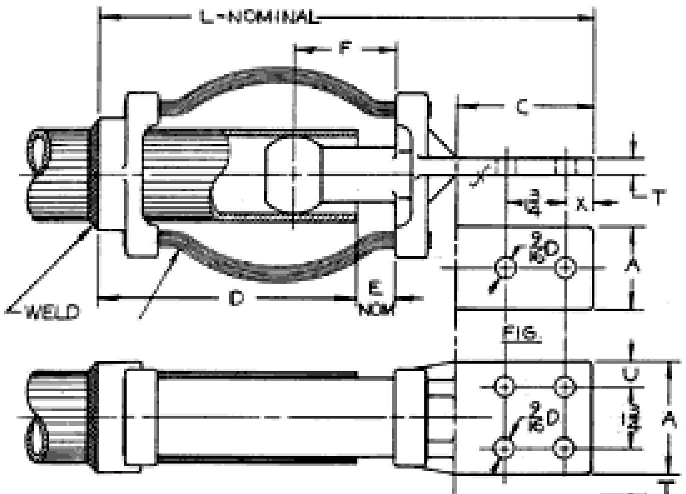


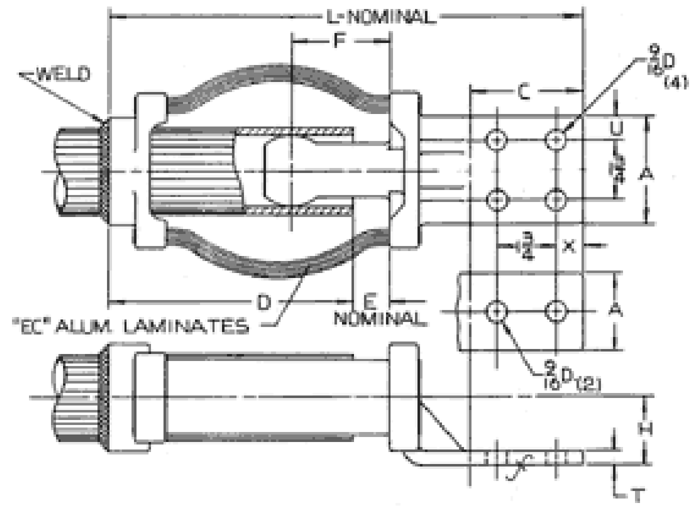


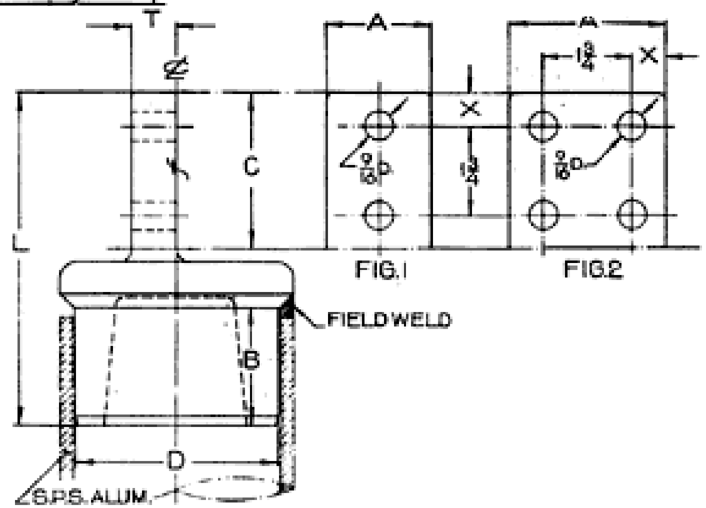
Welded Fittings



Welded Fittings







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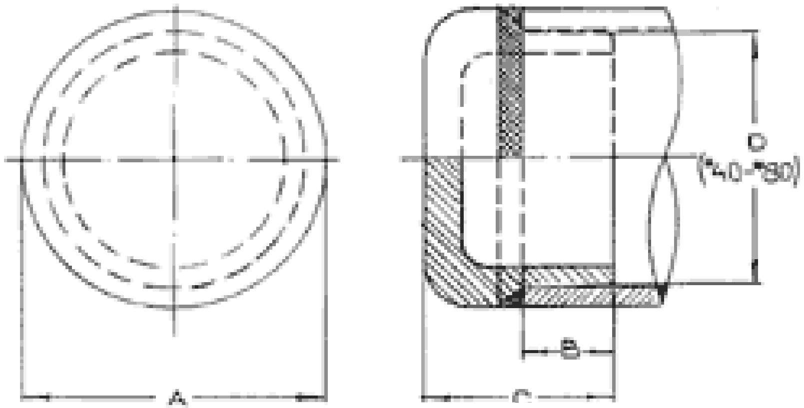
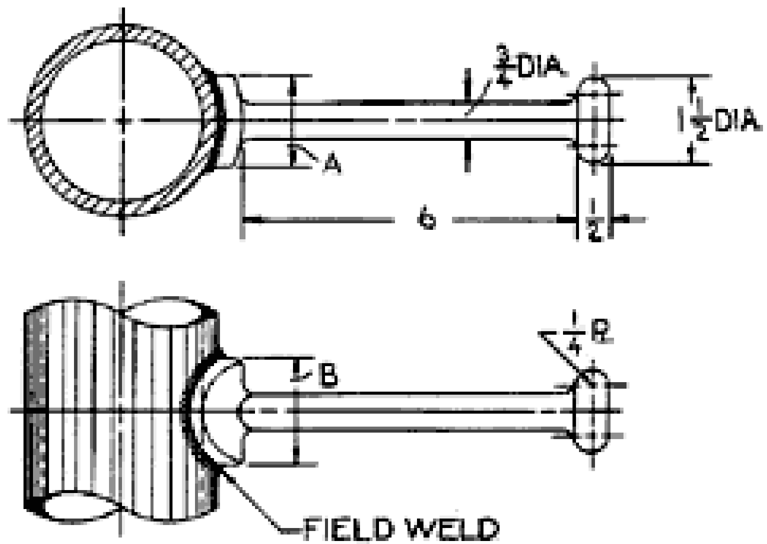
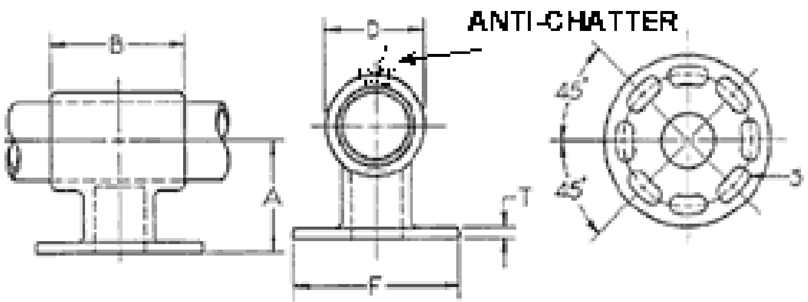
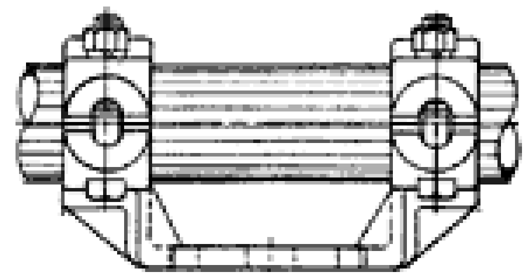
Welded Fittings

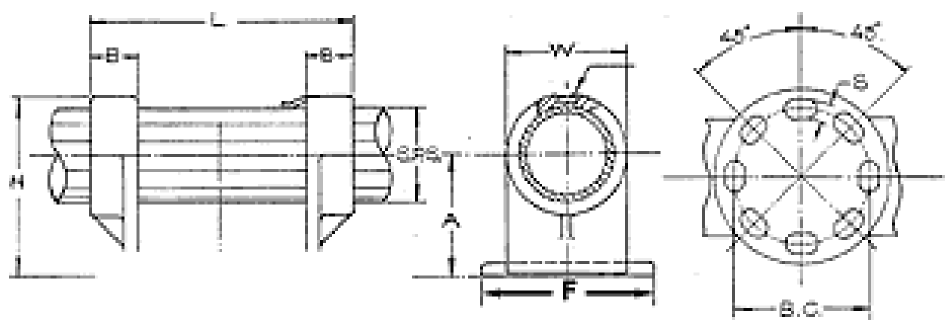




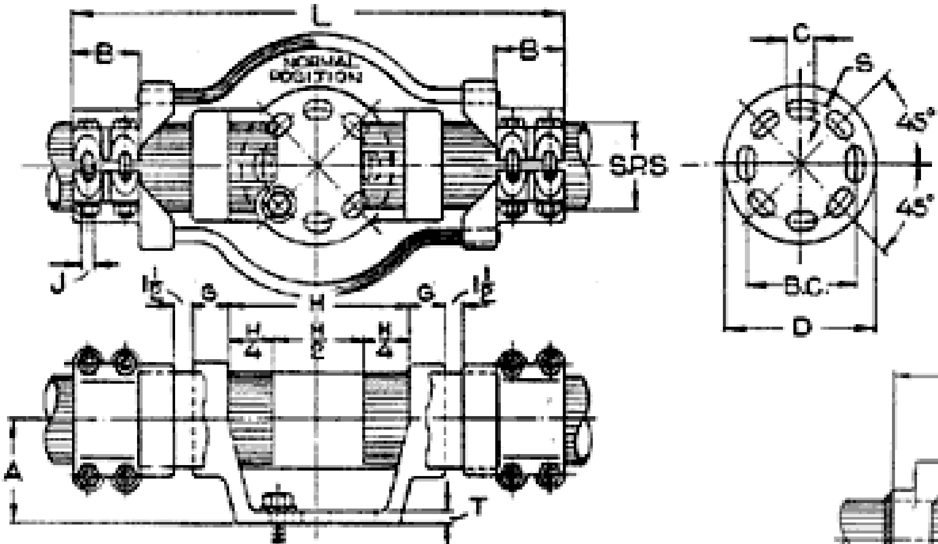
Bus Supports

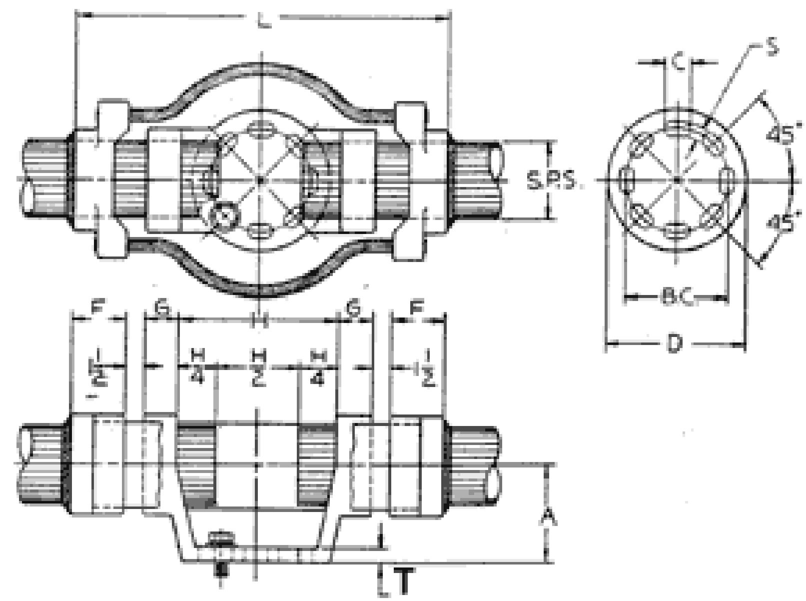




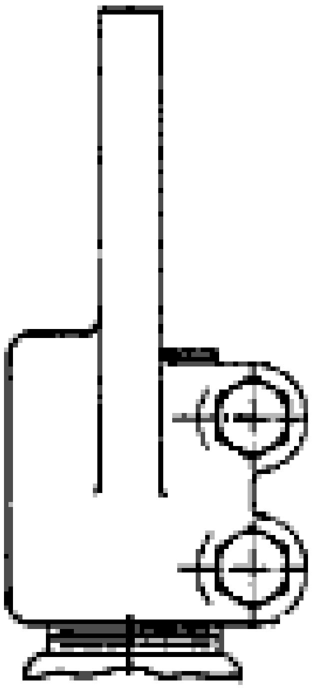


Bus Supports

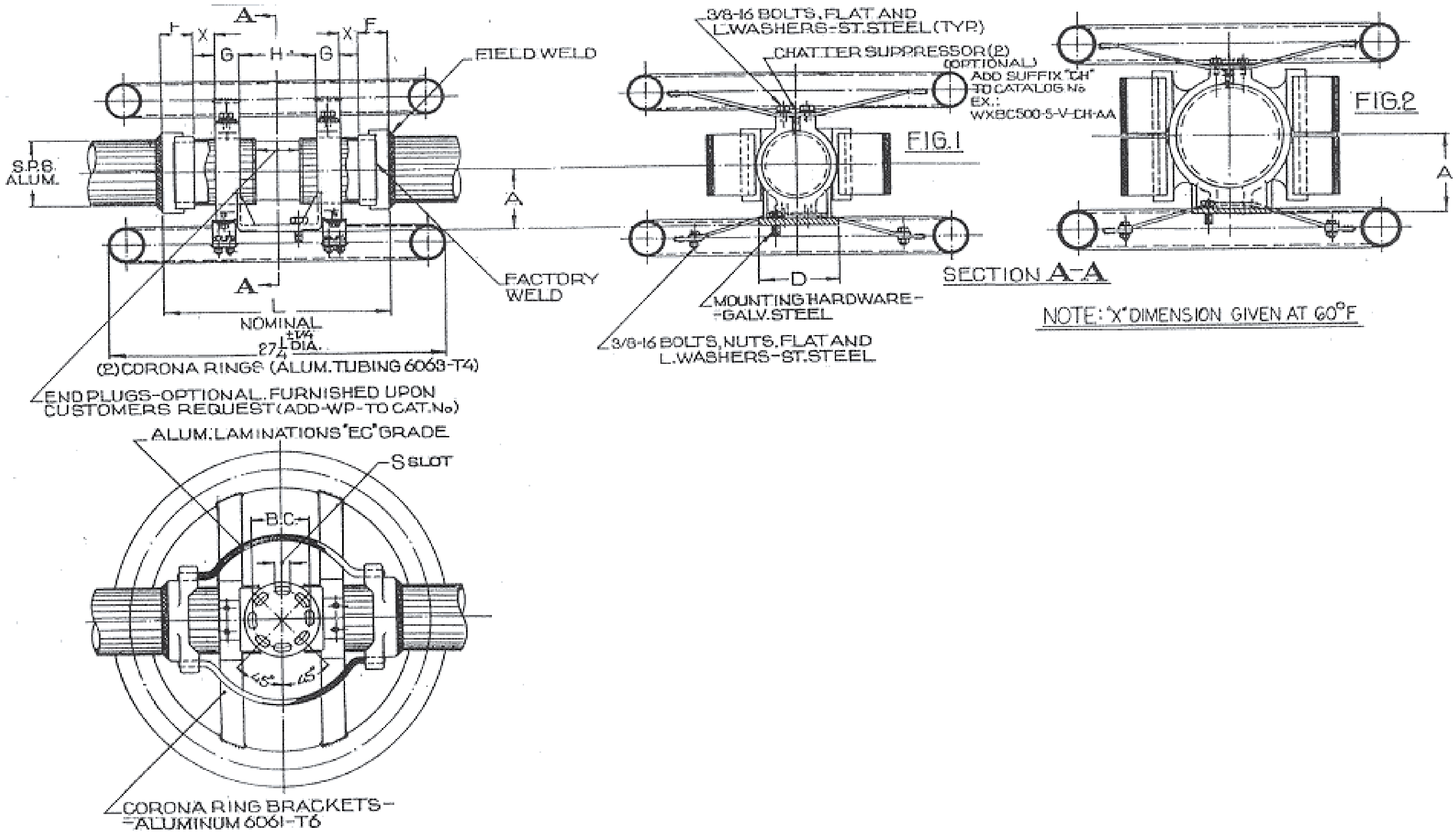




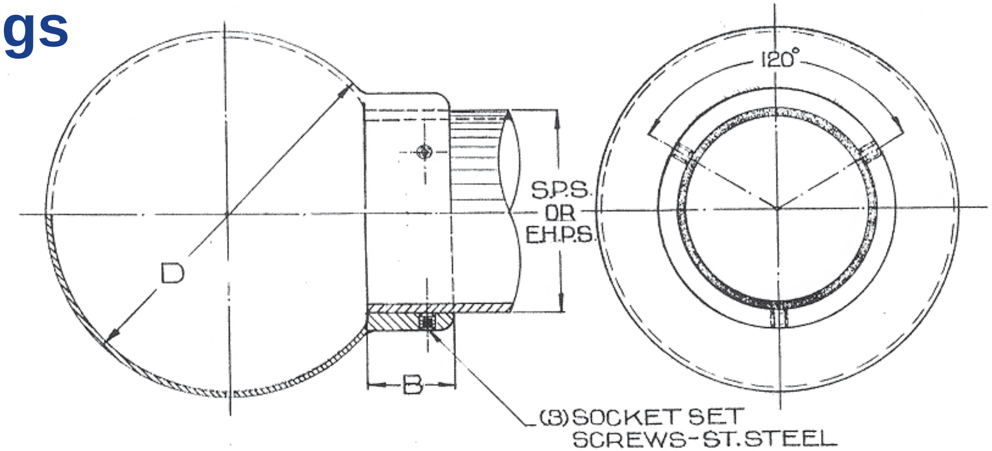
Stud Connectors

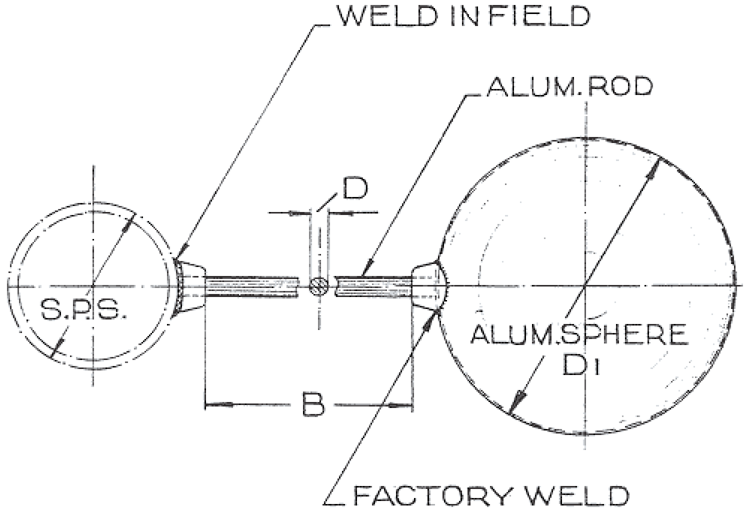


EHV Fittings

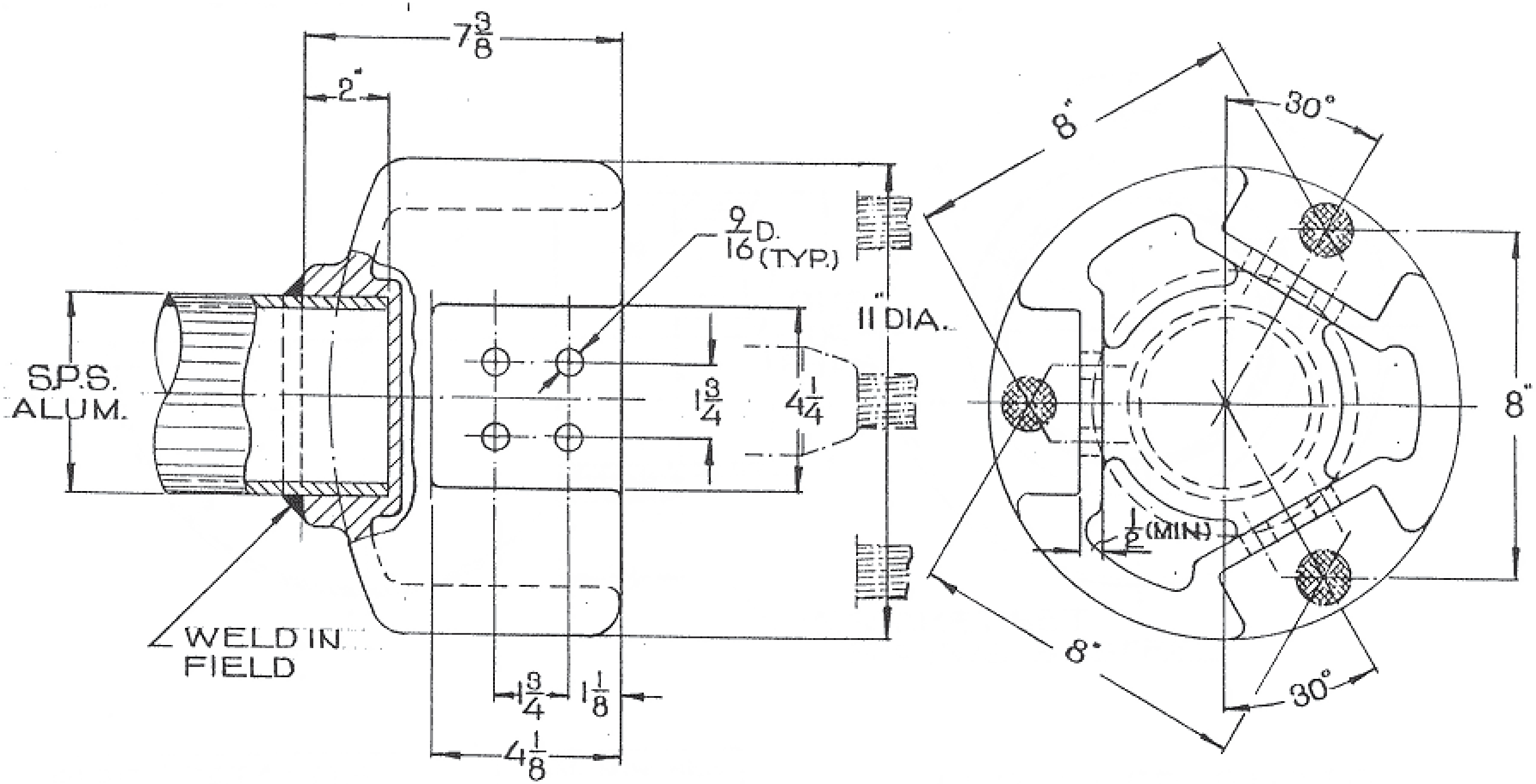


EHV Fittings

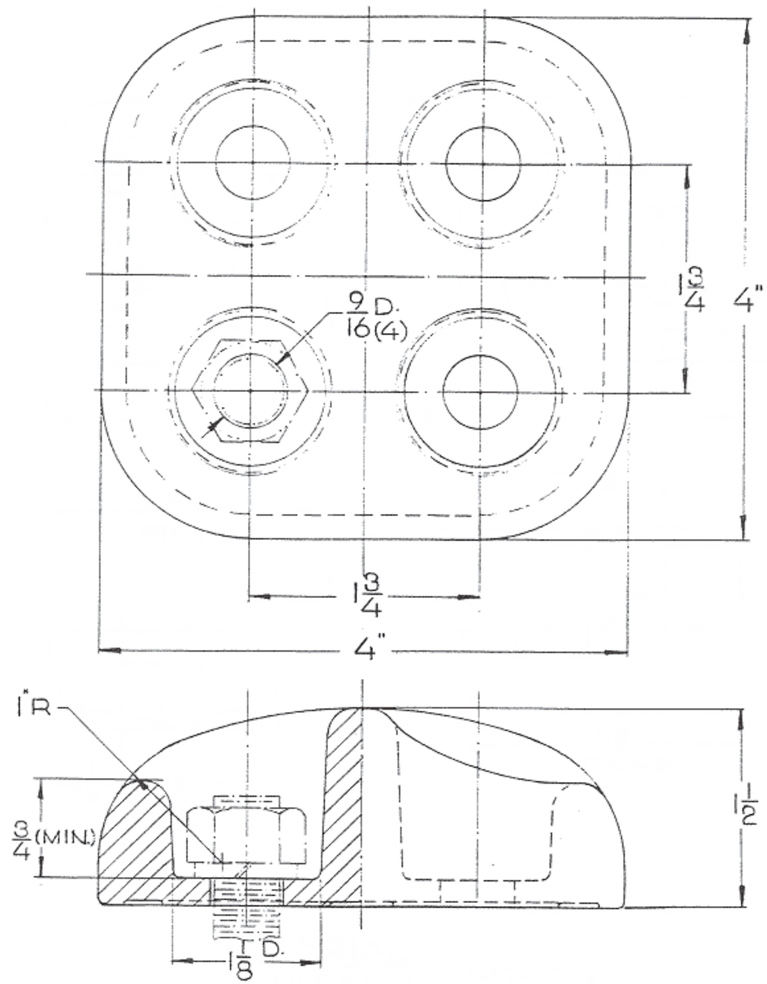




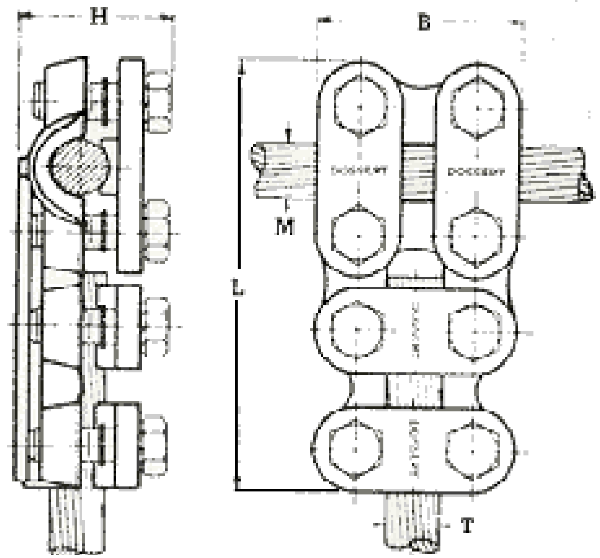
EHV Fittings



EHV Fittings



Good Practice



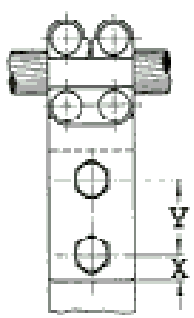


FIG. 1

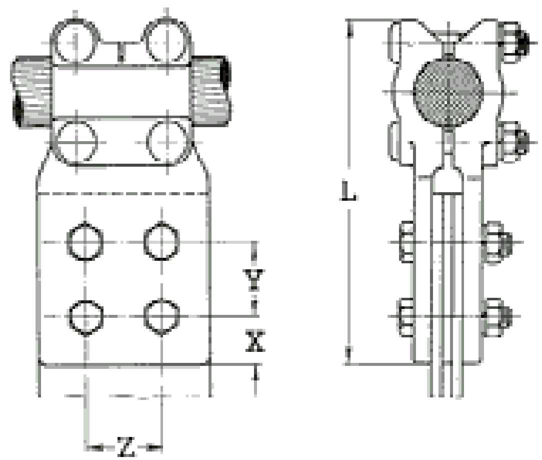
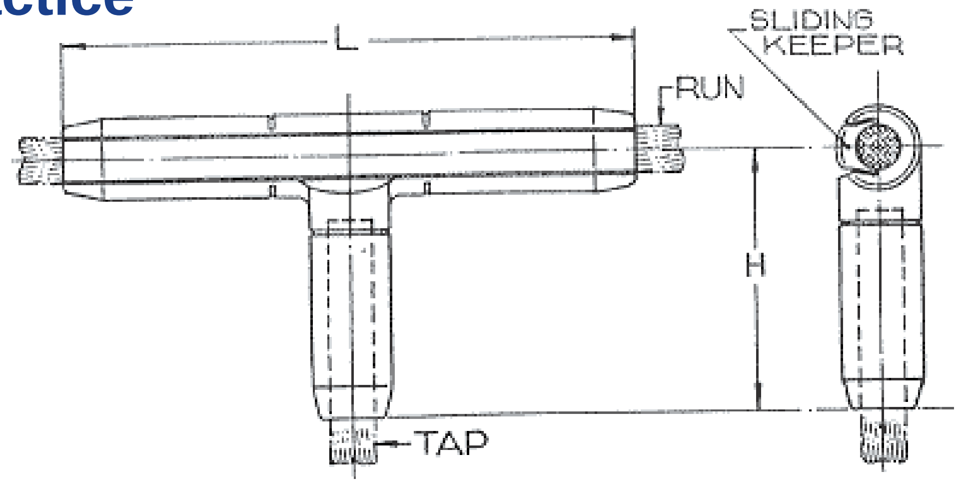
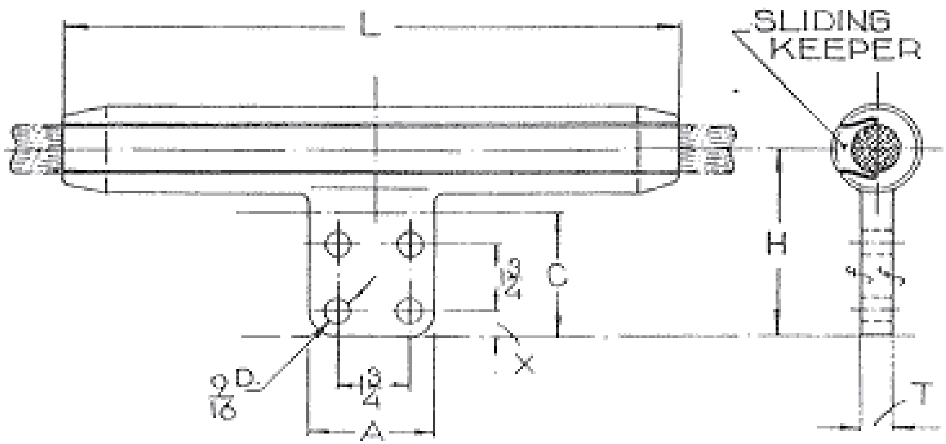


FIG. 2

Good Practice





Standardized USA AC Substation Voltages

Nominal kV-rms	Maximum kV-rms
13.8	15.5
23.5	25.8
34.5	38.0
46	48.3
69	72.5
115	121
138	145
161	169
230	242
345	362
500	550
765	800

Substation Insulation

- Self-Restoring (Bus Insulation)
  - Air
  - Porcelain
- Non-Self-Restoring (Equipment Insulation)
  - Mineral Oil
  - Polyethylene
  - Kraft/Oil Paper
  - SF_6 Gas

-

Insulators

- Post and Suspension
- Porcelain and Composites
- Specification
  - Creep (Leakage) Distance
  - Air Gap (Dry Arcing) Distance
  - 60 Hz Flashover (Dry and Wet)
  - Mechanical Strength
  - Impulse (BIL)

Definitions

- BIL - Basic Impulse Insulation Level
  - Conventional BIL
    - Certain No. of Test Waves - No Failure
    - Non-Self-Restoring Insulation Rated This Way
  - Statistical BIL
    - 90% Probability of Withstand When Tested
    - Applicable to Self-Restoring Insulation Only
- BSL - Basic Switching Impulse Insulation Level
  - Conventional BSL
  - Statistical BSL

External Insulation BIL (Lightning Impulse Withstand) Ratings for Maximum System Voltage

Rated Maximum Voltage (kV rms)	Rated Insulator Withstand Voltage, 1.2 x 50 μs Wave (kV Crest)
8.25	95
15.5	110
25.8	150
38.0	200
48.3	250
72.5	350
121	550
145	650
169	750
242	900
242	1,050

EHV Preferred BILs/BSLs

Maximum System Voltage V_m (rms) (kV)	Base for per Unit Values $V_m \frac{\sqrt{2}}{\sqrt{3}}$ (crest)	BSL (p.u.)	BSL (kV)		BIL (kV)
					825
362	296	2.53	750		900
		2.79	825	*	1,050
		3.04	900		1,175
		3.55	1,050		1,300
550	449	2.17	975		1,175
		2.34	1,050		1,300
		2.62	1,175	*	1,425
		2.90	1,300		1,550
		3.17	1,425		1,675
					1,800
800	653	1.99	1,300		1,675
		2.18	1,425		1,800
		2.37	1,500	*	1,925
		2.57	1,675		2,050
					2,175
					2,300
1,200	980	‡	‡		‡

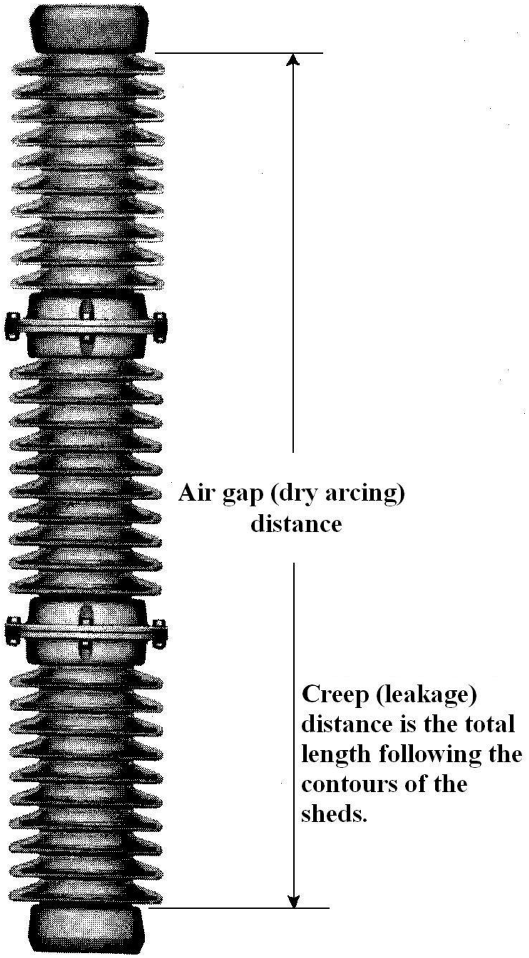
* Various Values of BIL and BSL May Be Used in Combination as Appropriate to Specific Apparatus or System Elements

‡ These Values Are Not Presently Specified

Altitude Correction Factors

Elevation		Correction
Feet	Meters	Factor
3,300	1,000	1.00
4,000	1,200	1.02
5,000	1,500	1.05
6,000	1,800	1.09
7,000	2,100	1.12
8,000	2,400	1.16
9,000	2,700	1.21
10,000	3,000	1.25
12,000	3,600	1.33
14,000	4,200	1.43
16,000	4,800	1.54
18,000	5,400	1.64
20,000	6,000	1.79

Insulator Definitions



Surface Leakage Current Increases With. . .

- Increased Voltage
- Degree and Type of Contamination
- Insulator Surface Characteristics
- Humidity

-

Suggested Leakage Distance for Contaminated Areas

Contamination Level	Equivalent Amount of NaCl mg/cm^2	Leakage Distance in./kV L - G
Very Light	0.0 - 0.03	About 1.0
Light	0.03 - 0.06	1.0 - 1.25
Moderate	0.06 - 0.1	1.5 - 1.75
Heavy	0.1 - 0.25	2.0 - 2.50

* From REA Bulletin 1724E-200

Minimum Quantity of Suspension Insulators

Nominal System Phase-to-Phase Voltage kV	BIL kV	Minimum Quantity of Suspension Insulators *
14.4	110	2
23	150	2
34.5	200	3
46	250	4
69	350	5
115	550	8
138	650	9
161	750	10
230	900	12
230	1,050	14

* For Standard 14.6 x 25.4 Centimeter (5-3/4 x 10 inch) Suspension Insulators

-

Substation Clearances

TABLE 1. MINIMUM ALLOWABLE SUBSTATION SPACINGS AND CLEARANCES

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
				Disconnecting Switches C_L to C_L Phase Spacing							
							Ground Clearance			Minimum Clearance to Unguarded Parts	
System Voltage kV	Maximum Rated Voltage kV	BIL kV	Minimum Metal-to-Metal Phase Spacing in.	Vertical and Double Side Break in.	Single Side Break in.	All Horn Gap in.	Minimum in.	Recommended in.	Minimum Oil Cond Clearance To Grade ft	Vertical ft-in.	Horizontal ft-in.
14.4	15.5	110	12	24	30	36	7	10	9	9-0	3-6
23	25.8	150	15	30	36	48	10	14	10	9-3	3-9
34.5	38	200	18	36	48	60	13	18	10	9-6	4-0
46	48.3	250	21	48	60	72	17	22	10	9-10	4-4
69	72.5	350	31	60	72	84	25	30	11	10-5	4-11
115	121	550	53	84	108	120	42	45	12	11-7	6-1
138	145	650	63	96	132	144	50	54	13	12-2	6-8
161	169	750	72	108	156	168	58	62	14	12-10	7-4
230	242	900	89	132	192	192	71	80	15	14-10	9-4
230	242	1,050	105	156	216	216	83	92	16	--	--
345	362	1,050	105	156	216	216	84	92	18	15-6	10-0
345	362	1,300	119	174	--	240	104	106	18	17-2	11-8
500	550	1,550	--	--	--	--	124	128	--	18-10	13-4
500	550	1,800	--	--	--	--	144	152	--	20-6	15-0
765	800	2,050	--	--	--	--	166	182	--	22-5	16-11
1,100	1,200	--	--	--	--	--	--	--	--	--	--

Notes:

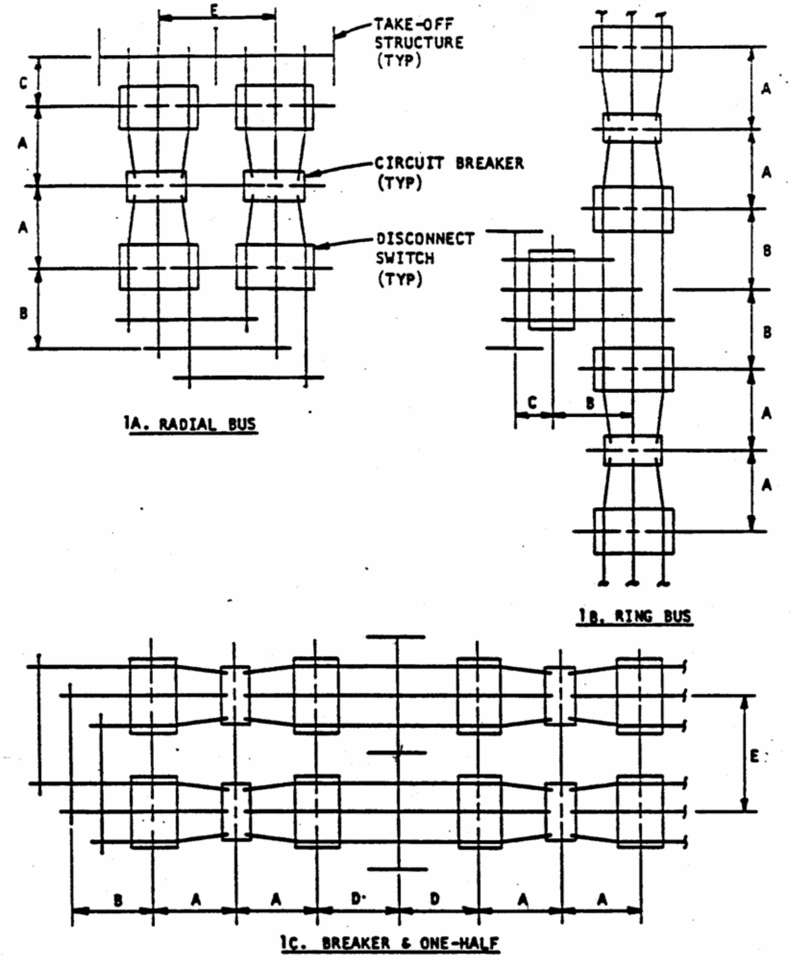
1. The values in Columns 2 through 7 for systems up to 345 kV are taken from ANSI C37.32, Table 5. The values in Columns 2 and 3 for systems above 345 kV are taken from ANSI C92.2.
2. The values in Columns 8 and 10 and the BIL for 800 kV maximum rated voltage (Column 3) are taken from NEMA SG6, Table 1. NEMA SG6 has been rescinded but these values are considered the best available.
3. The values in Columns 11 and 12 are taken from ANSI C2 (NESC), Table 124-1.
4. The values in Column 9 are the heights of station post insulators as given in NEMA Standard HV-1 and its proposed changes, and/or the Lapp Insulator Catalog.

Typical Substation Spacings

System Voltage kV	Rated Voltage kV	BIL kV	Bus Separation and Clearance: Horizontal ℄ to ℄ Phase Spacing ft	Height Above Grade: Low Bus ft	Height Above Grade: High Bus ft	Equipment and Structure Separation: A** ft	B** ft	C ft	D** ft	E ft
69	72.5	350	5	14	17.5	10	12	10	--	24
115	121	550	7	14	19	12	16	10	15	28
138	145	650	8	16	22	14	18	12	18	30
161	169	750	9	17	24	15	23	12	23	36
230	242	900	11	18	26	17	25	17	25	45
230	242	1,050	13	20	30	23	30	21	30	55
345	362	1,050	13	20	30	23	30	21	30	55
345	362	1,300	14.5	22	34	30	35	25	35	64
500	550	1,550	20	24	40	35	40	30	40	72
500	550	1,800	25	30	50	40	45	35	45	80
765	800	2,050	30	35	60	45	50	40	50	90

** Dimensions A, B, and D May Be Reduced if "Vee" Type Switches Are Used

Typical Substation Spacings



Larger Spacings Sometimes Required

- Short Circuit
- Equipment Projections
- Grounding Switches
- Switching Surge Requirements for EHV

Foundations

Foundations - Definition and Purpose

- In Interface Between Superstructure and Underlaying Soil or Rock
- Transmits Loads to Competent Bearing Stratum (Level)
- Controls Superstructure Settlement and Rotation

Foundation Design Philosophy

- Non-Homogeneous Material
- Below Grade Installation
- Appropriate Factor of Safety
  - Shallow Foundations, F.S. ≥3.0
  - Deep Foundations, F.S. ≥ 2.0
- Economics/Constructability

Foundation Design Procedure

- Determine Loads
- Develop Soil Parameters
- Determine Foundation Type
- Size Foundation
  - Anchor Bolt Pattern
  - Soil Parameters
- Design Concrete

-

Soil Borings

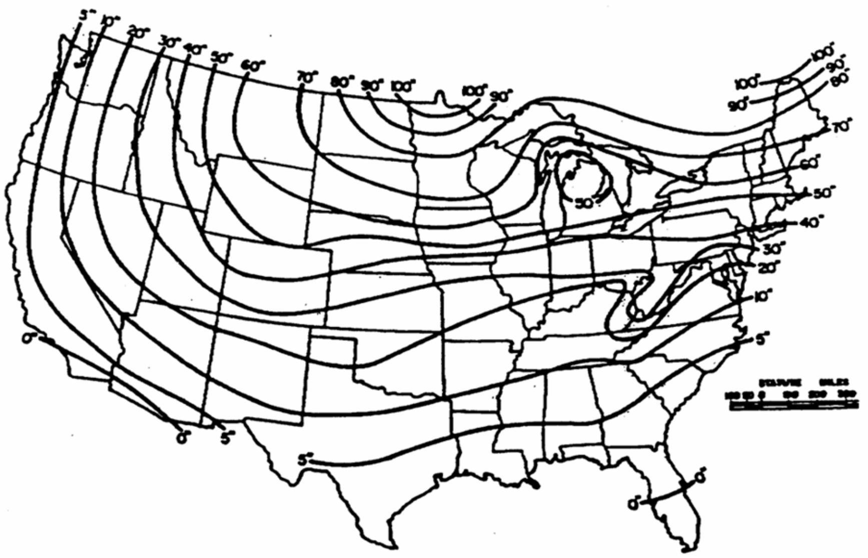
- Quantity
- Location
- Information from Boring
  - Soil Classification
  - Groundwater Level
  - Standard Penetration Values (Blow Count)
  - Rock RQD and Recovery
  - Samples to Test
- Soil Tests
  - Moisture Content
  - Density Determination
  - Atterberg Limits
  - Sieve Analysis
  - Unconfined Compressive Tests

Foundation Types

- Shallow Foundations
  - Slabs on Grade
  - Spread Footings
- Deep Foundations
  - Piles
  - Caisson (Drilled Pier)

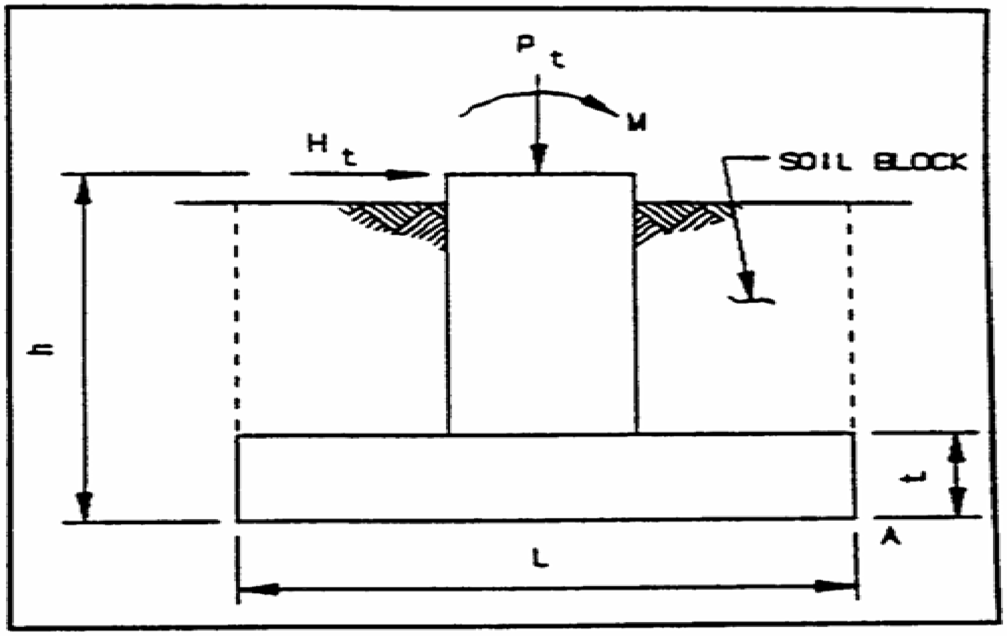
Extreme Frost Penetration

(In Inches) Based Upon State Average

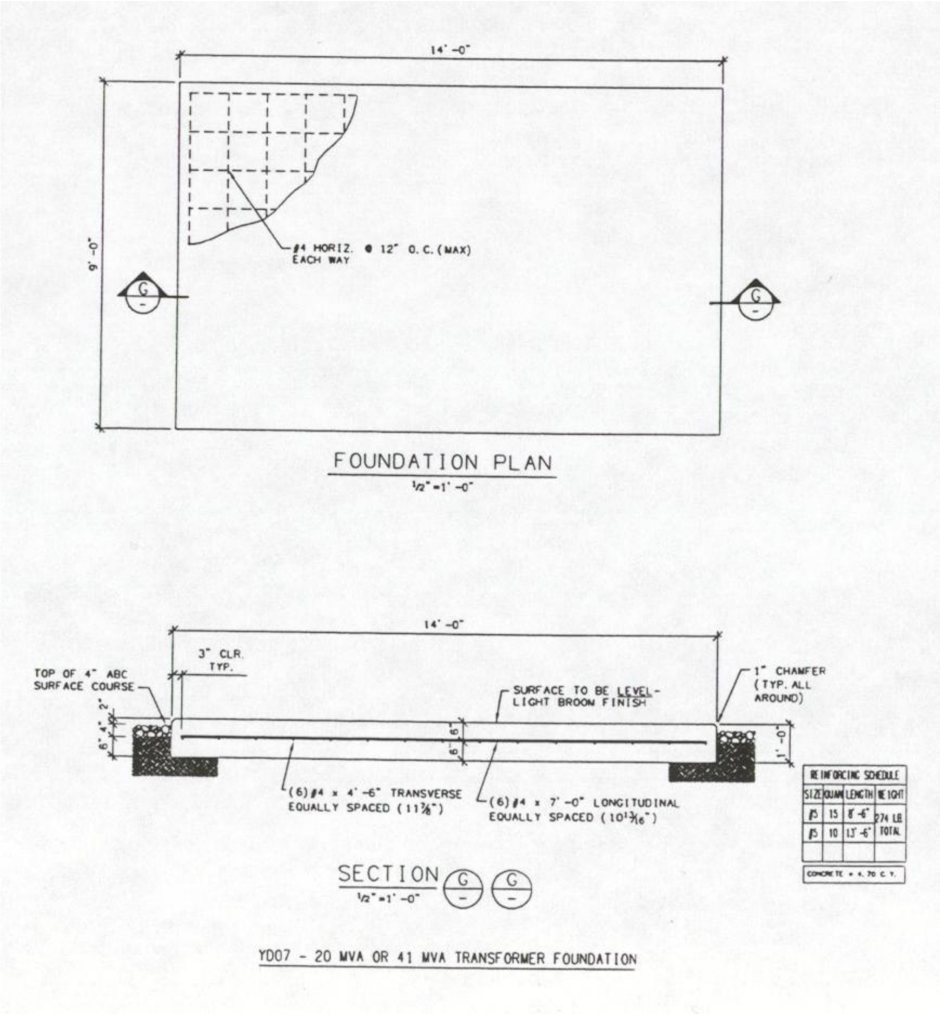


Extreme Frost Penetration
(In Inches) Based upon State Average
Figure 9-1
Source: Naval Facilities Engineering Command Design Manual 7.01 p. 7.1-42

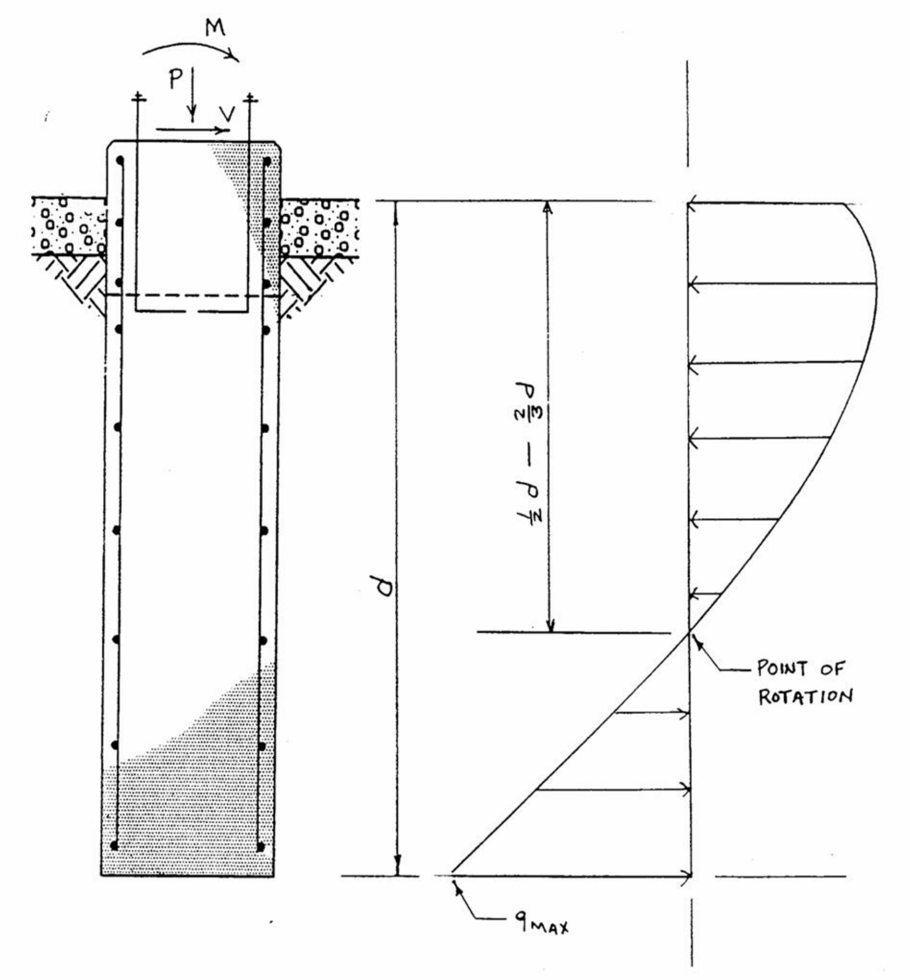
Eccentrically Loaded Spread Footing



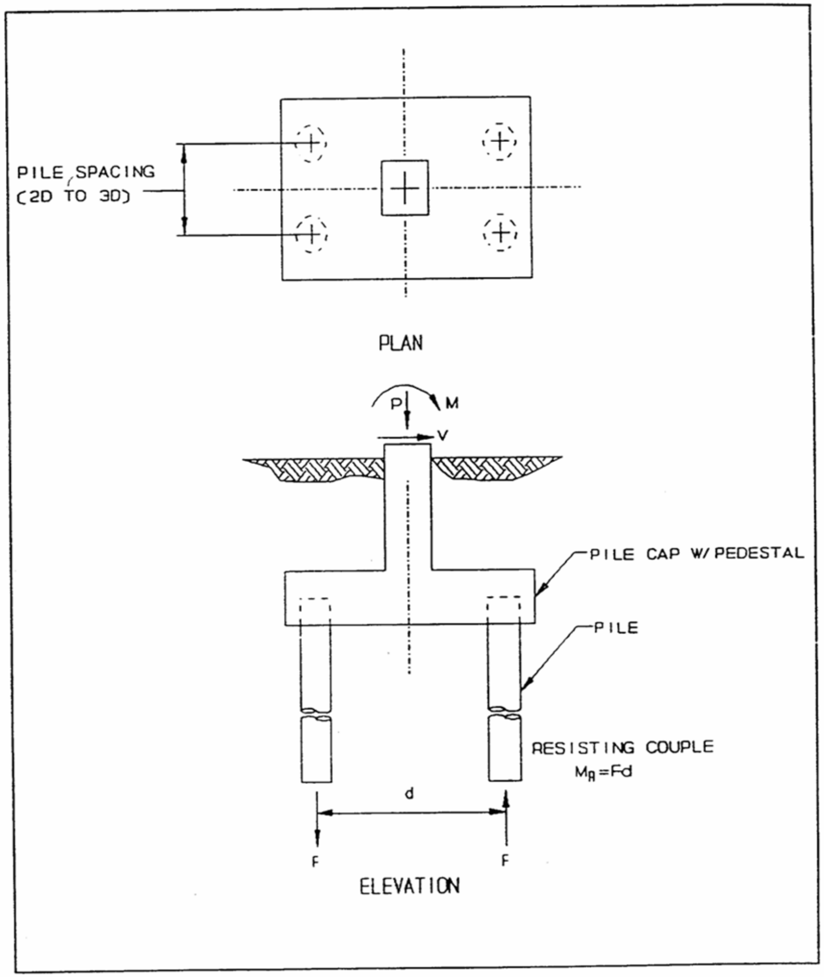
Transformer Slab



Pier Foundation

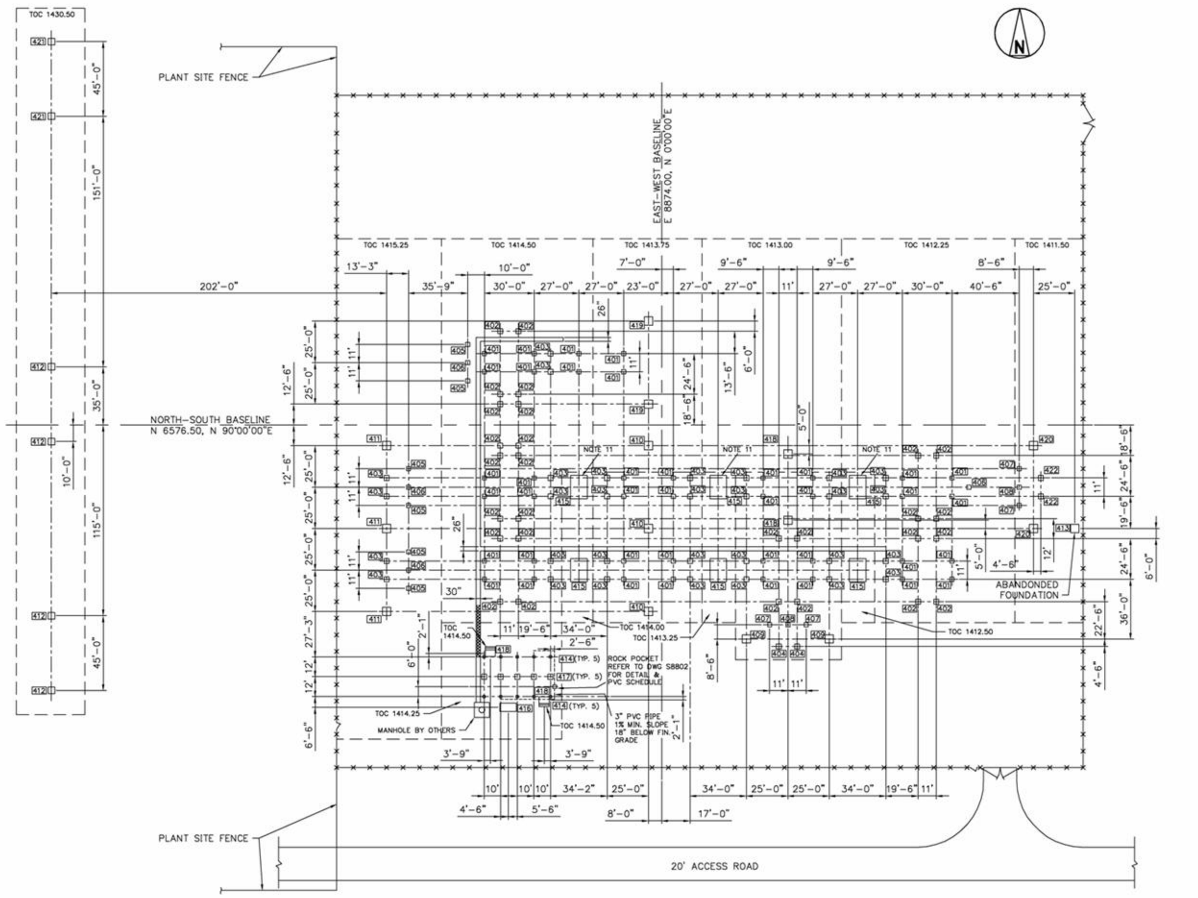


Pile Foundation



Recommendations for Successful Foundation Design and Installation

- Obtain Reliable Subsurface Information
- Know Construction Constraints
- Review Historical Foundation Performance of the Area
- Review Foundation Design with Contractor Prior to Construction



LEGEND:

T.O.C.	TOP OF CONCRETE ELEVATION
	CABLE TRENCH
	DRIVEABLE CABLE TRENCH
	MANHOLE 7' x 7' (9' x 9' OUTSIDE DIM.)
XXX	FOUNDATION MARK NUMBER

GENERAL NOTES:

1. ALL FOUNDATIONS WITHIN THE AREA BORDERED THUSLY (⟵⟶) HAVE THE SAME TOP OF CONCRETE (T.O.C.) ELEVATION AS INDICATED, UNLESS NOTED.
2. COORDINATE SYSTEM IS BASED ON CALIFORNIA STATE PLANE ZONE V, IN FEET (NAD 83) AT SEA LEVEL. ELEVATIONS ARE SHOWN IN FEET (NGVD 1929). ALL COORDINATES HAVE BEEN TRUNCATED. ADD 2,260,000 TO ALL NORTH COORDINATES AND 6,080,000 TO ALL EAST COORDINATES TO OBTAIN STATE PLANE COORDINATES.
3. ALL WORK SHALL BE PERFORMED IN ACCORDANCE WITH THE SPECIFICATIONS.
4. ALL CONCRETE SHALL BE MIX CLASS B-1 OR B-2, WITH A MINIMUM COMPRESSIVE STRENGTH OF 4,000 PSI, UNLESS NOTED OTHERWISE.
5. ALL EXPOSED CORNERS SHALL HAVE A 3/4" CHAMFER UNLESS NOTED OTHERWISE.
6. ALL KNOWN VISIBLE EXISTING UTILITIES AND MATERIALS WHICH WILL REQUIRE REMOVAL OR RELOCATION, BY OTHERS, PRIOR TO CONSTRUCTION, ARE IDENTIFIED ON DRAWING DS-0006. IN ADDITION, ALL OTHER KNOWN OR UNKNOWN UNDERGROUND UTILITIES ENCOUNTERED WITHIN THE SUBSTATION SHALL BE INDENTIFIED AND REMOVED OR REPLACED, AS REQUIRED, BY FOUNDATION CONTRACTOR.
7. SEE DRAWING CPPA-E7440 FOR CABLE TRENCH, RACEWAY, AND CONDUITS.
8. ALL DIMENSIONS ARE TO CENTERLINE OF FOUNDATIONS.
9. SEE DRAWINGS CPPA-S8802, CPPA-S8803 & CPPA-S8804 FOR FOUNDATION QUANTITIES AND DETAILS. SEE DRAWING CPPA-S8805 FOR STAIR / LANDING DETAILS.
10. INSTALL TRENCH SO THAT TOP OF TRENCH IS 0'-6" ABOVE FINISHED GRADE.
11. DEMOLISH TWO EXISTING PIER FOUNDATIONS TO 6" MIN. BELOW THE TOP OF CONCRETE OF THE NEW BREAKER FOUNDATION FOR EACH OF THE THREE NEW TYPE 415 FOUNDATIONS. ALL EXISTING REBAR SHALL BE CUT TO HAVE 3" MIN. COVER BY THE NEW CONCRETE.

REFERENCE DRAWINGS:

CPPA-S8802	230KV SUNRISE SUBSTATION FOUNDATION DETAILS SH. 1
CPPA-S8803	230KV SUNRISE SUBSTATION FOUNDATION DETAILS SH. 2
CPPA-S8804	230KV SUNRISE SUBSTATION FOUNDATION DETAILS SH. 3
CPPA-S8805	230KV SUNRISE SUBSTATION STAIR / LANDING DETAILS

NO	DATE	REVISIONS AND RECORD OF ISSUE	DRN	DES	CHK	PDE	APP
4	06-30-2003	PHASE II - CONFORMED TO CONSTRUCTION RECORD	JEF	JJR	JJR	RWC	RWC
3	06-17-2002	PHASE II - ISSUED FOR CONSTRUCTION	JEF	PTS	AGR	AGR	AGR
2	07-01-2001	CONFORMED TO CONSTRUCTION RECORD	IWH	EPC	JTH	RWC	RWC
1	12-21-2000	ISSUED FOR CONSTRUCTION	IWH	EPC	JTH	RWC	RWC
0	10-02-2000	ISSUED FOR CEC REVIEW	IWH	EPC	JTH	RWC	RWC

30' 15' 0 30' 60'
1"=30'

BLACK & VEATCH CONSTRUCTION, INC.

ENGINEER EPC | DRAWN IWH | CHECKED JTH | DATE 02-10-2000

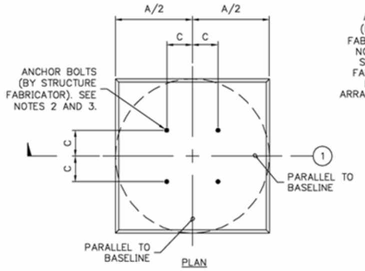
SUNRISE POWER CO.
SUNRISE POWER PROJECT
FELLOWS, CALIFORNIA

FOUNDATION PLAN

PROJECT / DRAWING NUMBER: 99498-CPPA-S8800 | REV 4

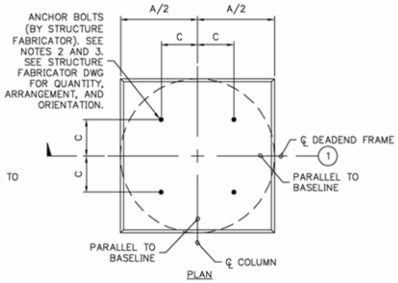
CODE
AREA

JEF A1APL005 6-29-01 D1 ACAD 15 1=1



FOUNDATION 401 402 405 406 407 408

SEE PIER FOUNDATION LIST
NOT TO SCALE



FOUNDATION 409 410 411 413 418 419 420

SEE PIER FOUNDATION LIST
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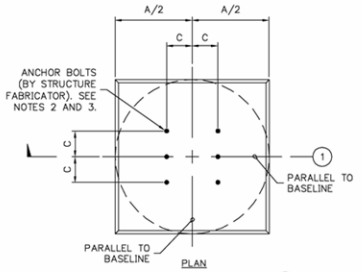
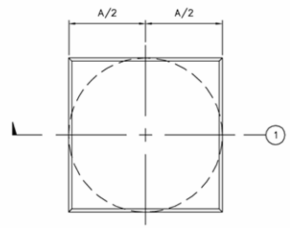


FOUNDATION 403 422

SEE PIER FOUNDATION LIST
NOT TO SCALE

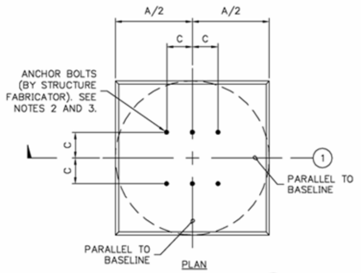


NOTE:
THE EXPANSION ANCHORS AND CLIPS FOR ANCHORING THE CONTROL BUILDING TO THE DRILLED PIERS ARE SUPPLIED AND INSTALLED BY THE CONTROL BUILDING SUPPLIER.

PLAN

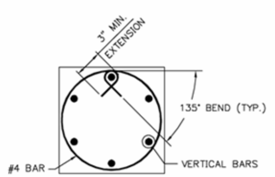
FOUNDATION 414 417

SEE PIER FOUNDATION LIST
NOT TO SCALE



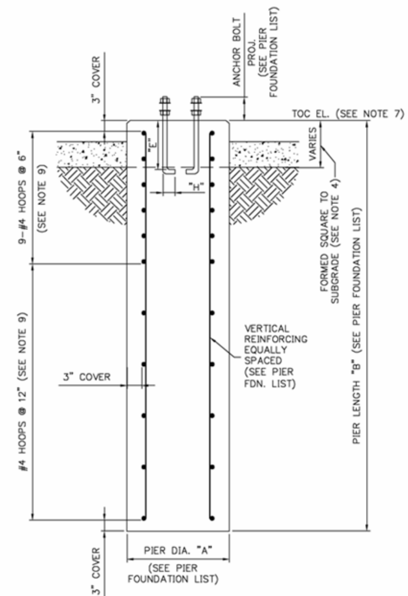
FOUNDATION 404

SEE PIER FOUNDATION LIST
NOT TO SCALE



HOOP DETAIL

NOT TO SCALE



SECTION 1

SEE PIER FOUNDATION LIST
NOT TO SCALE

GENERAL NOTES:

1. FOUNDATION TYPES AND LOCATIONS ARE SHOWN ON FOUNDATION PLAN DRAWING CPPA-S8800.
2. ANCHOR BOLTS AND SETTING TEMPLATES WILL BE FURNISHED BY THE STEEL STRUCTURE SUPPLIER AND INSTALLED BY THE SWITCHYARD DRILLED PIER CONTRACTOR UNLESS NOTED OTHERWISE.
3. FOR ANCHOR BOLT EMBEDMENT LENGTHS, PROJECTION LENGTHS, AND OTHER DETAILS, SEE THE STEEL STRUCTURE SUPPLIER'S DRAWINGS.
4. PIERS SHALL BE CONSTRUCTED MONOLITHICALLY WITH THE TOP SECTION FORMED AS SHOWN.
5. THE TOP OF ALL DRILLED PIERS SHALL HAVE A 3/4" CHAMFERED EDGE.
6. THE TOP OF ALL DRILLED PIERS SHALL RECEIVE A TROWEL FINISH.
7. FOR THE TOP OF CONCRETE (TOC) ELEVATIONS, SEE DRAWING CPPA-S8800.
8. THE CONCRETE QUANTITY SHOWN IS BASED ON DIMENSIONS GIVEN IN THE PIER FOUNDATION LIST. THE ACTUAL QUANTITY REQUIRED COULD EXCEED THE QUANTITY GIVEN, BASED ON CONSTRUCTION PRACTICES.
9. CONTRACTOR HAS OPTION TO USE #4 ASTM A615 GR60 SPIRAL WITH 6" PITCH FOR TOP 2'-6" AND 12" PITCH ELSEWHERE WITH 1 1/2 EXTRA TURNS AT TOP AND BOTTOM INSTEAD OF #4 ASTM A615 GR60 HOOPS AS SHOWN.

PIER FOUNDATION LIST

FDN. NO.	PHASE I QTY.	PHASE II QTY.	DESCRIPTION	PIER DIA. "A"	LENGTH "B"	CU. YD. CONC.	VERTICAL REINF.	ANCHOR BOLTS "C"	QTY.	DIA.	PROJ.	"E"	"H"
401	38	8	230KV LOW BUS 3-PHASE	30"	8'-0"	1.45	5-#8	6"	4	1 1/4"	6"	38"	4"
402	20	8	230KV HIGH BUS 3-PHASE	36"	8'-0"	2.10	7-#8	7"	4	1 1/4"	6"	38"	4"
403	20	10	230KV SWITCH	36"	9'-0"	2.36	7-#8	7"	6	1 1/4"	6"	38"	4"
404	2	0	230KV SWITCH W/ GROUND SWITCH	36"	9'-0"	2.36	7-#8	7"	6	1 1/4"	6"	38"	4"
405	4	2	PT	30"	8'-0"	1.45	5-#8	6"	4	1 1/4"	6"	38"	4"
406	2	2	PT W/ J-BOX	30"	8'-0"	1.45	5-#8	6"	4	1 1/4"	6"	38"	4"
407	2	2	METERING UNIT	30"	8'-0"	1.45	5-#8	6"	4	1 1/4"	6"	38"	4"
408	1	1	METERING UNIT W/ J-BOX	30"	8'-0"	1.45	5-#8	6"	4	1 1/4"	6"	38"	4"
409	2	0	LINE TERMINATION STRUCTURE, 1-BAY	60"	13'-0"	9.45	12-#10	12 3/8"	4	2 1/4"	10"	8'-5"	–
410	3	0	DEADEND STRUCTURE, 2-BAY	60"	14'-0"	10.18	12-#10	12 3/8"	4	2 1/4"	10"	8'-5"	–
411	3	0	DEADEND STRUCTURE, 2-BAY	60"	14'-0"	10.18	12-#10	12 3/8"	4	2 1/4"	10"	8'-5"	–
413	1	0	SHIELD WIRE MAST	60"	12'-0"	8.73	12-#10	14 1/4"	4	2 1/4"	9 1/2"	3'-2 1/2"	–
414	10	0	CONTROL BUILDING	18"	12'-0"	0.83	5-#5	–	–	–	–	–	–
417	5	0	CONTROL BUILDING	36"	8'-0"	2.10	7-#8	–	–	–	–	–	–
418	0	2	DEADEND STRUCTURE, 1-BAY (#214)	54"	12'-0"	7.07	12-#9	12 3/8"	4	2 1/4"	9"	6'-0"	–
419	0	2	DEADEND STRUCTURE, 1-BAY (#215)	54"	15'-0"	8.84	12-#9	12 3/8"	8	2 1/4"	9"	6'-9"	–
420	0	2	LINE TERMINATION STRUCTURE, (#216)	54"	13'-0"	7.66	12-#9	12 3/8"	4	2 1/4"	9"	8'-9"	–
422	0	2	230KV SWITCH W/ GROUND SWITCH	36"	9'-0"	2.36	7-#8	7"	6	1 1/4"	6"	38"	4"

NO	DATE	REVISIONS AND RECORD OF ISSUE	DRN	DES	CHK	PDE	APP
4	06-30-2003	PHASE II -CONFORMED TO CONSTRUCTION RECORD	JEF	JJR	JJR	RWC	RWC
3	06-17-2002	PHASE II - ISSUED FOR CONSTRUCTION	IWH	PDS	EPC	AGR	AGR
2	07-01-2001	CONFORMED TO CONSTRUCTION RECORD	IWH	EPC	BGB	RWC	RWC
1	12-21-2000	ISSUED FOR CONSTRUCTION	IWH	EPC	BGB	RWC	RWC
0	10-02-2000	ISSUED FOR CEC REVIEW	IWH	EPC	BGB	RWC	RWC

SCALE: AS NOTED

BLACK & VEATCH CONSTRUCTION, INC.

ENGINEER EPC | DRAWN IWH | CHECKED BGB | DATE 01/07/00

SUNRISE POWER CO.
SUNRISE POWER PROJECT
FELLOWS, CALIFORNIA

FOUNDATION DETAILS SH. 2

PROJECT 99498-CPPA-S8803 | DRAWING NUMBER | REV 4

CODE | AREA

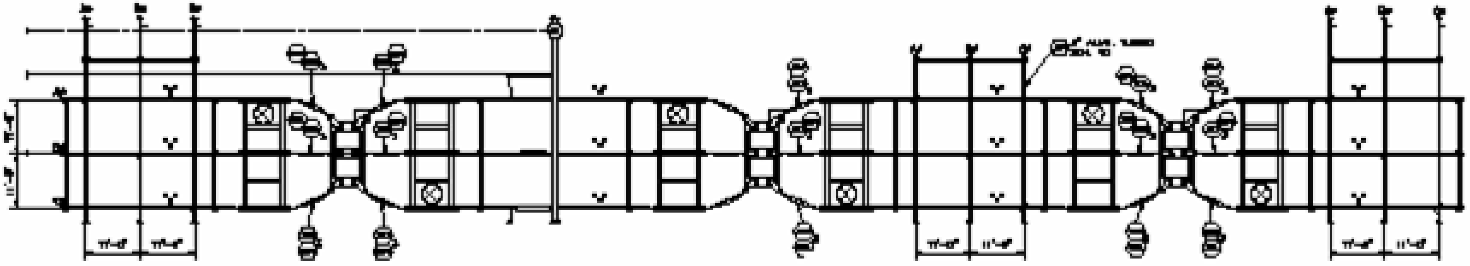
IWH A1APL005 6/5/01 D1 ACAD 15 1=1

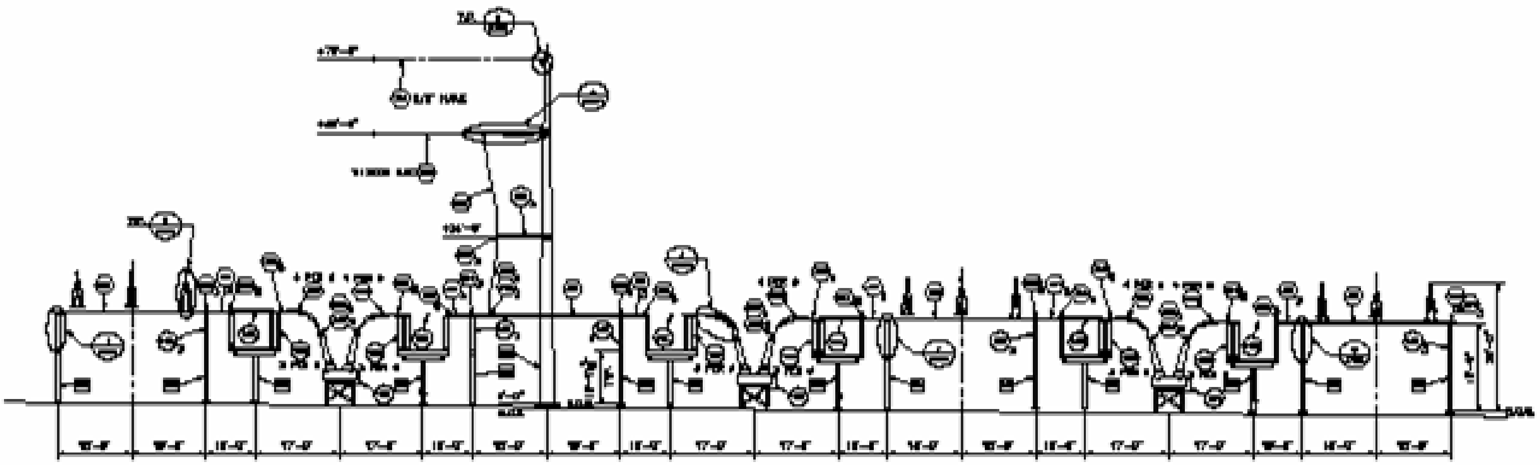
Structure Design

Structure Type

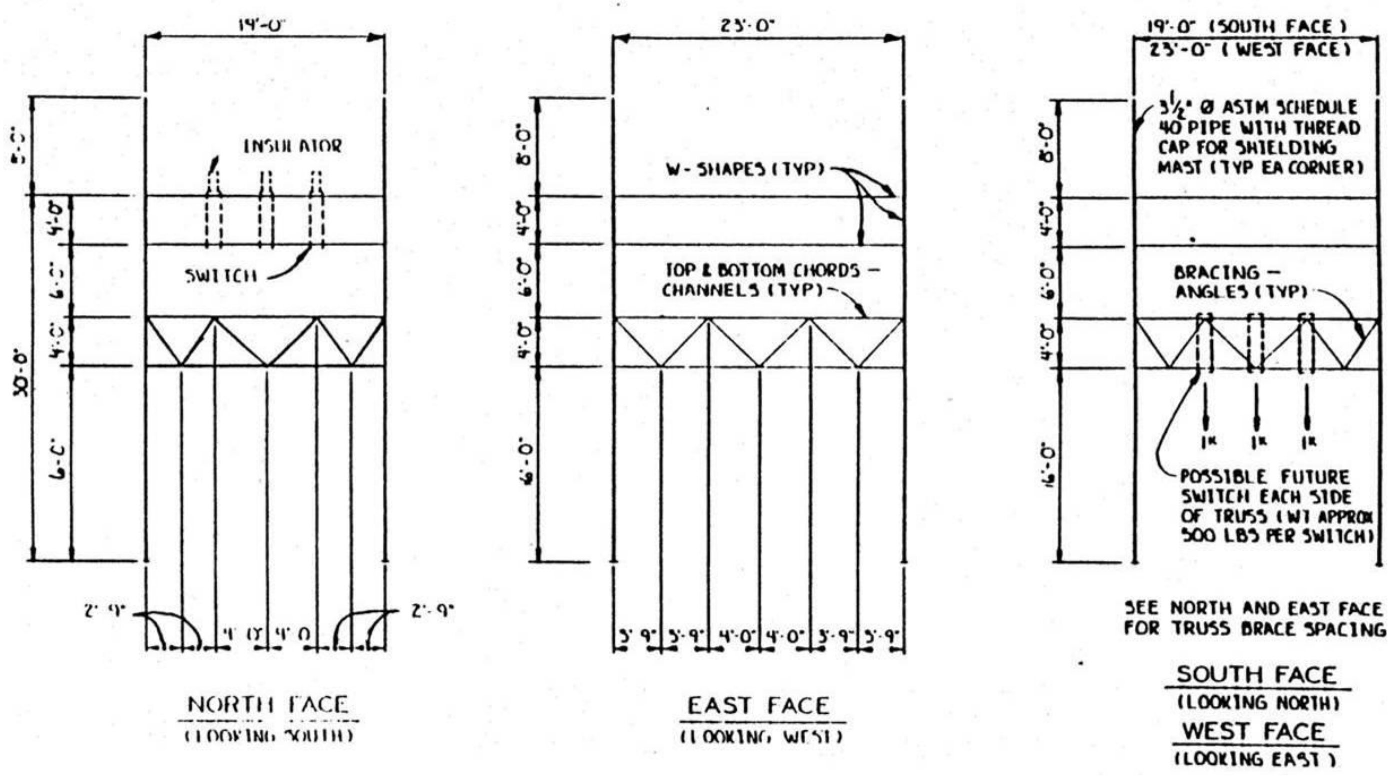
- Low Profile Structures
- Box Structures
- Strain Bus Structures

Structure Type - Low Profile



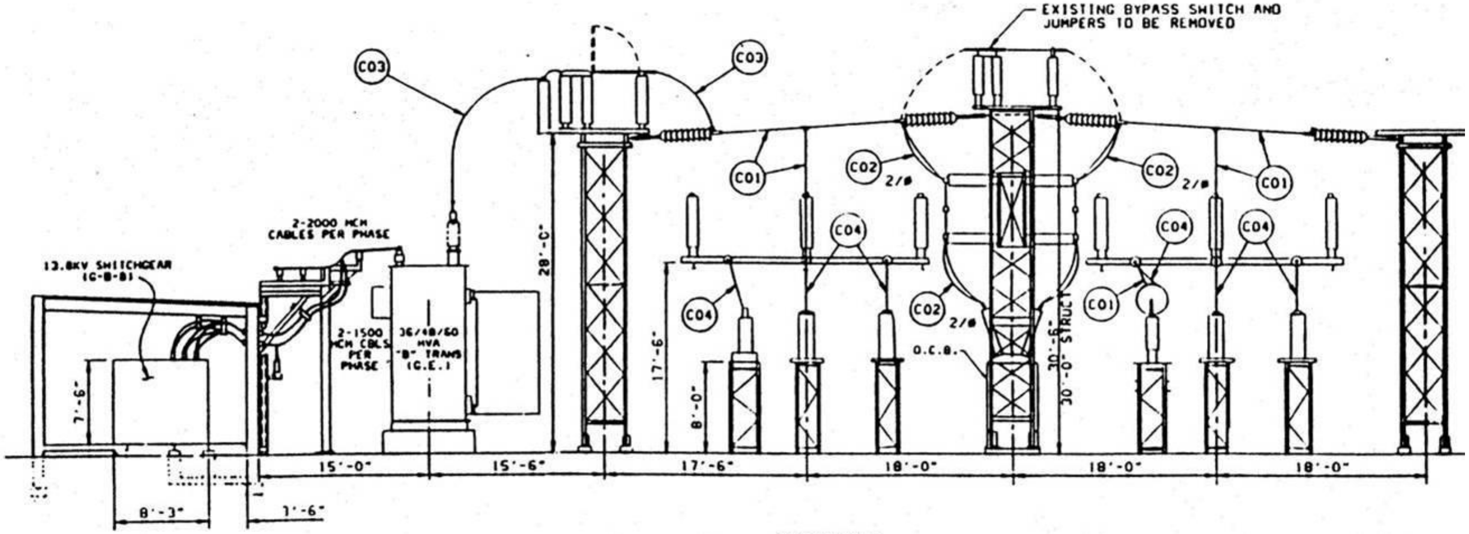


Structure Type - Box



-

Structure Type - Strain Bus

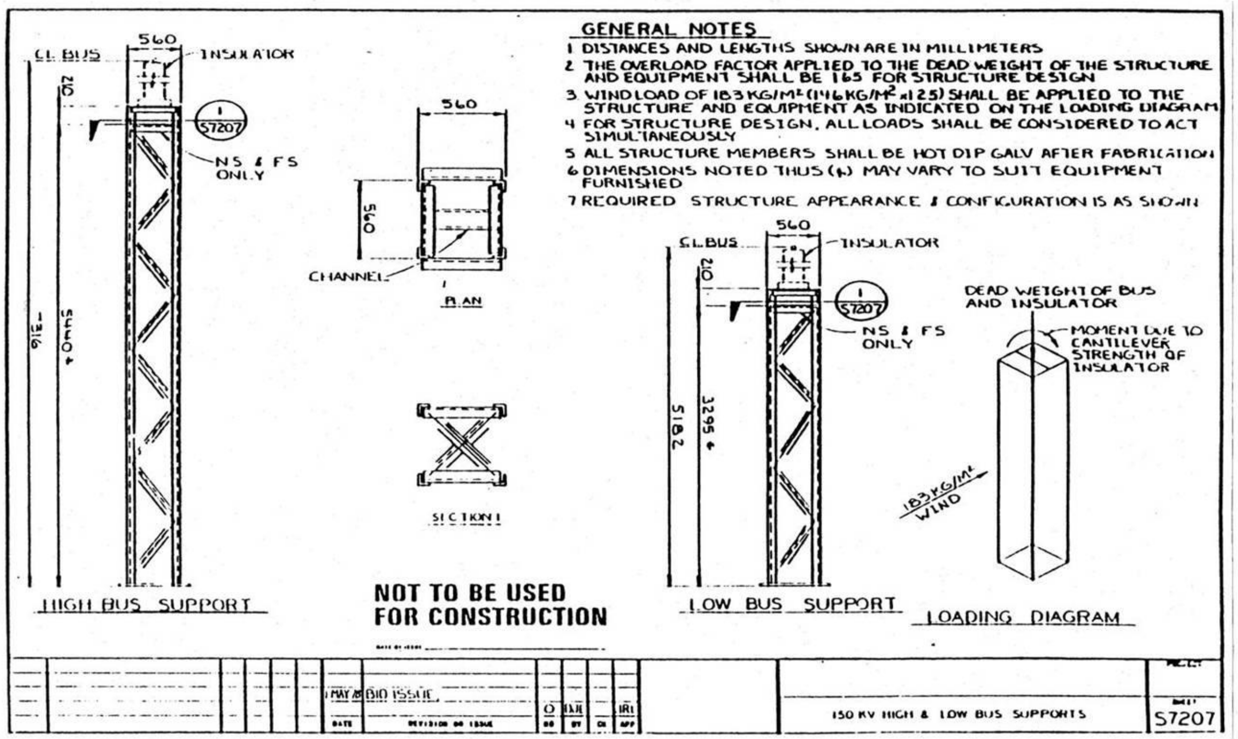


Structure Construction Type Selection

Lattice

- Angle Members
- Least Structure Weight
- Very Stable and Rigid
- Large Amount of Bolting and Erection Time

Structure Construction Type Selection



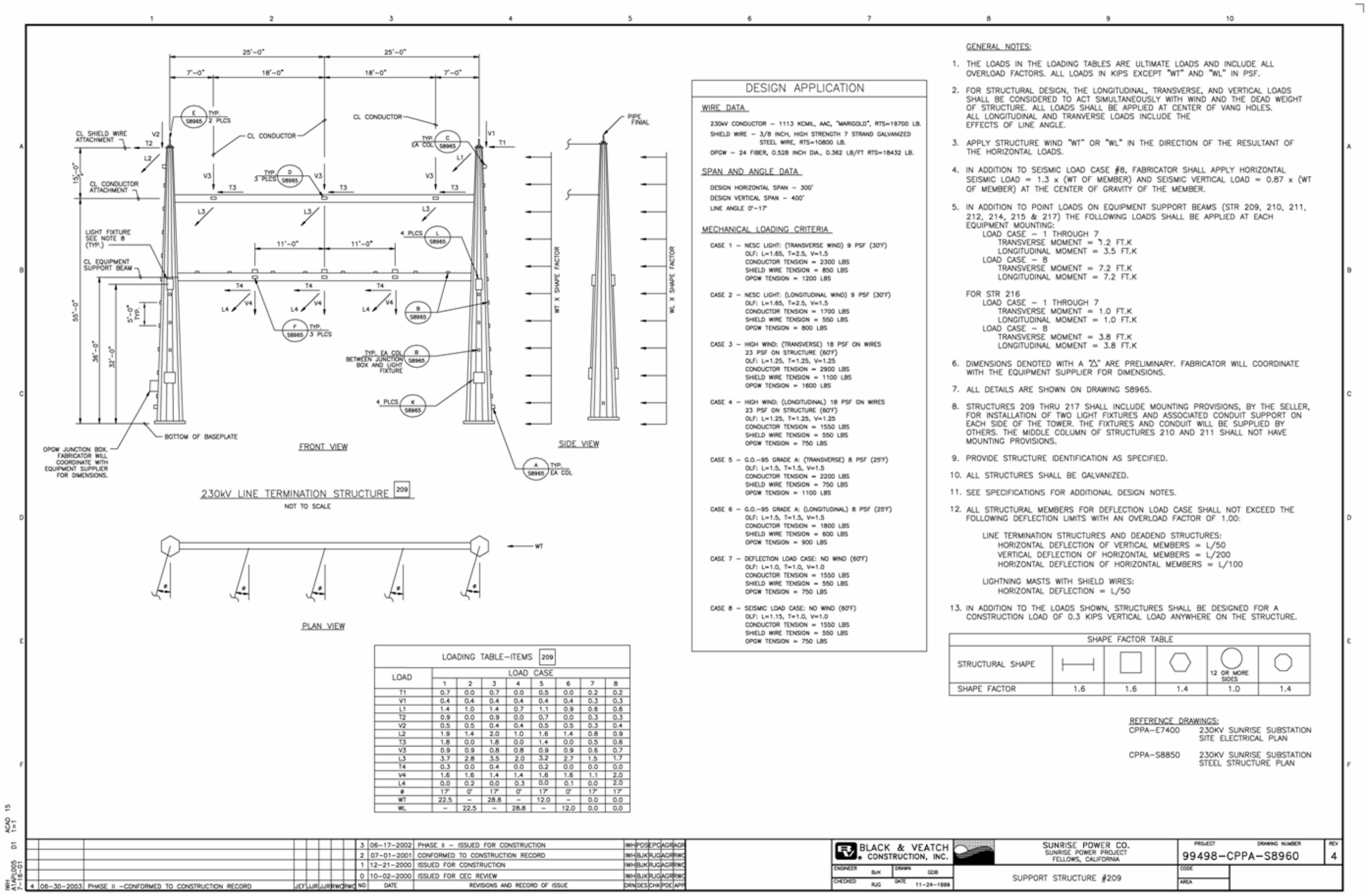
Lattice Structures

Structure Construction Type Selection

Tubular Steel

- Polygonal Shapes, Meaning With More Than Four Sides
- Common Shapes Are:
  - Octagon - Eight Sides
  - Dodecagon -Twelve Sides
- Short Erection Time
- Aesthetically Pleasing

Structure Construction Type Selection
Tubular Steel Shapes

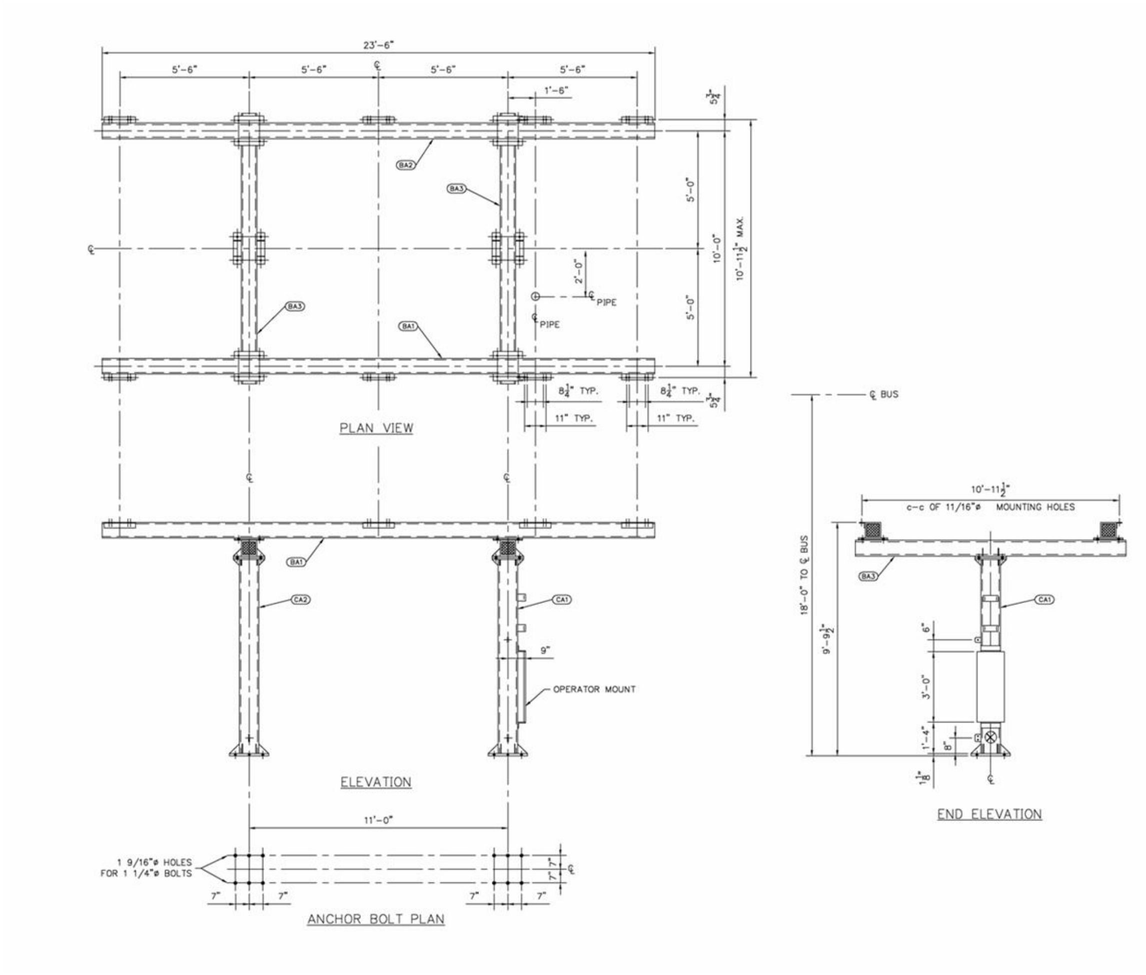


Structure Construction Type Selection

Standard Shapes

- Wide Flange, Channels, Pipes, Structural Tubing
- Short Erection Time
- Aesthetically Pleasing
- Most Sizes Readily Available

Standard Shape Switch Structure



Economic Considerations

- Design Costs
- Material Costs
- Fabrication Costs
- Delivery Costs
- Erection Costs

Field Considerations in Design

- Assembly
- Standardization
- Leveling Nuts
- Connection Details
- Venting of Galvanized Tubular Structures
- Grounding Ears vs. Tapped Holes

Design Methods

- The Working Stress Design Method by AISC in the "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings"
- The Yield Stress Design Method by American Society of Civil Engineers (ASCE)
  - Design of Latticed Steel Transmission Structures, ANSI/ASCE 10-90
  - Design of Steel Transmission Pole Structures Manual No. 72

Considerations

- Axial Loads
  - Tension
  - Compression
- Shear
- Bending
- Torsion
- Combined Stresses

Deflection

Class A: Those Structures Intended for the Support of High Voltage Equipment Which Requires Sufficient Rigidity for Proper Operation (i.e., Air Switches, etc.)

Description	Deflection Limit
Class A Structures	
Horizontal Deflection of Vertical Members	$\ell/100$
Vertical Deflection of Horizontal Members	$\ell/200$
Horizontal Deflection of Horizontal Members	$\ell/200$

Deflection

Class B: Those Structures on Which the Deflections Within the Limit Stated Do Not Affect the Performance of the Support Equipment (i.e., Bus Support, Line Termination Structures, etc.)

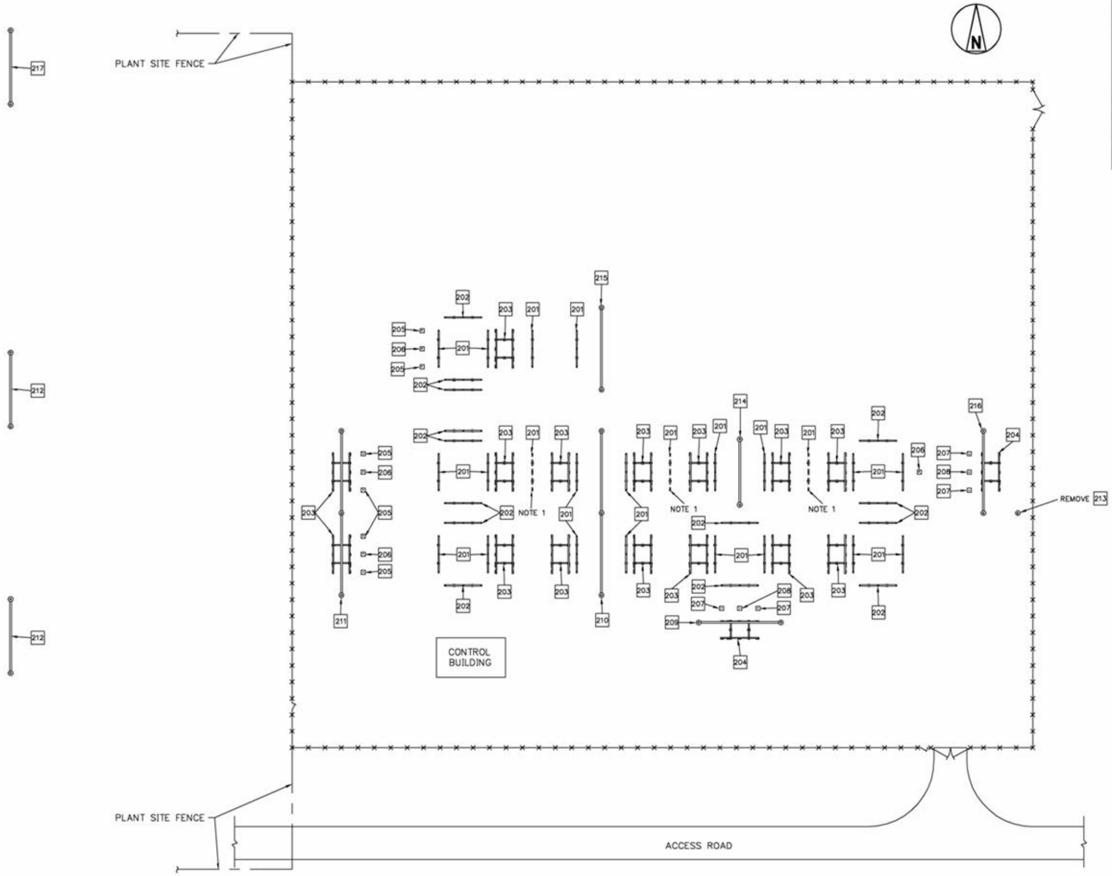
Description	Deflection Limit
Class B Structures	
Horizontal Deflection of Vertical Members	$\ell/50$
Vertical Deflection of Horizontal Members	$\ell/200$
Horizontal Deflection of Horizontal Members	$\ell/100$

Specification

- Codes/Standards
- Drawings/Calculations
- Materials
- Design
- Fabrication
- Welding
- Galvanizing/Painting
- Identification

STEEL STRUCTURE SCHEDULE

ITEM	PHASE I QTY	PHASE II QTY	DESCRIPTION	DWG. NO.
201	19	1	BUS SUPPORT, 3-PHASE, LOW-BUS	62268-CPPA-S8858
202	10	4	BUS SUPPORT, 3-PHASE, HIGH BUS	62268-CPPA-S8856
203	10	5	SWITCH STRUCTURE	62268-CPPA-S8852
204	1	1	SWITCH STRUCTURE, GROUNDING SWITCH	62268-CPPA-S8854
205	4	2	PT STAND, SINGLE PHASE	62268-CPPA-S8861
206	2	2	PT STAND, SINGLE PHASE, W/J-BOX	62268-CPPA-S8861
207	2	2	METER STAND, SINGLE PHASE	62268-CPPA-S8860
208	1	1	METER STAND, SINGLE PHASE, W/J-BOX	62268-CPPA-S8860
209	1	0	LINE TERMINATION STRUCTURE	99498-CPPA-S8950
210	1	0	DEADEND STRUCTURE	99498-CPPA-S8961
211	1	0	DEADEND STRUCTURE	99498-CPPA-S8962
212	2	0	TAKE-OFF STRUCTURE	99498-CPPA-S8963
213	1	0	SHIELD WIRE MAST	99498-CPPA-S8964
214	0	1	DEADEND STRUCTURE	99498-CPPA-S8966
215	0	1	DEADEND STRUCTURE	99498-CPPA-S8967
216	0	1	DEADEND STRUCTURE	99498-CPPA-S8968
217	0	1	TAKE OFF STRUCTURE	99498-CPPA-S8969



GENERAL NOTES:

1. THREE STRUCTURES (ITEM 201) SHALL BE REMOVED FROM CURRENT LOCATIONS AND RELOCATED TO NEW LOCATIONS

REFERENCE DRAWINGS:

CPPA-E7400 230KV SUNRISE SUBSTATION SITE ELECTRICAL PLAN

NO	DATE	REVISIONS AND RECORD OF ISSUE	DRN	DES	CHK	PDE	APP
5	06-30-2003	PHASE II -CONFORMED TO CONSTRUCTION RECORD	JEF	JJR	JJR	RWC	RWC
4	06-17-2002	PHASE II - ISSUED FOR CONSTRUCTION	IWH	IWH	EPC	AGR	AGR
3	07-01-2001	CONFORMED TO CONSTRUCTION RECORD	IWH	EPC	RJG	AGR	RWC
2	12-21-2000	ISSUED FOR CONSTRUCTION	IWH	EPC	RJG	AGR	RWC
1	02-11-2000	RELEASED FOR FABRICATION (SPEC. 63.4402)	IWH	EPC	RJG	AGR	RWC
0	11-24-1999	ISSUED FOR BID (SPEC. 63.4402)	IWH	EPC	RJG	AGR	

30' 15' 0 30' 60'
1"=30'

BLACK & VEATCH CONSTRUCTION, INC.

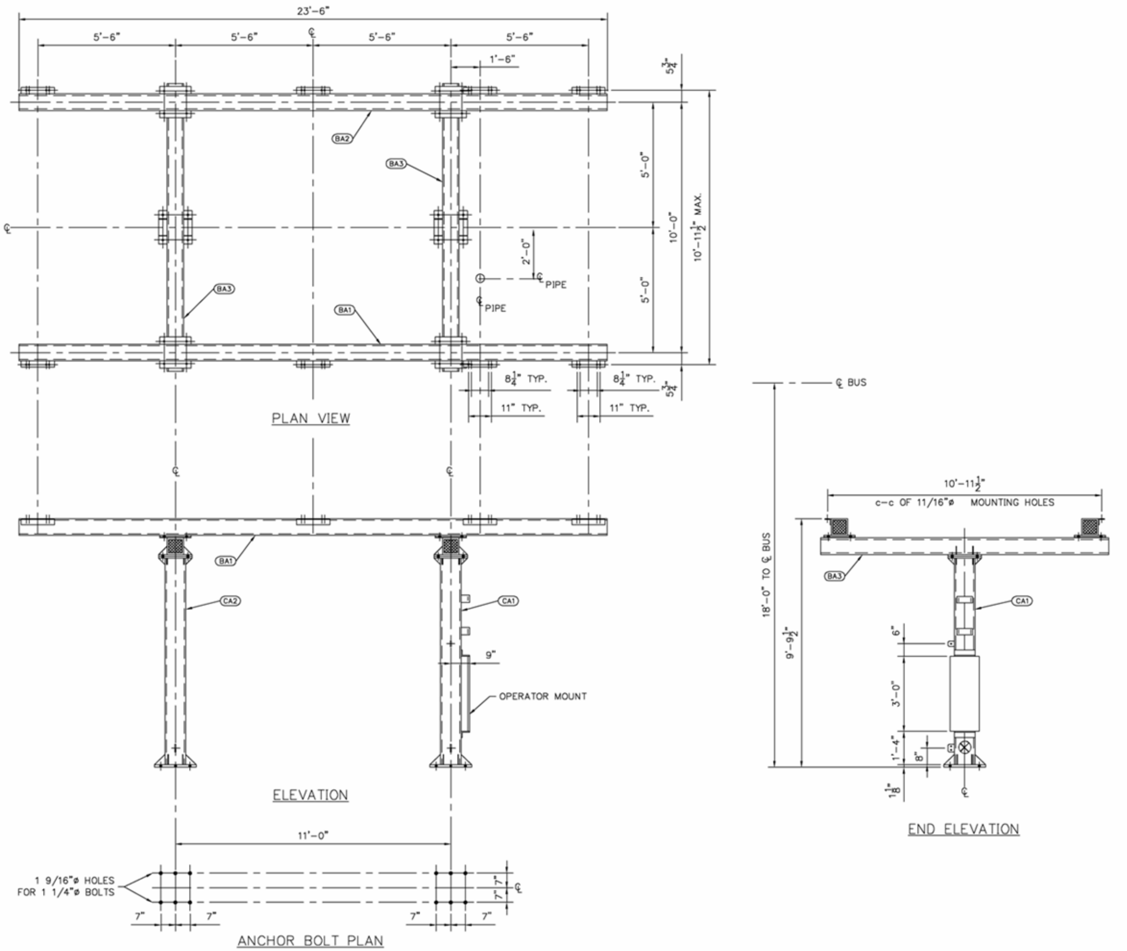
ENGINEER EPC | DRAWN IWH
CHECKED RJG | DATE 11-24-1999

SUNRISE POWER CO.
SUNRISE POWER PROJECT
FELLOWS, CALIFORNIA

STEEL STRUCTURE PLAN

PROJECT DRAWING NUMBER: 62268-CPPA-S8850
REV: 5
CODE
AREA

ACAD 15 1=1 D1 IWH A1APL005 6-29-01



ERECTION NOTES

1. ESTIMATED STRUCTURE WEIGHT – 3885 LBS.
2. ALL BOLTED CONNECTIONS SHALL BE 5/8" GALVANIZED A325 BOLTS WITH NUTS, LOCKING DEVICES AND WASHERS UNLESS NOTED.
3. ERECTION SHALL BE IN ACCORDANCE WITH SUNRISE PROJECT CONSTRUCTION SPECIFICATIONS.

FABRICATION NOTES:

1. FABRICATION & MATERIALS SHALL BE IN ACCORDANCE WITH SUNRISE PROJECT "SUBSTATION STRUCTURES AND EQUIPMENT" TECHNICAL REQUIREMENTS – SECTION 2A & 2B.
2. ALL HOLES SHALL BE 11/16" DIA. UNLESS NOTED.
3. EQUIPMENT MOUNTING DIMENSIONS SHOWN ARE BASED ON ASSUMED EQUIPMENT. THE STEEL FABRICATOR SHALL COORDINATE WITH EQUIPMENT SUPPLIER AND ADJUST MOUNTING AS REQUIRED FOR PURCHASED EQUIPMENT. <HAMBY YOUNG VERIFIED EQUIPMENT MOUNTING DIMENSIONS>
4. PROVIDE MOUNTING DETAILS FOR SWITCH OPERATOR, AUXILIARY SWITCH BRACKET, INTERLOCK MECHANISM BRACKET, AND CONDUIT BRACKETS BASED ON ACTUAL EQUIPMENT PURCHASED. (CA1 ONLY) <HAMBY YOUNG VERIFIED SWITCH MECHANISM DETAILS>
5. STAMP ALL GENERAL ASSEMBLIES WITH THE PROPER MK-NO. ON THE BASE PLATE OR CONNECTION PLATE. USE 1/2" DIE.

NO	DATE	REVISIONS AND RECORD OF ISSUE	DRN	DES	CHK	PDE	APP
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0	11-24-1999	ISSUED FOR BID (SPEC. 63.4402)	IWH	EPC	RJG	AGR	

1/2"=1'-0"

BLACK & VEATCH CONSTRUCTION, INC.

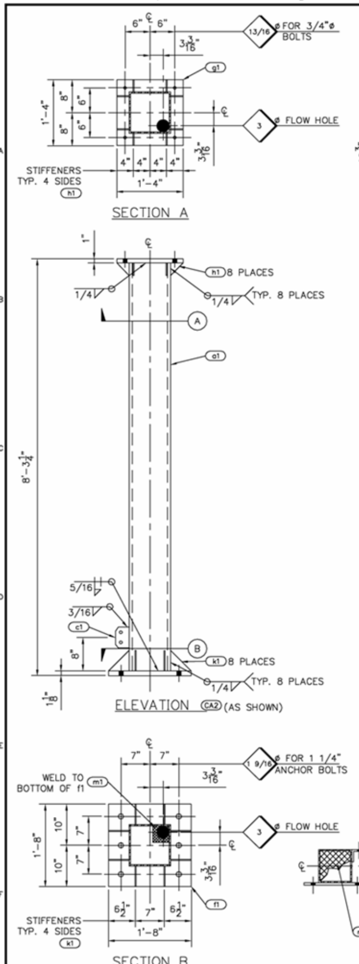
ENGINEER EPC | DRAWN IWH | CHECKED RJG | DATE 11-24-1999

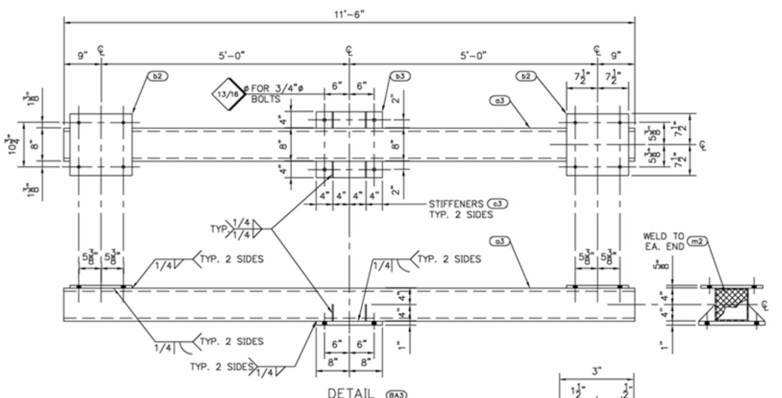
SUNRISE POWER CO.
SUNRISE POWER PROJECT
FELLOWS, CALIFORNIA

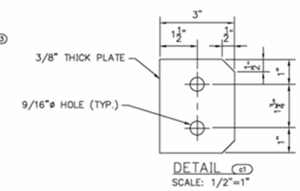
230KV SWITCH STRUCTURE WITHOUT GROUNDING SWITCH 203

PROJECT – DRAWING NUMBER: 62268-CPPA-S8852 | REV 5

ACAD 15 D1 1=1
IWH A1APL005 7-16-01





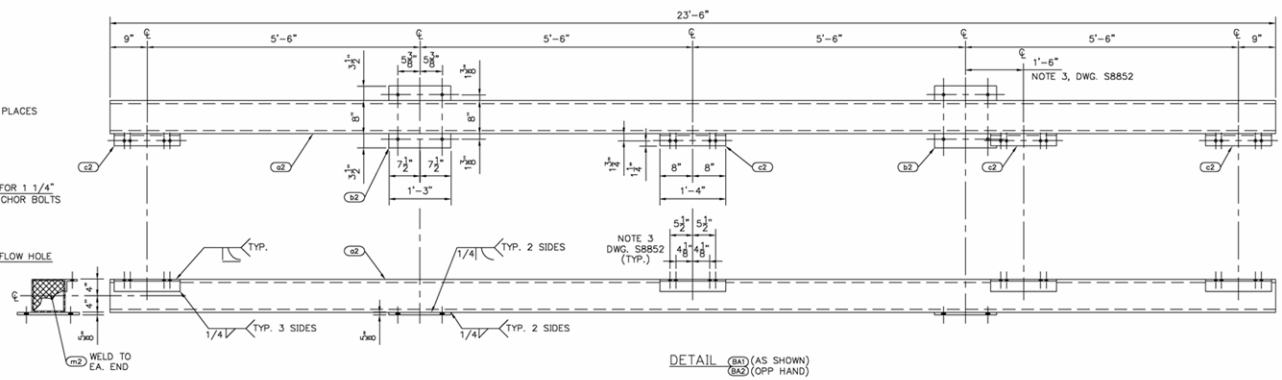


BILL OF MATERIAL

MK	PHASE I QTY	PHASE II QTY	DESCRIPTION		LENGTH FT	LENGTH INCHES	REMARKS
203	10	5		DISC. SW. STAND W/OUT GROUNDING SW.			MK(CA1, CA2, BA1, BA2, BA3)
CA2	1	1		COLUMN ASSEMBLY			QTY. FOR ONE CA2
a1	1	1	TS	10 x 10 x 5/16	8	1 1/8	
c1	1	1	PL	3/8 x 3	0	3 3/4	CLIP
f1	1	1	PL	1 1/8 x 20	1	8	
g1	1	1	PL	1 x 16	1	4	FIT TO b3
h1	8	8	PL	1/4 x 4	0	4	CLIP (STIFFENERS)
k1	8	8	PL	3/8 x 5	0	5	CLIP (STIFFENERS)
m1	1	1		1/2 x 16GA x 4	0	4	FLAT. EXP. METAL
BA1	1	1		BEAM ASSEMBLY			QTY. FOR ONE BA1
a2	1	1	TS	8 x 8 x 5/16	23	6	
b2	2	2	PL	5/8 x 15	1	3	
c2	4	4	L	3 x 3 x 7/16	1	4	NOTE 3, DWG. S8852
m2	2	2		1/2 x 16GA x 8	0	8	FLAT. EXP. METAL
BA2	1	1		BEAM ASSEMBLY			(OPPOSITE HAND) FOR ONE BA2
a2	1	1	TS	8 x 8 x 5/16	23	6	
b2	2	2	PL	5/8 x 15	1	3	
c2	4	4	L	3 x 3 x 1/2	1	4	NOTE 3, DWG. S8852
m2	2	2		1/2 x 16GA x 8	0	8	FLAT. EXP. METAL
BA3	2	2		BEAM ASSEMBLY			(QTY'S FOR TWO BA3)
a3	2	2	TS	8 x 8 x 1/4	11	6	SHOP WELD
b2	4	4	PL	5/8 x 15	1	3	INTO
b3	2	2	PL	1 x 16	1	4	FIT TO g1 — 2- BEAMS
c3	8	8	PL	1/4 x 4	0	4	CLIP (STIFFENERS) BA3
m2	4	4		1/2 x 16GA x 8	0	8	FLAT. EXP. METAL
	16	16	BOLT	5/8" DIA.			A325 W/ NUTS & WASHERS
	8	8	BOLT	3/4" DIA.			A325 W/ NUTS & WASHERS
	12	12	BOLT	1 1/4" DIA. ANCHOR			A307 W/ NUTS, WASHER, TEMPLATE

FABRICATION NOTES:

1. SEE FABRICATION NOTES ON DRAWING CPPA-S8852.



NO	DATE	REVISIONS AND RECORD OF ISSUE	DRN	DES	CHK	PDE	APP
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0	11-24-1999	ISSUED FOR BID (SPEC. 63.4402)	IWH	EPC	RJG	AGR	

1"=1'-0"

BLACK & VEATCH CONSTRUCTION, INC.

ENGINEER EPC DRAWN IWH
CHECKED RJG DATE 11-24-1999

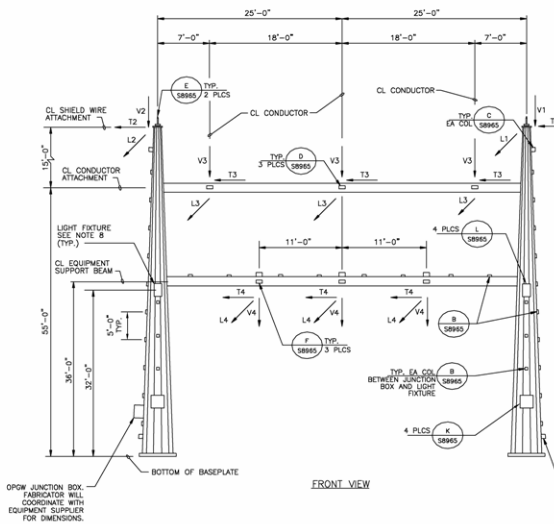
SUNRISE POWER CO.
SUNRISE POWER PROJECT
FELLOWS, CALIFORNIA

230KV SWITCH STRUCTURE WITHOUT GROUNDING SWITCH 203

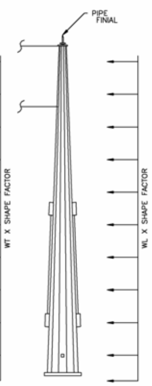
PROJECT DRAWING NUMBER 62268-CPPA-S8853 REV 5

CODE
AREA

IWH A1APL005 4-16-01 D1 ACAD 15 1=1



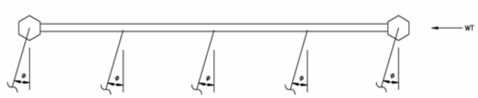
FRONT VIEW



SIDE VIEW

230kV LINE TERMINATION STRUCTURE 209

NOT TO SCALE



PLAN VIEW

LOADING TABLE-ITEMS 209								
LOAD	LOAD CASE							
	1	2	3	4	5	6	7	8
T1	0.7	0.0	0.7	0.0	0.5	0.0	0.2	0.2
V1	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3
L1	1.4	1.0	1.4	0.7	1.1	0.9	0.6	0.6
T2	0.9	0.0	0.9	0.0	0.7	0.0	0.3	0.3
V2	0.5	0.5	0.4	0.4	0.5	0.5	0.3	0.4
L2	1.9	1.4	2.0	1.0	1.6	1.4	0.8	0.9
T3	1.8	0.0	1.8	0.0	1.4	0.0	0.5	0.6
V3	0.9	0.9	0.8	0.8	0.9	0.9	0.6	0.7
L3	3.7	2.8	3.5	2.0	3.2	2.7	1.5	1.7
T4	0.3	0.0	0.4	0.0	0.2	0.0	0.0	0.0
V4	1.6	1.6	1.4	1.4	1.6	1.6	1.1	2.0
L4	0.0	0.2	0.0	0.3	0.0	0.1	0.0	2.0
ø	17°	0°	17°	0°	17°	0°	17°	17°
WT	22.5	–	28.8	–	12.0	–	0.0	0.0
WL	–	22.5	–	28.8	–	12.0	0.0	0.0

DESIGN APPLICATION

WIRE DATA

230kV CONDUCTOR – 1113 KCMIL, AAC, "MARIGOLD", RTS=19700 LB.

SHIELD WIRE – 3/8 INCH, HIGH STRENGTH 7 STRAND GALVANIZED STEEL WIRE, RTS=10800 LB.

OPGW – 24 FIBER, 0.528 INCH DIA., 0.362 LB/FT RTS=18432 LB.

SPAN AND ANGLE DATA

DESIGN HORIZONTAL SPAN – 300'

DESIGN VERTICAL SPAN – 400'

LINE ANGLE 0°–17°

MECHANICAL LOADING CRITERIA

CASE 1 – NESC LIGHT: (TRANSVERSE WIND) 9 PSF (30°F)
OLF: L=1.65, T=2.5, V=1.5
CONDUCTOR TENSION = 2300 LBS
SHIELD WIRE TENSION = 850 LBS
OPGW TENSION = 1200 LBS

CASE 2 – NESC LIGHT: (LONGITUDINAL WIND) 9 PSF (30°F)
OLF: L=1.65, T=2.5, V=1.5
CONDUCTOR TENSION = 1700 LBS
SHIELD WIRE TENSION = 550 LBS
OPGW TENSION = 800 LBS

CASE 3 – HIGH WIND: (TRANSVERSE) 18 PSF ON WIRES
23 PSF ON STRUCTURE (60°F)
OLF: L=1.25, T=1.25, V=1.25
CONDUCTOR TENSION = 2900 LBS
SHIELD WIRE TENSION = 1100 LBS
OPGW TENSION = 1600 LBS

CASE 4 – HIGH WIND: (LONGITUDINAL) 18 PSF ON WIRES
23 PSF ON STRUCTURE (60°F)
OLF: L=1.25, T=1.25, V=1.25
CONDUCTOR TENSION = 1550 LBS
SHIELD WIRE TENSION = 550 LBS
OPGW TENSION = 750 LBS

CASE 5 – G.O.–95 GRADE A: (TRANSVERSE) 8 PSF (25°F)
OLF: L=1.5, T=1.5, V=1.5
CONDUCTOR TENSION = 2200 LBS
SHIELD WIRE TENSION = 750 LBS
OPGW TENSION = 1100 LBS

CASE 6 – G.O.–95 GRADE A: (LONGITUDINAL) 8 PSF (25°F)
OLF: L=1.5, T=1.5, V=1.5
CONDUCTOR TENSION = 1800 LBS
SHIELD WIRE TENSION = 600 LBS
OPGW TENSION = 900 LBS

CASE 7 – DEFLECTION LOAD CASE: NO WIND (60°F)
OLF: L=1.0, T=1.0, V=1.0
CONDUCTOR TENSION = 1550 LBS
SHIELD WIRE TENSION = 550 LBS
OPGW TENSION = 750 LBS

CASE 8 – SEISMIC LOAD CASE: NO WIND (60°F)
OLF: L=1.15, T=1.0, V=1.0
CONDUCTOR TENSION = 1550 LBS
SHIELD WIRE TENSION = 550 LBS
OPGW TENSION = 750 LBS

GENERAL NOTES:

1. THE LOADS IN THE LOADING TABLES ARE ULTIMATE LOADS AND INCLUDE ALL OVERLOAD FACTORS. ALL LOADS IN KIPS EXCEPT "WT" AND "WL" IN PSF.
2. FOR STRUCTURAL DESIGN, THE LONGITUDINAL, TRANSVERSE, AND VERTICAL LOADS SHALL BE CONSIDERED TO ACT SIMULTANEOUSLY WITH WIND AND THE DEAD WEIGHT OF STRUCTURE. ALL LOADS SHALL BE APPLIED AT CENTER OF VANG HOLES. ALL LONGITUDINAL AND TRANVERSE LOADS INCLUDE THE EFFECTS OF LINE ANGLE.
3. APPLY STRUCTURE WIND "WT" OR "WL" IN THE DIRECTION OF THE RESULTANT OF THE HORIZONTAL LOADS.
4. IN ADDITION TO SEISMIC LOAD CASE #8, FABRICATOR SHALL APPLY HORIZONTAL SEISMIC LOAD = 1.3 x (WT OF MEMBER) AND SEISMIC VERTICAL LOAD = 0.87 x (WT OF MEMBER) AT THE CENTER OF GRAVITY OF THE MEMBER.
5. IN ADDITION TO POINT LOADS ON EQUIPMENT SUPPORT BEAMS (STR 209, 210, 211, 212, 214, 215 & 217) THE FOLLOWING LOADS SHALL BE APPLIED AT EACH EQUIPMENT MOUNTING:
   LOAD CASE – 1 THROUGH 7
   TRANSVERSE MOMENT = 1.2 FT.K
   LONGITUDINAL MOMENT = 3.5 FT.K
   LOAD CASE – 8
   TRANSVERSE MOMENT = 7.2 FT.K
   LONGITUDINAL MOMENT = 7.2 FT.K

   FOR STR 216
   LOAD CASE – 1 THROUGH 7
   TRANSVERSE MOMENT = 1.0 FT.K
   LONGITUDINAL MOMENT = 1.0 FT.K
   LOAD CASE – 8
   TRANSVERSE MOMENT = 3.8 FT.K
   LONGITUDINAL MOMENT = 3.8 FT.K
6. DIMENSIONS DENOTED WITH A "△" ARE PRELIMINARY. FABRICATOR WILL COORDINATE WITH THE EQUIPMENT SUPPLIER FOR DIMENSIONS.
7. ALL DETAILS ARE SHOWN ON DRAWING S8965.
8. STRUCTURES 209 THRU 217 SHALL INCLUDE MOUNTING PROVISIONS, BY THE SELLER, FOR INSTALLATION OF TWO LIGHT FIXTURES AND ASSOCIATED CONDUIT SUPPORT ON EACH SIDE OF THE TOWER. THE FIXTURES AND CONDUIT WILL BE SUPPLIED BY OTHERS. THE MIDDLE COLUMN OF STRUCTURES 210 AND 211 SHALL NOT HAVE MOUNTING PROVISIONS.
9. PROVIDE STRUCTURE IDENTIFICATION AS SPECIFIED.
10. ALL STRUCTURES SHALL BE GALVANIZED.
11. SEE SPECIFICATIONS FOR ADDITIONAL DESIGN NOTES.
12. ALL STRUCTURAL MEMBERS FOR DEFLECTION LOAD CASE SHALL NOT EXCEED THE FOLLOWING DEFLECTION LIMITS WITH AN OVERLOAD FACTOR OF 1.00:

    LINE TERMINATION STRUCTURES AND DEADEND STRUCTURES:
    HORIZONTAL DEFLECTION OF VERTICAL MEMBERS = L/50
    VERTICAL DEFLECTION OF HORIZONTAL MEMBERS = L/200
    HORIZONTAL DEFLECTION OF HORIZONTAL MEMBERS = L/100

    LIGHTNING MASTS WITH SHIELD WIRES:
    HORIZONTAL DEFLECTION = L/50
13. IN ADDITION TO THE LOADS SHOWN, STRUCTURES SHALL BE DESIGNED FOR A CONSTRUCTION LOAD OF 0.3 KIPS VERTICAL LOAD ANYWHERE ON THE STRUCTURE.

SHAPE FACTOR TABLE					
STRUCTURAL SHAPE				12 OR MORE SIDES	
SHAPE FACTOR	1.6	1.6	1.4	1.0	1.4

REFERENCE DRAWINGS:

CPPA-E7400 230KV SUNRISE SUBSTATION SITE ELECTRICAL PLAN

CPPA-S8850 230KV SUNRISE SUBSTATION STEEL STRUCTURE PLAN

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0	10-02-2000	ISSUED FOR CEC REVIEW	IWH	BJK	RJG	AGR	RWC

BLACK & VEATCH CONSTRUCTION, INC.

ENGINEER BJK DRAWN GDB
CHECKED RJG DATE 11-24-1999

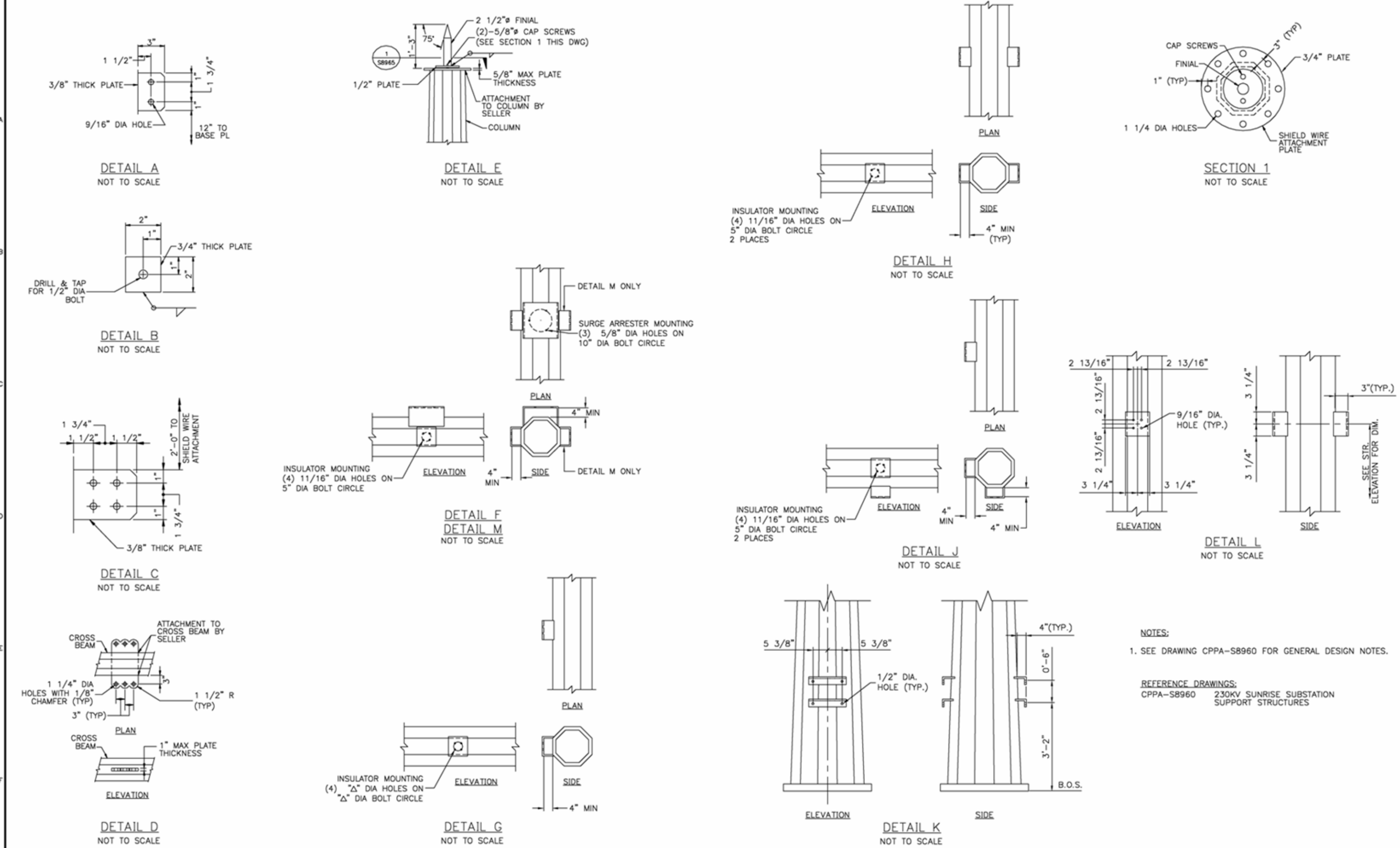
SUNRISE POWER CO.
SUNRISE POWER PROJECT
FELLOWS, CALIFORNIA

SUPPORT STRUCTURE #209

PROJECT DRAWING NUMBER 99498–CPPA–S8960 REV 4

CODE
AREA

IWH A1APL005 7-16-01 D1 ACAD 15 1=1



NOTES:

1. SEE DRAWING CPPA-S8960 FOR GENERAL DESIGN NOTES.

REFERENCE DRAWINGS:

CPPA-S8960 230KV SUNRISE SUBSTATION SUPPORT STRUCTURES

NO	DATE	REVISIONS AND RECORD OF ISSUE	DRN	DES	CHK	PDE	APP
4	06-30-2003	PHASE II -CONFORMED TO CONSTRUCTION RECORD	JEF	JJR	JJR	RWC	RWC
3	06-17-2002	PHASE II – ISSUED FOR CONSTRUCTION	IWH	PDS	EPC	AGR	AGR
2	06-05-2001	CONFORMED TO CONSTRUCTION RECORD	IWH	BJK	RJG	AGR	RWC
1	12-21-2000	ISSUED FOR CONSTRUCTION	IWH	BJK	RJG	AGR	RWC
0	10-02-2000	ISSUED FOR CEC REVIEW	IWH	BJK	RJG	AGR	RWC

BLACK & VEATCH CONSTRUCTION, INC.

SUNRISE POWER CO.
SUNRISE POWER PROJECT
FELLOWS, CALIFORNIA

SUPPORT STRUCTURE DETAILS

ENGINEER BJK | DRAWN GDB | CHECKED RJG | DATE 11-24-1999

PROJECT 99498 – DRAWING NUMBER CPPA-S8965 – REV 4

CODE | AREA

ACAD 15 1=1 D1 IWH A1APL005 7-16-01

Ground Grid Design

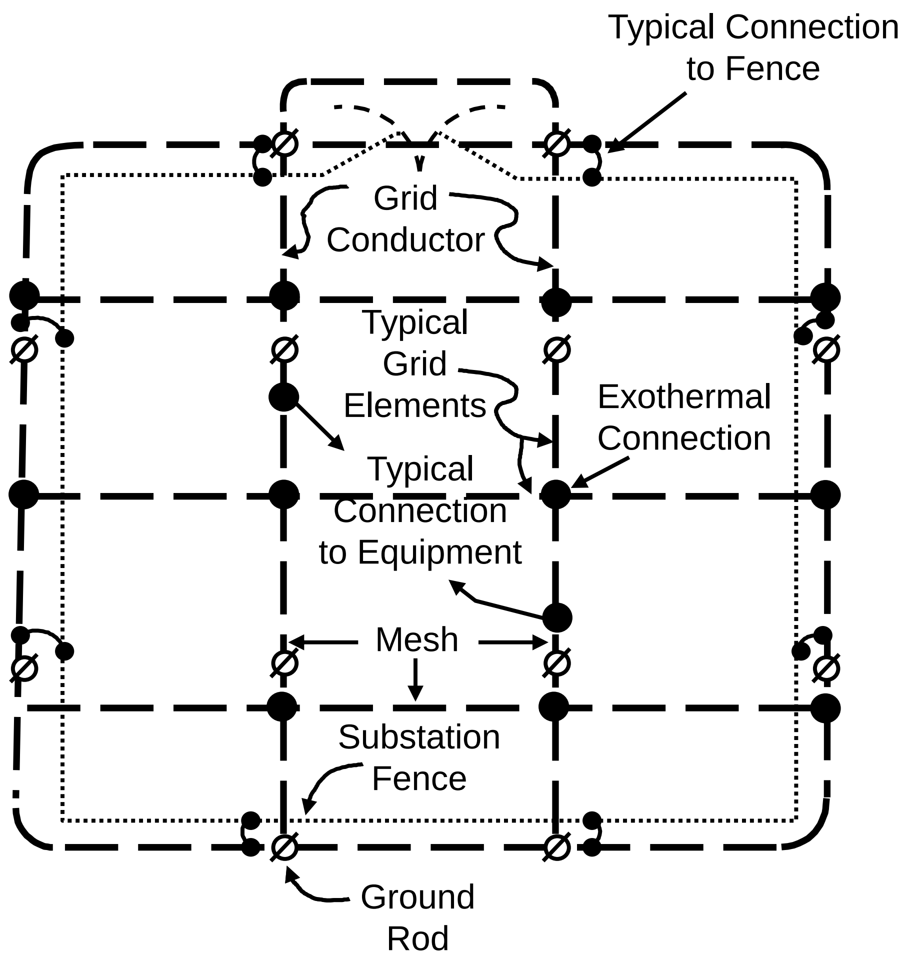
Grounding Objectives

1. Assure that persons in or near any substation are not exposed to electric shock **above tolerable limits**.
2. Provide means to dissipate normal and abnormal electric currents into the earth **without exceeding** any **operating** or **equipment limits**.

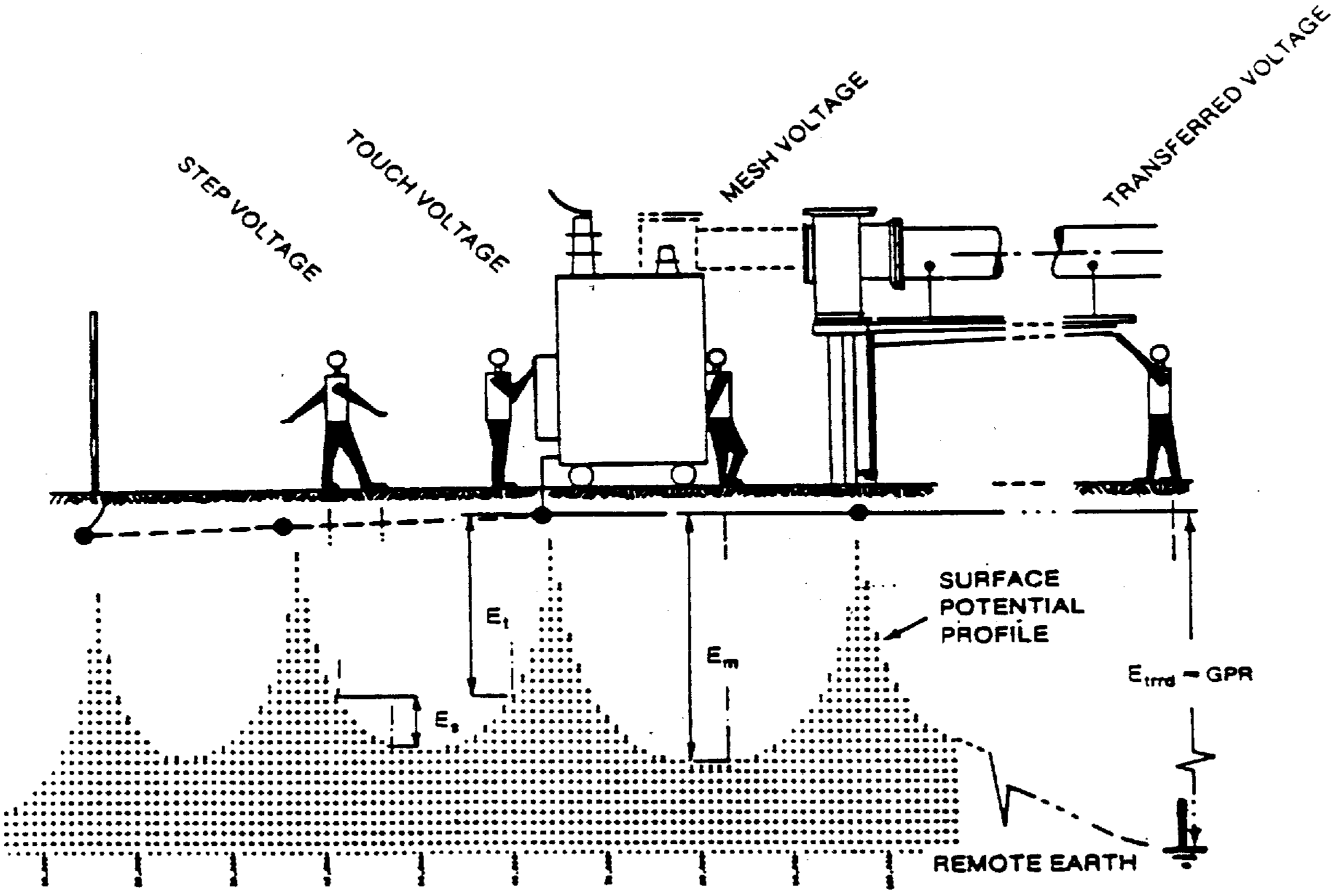
Causes of Electric Shock

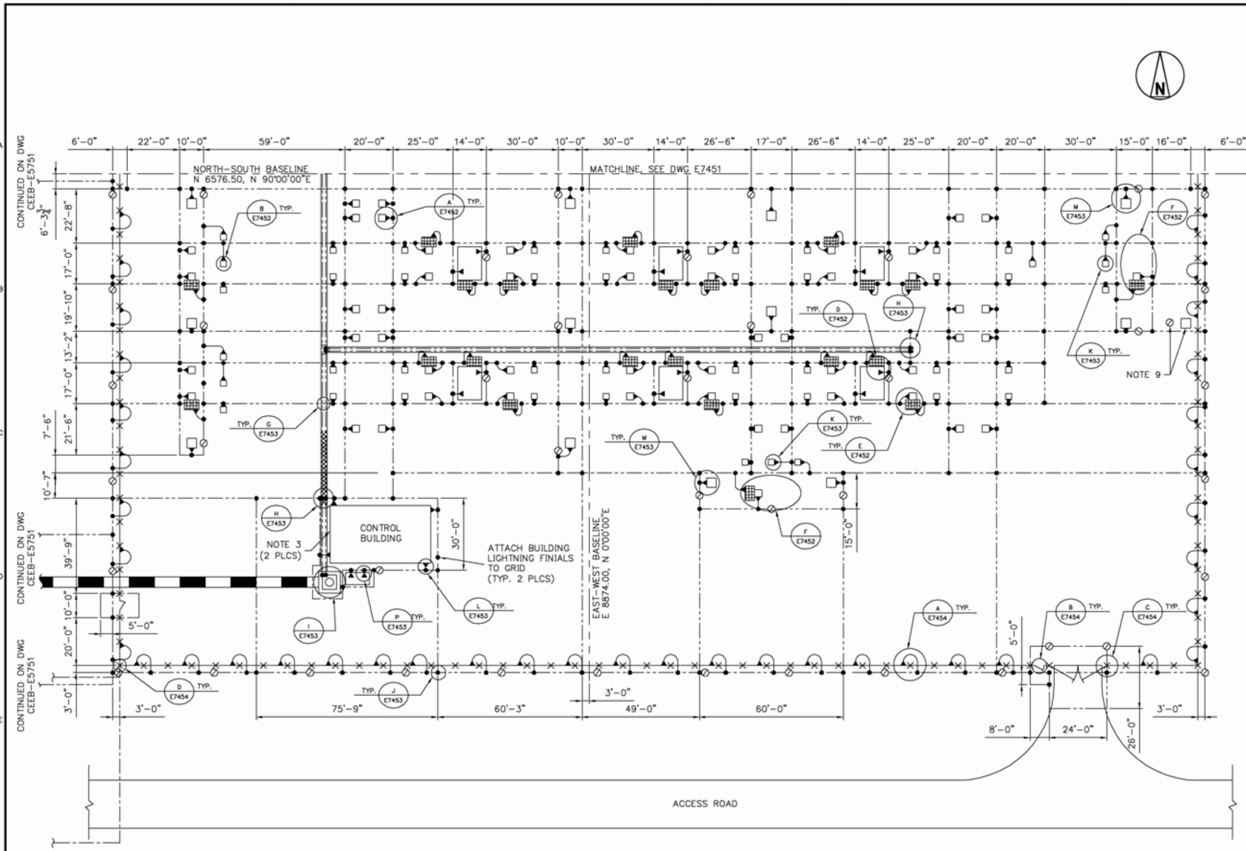
1. High fault current to ground
2. Soil resistivity and distribution of ground currents
3. Body bridging two points of high potential difference
4. Absence of sufficient contact resistance
5. Duration of the fault and body contact

Grounding Grid (based on IEEE-80)



Basic Shock Situations





LEGEND:

- CABLE TRENCH
- DRIVEABLE CABLE TRENCH
- MANHOLE 7' x 7' (9' x 9' OUTSIDE DIM.)
- 3/4" x 20' COPPER-CLAD STEEL GROUNDING ROD
- 4/0 AWG STRANDED COPPER GROUND CONDUCTOR
- 4/0 AWG STRANDED COPPER GROUND STINGER
- EXOTHERMAL WELD
- SWITCH OPERATOR SAFETY MAT
- PLANT SITE FENCE
- SUBSTATION FENCE
- DUCT BANK

GENERAL NOTES:

1. CONTRACTOR SHALL INSTALL GROUND GRID 24" BELOW FINISHED GRADE.
2. CONTRACTOR SHALL COORDINATE STINGER STUB-UP LOCATION WITH STRUCTURES. ALL GROUNDING STINGERS SHALL BE CUT 3'-0" ABOVE FINISHED GRADE AND LEFT FOR ABOVE GRADE CONSTRUCTION.
3. ROUTE 4/0 AWG GROUND CONDUCTOR THROUGH CABLE RISER FROM CABLE TRENCH AND INTO CONTROL BUILDING FOR TERMINAL BOARD CABINET (TBC) GROUNDING.
4. GROUND STATION FENCE TO GRID EVERY 20'-0" MAX. FENCE SHALL BE GROUNDED AT ALL CORNER POSTS AND GATE POSTS. SEE DRAWING CPPA-E7454 (FENCE GROUNDING DETAILS).
5. SEE DRAWING CPPA-E7453 FOR SURGE ARRESTER GROUNDING DETAIL.
6. SUBSTATION GROUND GRID SHALL EXTEND 3'-0" BEYOND FENCE.
7. FINISHED GRADE SHALL INCLUDE 6" OF CRUSHED, WASHED, 1/2"-3/4" ROCK. FINISHED GRADE SHALL EXTEND 3'-0" BEYOND THE SUBSTATION FENCE.
8. SEE DRAWING CPPA-E7452 – DETAIL "A" – FOR PLANT YARD DEADEND GROUNDING.
9. ABANDON FOUNDATION. REMOVE AND RECYCLE GROUND STINGERS. ABANDON GROUNDING ROD.

REFERENCE DRAWINGS:

CPPA-E7451	230KV SUNRISE SUBSTATION GROUNDING PLAN SH. 2
CPPA-E7452	230KV SUNRISE SUBSTATION GROUNDING DETAILS SH. 1
CPPA-E7453	230KV SUNRISE SUBSTATION GROUNDING DETAILS SH. 2
CPPA-E7454	230KV SUNRISE SUBSTATION FENCE GROUNDING DETAILS
CPPA-E7455	230KV SUNRISE SUBSTATION GROUNDING MATERIALS LIST

ACAD 15 1=1
D1
IWH A1APL005 10-19-01

NO	DATE	REVISIONS AND RECORD OF ISSUE	DRN	DES	CHK	PDE	APP
4	06-30-2003	PHASE II – CONFORMED TO CONSTRUCTION RECORD	JEF	JJR	ALL	RWC	RWC
3	06-17-2002	PHASE II – ISSUED FOR CONSTRUCTION	IWH	IWH	PTS	RWC	RWC
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1	12-21-2000	ISSUED FOR CONSTRUCTION	IWH	IWH	JTH	RWC	RWC
0	10-02-2000	ISSUED FOR CEC REVIEW	IWH	IWH	JTH	RWC	RWC

20' 10' 0 20' 40'
1"=20'

BLACK & VEATCH CONSTRUCTION, INC.
ENGINEER RWC | DRAWN IWH
CHECKED JTH | DATE 02-10-2000

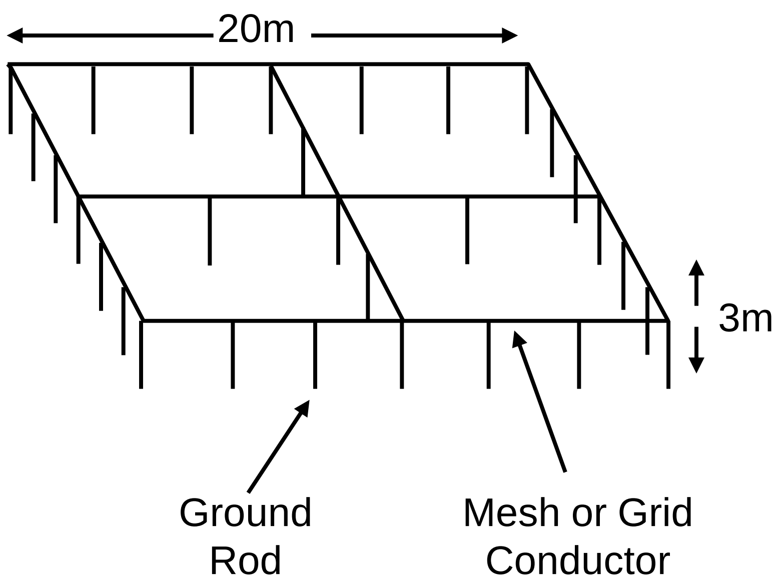
SUNRISE POWER CO.
SUNRISE POWER PROJECT
FELLOWS, CALIFORNIA

GROUNDING PLAN SH. 1

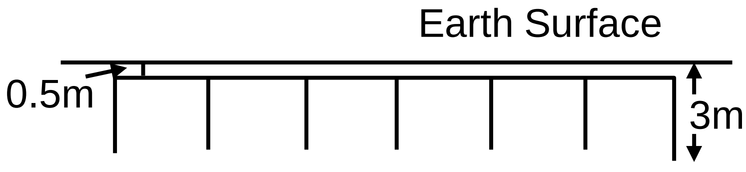
PROJECT 99498 | DRAWING NUMBER CPPA-E7450 | REV 4
CODE
AREA

Exothermic Weld Process

Simple Grounding System



3-D View



Side View

Field Data

- Soil Structure
- Proposed Substation Ground Grid Layout
- Symmetrical Ground Fault Current e.g. 40 kA
- Fault Duration e.g. 0.25 seconds
- Soil Resistivity e.g. 150 ohm-meters uniform
- Crushed Wet Rock Resistivity e.g. 3000 ohm-meters
- Crushed Rock Layer Thickness e.g. 0.5 ft
- Ties to Other Grids
- Shield Wires/Underground Cables

Soil Structure

Methods of Soil Resistivity Measurement

- Geological Information and Soil Samples
- Variation of Depth Method
- Four-Point Method
  - Wenner Arrangement

Typical Resistivity Values

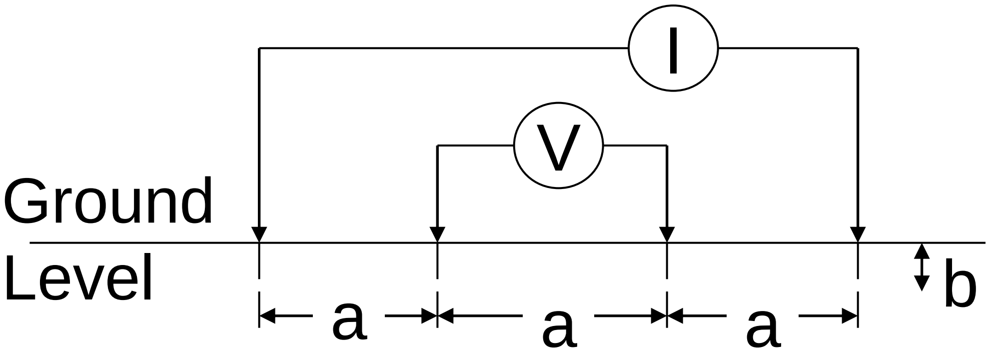
TYPE	MATERIAL	RESISTIVITY Ω-m
REFINED METALS	Silver	1.5×10^{-8}
	Copper	1.6×10^{-8}
	Gold	2.0×10^{-8}
	Aluminum	2.5×10^{-8}
	Sodium	4.3×10^{-8}
	Zinc	5.5×10^{-8}
	Lithium	8.5×10^{-8}
	Iron	$9. \times 10^{-8}$
	Lead	$19. \times 10^{-8}$
	Bismuth	$100. \times 10^{-8}$
NATIVE MINERALS	Copper	1.2×10^{-8} to 30×10^{-8}
	Graphite depending on direction of current flow with respect to cleavage	28×10^{-8} to 99×10^{-4}
SEMI-CONDUCTING MINERALS	(PBS) Galena	0.3×10^{-6} to 50×10^{-8}
	(FeS) Pyrite	1.2×10^{-3} to 600×10^{-3}
	(MoS) Molybdenite	0.08 to 7.5
	(CU 0) Cuprite	10 to 50
	(Fe 0) Magnetite	52×10^{-6}
	(CUO) Malaconite	6000

TYPE	MATERIAL	RESISTIVITY Ω-m
WATER	Chemiccally clean water	25×10^{4}
	Distilled water	5000
	Rain water	100 to 1000
	Surface water (lake, rivers)	100 to 500
	Ground water, well and spring water	10 to 150
	Sea water	0.1 to 1
SOILS TYPICAL VALUES	Loams, garden soils	5 to 50
	Clay, chalk	10 to 70
	Clay, sand & gravel mixtures	40 to 250
	Peat, marsh soil & cultivated soil	50 to 250
	Diabase, shale, limestone & sandstone	100 to 500
	Sand, cambrian limestone & sandstone	1×10^{3} to 3×10^{3}
	Moraine, quaternary surface coarse sand & gravel	1×10^{3} to 1×10^{4}
	Igneous, rocks granite	3×10^{5} to 4×10^{7}
	Wet concrete	50 to 100
	Dry concrete	2×10^{3} to 1×10^{4}

**Note : The large range in values are due to the variations in the composition of the materials.*

Soil Resistivity Measurement

Wenner Four Point Arrangement



$$\rho_a = \frac{4\pi a R}{1 + \frac{2a}{\sqrt{a^2 + 4b^2}} - \frac{a}{\sqrt{a^2 + b^2}}}$$

If $b \leq 0.1a$, *then it is assumed that* $b = 0$ *and* $\rho = 2\pi a R$

Touch and Step Criteria

Body Resistance

Assumptions:

1. Hand and foot contact resistances are equal to zero
2. Glove and shoe resistances are equal to zero
3. R_B = 1000Ω representing the resistance of a human body from hand-to-feet and also hand-to-hand, or from one foot to the other foot

Body Current Threshold

Effect of Magnitude and Duration

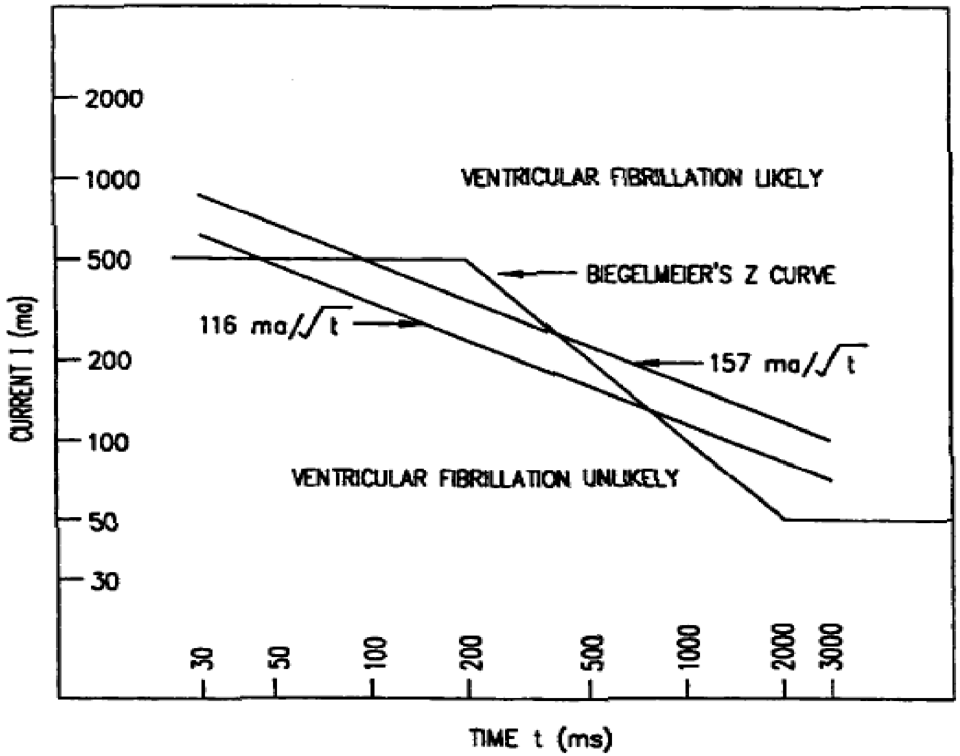


Figure 5—Body current versus time

Maximum Grid Current

Current Division (Split) Factor

Assumptions

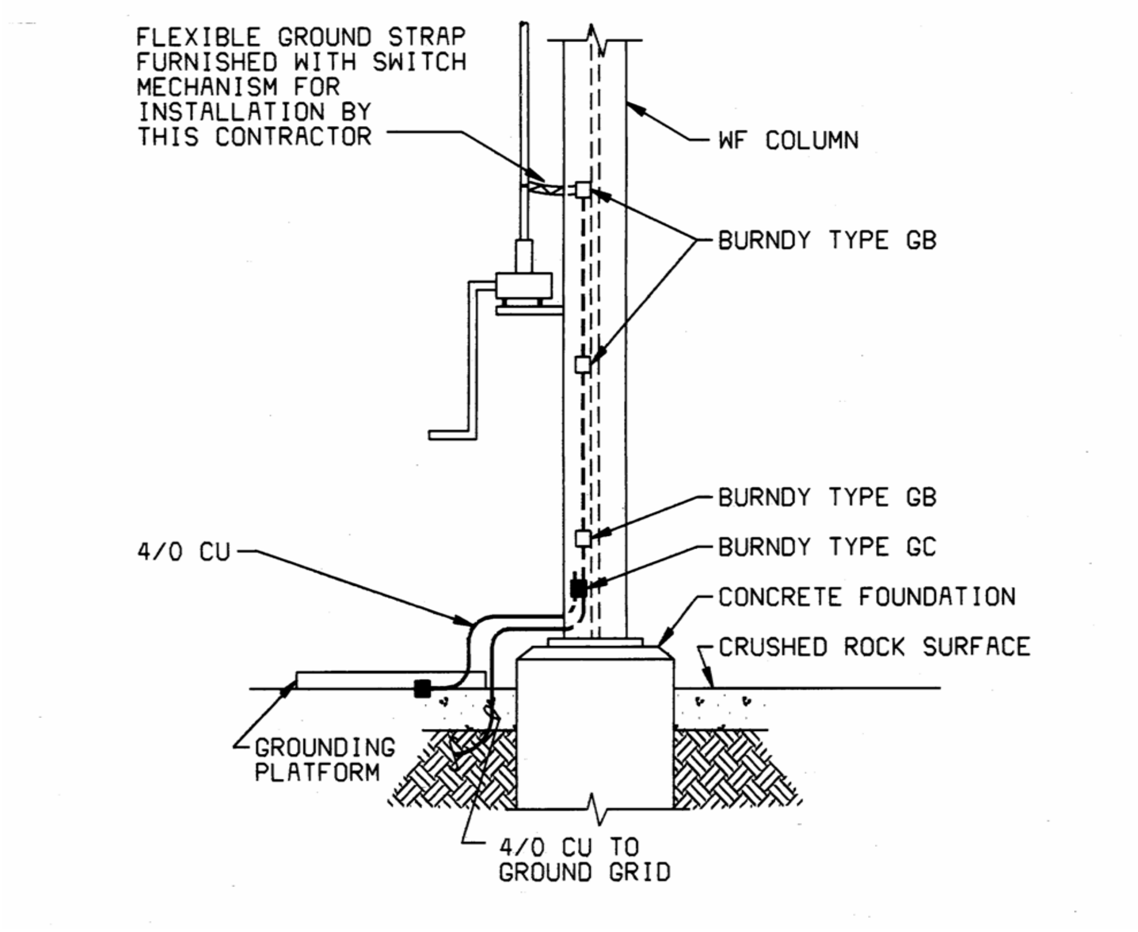
1. Grounding Grid Resistance
2. Remote Fault Contribution
3. Transmission Tower Footing Resistance
4. Feeder Tower Footing Resistance
5. The Number of Transmission Lines

Substation Grounding System Design

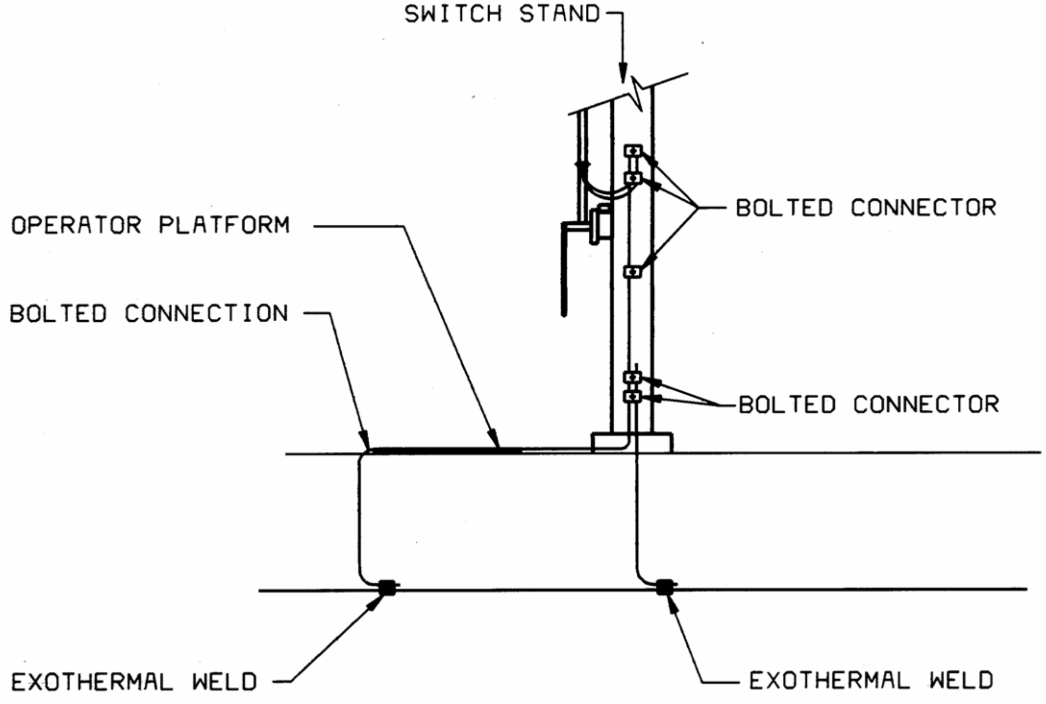
Design Modifications/Remedial Actions for Unsafe Areas

- Additional Copper
- Increase Number of Ground Rods
- Increase Ground Rod Lengths
- Surface Treatment
- Reduce Clearing Time - Faster Relays
- Installation of Ground Wells

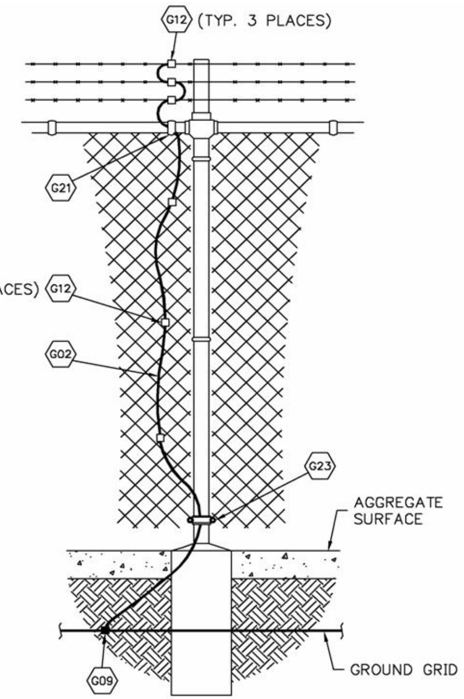
Typical Manual Operated Switch Grounding



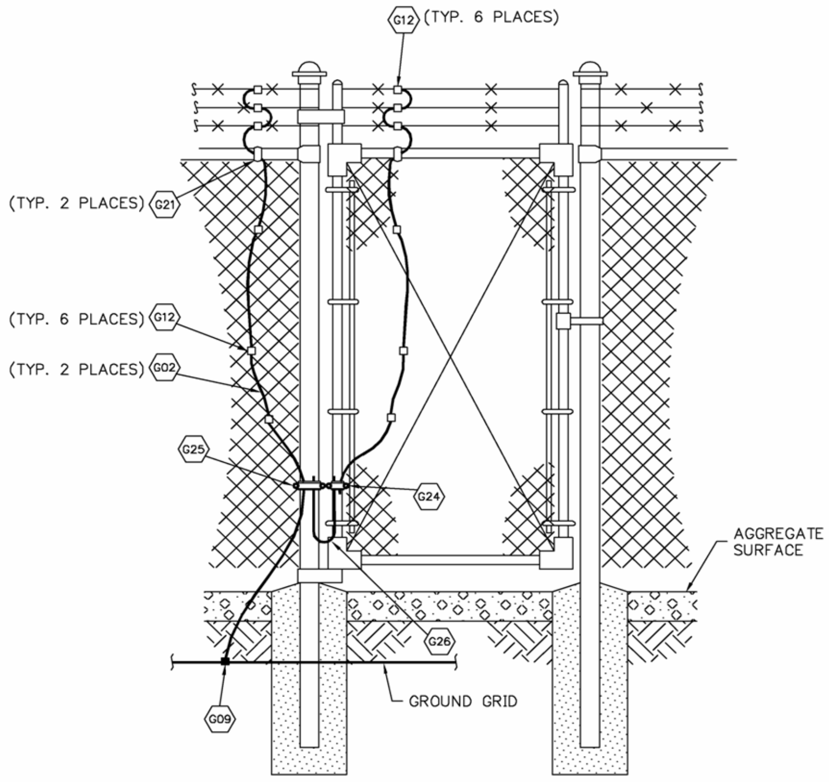
Switch Operator Grounding Platform



Typical Fence Grounding

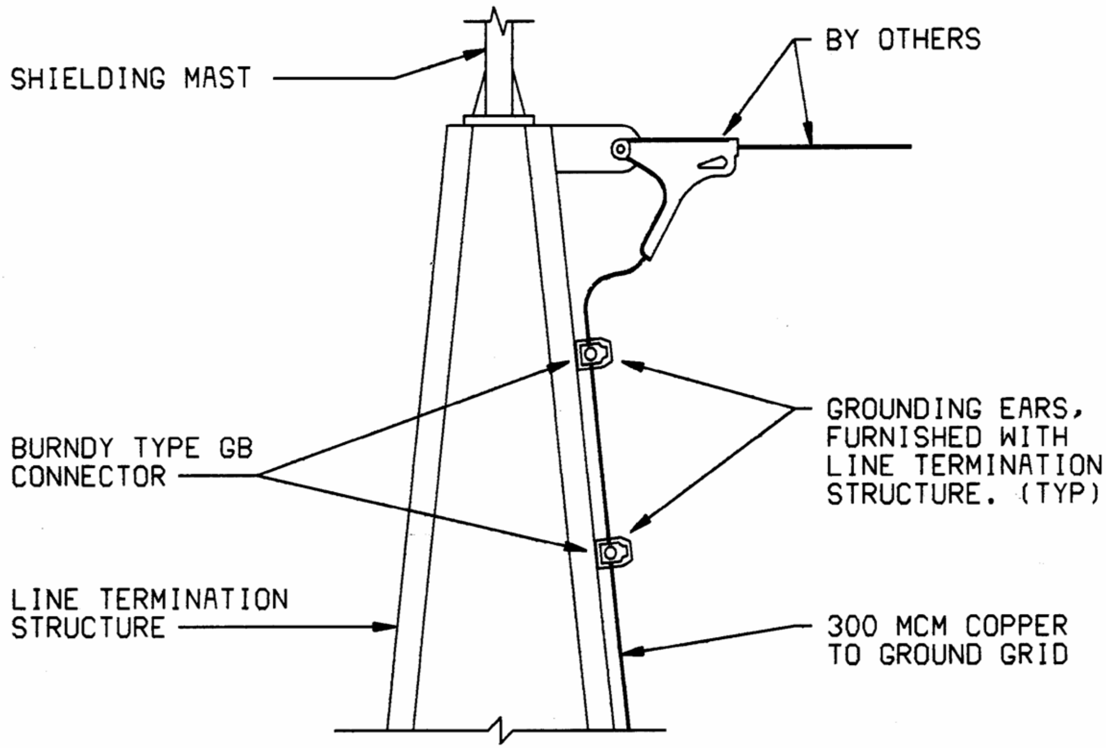


DETAIL A
TYPICAL FENCE LINE POST GROUNDING
NOT TO SCALE

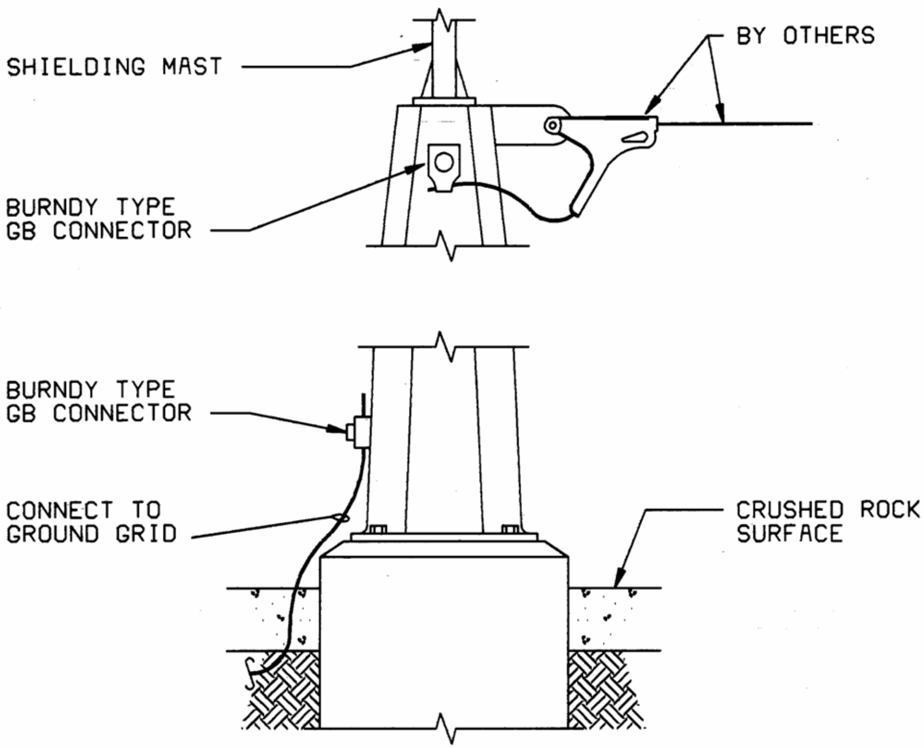


DETAIL B
TYPICAL PERSONNEL GATE GROUNDING
NOT TO SCALE

Typical Shield Wire Attachment



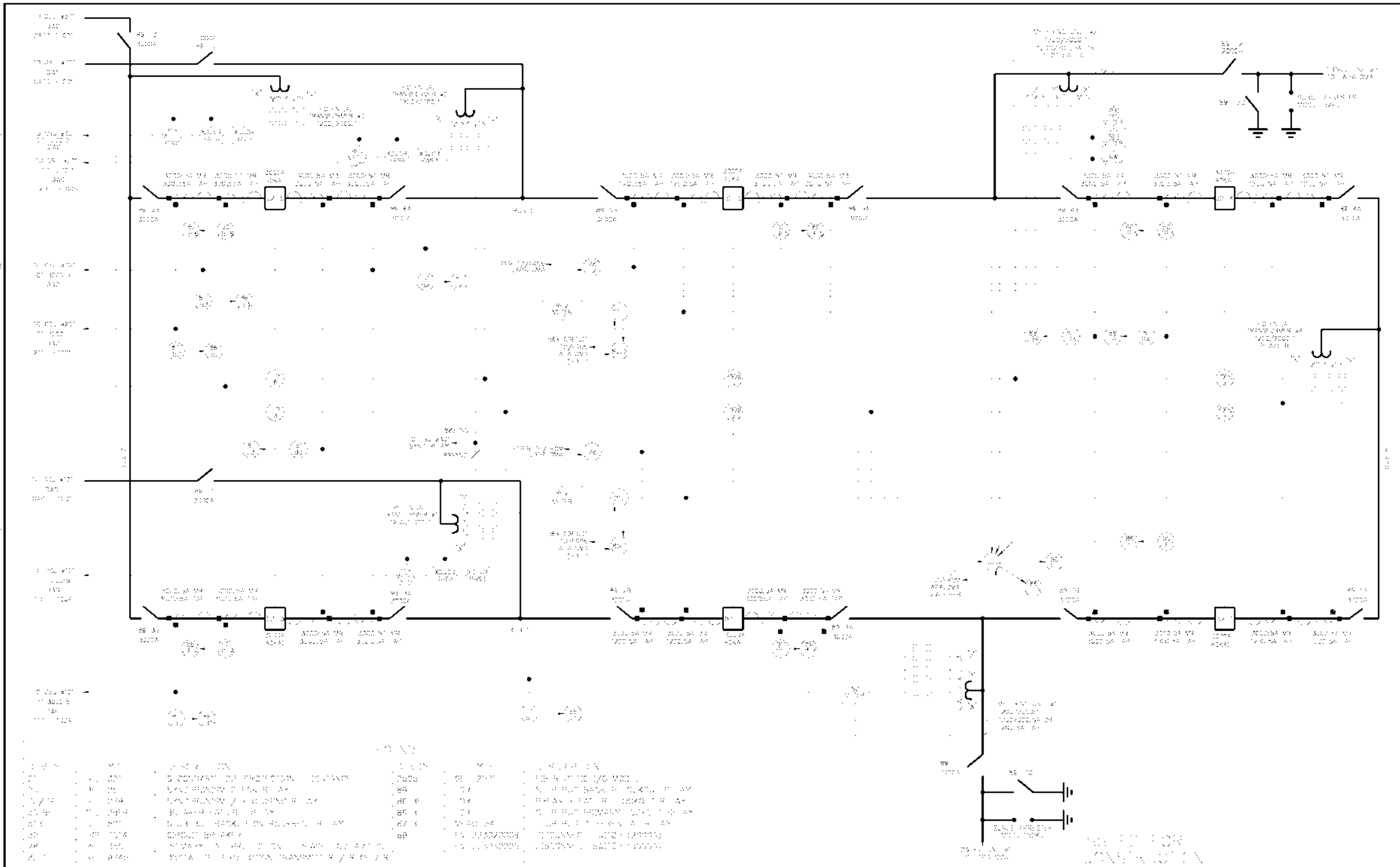
Typical Take-Off Tower Grounding and Shield Wire Attachment



Reference Material

- ANSI/IEEE STD. 80 -2000, “ Guide for Safety in AC Substation Grounding”
- ANSI/IEEE Std. 665, “IEEE Standard for Generating Station Grounding
- IEC 479
- NEC Section 250
- Black & Veatch Recommended Practice 06.2260.1001 Substation Grounding
- SES Technical Papers by F. P. Dawalibi & Staff

Electrical Equipment



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SUNRISE POWER CO.

99498-CPPA-E7001

5

Circuit Interrupters

Objectives

- What are Circuit Interrupters
- What are the Characteristics of Various Kinds of High Voltage Circuit Interrupters
- What are Appropriate Applications for Each Type of Circuit Interrupter
- Concentrate on Substation Applications

Circuit Interrupters

Circuit Interrupters are Part of the Substation Switching Equipment System. They Include:

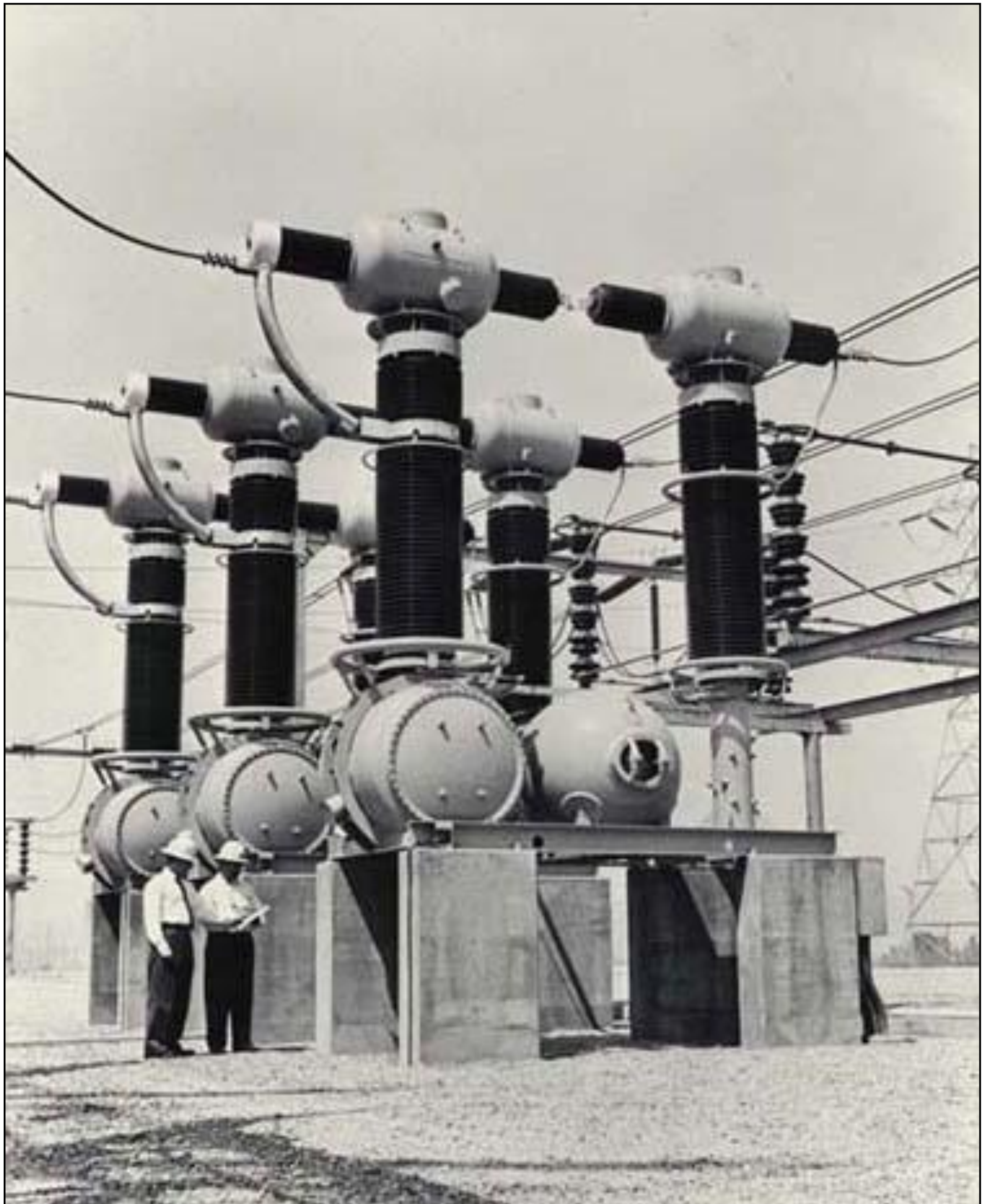
- Circuit Breakers
- Automatic Circuit Reclosers
- Circuit Switchers
- Power Fuses

Circuit Breakers Utilize a Variety of Interruption Media:

- Air
- Oil
- SF_6 Gas
- Vacuum

Circuit Breakers Can Be:

- Live Tank
- Dead Tank
- High Voltage - Rated > 1,000 Volts AC
- Low Voltage - Rated < 1,000 Volts AC



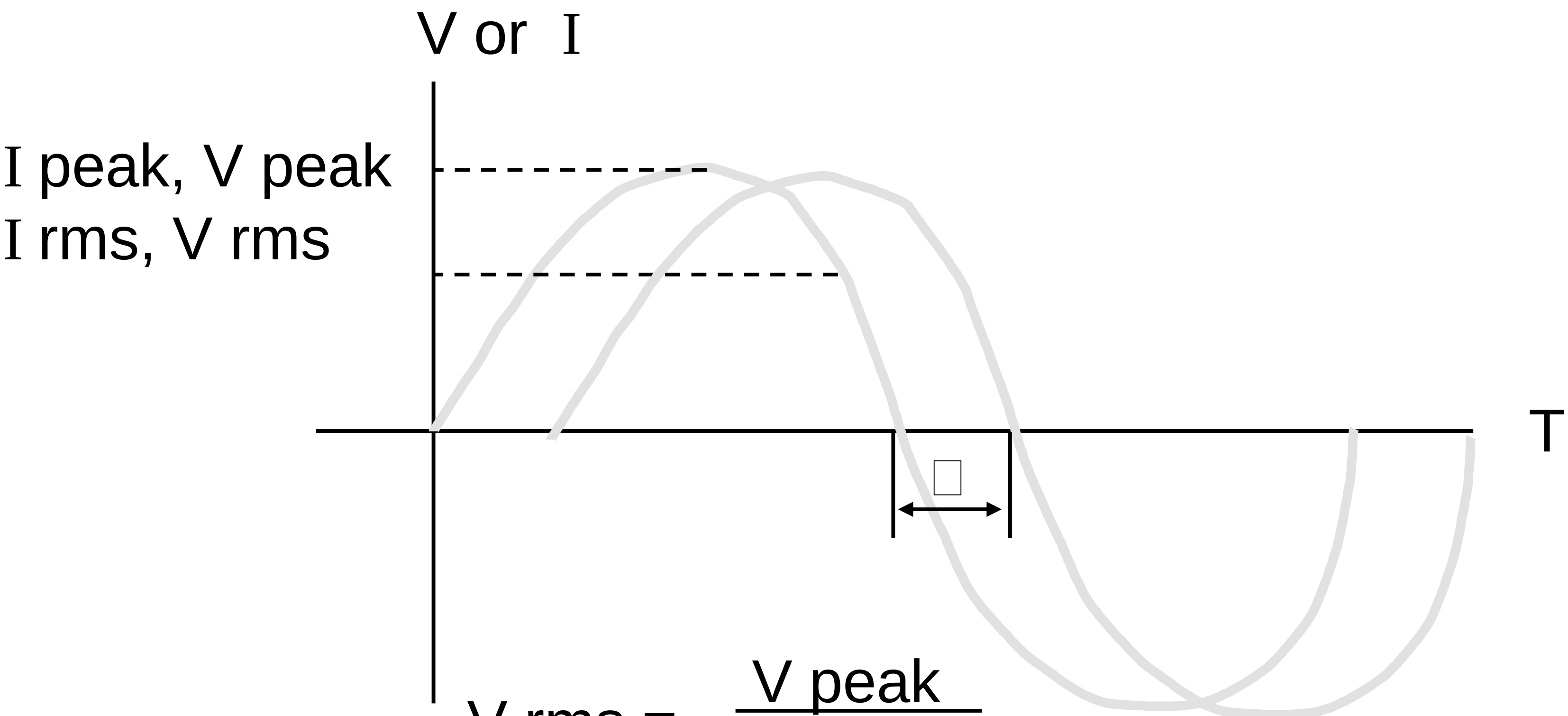

JUN 20 2003


ABB
DANGER


6
4
2

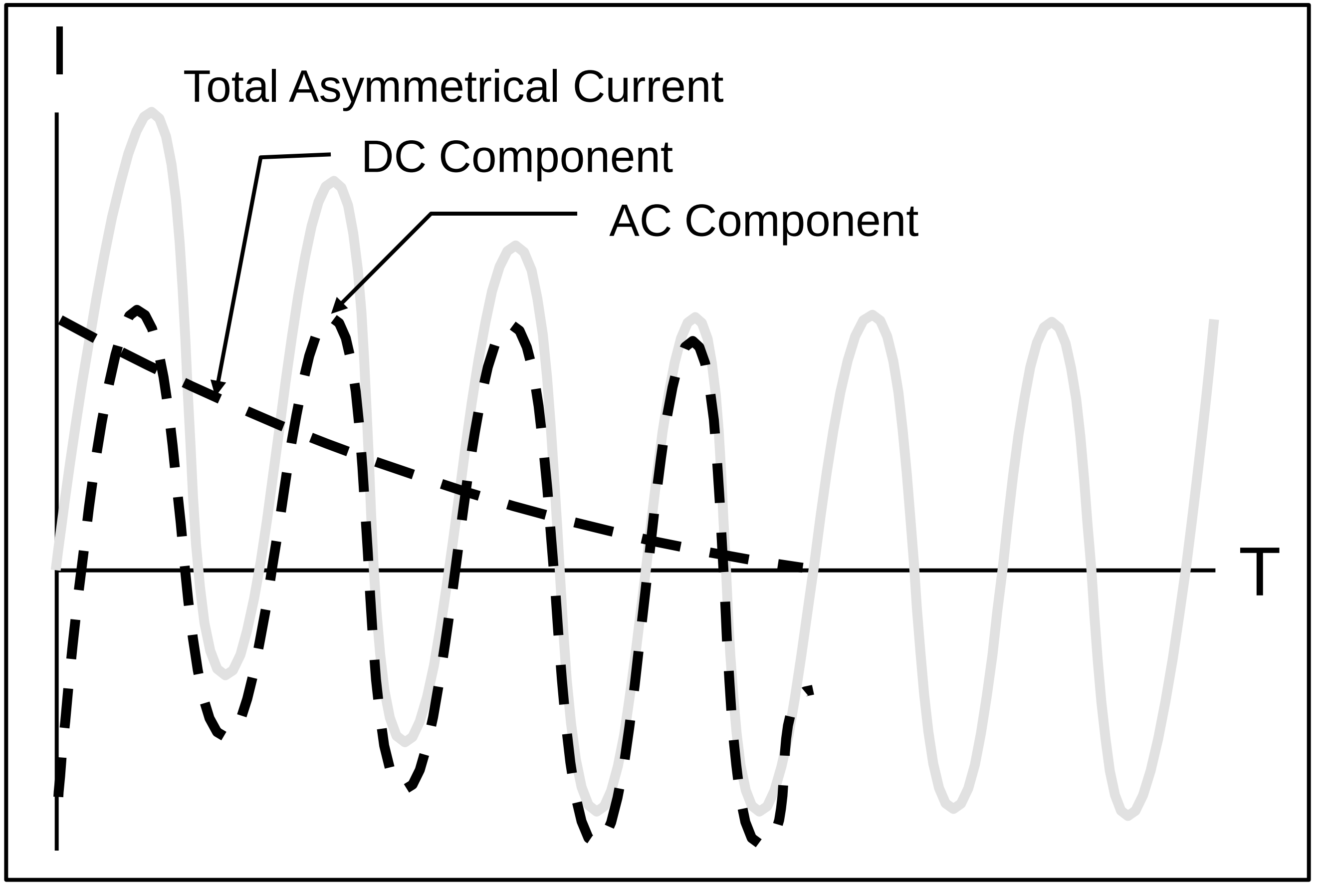
Circuit Breaker Ratings

- In Accordance with ANSI C37.06-1987
  - Rated Maximum Voltage
  - Rated Continuous Current
  - Rated Short Circuit Current At Max. Voltage
  - Rated Transient Recovery Voltage
  - Rated Interrupting Time
  - Rated Closing & Latching Current
  - Rated Capacitance Switching



$$V_{rms} = \frac{V_{peak}}{\sqrt{2}}$$

$$I_{rms} = \frac{I_{peak}}{\sqrt{2}}$$


I
Total Asymmetrical Current
DC Component
AC Component
T

Power Circuit Breakers

Special Applications (TRV)

- Capacitor Switching
- Short Line Faults
- Interrupting Faults on Transformer Secondary
- Reactor Switching

Faults Are Typically Caused By:

- Overvoltages Due to Lightning
- Overvoltages Due to Switching and Ferroresonance
- Insulation Degradation and Breakdown Due to Aging and Contamination
- Breakage of Conductors, Insulation, and Support Structures Such as Poles Due to Wind, Snow, Ice, Trees, Earth Digging Equipment, etc.
- Shorting of Insulation by Rodents, Birds, Snakes, etc.
- Equipment Failure and Wiring Errors
- Fires

What Is an Automatic Circuit Recloser?

A Self-Controlled Device for Automatically Interrupting and Reclosing an AC Circuit, with a Predetermined Sequence of Opening and Reclosing followed by Resetting, Hold-Closed, or Lockout Operation

Automatic Circuit Reclosers

- Distribution Devices - 2.4 kV - 38 kV
- Smaller Current Ratings
  - Continuous
  - Interrupting
- Typically SF6 or Vacuum
- Pad Mounted, Pole Mounted, or Station

See ANSI Standard C37.61


12KV CIR 532

Reclosers Differ from Circuit Breakers as Follows:

- Self-Contained, Automatic Operation, does not Require External Control Circuits, Relays, Current Transformers, Batteries, etc.
- Single-Phase or Three-Phase, and Three-Phase Units Provide Single-Phase Operation
- Range of Operation for Recloser is not as Wide as Relay Operated Circuit Breakers
- Reclosers are Usually Adjusted for Four Operations. Circuit Breakers Usually have One Reclosing Operation to Lockout
- Circuit Breakers have Greater Interrupting Capacity than Reclosers
- Reclosers can be Located Out on the Distribution Circuit Offering Some Flexibility in Coordination
- Reclosers are Considerably Less Expensive than Breakers

Recloser Ratings

- Maximum Voltage
- Frequency
- Continuous Current
- Minimum Tripping Current (Series Coil Type Only)
- Symmetrical Interrupting Current
- Making Current
- Impulse Withstand Voltage (BIL)

What is a Circuit Switcher?

- A Limited Duty Circuit Interrupter
- Often has an Air Break Disconnect Switch in Series with the Interrupter


NO PARKING
HIGH VOLTAGE
25 10:35 AM




Circuit Switchers

- Do Not Meet Circuit Breaker Ratings
- Have Lower Fault Current Interruption Ratings (Up to 20 KA)
- Used Primarily for Radial Transformer Protection and Capacitor Bank Switching
- Read the "Fine Print"

What Is a Power Fuse?

An Overcurrent Protective Device with a Circuit Opening Element that is Heated and Severed by the Passage of Fault Current

- Power Fuses Used Primarily for Small Transformer Protection
- Fuse Must Be Replaced After Interruption
- Only Opens Faulted Phase
- No Remote Indication of Operation

Power Fuse Types

- Expulsion Fuses
- Boric Acid Fuses
- Current Limiting Fuses

Power Fuse Considerations

The Following Circuit Parameters Must Prevail

- System Line-to-Line Voltage of 169 kV or Less
- Fault Currents within the Interrupting Rating
- Load Requirements within the Current Rating
- Single Phase Interruptions are Tolerable
- Must Withstand Inrush and Cold Load Pickup

What is Metal Clad Switchgear?

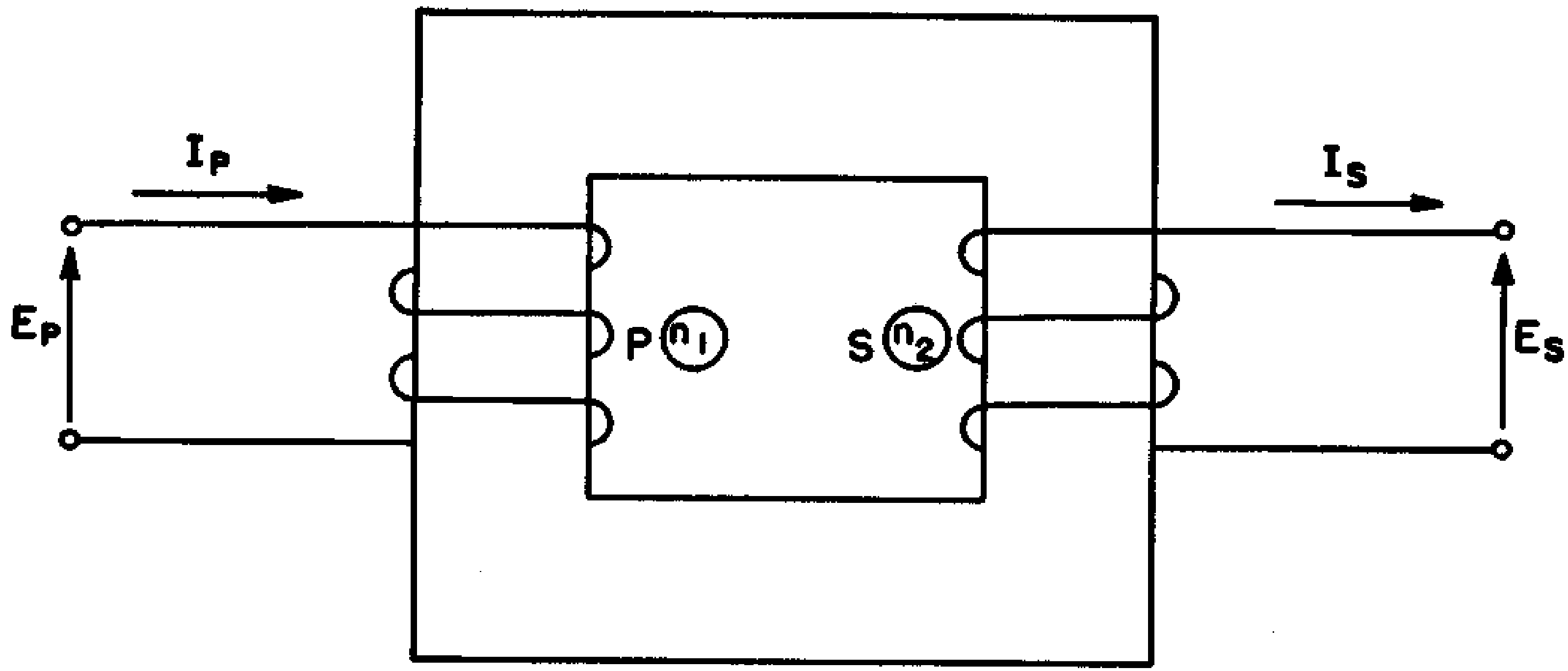
Metal clad switchgear is self contained, indoor or outdoor panel style equipment for switching distribution circuits.

Voltages are usually below 34.5 kV

Factors to be Considered in Circuit Interrupter Selection

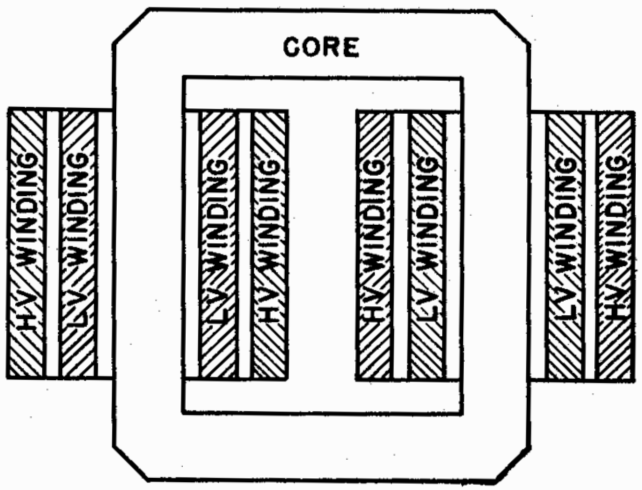
- Voltage
- Current
  - Continuous
  - Interrupting
- Application
  - Need for Reclosing
  - Reliability
  - Service Conditions
  - Installation Location
- Cost

Power Transformers

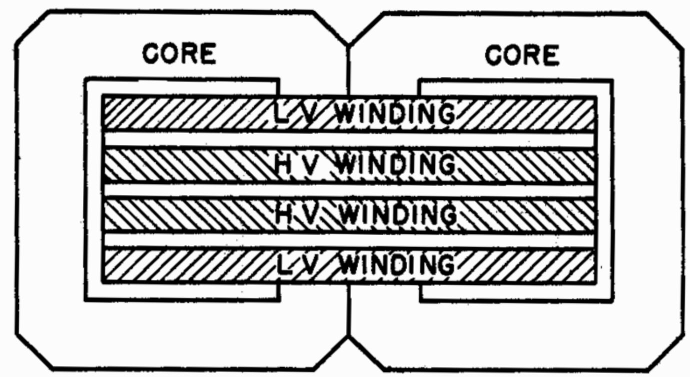


Two-winding transformer

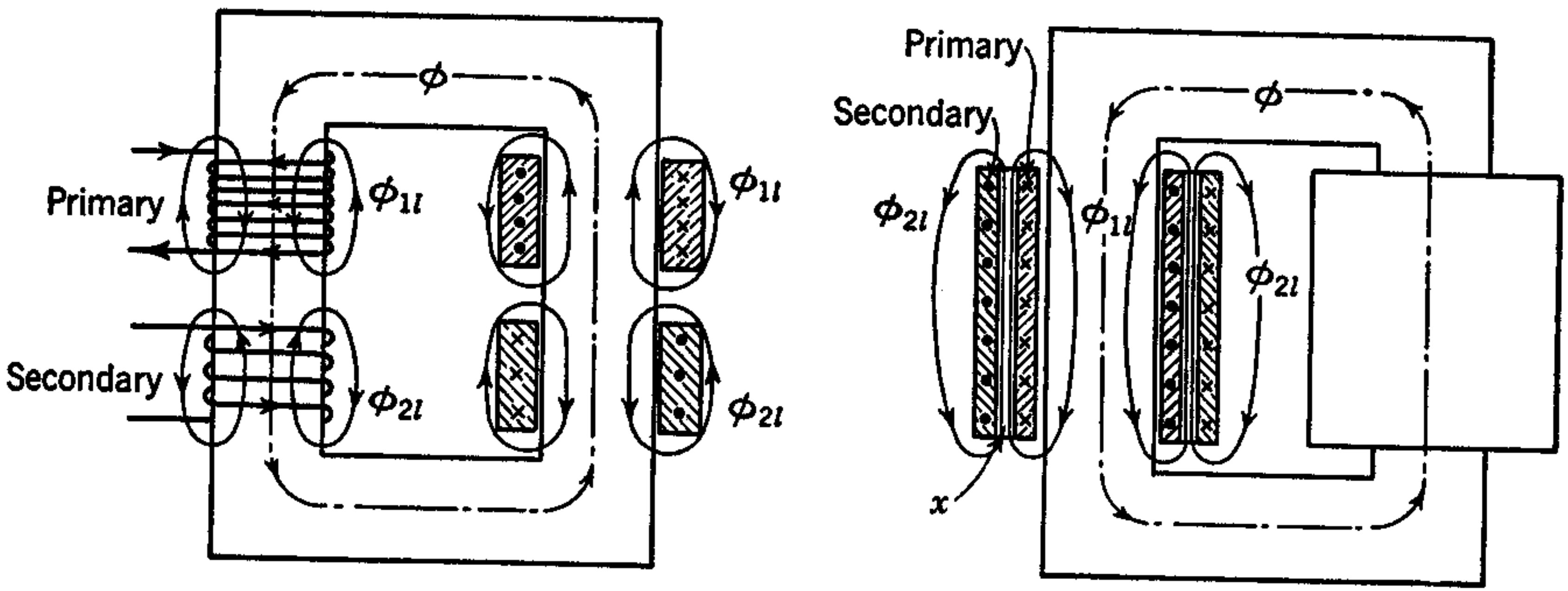
$$\frac{N_1}{N_2} = \frac{I_s}{I_p} = \frac{E_p}{E_s}$$



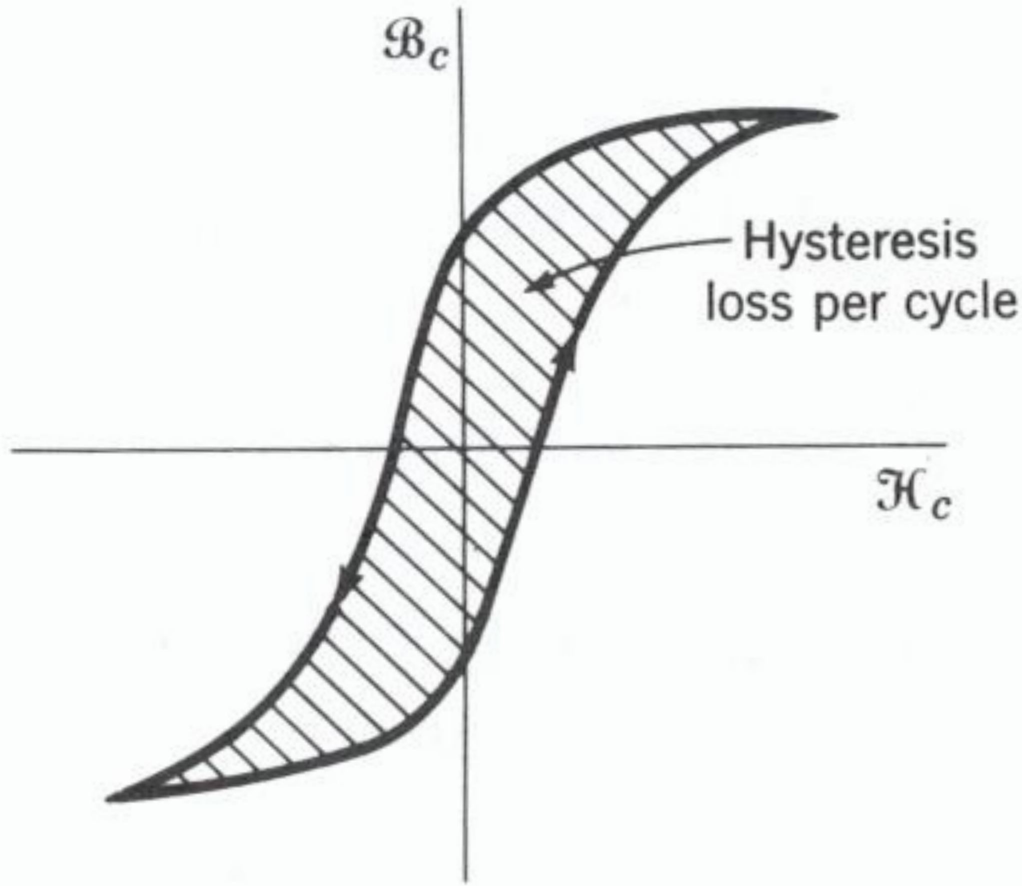
Core form construction



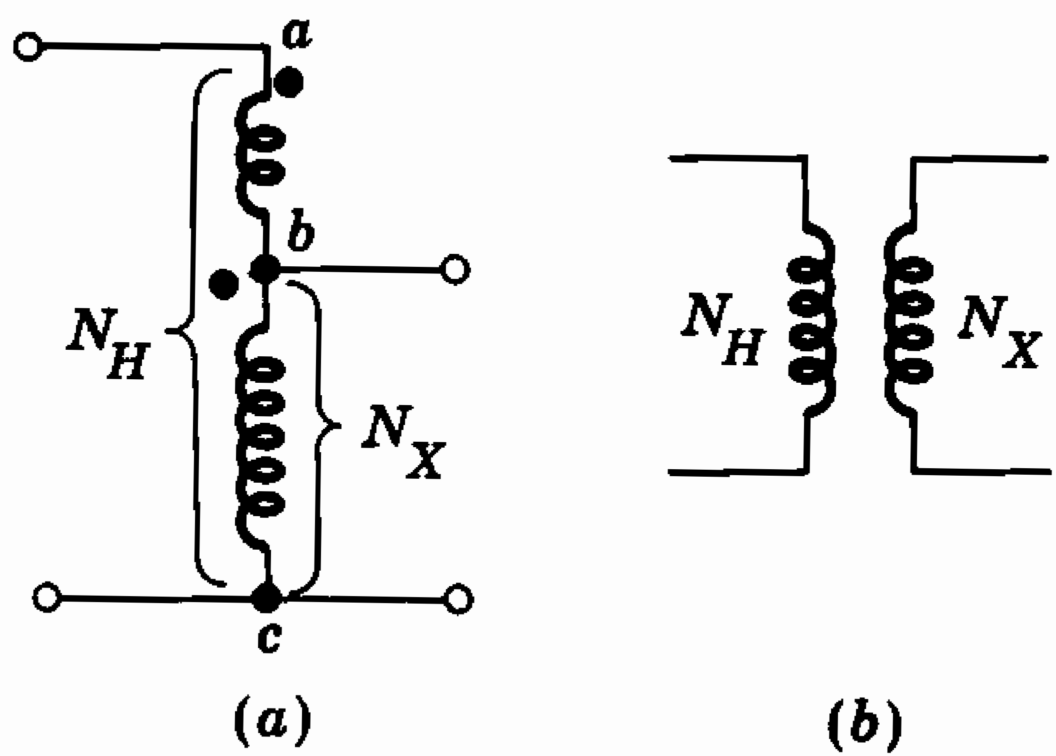
Shell form construction



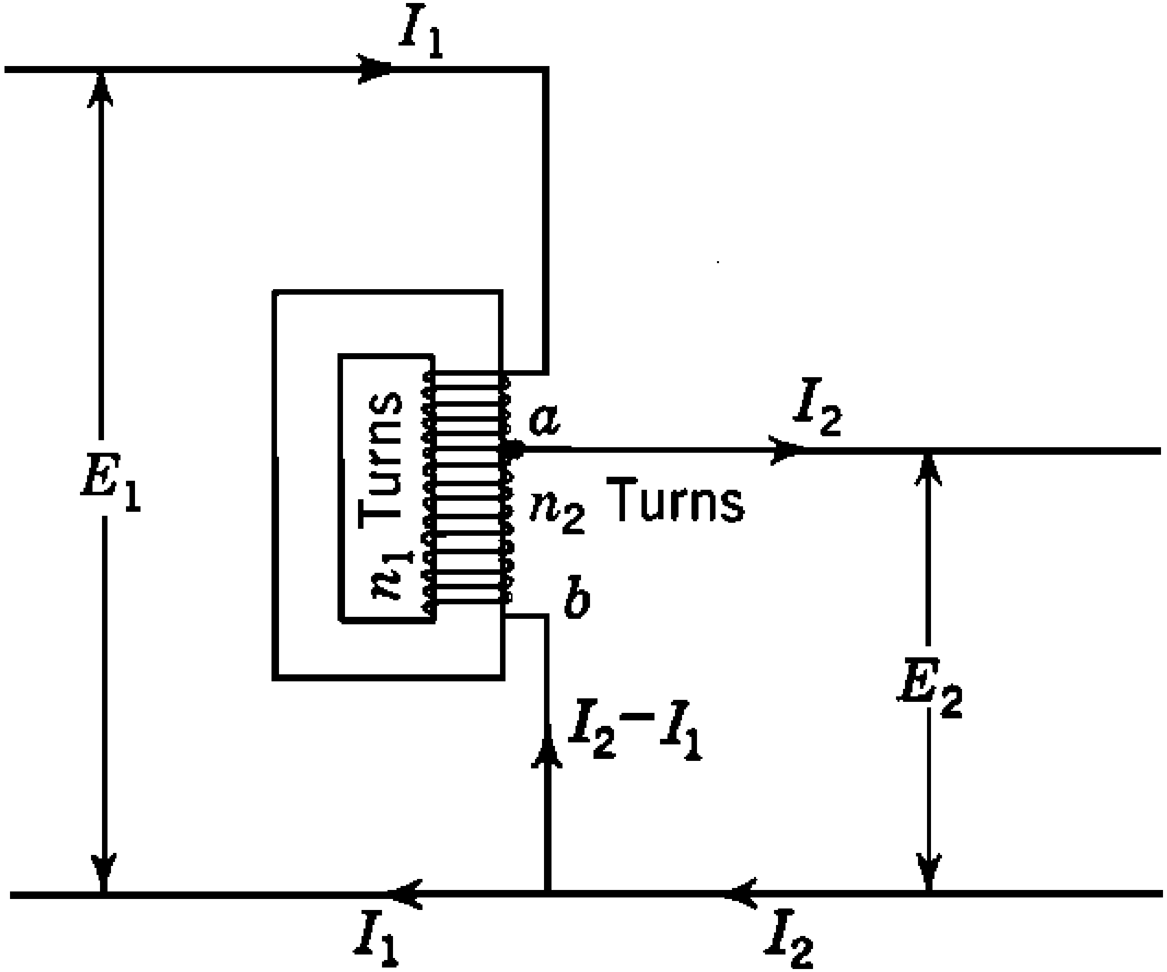
Leakage flux of transformers



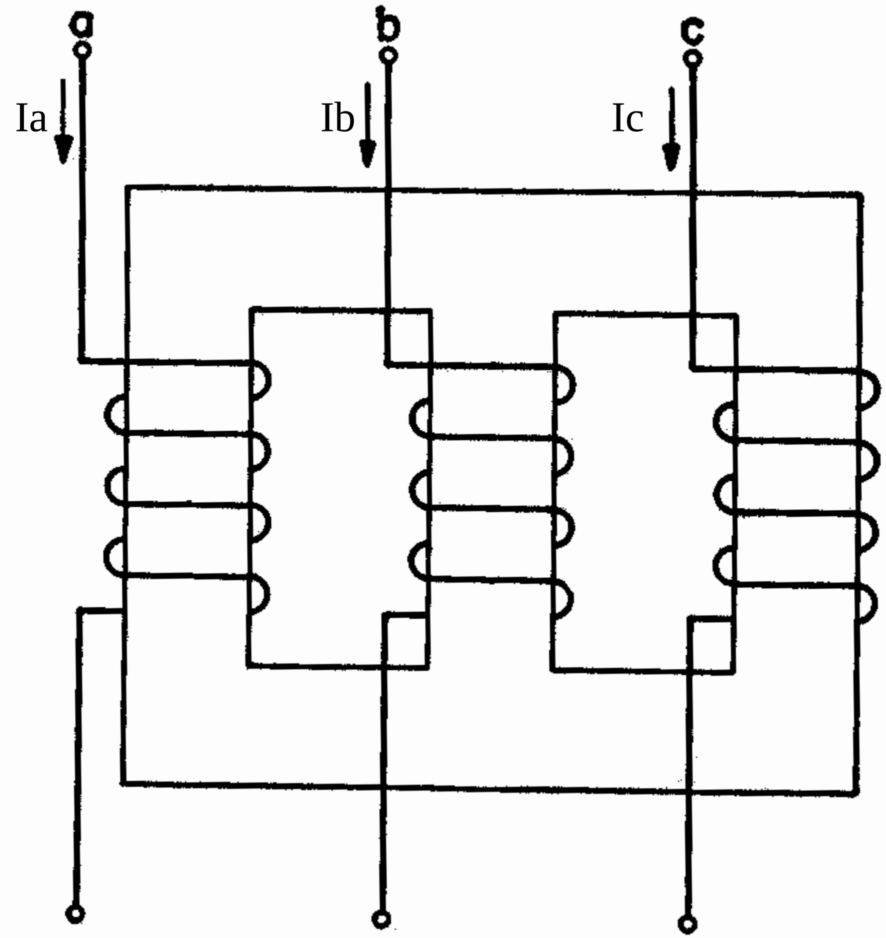
Symmetrical hysteresis loop.



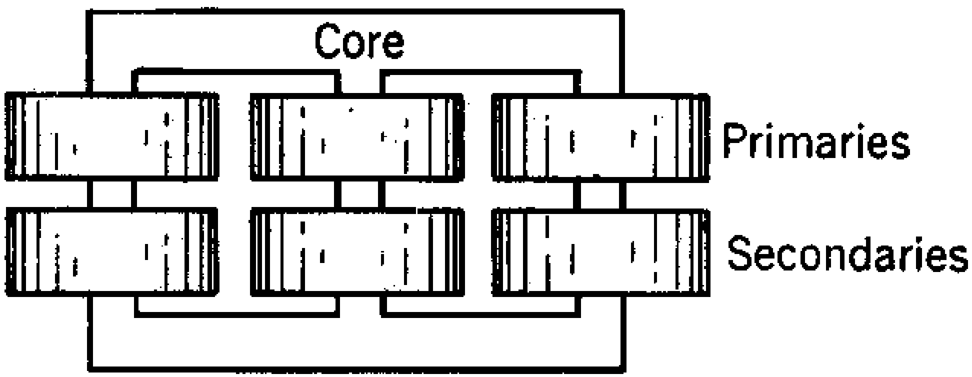
(a) Autotransformer compared with
(b) 2-winding transformer



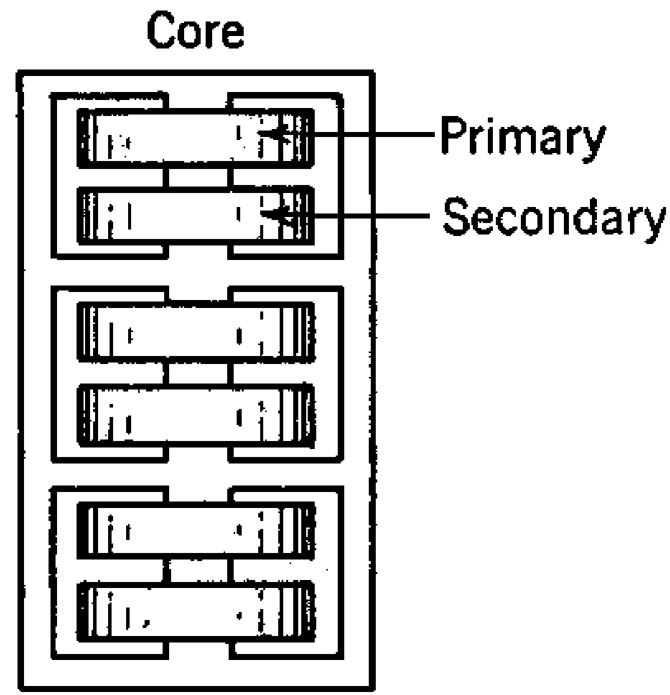
Autotransformer



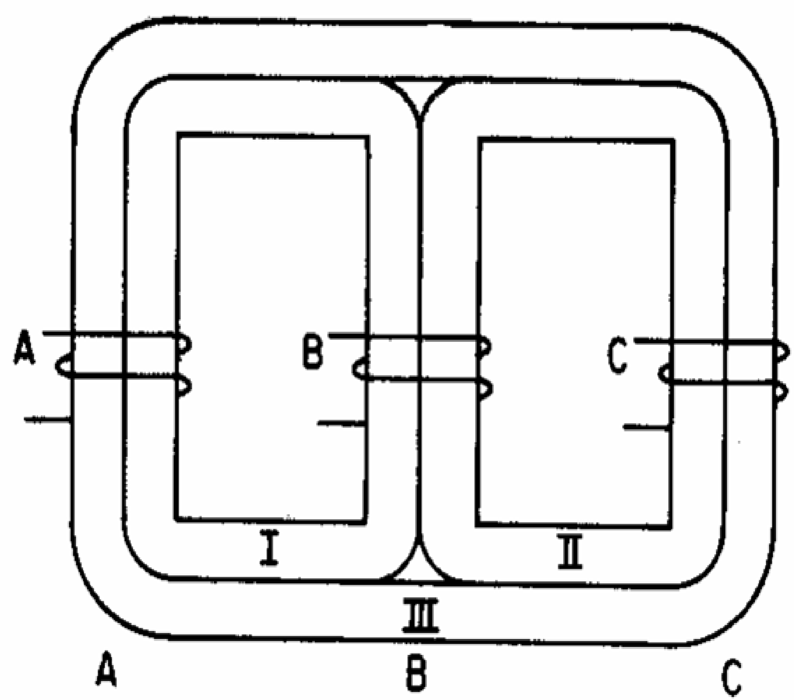
Three phase transformer – Core form design



Three-phase core-type transformer



Three-phase shell-type transformer


A
B
C
I
II
III
A
B
C

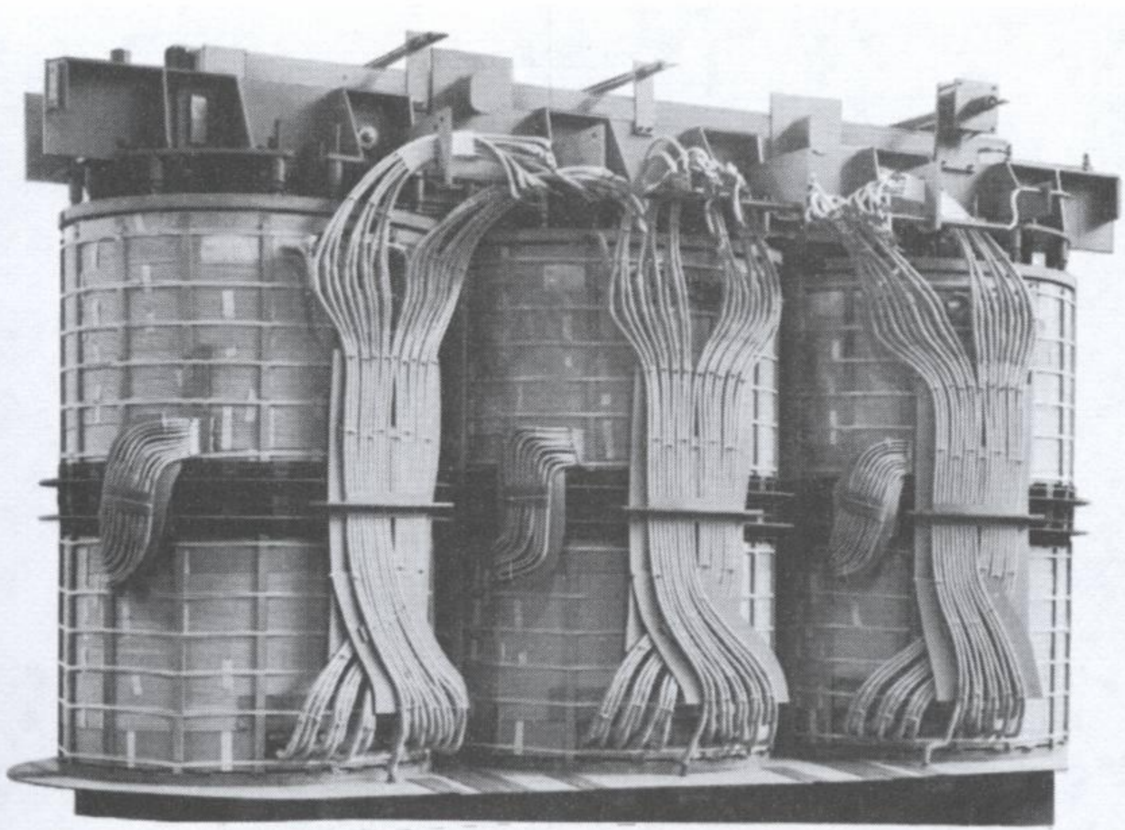
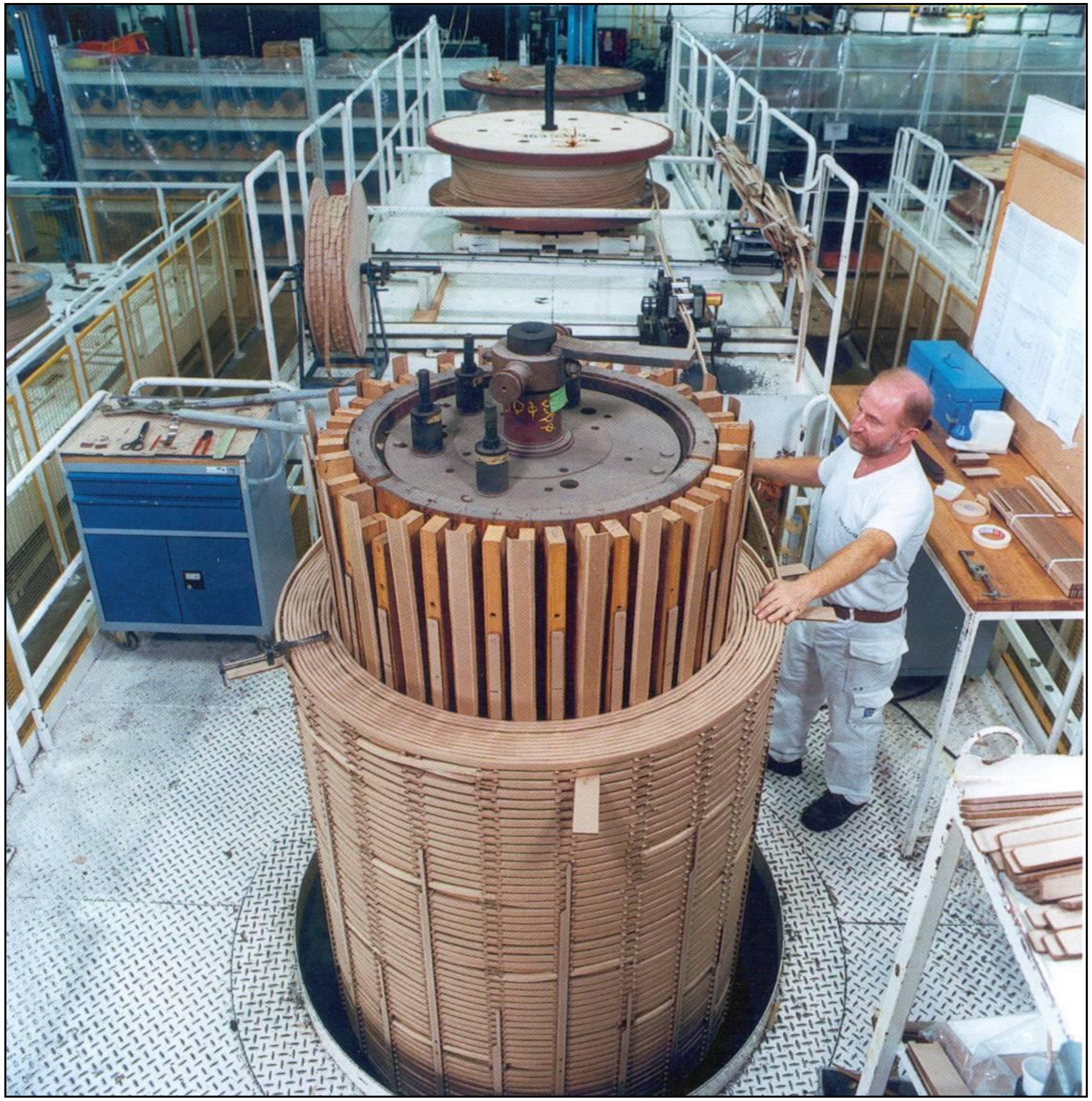
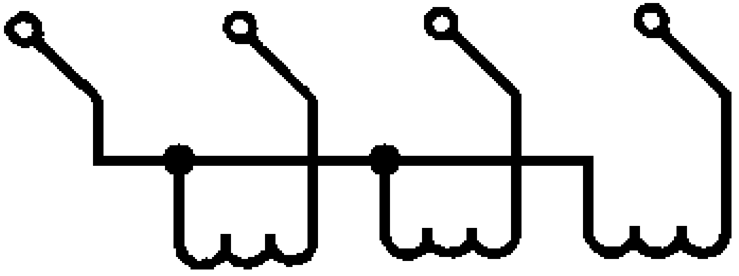


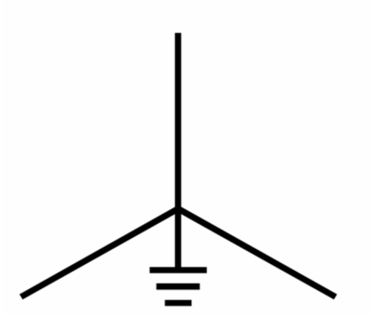
Figure 4.125 Three-phase 60 MVA, 132/33 kV, 50 Hz core and windings showing the outer tapping winding and the tapping leads assembly (ABB Power T&D Ltd)




K

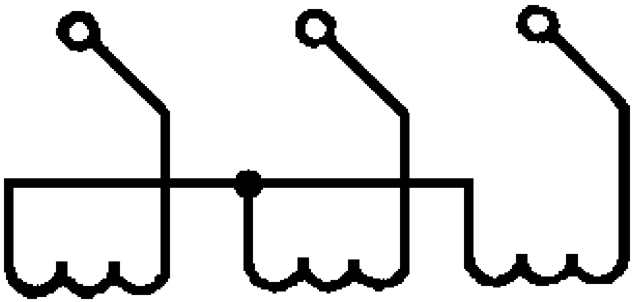
Transformer Connections

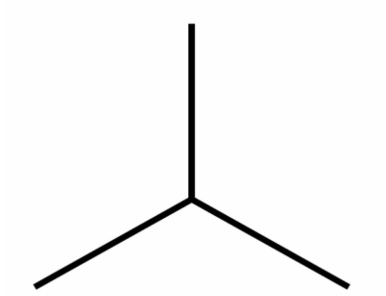




Grounded wye

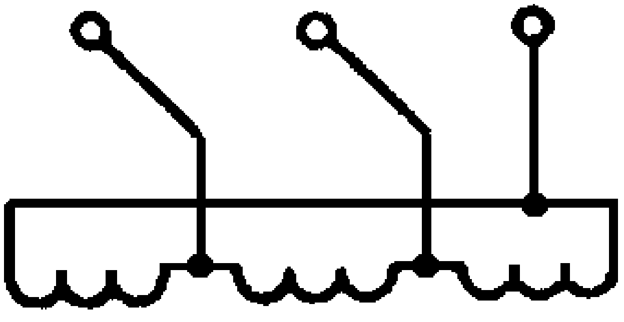
Transformer Connections

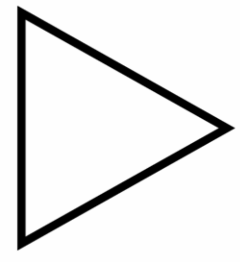




Ungrounded Wye

Transformer Connections





Delta

Present designations	Previous designations
ONAN	OA
ONAF	FA
ONAN/ONAF/ONAF	OA/FA/FA
ONAN/ONAF/OFAF	OA/FA/FOA
ONAN/ODAF	OA/FOA[a]
ONAN/ODAF/ODAF	OA/FOA[a]/FOA[a]
OFAF	FOA
OFWF	FOW
ODAF	FOA[a]
ODWF	FOW[a]

[a]Indicates directed oil flow per Table 9, NOTE 2 of IEEE Std C57.12.00-1993.

kVA Ratings

Kilovolt-Ampere Ratings,
Self-Cooled (ONAN), Forced Cooled First-Stage, and
Forced-Cooled Second-Stage Three-Phase
(With or Without Load Tap Changing),
12,000 - 100,000 kVA

ONAN	First-Stage	Second-Stage
12,000	16,000	20,000
15,000	20,000	25,000
20,000	26,667	33,333
25,000	33,333	41,667
30,000	40,000	50,000
37,500	50,000	62,500
50,000	66,667	83,333
60,000	80,000	100,000

What is a Load Tap Changer?

A device on power transformers to maintain a constant secondary voltage with a variable primary voltage; to maintain a constant primary voltage with a variable secondary voltage; to control the flow of reactive kVA; to control the division of power.

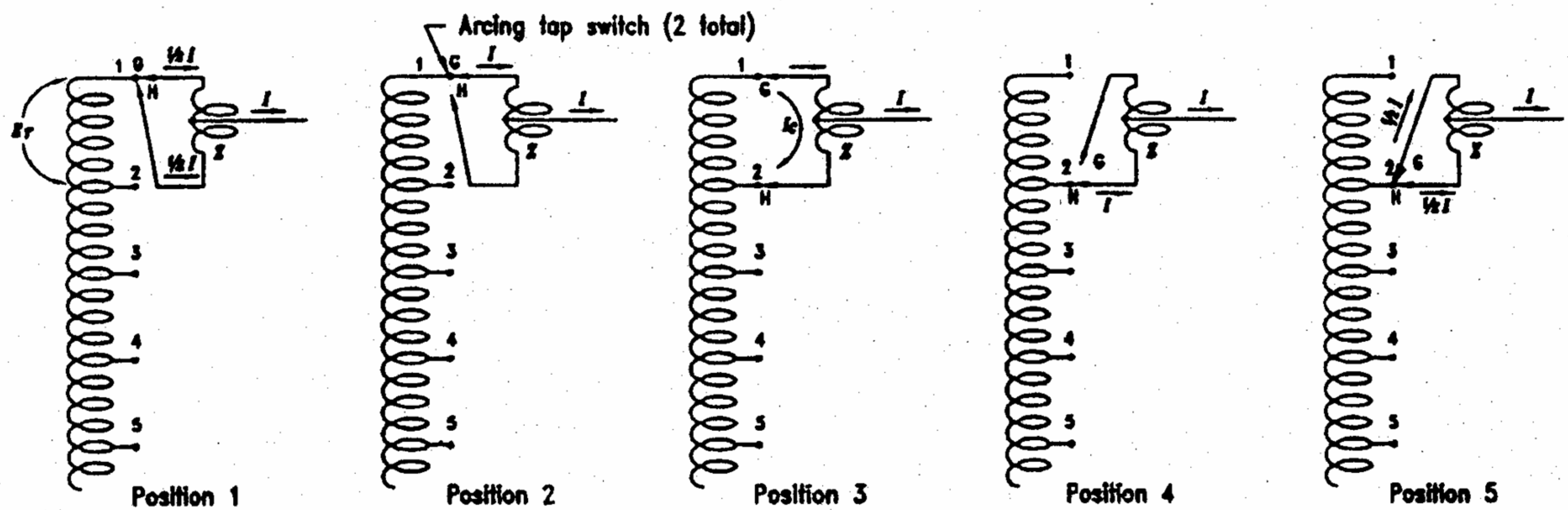
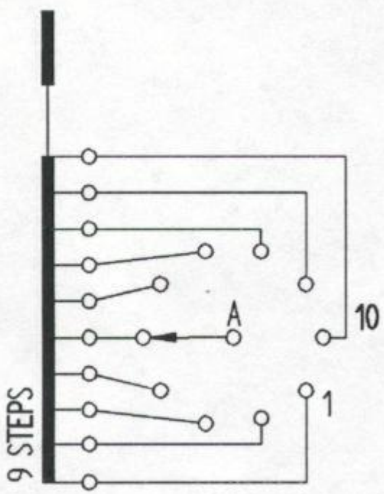
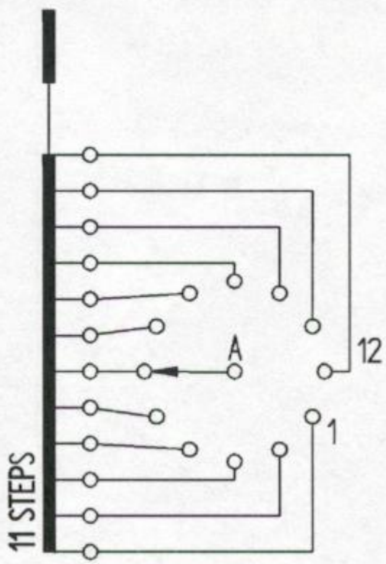


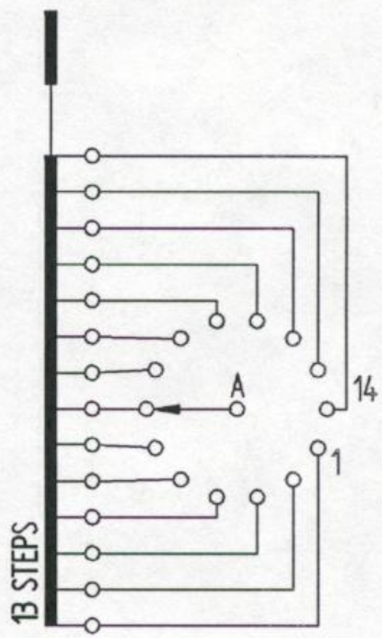
Figure B.1—Operating sequence of arcing tap switch



9 STEPS



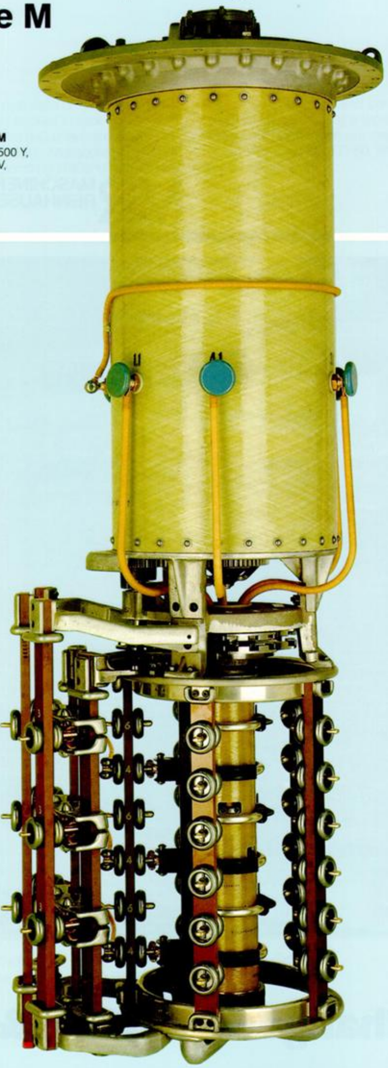
11 STEPS



13 STEPS

Tap changer oil compartment, doors removed

On-Load Tap Changer Type M



OLTC type M
model M III 500 Y,
U_m = 123 kV,
500 A,
± 9 steps

The type M & MS on-load tap changers are used to vary the ratio of oil-immersed transformers under load. In general, they are designed for network transformer as well as industrial transformer applications. The tap changers comprise a diverter switch and a tap selector in a single column design and represent the most recent state of technology. The tap changers offer both transformer manufacturer and user a great number of essential advantages.

On-load tap changers type M & MS

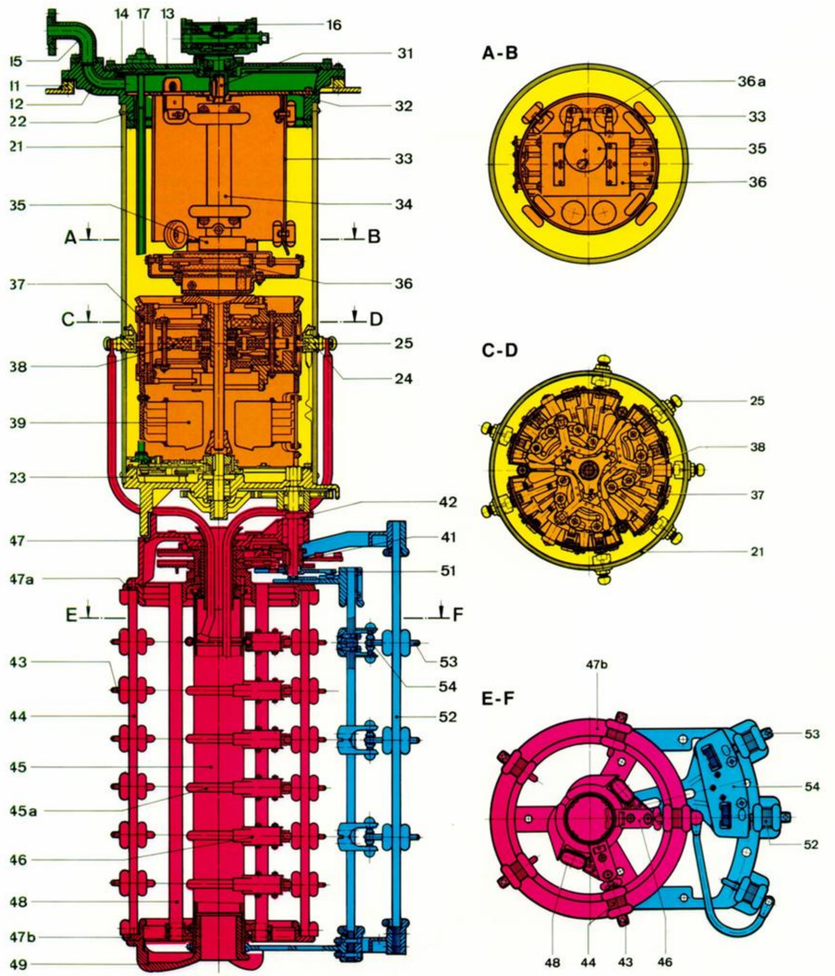
Versatility

- ☐ three-pole design for neutral application at 300 A[1], 350 A, 500 A and 600 A ratings for three-phase wye-connected windings
- ☐ three-pole fully insulated design, at 350 A, 500 A and 600 A ratings for three-phase delta or auto connected windings
- ☐ single-pole designs at 300 A[1], 350 A, 500 A, 600 A, 800 A, 1200 A, 1500 A and 1800 A ratings for auto connected windings or single-phase transformers
- ☐ available with ± 9[1], ± 11[1], ± 13[1], ± 15, ± 17 steps
- ☐ insulation to ground and tap selector size can be selected independently of one another
- ☐ convenient for bell-type tank installation
- ☐ additional devices for potential tie-in of tap winding during change-over operation of the change-over selector (tie-in resistors, tie-in contact)
- ☐ optional extras, especially for the application in industrial transformers, please refer to our documentation VK 04

Compactness

- ☐ high speed transition resistor type diverter switch with arc extinction at the first current zero
- ☐ diverter switch uses snap-action mechanics by energy accumulator mounted directly on the diverter switch
- ☐ minimum possible tap selector dimensions because four available sizes ensure matched impulse voltage withstandability
- ☐ radial dimensions of the tap selector are reduced by special shaping of all parts on high potential, distances between tap selector bars determined by actual voltage stress
- ☐ optimised integration of the change-over selector into the fine selector contact circle

[1] applicable to type MS



Group 10 – Tap changer head

11 mounting flange
12 tap changer head casing
13 tap changer cover
14 position indication disc
15 pipe connection (can be swivelled)
16 upper gear unit (can be swivelled)
17 bleeder screw

Group 20 – Diverter switch oil compartment

21 oil compartment
22 upper flange with gasket
23 lower flange with gasket
24 sliding contact socket
25 connecting terminal

Group 30 – Diverter switch unit

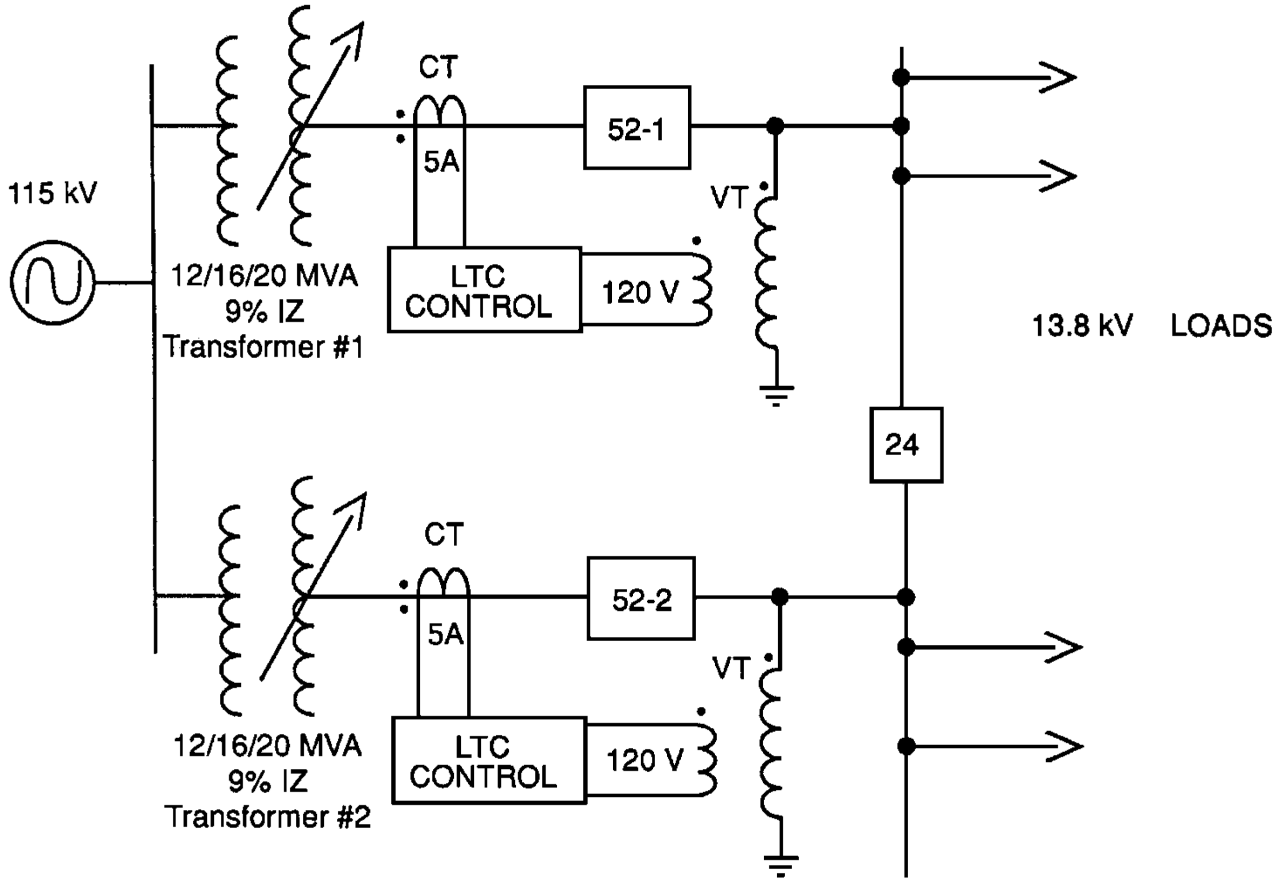
31 coupling
32 supporting plate
33 supporting cylinder
23 drive shaft
35 eccentric
36 energy accumulator with pawl 36a
37 stationary contact system
38 movable contact system
39 transition resistor

Group 40 – Fine tap selector

41 tap selector gear
42 coupling
43 connecting terminal
44 laminated paper terminal bar
45 tap selector column with take-off ring 45a
46 tap selector contact bridge
47 tap selector attachment
47a upper cage ring
47b lower cage ring
48 drive tube
49 bottom

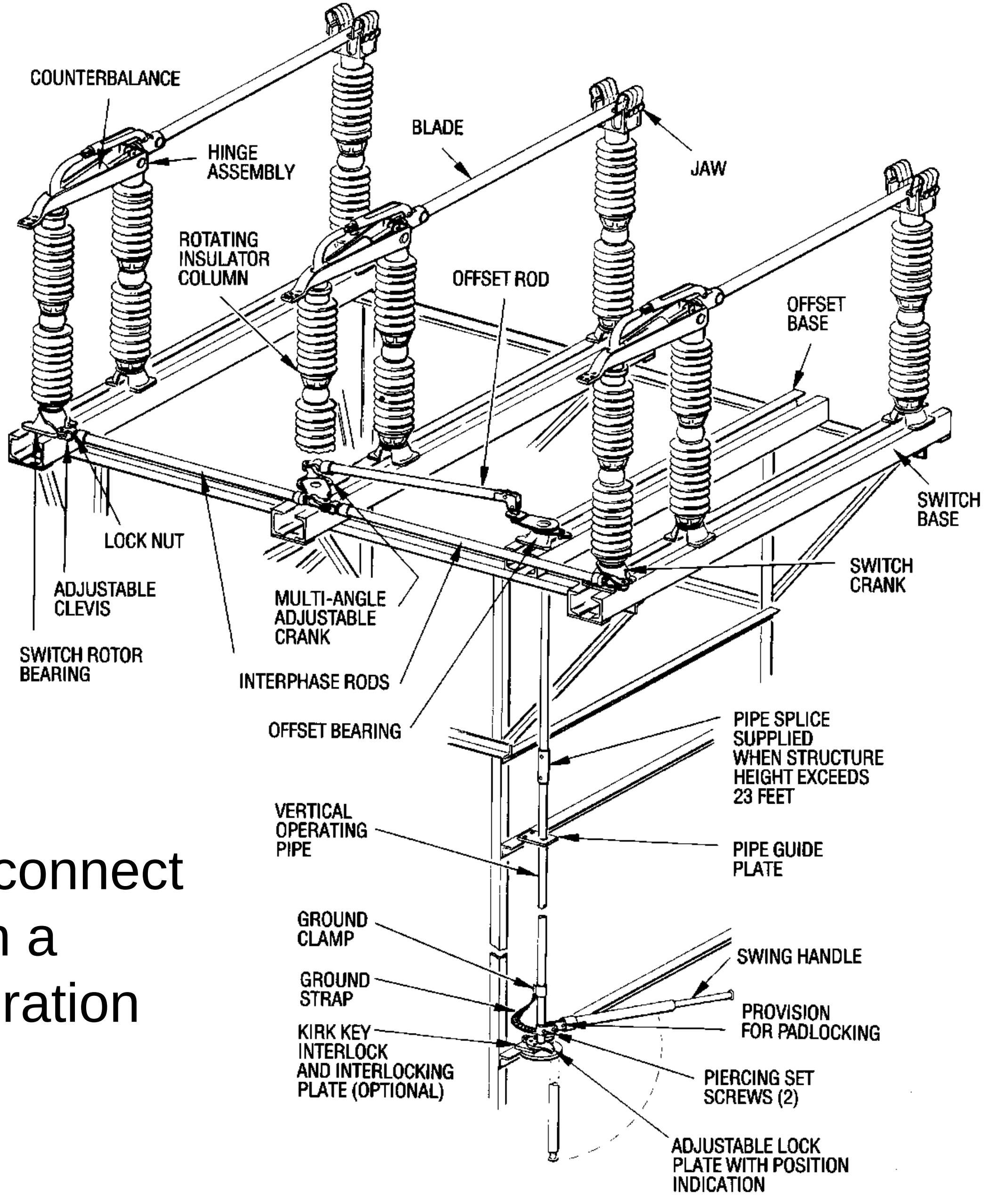
Group 50 – Change-over selector

51 change-over selector drive
52 change-over selector terminal bar
53 connecting terminal
54 movable contact

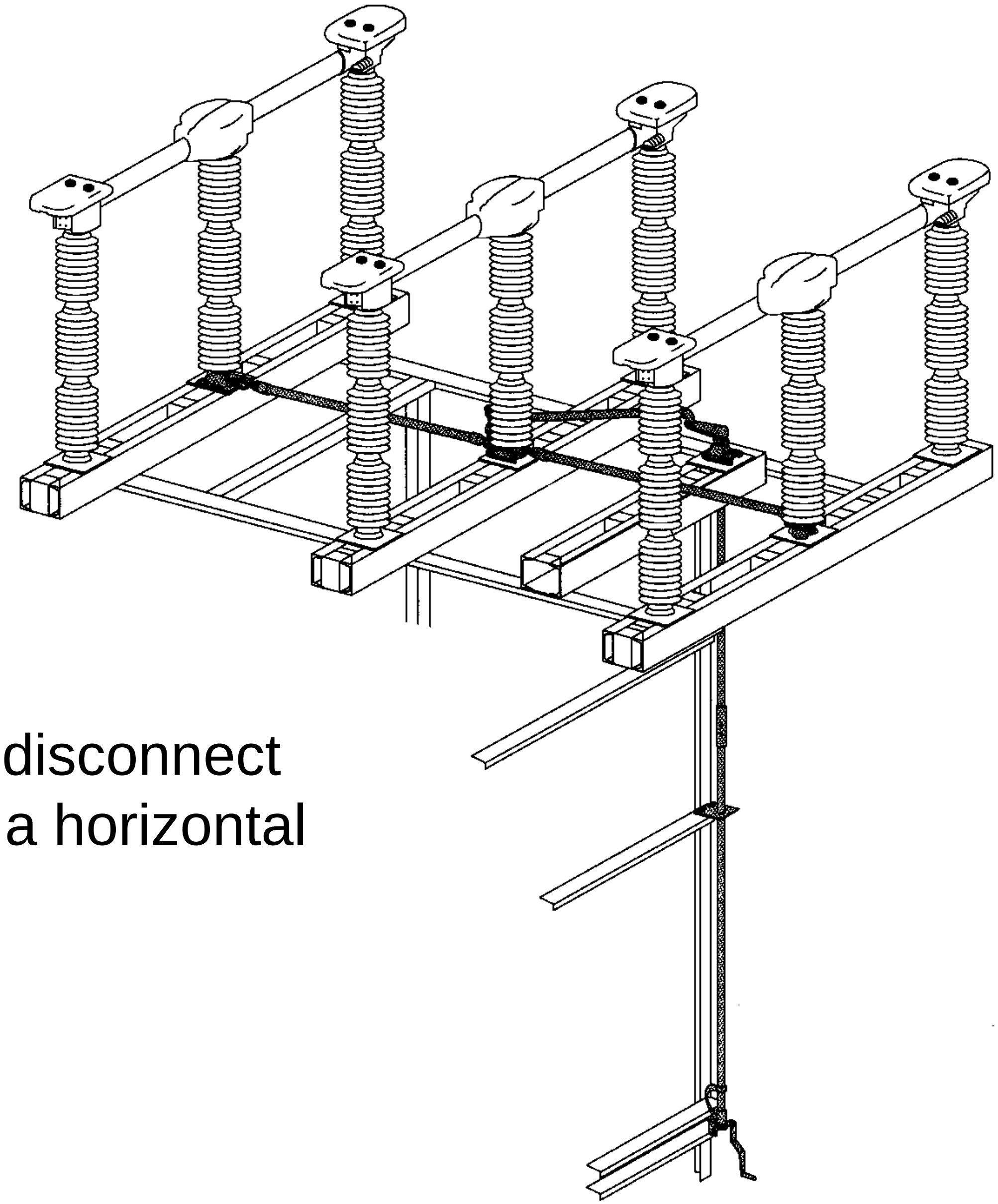


System for Study of LTC Transformer Paralleling

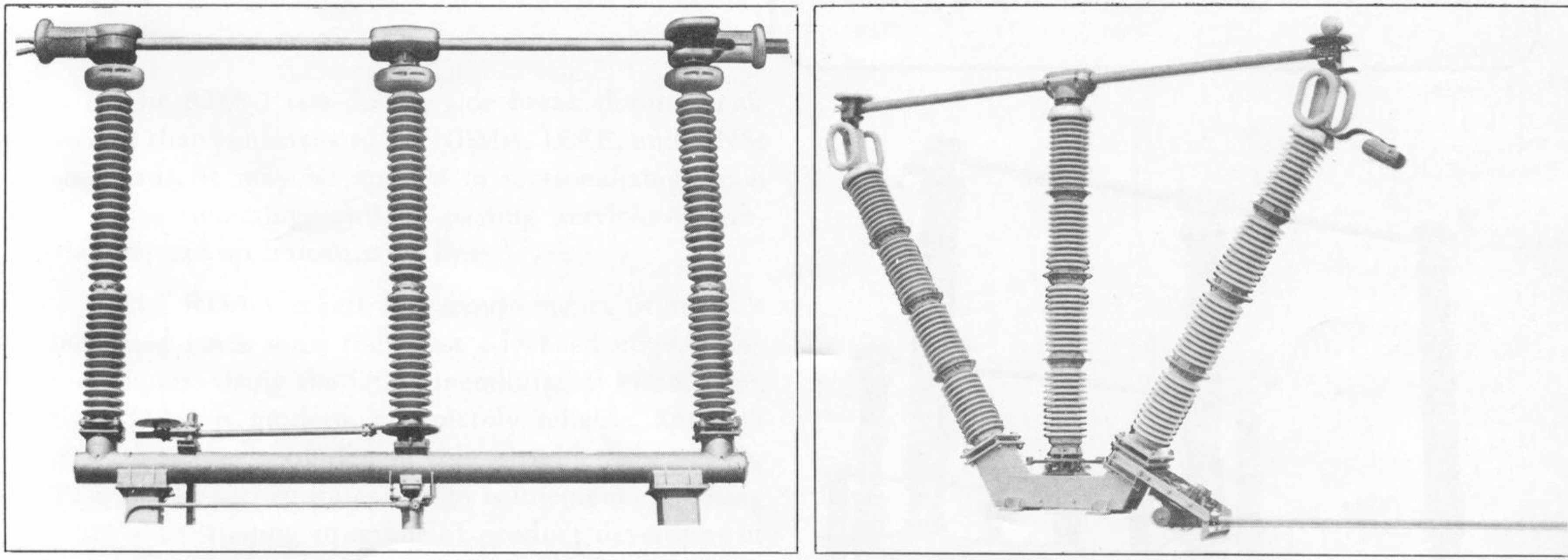
Disconnect Switches



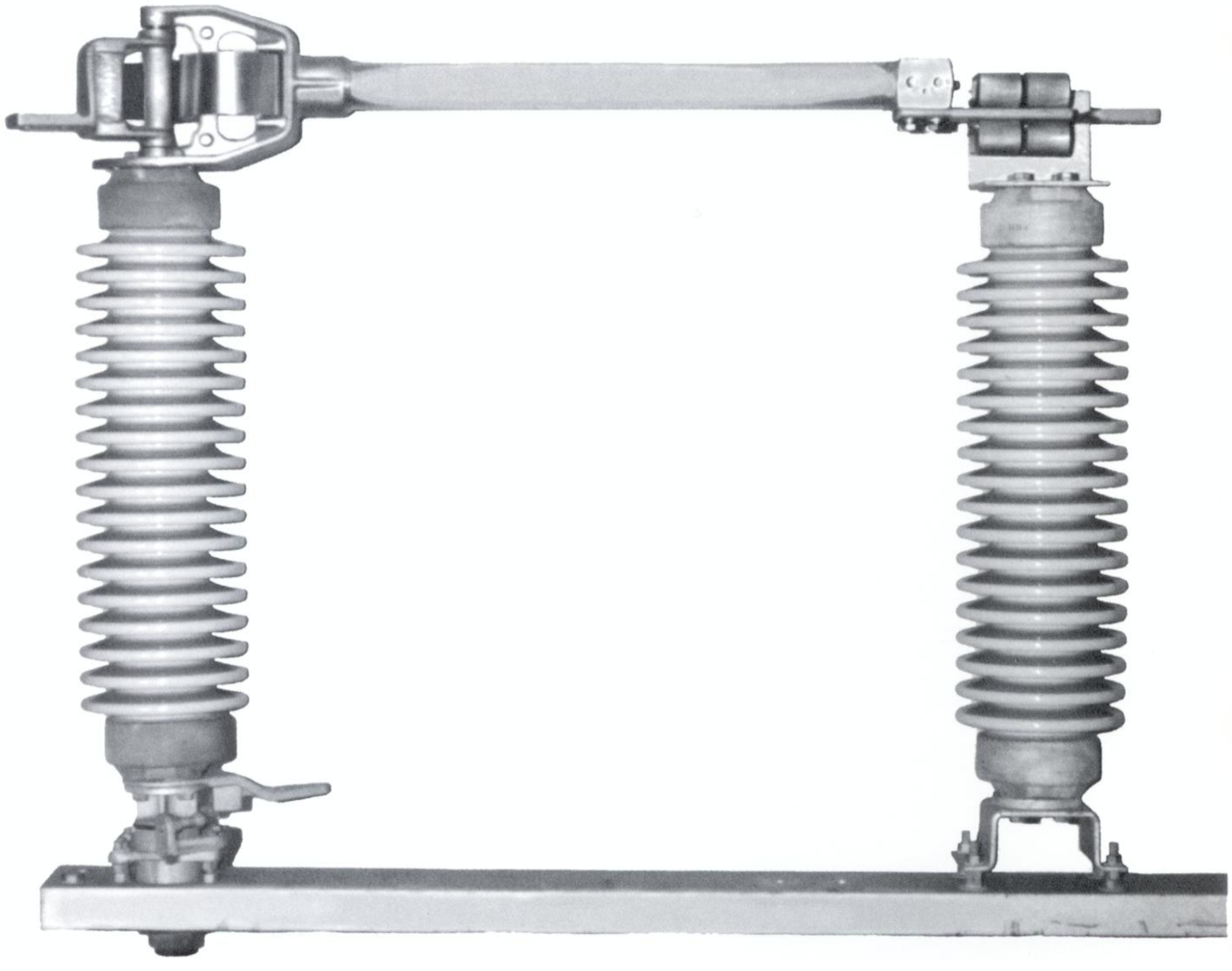
Vertical break disconnect switch mounted in a horizontal configuration



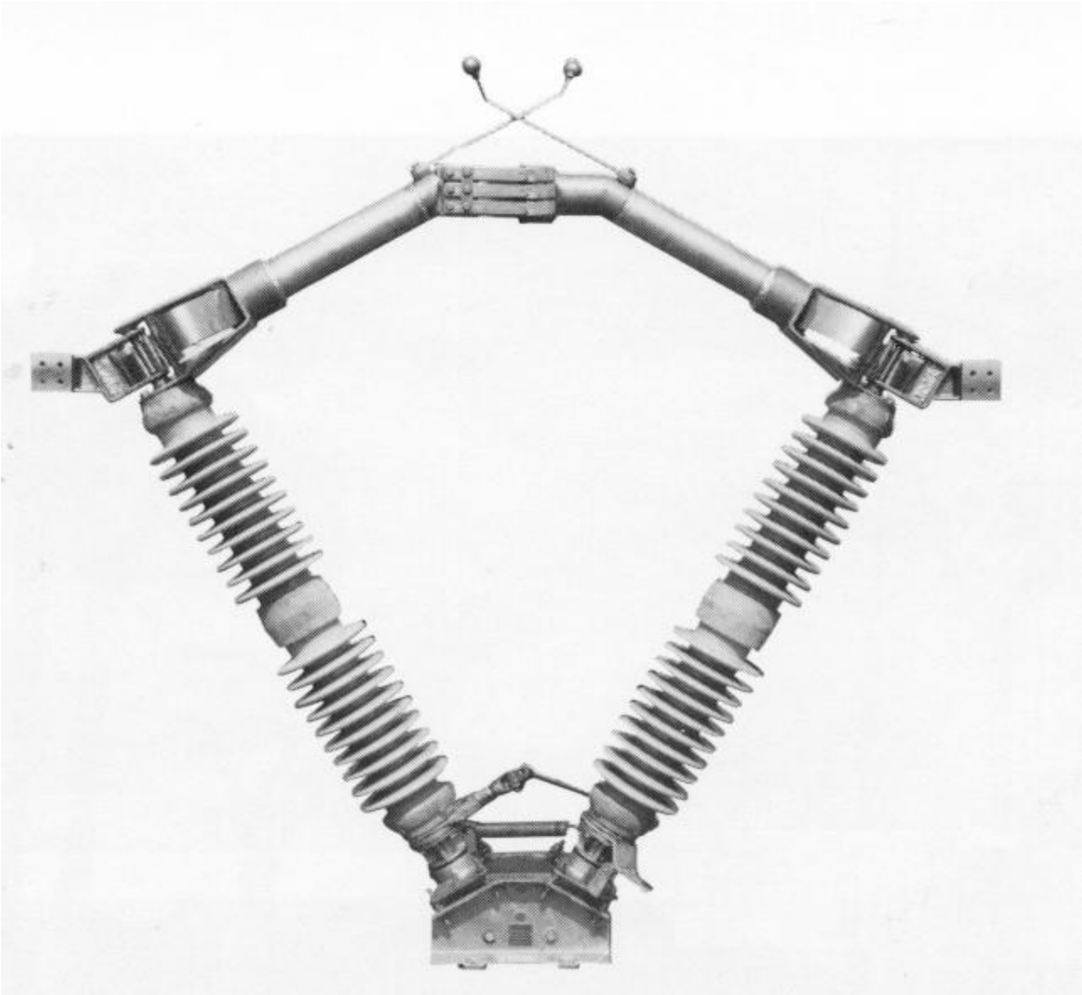
Double-end break disconnect switch mounted in a horizontal configuration



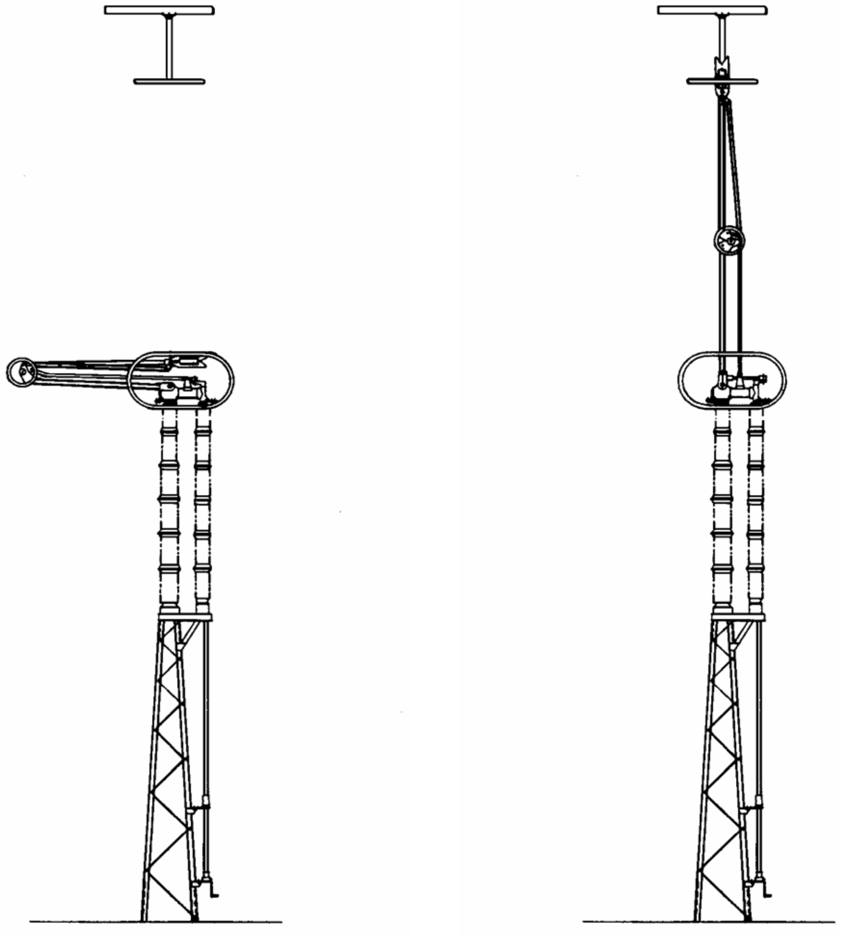
Comparison of two types of double end break disconnect switches.



Single side break disconnect switch



V break disconnect switch



Open

Closed

Vertical reach (Pentagraph) disconnect switch

PTs, CCVTs, CT,s Metering Units and Surge Arresters

What is a PT?

- Potential (Voltage) Transformer
- Provides a Representative Voltage for Metering or Relaying Applications

What is a CCVT?

- Capacitive Coupled Voltage Transformer
- Provides a Representative Voltage for Metering or Relaying Applications
- Accuracy Proportional to Value of Capacitance
- Less expensive than PTs at Voltages Greater than 115 kV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What is a CT?

- Current Transformer
- Provides a Representative Current for Metering or Relaying Applications
- Dangerous Voltages Can Occur on Open Circuited Secondaries


DANGER

What is a Metering Unit?

- Potential (Voltage) Transformer (PT) and Current Transformer (CT) Combination
- Provides a Representative Voltage and Current for Metering Applications

What is a Surge Arrester?

- Device for Protecting Electrical Equipment from Lightning and Switching Surges
- Shunts Voltage Surges to Ground

Surge Arrester Characteristics

- Maximum Continuous Operating Voltage (MCOV)
- Maximum Discharge Voltage (0.5 µs to Crest Voltage)
- Maximum Switching Surge Protection Level Voltage (45 µs to Crest Voltage)
- Maximum Discharge Voltage (8 x 20 µs Current Wave)*

*Varies with Current Peak

Arrester Application

- Assume Substation Shielded
- Use Procedure in ANSI STD. C62.2-1987, Modified for MOV-Type
- Arrester Types
  - Station
  - Intermediate
  - Distribution
  - Secondary
- Arrester Location
  - Transmission Terminals
  - Terminals of Equipment W/Non-Self-Restoring Insulation

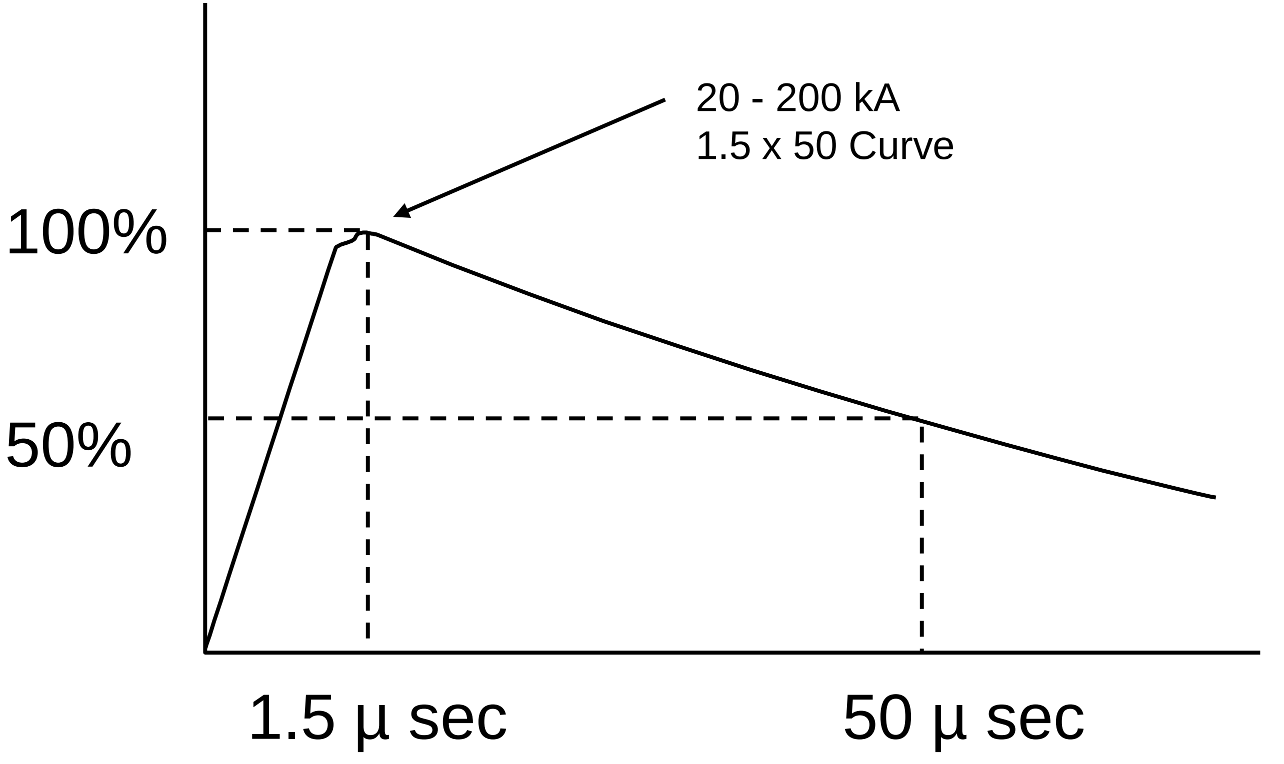
Arrester Rating in (kV) RMS

Duty-Cycle Voltage	MCOV	Duty-Cycle Voltage	MCOV	Duty-Cycle Voltage	MCOV
3	2.55	60	48	264	212
6	5.10	72	57	276	220
9	7.65	90	70	288	230
10	8.40	96	76	294	235
12	10.20	108	84	312	245
15	12.70	120	98	396	318
18	15.30	132	106	420	335
21	17.00	144	115	444	353
24	19.50	168	131	468	372
27	22.00	172	140	492	392
30	24.04	180	144	540	428
36	29.00	192	152	564	448
39	31.50	228	180	576	462
45	36.50	240	190	588	470
48	39.00	258	209	612	485
54	42.00				

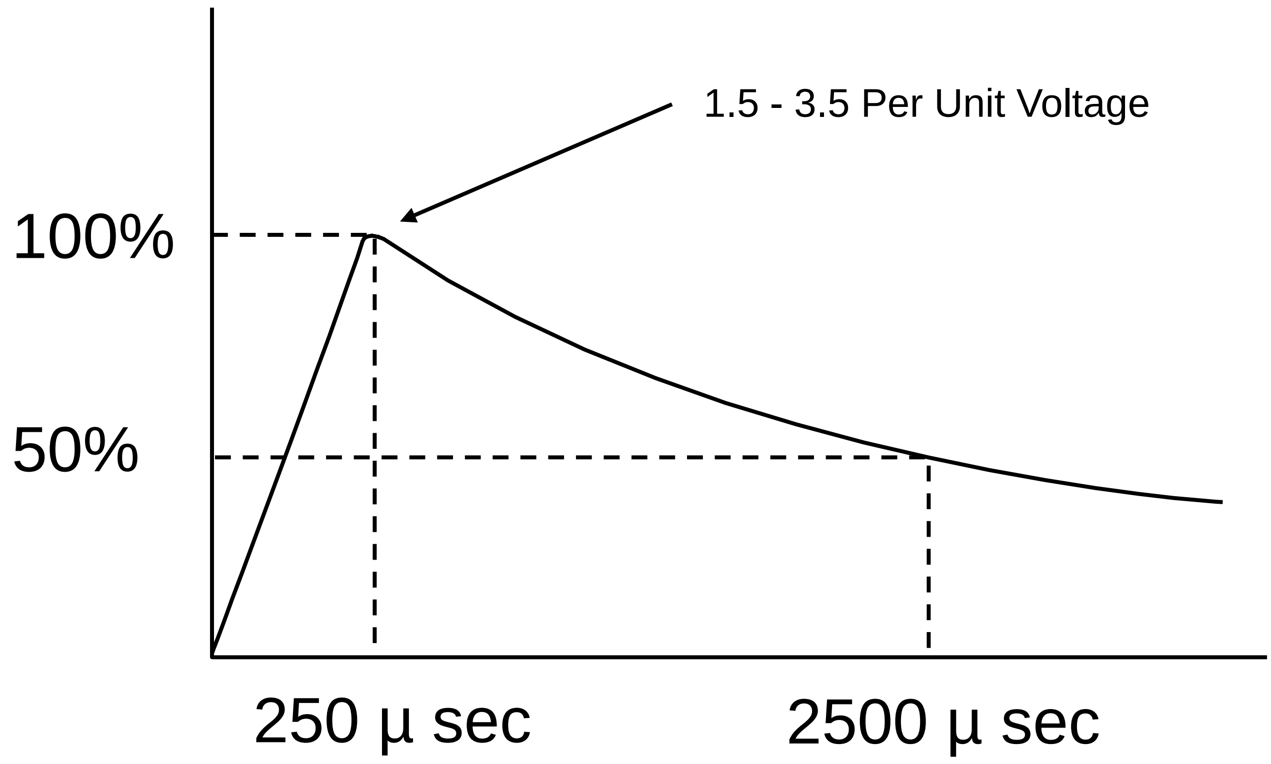
Lightning Overvoltage

- Substation Usually "Shielded" From Largest Direct Strokes
- Lightning Currents Enter Substation from Transmission Lines
  - Backflashover
  - Shielding Failure
  - Traveling Surge
- Voltage Produced Dependent on
  - Stroke Magnitude
  - Surge Impedances
  - Tower/Footing Impedance

Lightning Impulse Test Wave



Switching Surge Standard Impulse Test Wave



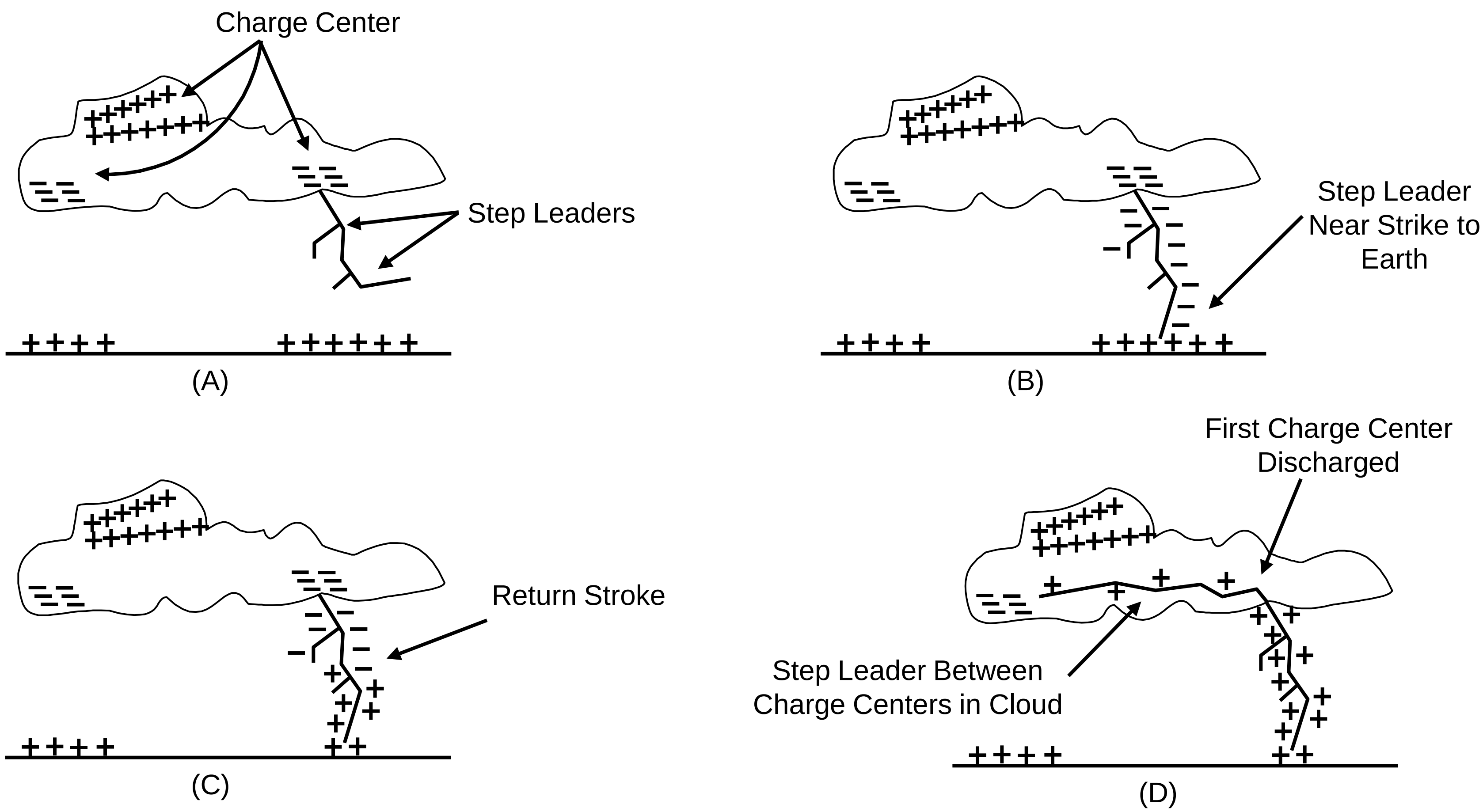
Surge Arrester Selection Is Key

Two Approaches

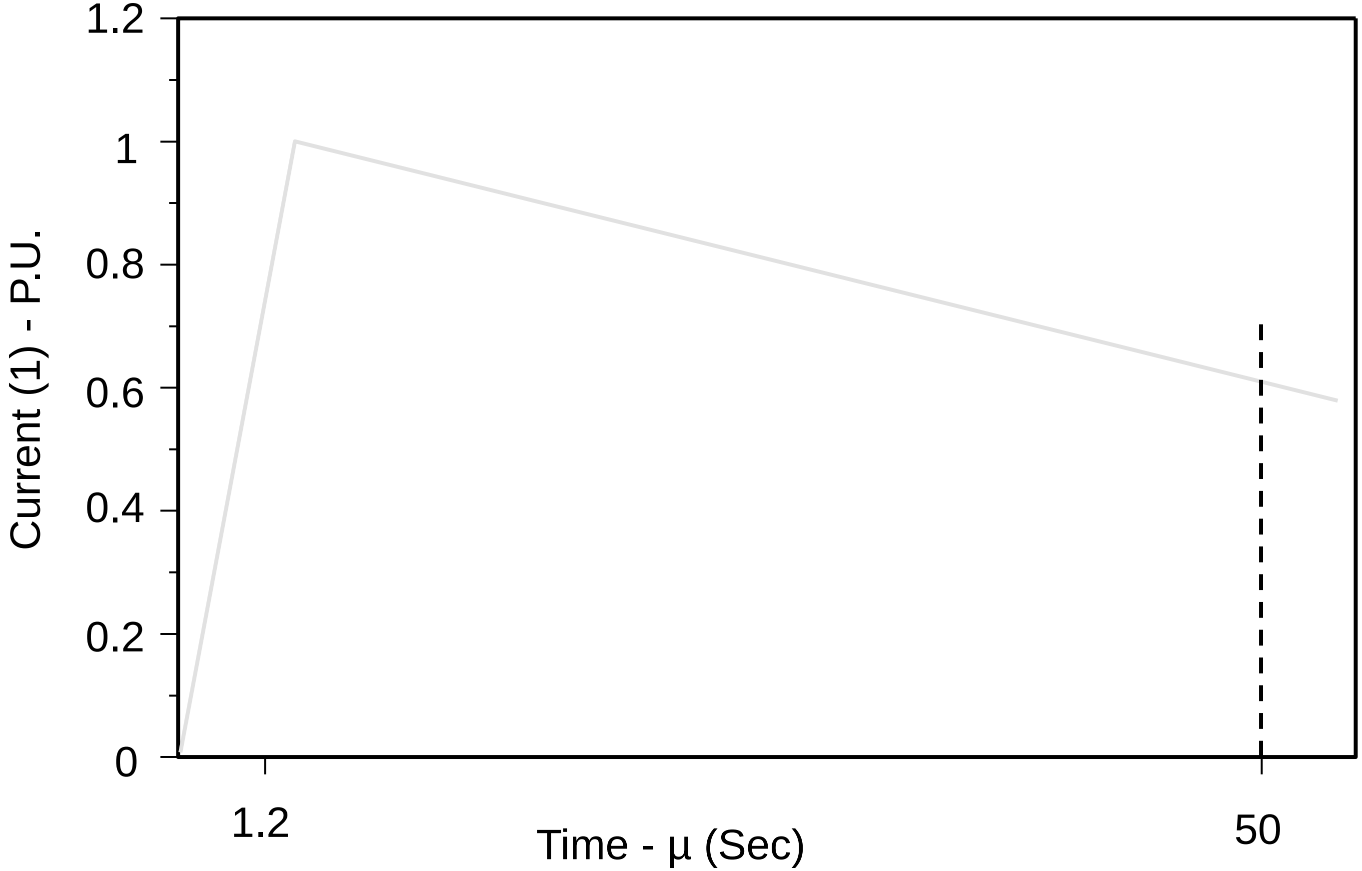
- Match Equipment Insulation to Specific Arrester Characteristics
- Match Arresters to Insulation Already Determined

Lightning Protection

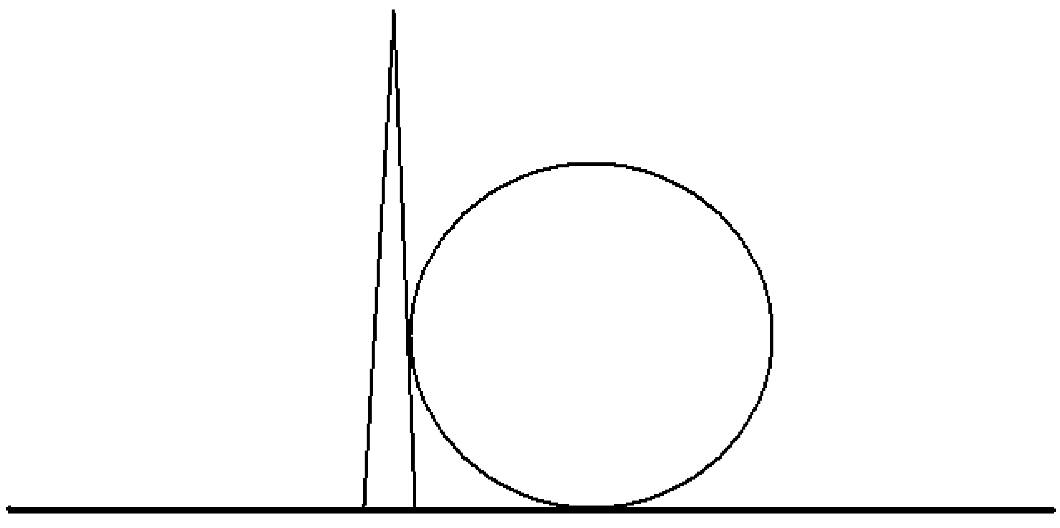
Charge Distribution at Various Stages of Lightning Discharge



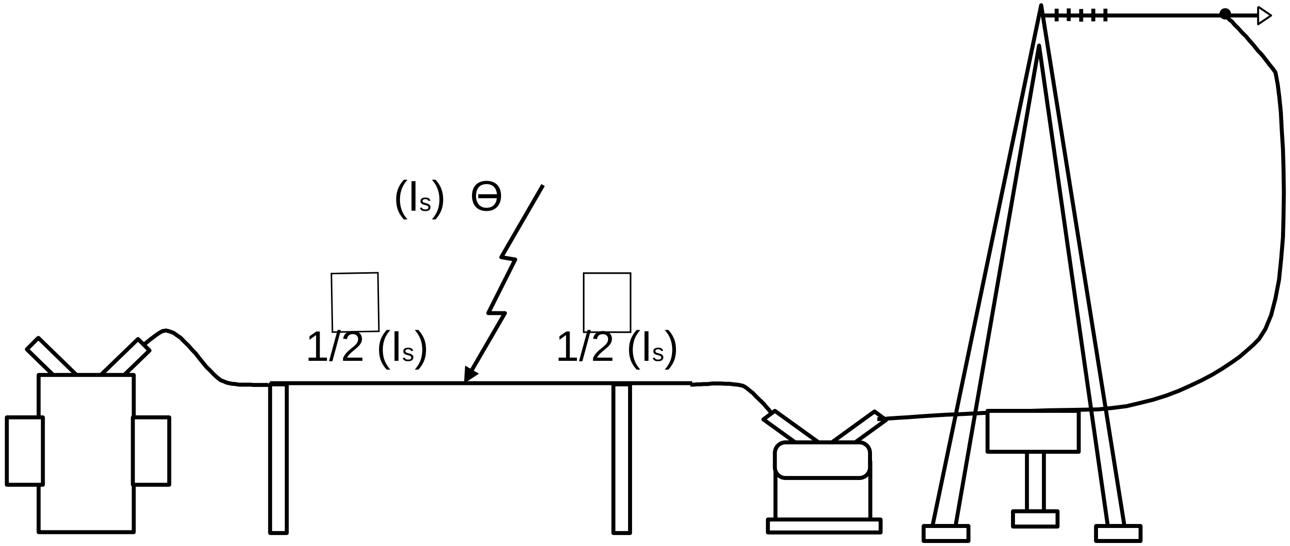
Simplified Industry Standard Lightning Stroke Waveshape



Sphere vs Tower Height



Lightning Stroke to Substation Bus



$$E_s = 1/2\ (I_s)\ (Z_s)$$

Where

E_s = Voltage Wave in Volts,

I_s = Stroke Current in Amperes, and

Z_s = Line Surge Impedance in Ohms

(1.1) = Factor to Account for the Reduction of Stroke Current Terminating on a Conductor as Compared to Zero Impedance Earth

To Prevent Flashover,

Let E_s = BIL

$$I_s = \frac{2.0\ (BIL)\ (1.1)}{Z_s}$$

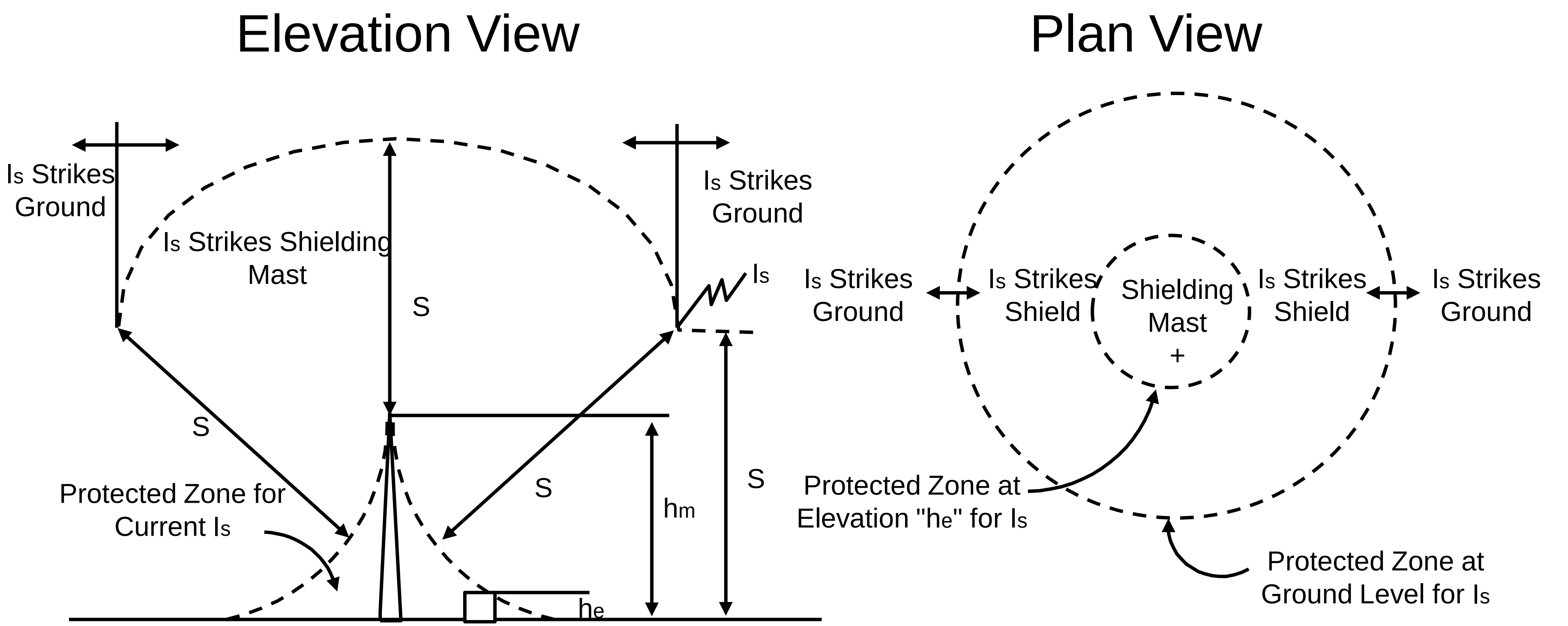
Strike Distance

- Where
  - $S = 26.25(k)(Is)^{0.65}$
  - S = Strike Distance in Feet, and
  - Is = Stroke Current in Kiloamperes
  - $Is = 2.0\ (BIL)(1.1)/Z_s$

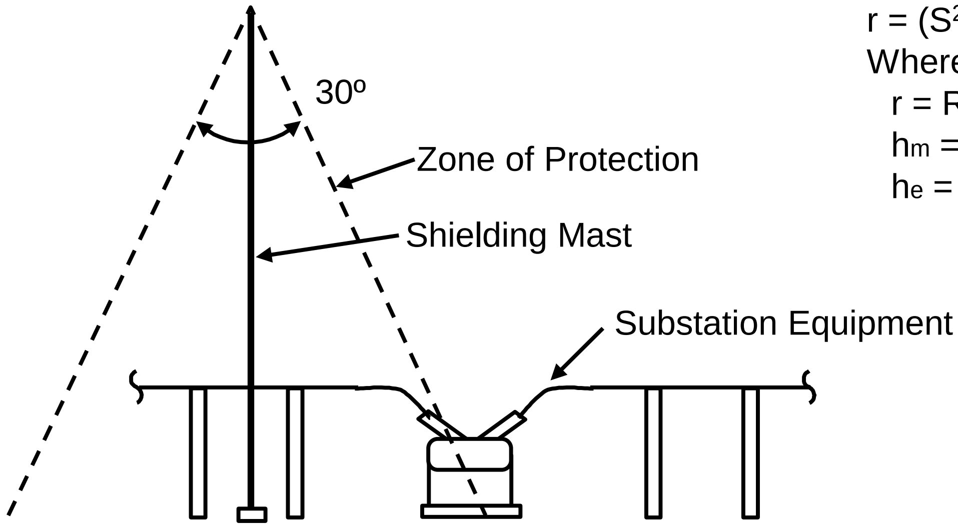
k = Coefficient to Account for Different Striking Distances to a Mast, a Shield Wire or the Ground Plane. k = 1 for Strokes to Wires or the Ground Plane and a Value of k = 1.2 for Strokes to a Lighting Mast

BIL Class	Stroke Current, I_s	Strike Distance, s K = 1.0
kV	kA	Feet
110	0.89	24.3
150	1.22	29.9
200	1.62	35.9
250	2.03	41.6
350	2.84	51.7
550	4.46	69.4
650	5.27	77.3
750	6.08	84.9
900	7.29	95.5
1050	8.51	105.6
1300	10.53	121.3
1400	11.34	127.2

Shielding Mast Protection for Stroke Current



Zone Protected by One Shielding Mast



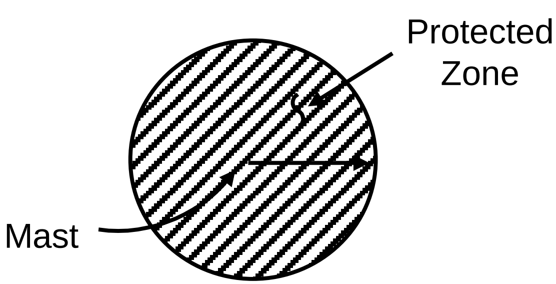
$r = (S^2 - (S-h_m)^2)^{1/2} - (S^2 - (S-h_e)^2)^{1/2}$

Where

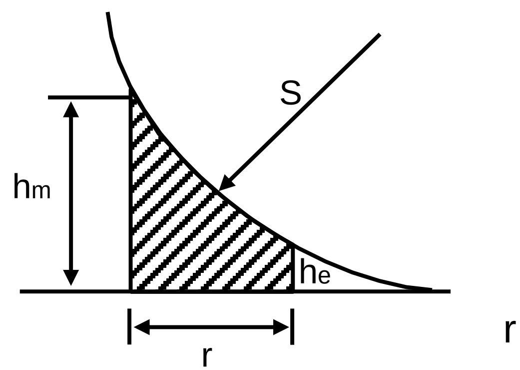
r = Radius of the Protected Area in Feet

h_m = Height of the Mast in Feet, and

h_e = Height of Protected Equipment in Feet

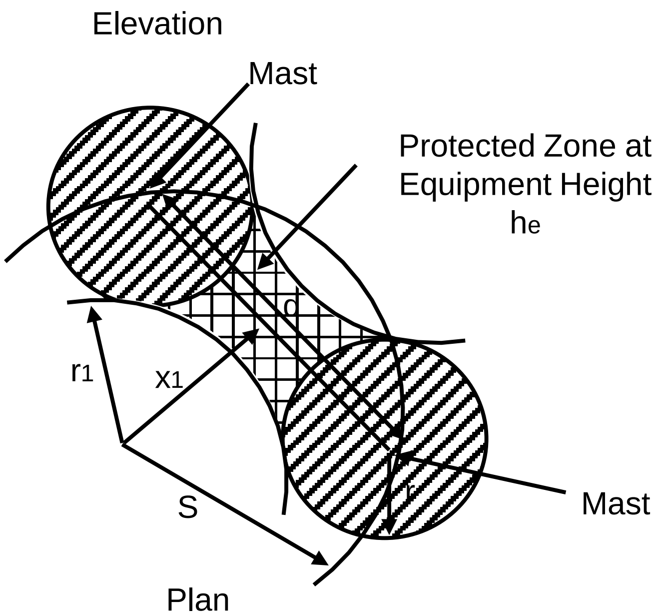


Plan



Elevation

Zone Protected by Two Shielding Masts



$x_1 = (S^2 - (\frac{d}{2})^2 - (S - h_m)^2)^{1/2}$

Where

d = Distance Between the Two Masts in Feet, and

h_m = Height of the Mast in Feet

The Radius of Curvature of the Protected Area (r_1) Is Given by the Following Equation

$r_1 = (S^2 - (S - h_e)^2)^{1/2}$

Where

h_e = Height of the Equipment in Feet

$d_{max} = [S^2 - (S - h_m + h_e)^2]^{1/2} + [S^2 - (S - h_{m2} + h_e)^2]^{1/2}$

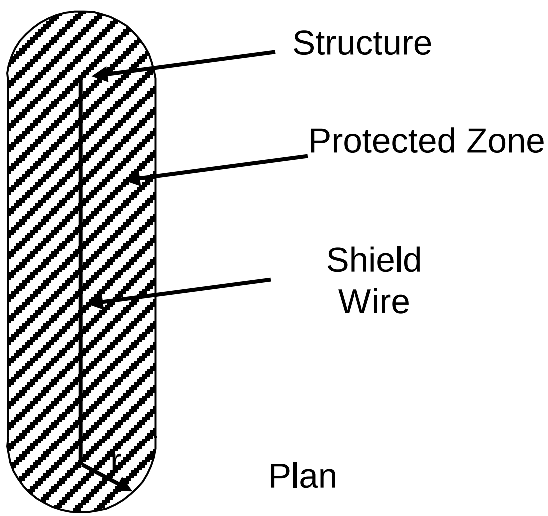
h_{m2} = Height of 2nd Mast if Different Than First

Zone of Protection for a Shield Wire Between Two Structures

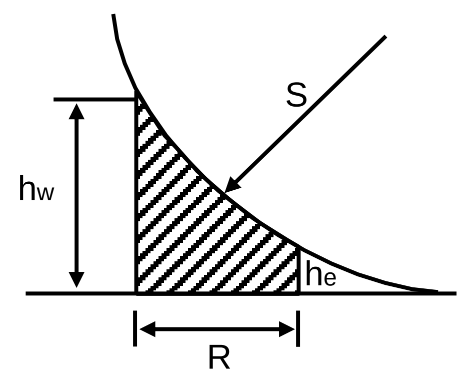
$r = S^2 - (S-h_w)^2)^{1/2} - (S^2 -(S-h_e)^2)^{1/2}$

Where

hw = Height of the Shield Wire at Mid-Span Between Supports

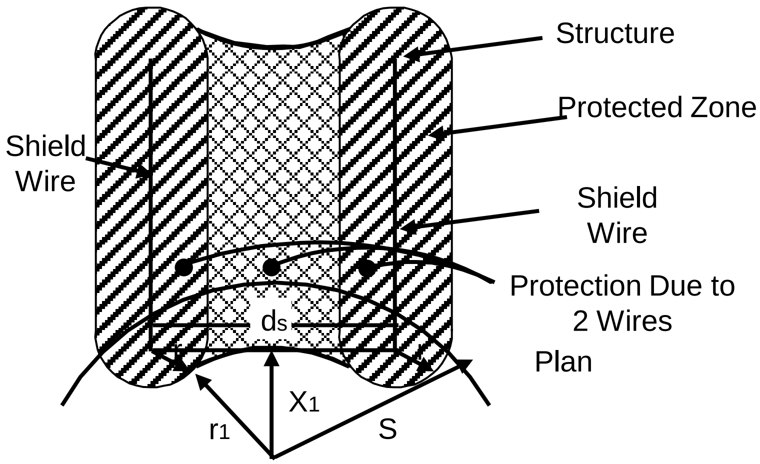


Plan



Elevation

Zone of Protection for Two Parallel Shield Wires



$$X_1 = \left(S^2 - \left(\frac{d_s}{2}\right)^2 - (S - h_w)^2\right)^{1/2}$$

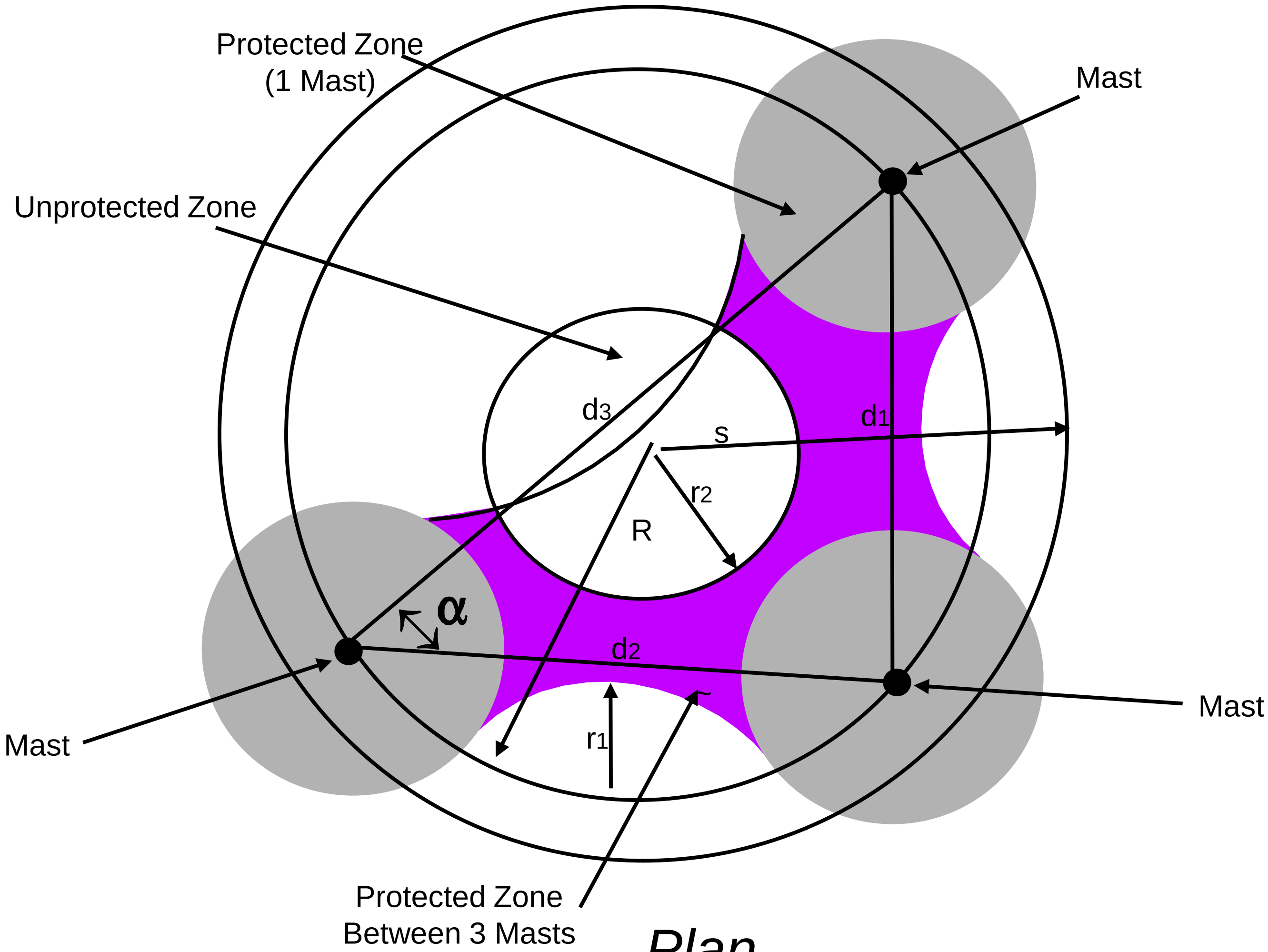
Where

d_s = Distance Between the Two Structures (Feet)

The Radius of Curvature of Protected Area (r) Is Given by the Following Equation

$$r_1 = \left(S^2 - (S - h_e)^2\right)^{1/2}$$

Zone Protected by Three Shielding Masts



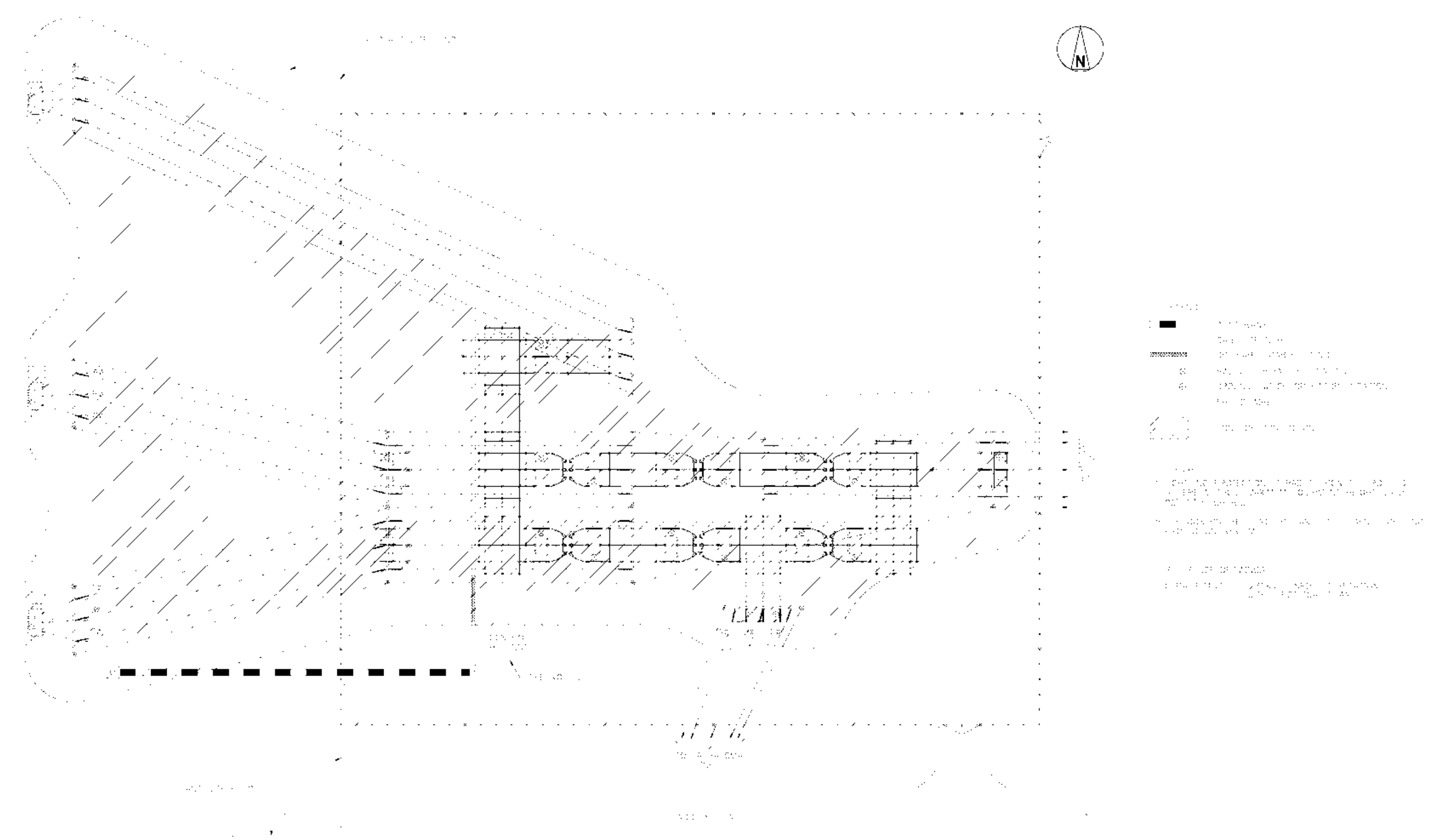
Plan

Failure Probability

- Determine Strike Distance Required to Shield Unprotected Areas
- Calculate Corresponding Stroke Current for Unprotected Area
- Calculate the Probability of Those Stroke Currents Occurring
- Using Isokeraunic Data for the Area, Calculate the Frequency of the Stokes
- Determine Failure Rate Based on the Frequency of the Strokes

Analysis Procedure

- Calculate Stroke Current Based on Equipment BIL
- Calculate Strike Distance From Stroke Current
- Prepare Trial Design for Shielding System
- Calculate Zones of Protection for Trial Design
- Draw Zones of Protection on Plan Arrangement Drawing of Switchyard
- Determine Strike Distance Required to Completely Shield All Nonprotected Areas
- Calculate Failure Rate. If Unacceptable, Modify Design



BLACK & VEATCH CONSTRUCTION, INC.

SUNRISE POWER CO.

99498-CPPA-E7401

4

Design of Substation Metering Systems

Substation Metering

Substation Metering

Typical Parameters Measured

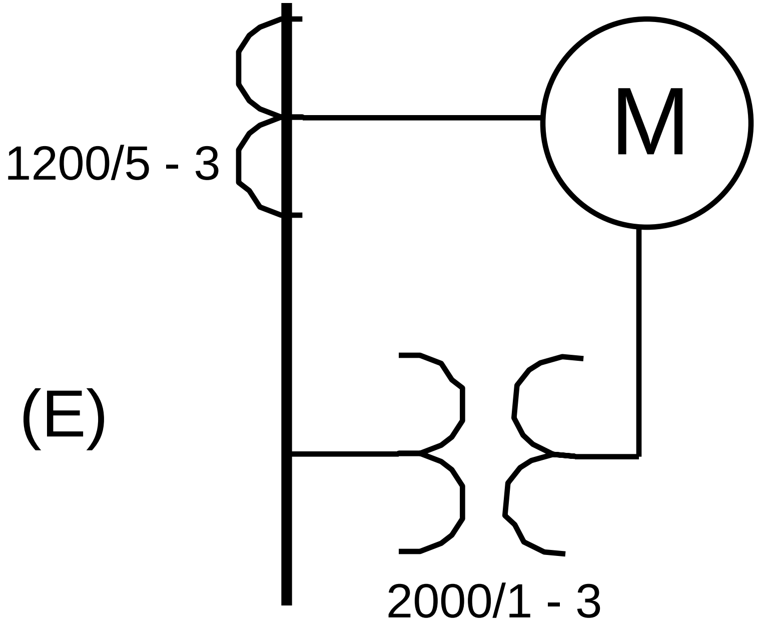
- Volts, Amps, Watts, VARS, PF
- VA, Frequency
- Demand (peak watts and vars)
- Other-Harmonics, THD, Neutral Current

(Single Phase and Per Phase)

Substation Metering

Actual Measured Values

- Current (I)
- Voltage (V) (E)



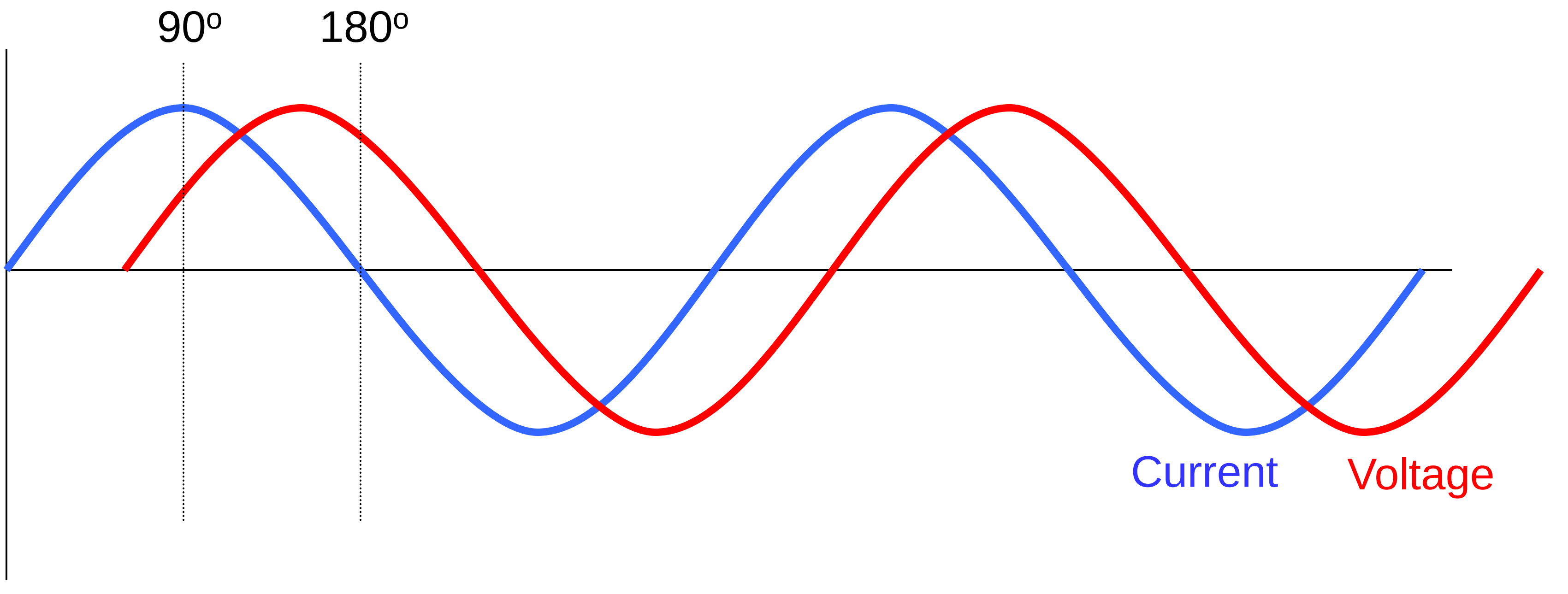
Substation Metering

To Find	Single Phase	Three Phase	Direct Current
AMPERES when KVA is known	KVA x 1000 / E	KVA x 1000 / E X 1.73	Not Applicable
AMPERES when horsepower is known	HP x 746 / E x % Eff.x PF	HP x 746 / E x 1.73 x % Eff. x PF	HP x 746 / E x % Eff.
AMPERES when kilowatts are known	KW x 1000 / E x PF	KW x 1000 / E x 1.73 x PF	KW x 1000 / E
KILOWATTS	I x E x PF / 1000	I x E x 1.73 x PF / 1000	I x E / 1000
KILOVOLT/ AMPERES	I x E / 1000	I x E x 1.73 / 1000	Not Applicable
HORSEPOWER	I x E x % Eff. x PF / 746	I x E x 1.73 x % Eff. x PF / 746	I x E x % Eff. / 746
WATTS	E x I x PF	E x I x 1.73 x PF	E x I

Substation Metering

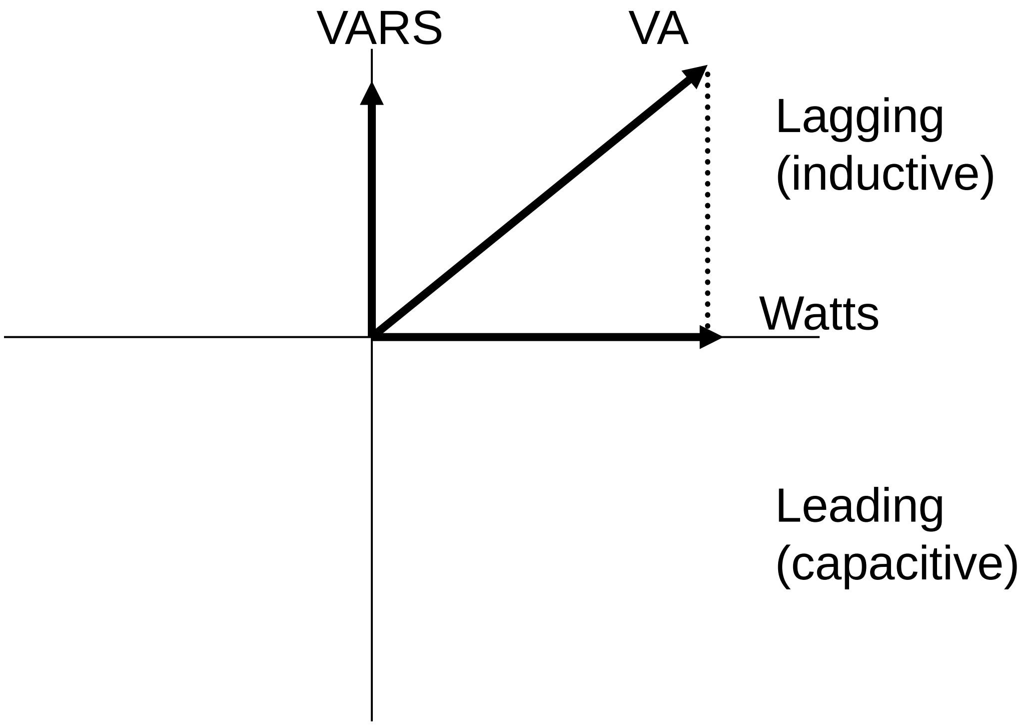
Power Factor

- Relationship Between Voltage and Current



Substation Metering

VARS



Substation Metering

Most Common Quantities

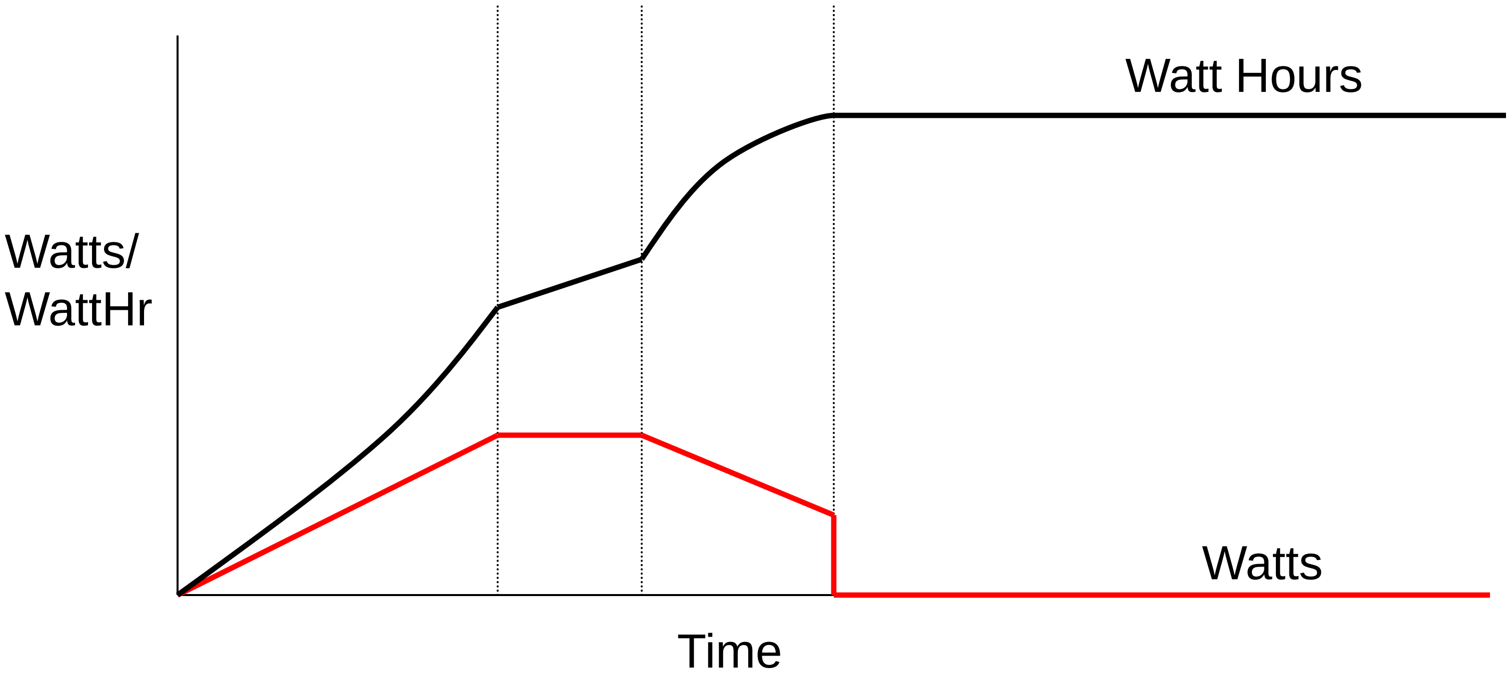
- Volts and Amps
- Watts = E x I x PF
- VARS = E x I x (1-PF)

Substation Metering

The Meter's Real Purpose

Substation Metering

Indication Metering vs. Revenue Metering

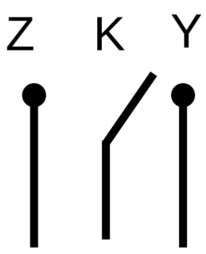


Speedometer vs. Odometer

Substation Metering

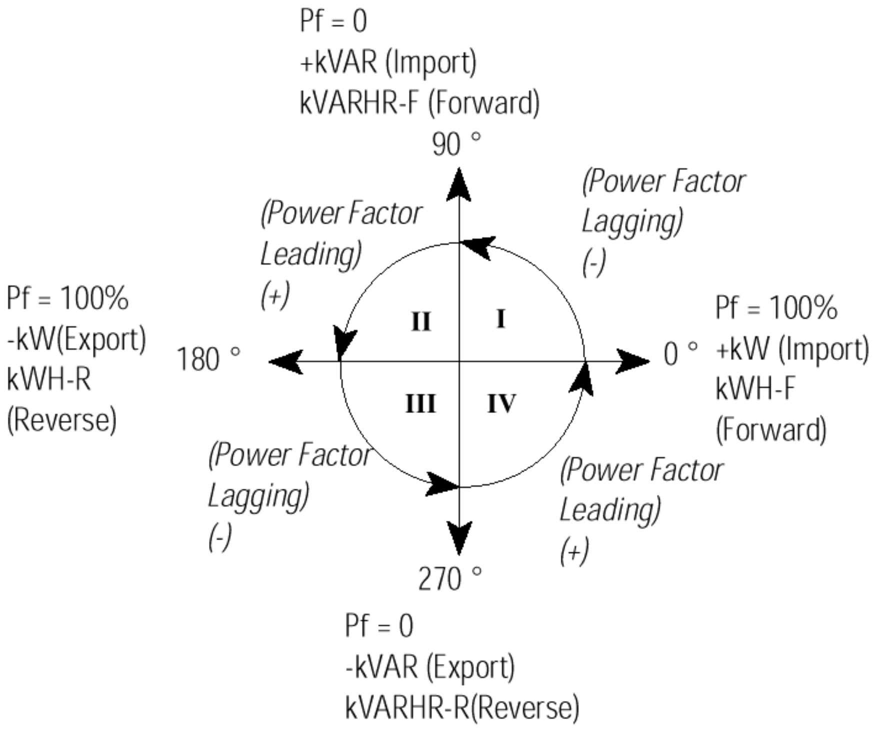
KWH

- Represented as Pulses
  - KYZ (3 wire)
  - KY (2 wire)



Substation Metering

Quadrant Conventions



Substation Metering

Real Time or Instantaneous Data

- Volts, Amps, Watts, Vars, etc.
- Used by Operations

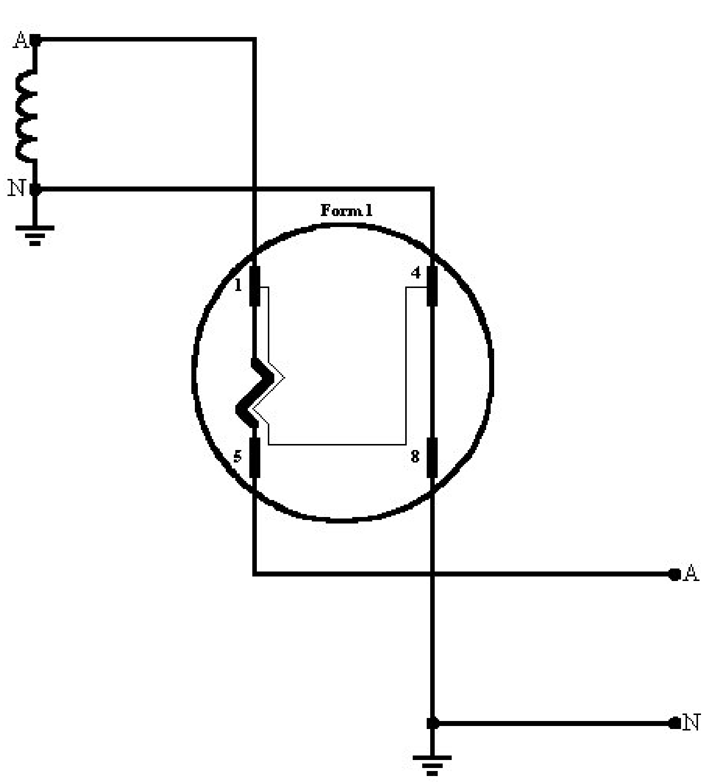
Substation Metering

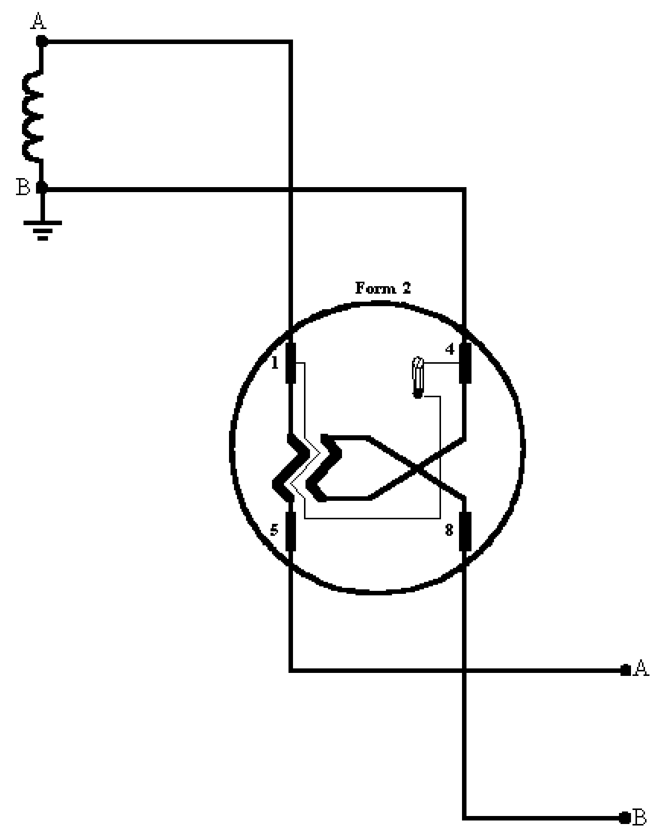
Cumulative (Integrated) Data

- Watt Hours, Var Hours
- Used for Billing

Substation Metering

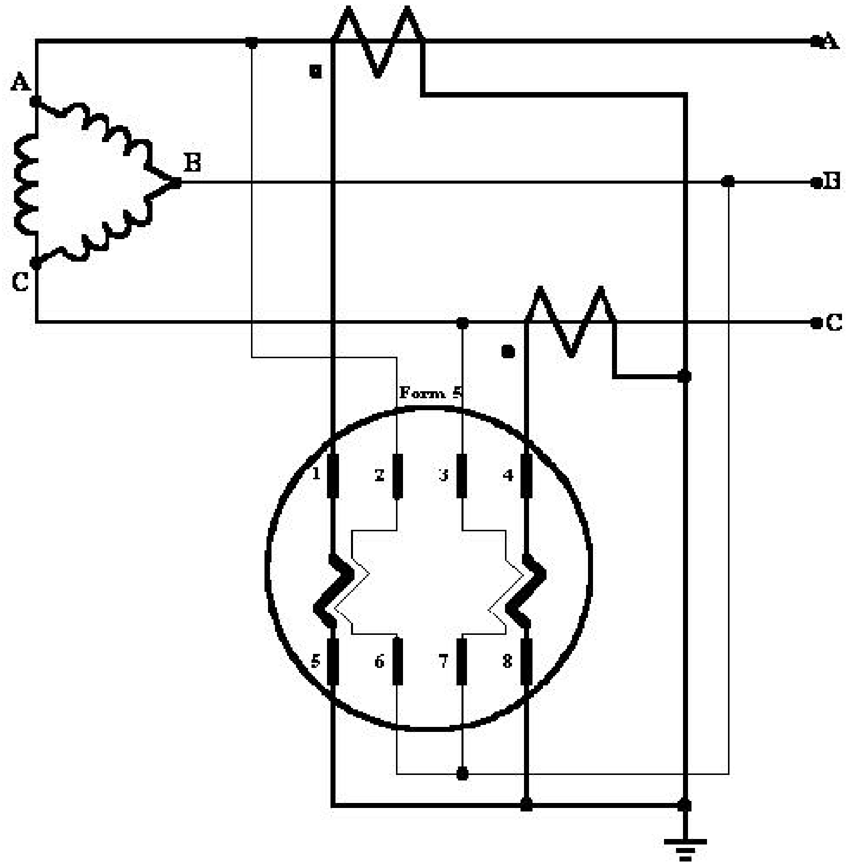
Single Element (2 wire) Single Phase





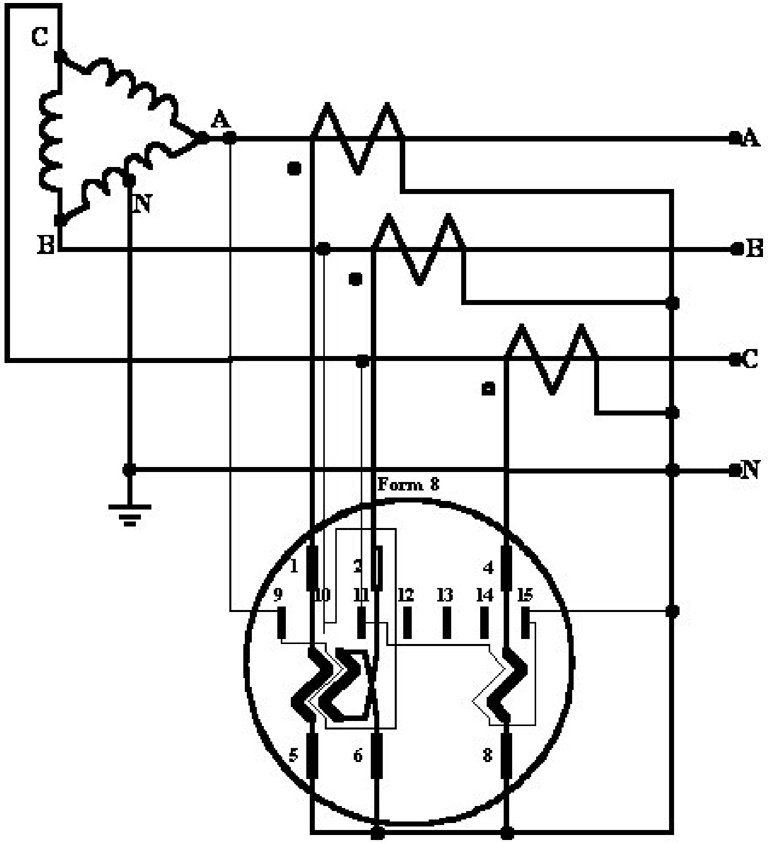
Substation Metering

2 Element (3 wire Delta) Three Phase



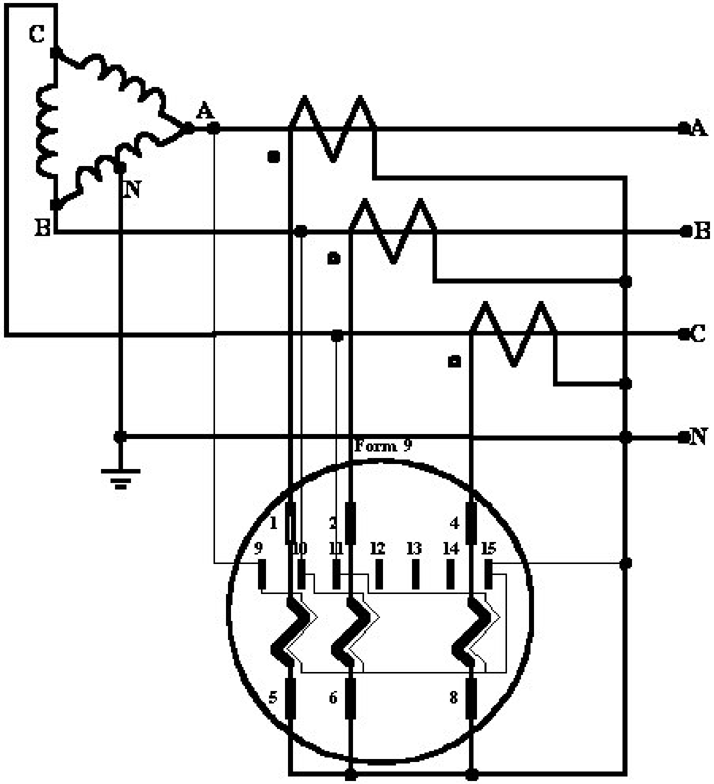
Substation Metering

2 1/2 Element (4 wire Delta) Three Phase



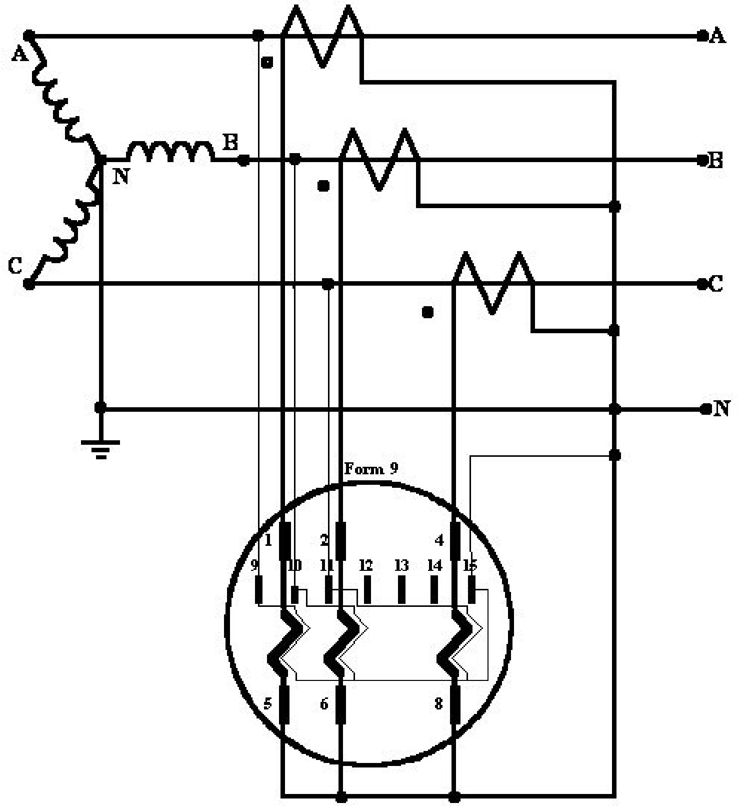
Substation Metering

3 Element (4 wire Delta) Three Phase

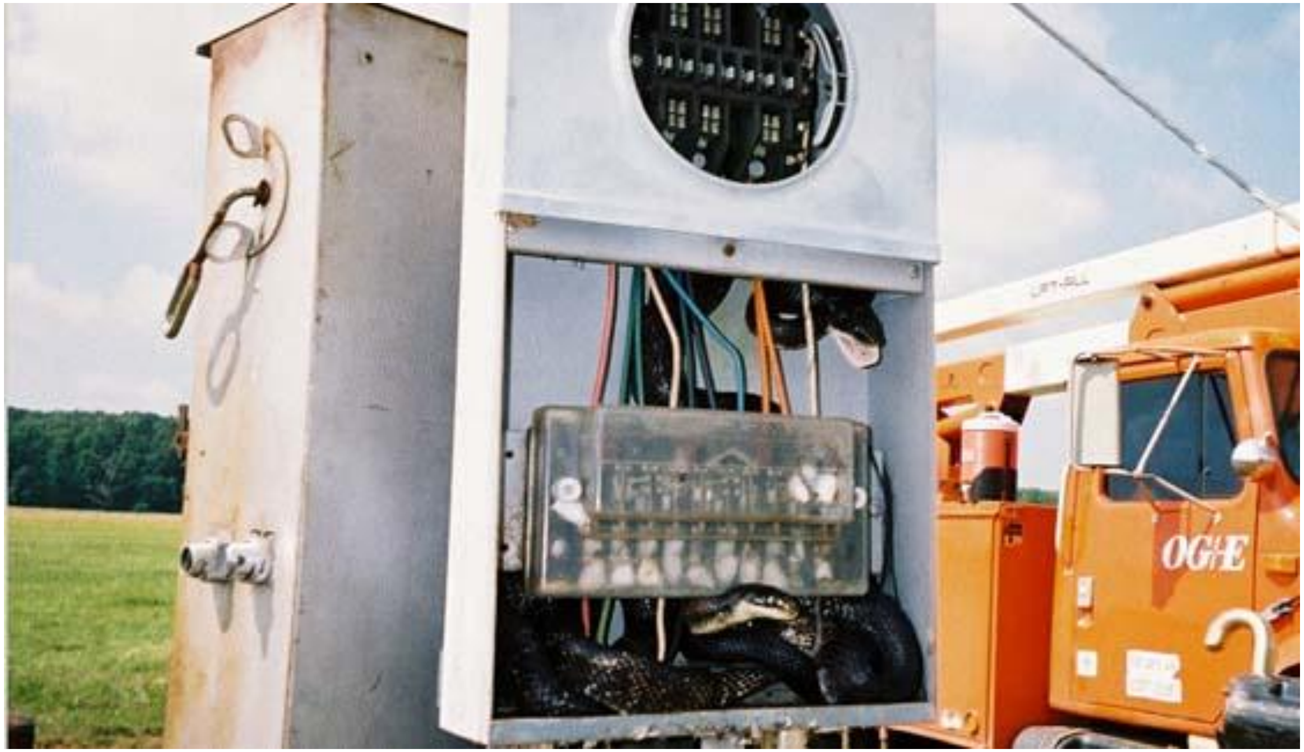


Substation Metering

3 Element (4 wire Wye) Three Phase



Substation Metering



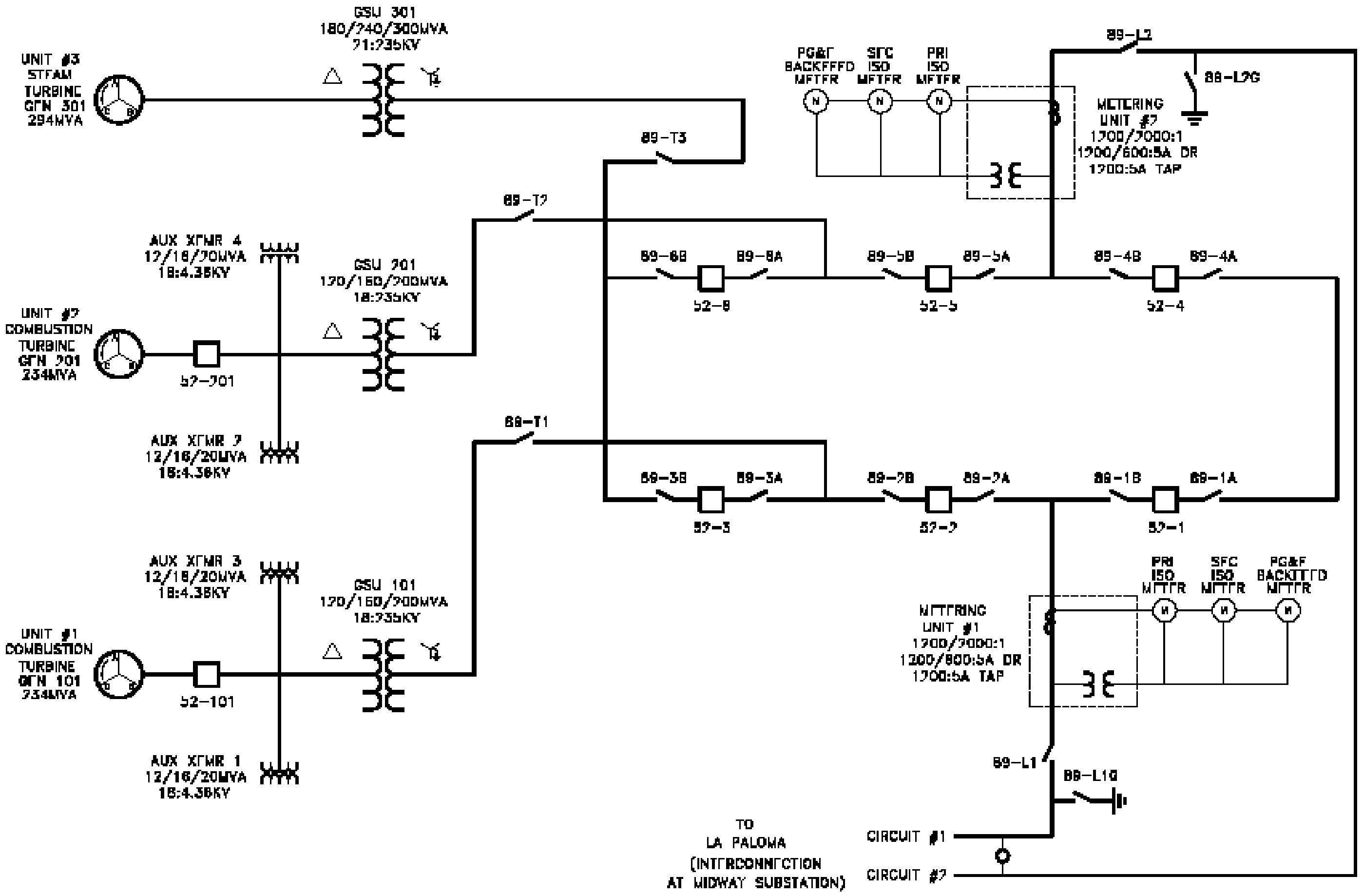
Substation Metering

Substation Metering

Design:

- Where to Meter
  1. Generator Output (Gross Power)
  2. Lowside of Transformer (Net Power)
  3. Highside of Transformer (Net Compensated Power)
  4. Outgoing Line (Total Net Compensated Power)

Substation Metering



Substation Metering

Meter Compensation

- Transformer Loss Compensation (TLC)
- Line Loss Compensation (LLC)

Substation Metering

Meter Compensation

- Two Components
  - Copper Losses $\rightarrow$ Watt Losses = $I^2 \times R$
  - Iron Losses $\rightarrow$ VAR Losses = V^2/X

Substation Metering

Meter Compensation

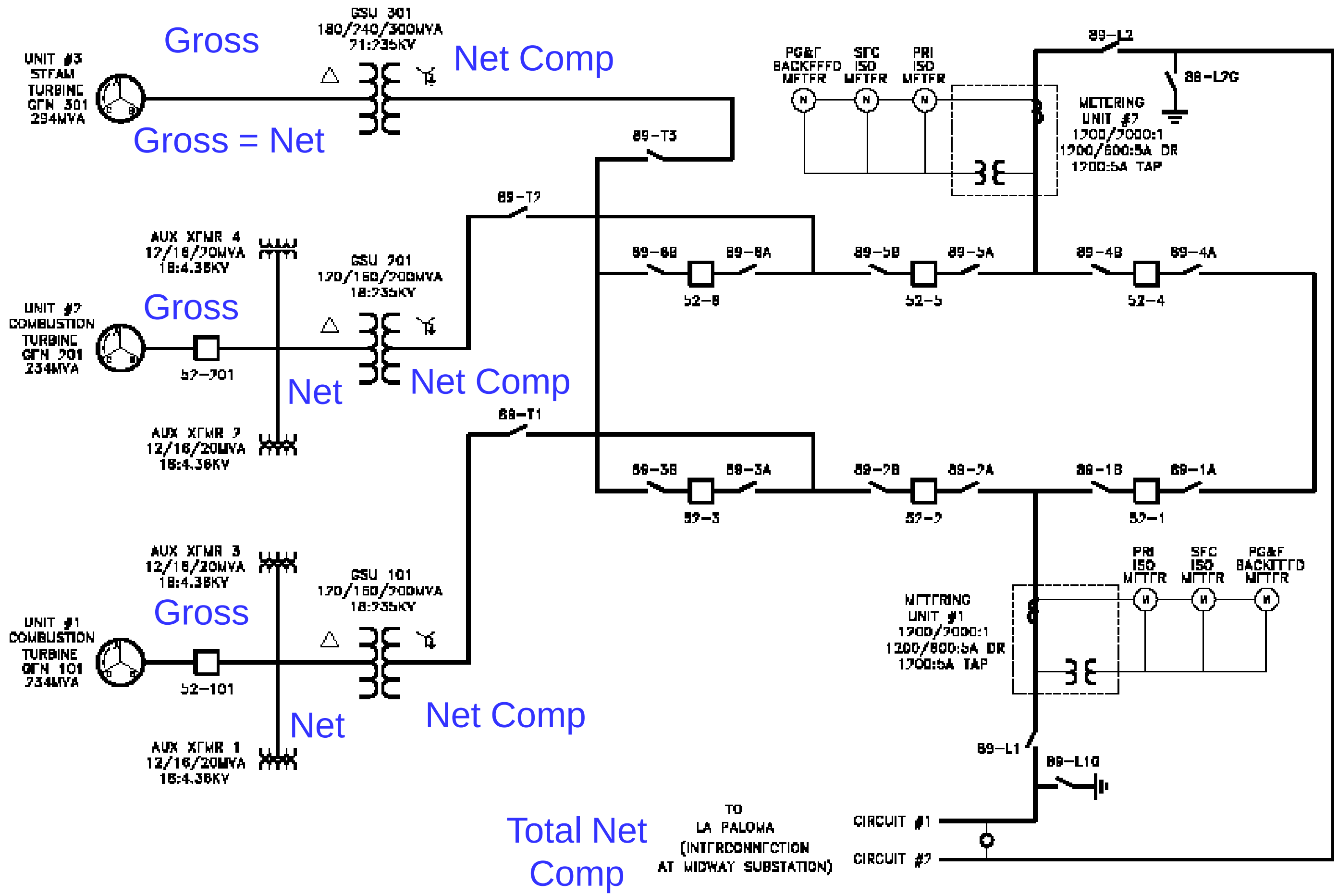
Gross Power – Auxiliary Loads = Net Power

Net Power – TLC Losses = Net Compensated

Net Compensated - LLC = Total Net Compensated

(multiple levels of LLC and TLC can be used)

Substation Metering



Substation Metering

Design:

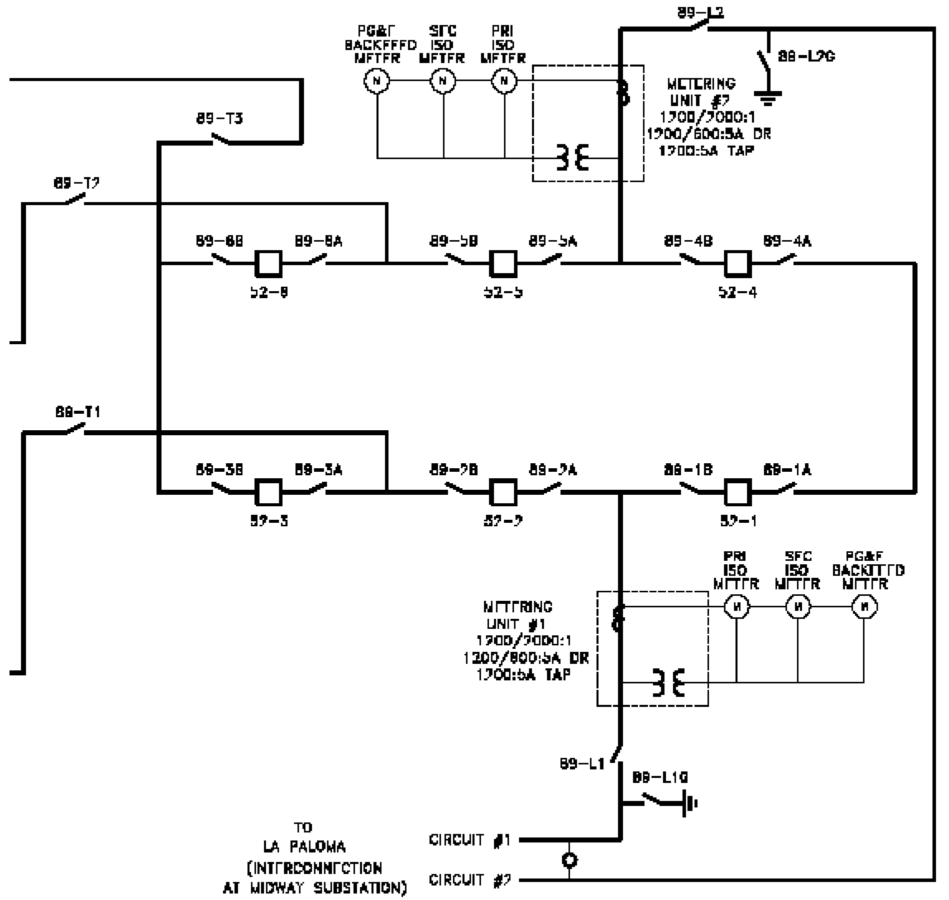
- Metering Gross Output
  - CTs and PTs are smaller
  - Need only two each (Form 5S)
  - Without additional Revenue Meters on Aux Loads cannot calculate TLC
  - With two lines out of substation it's difficult to calculate LLC

Substation Metering

Design:

- Metering Net Output
  - CTs and PTs are smaller
  - Need only two each (Form 5S)
  - Difficult to calculate LLC
  - Operations cannot “see” Aux loads when unit is running
  - Better accuracy for metering back-feed power

Substation Metering



Substation Metering

Design:

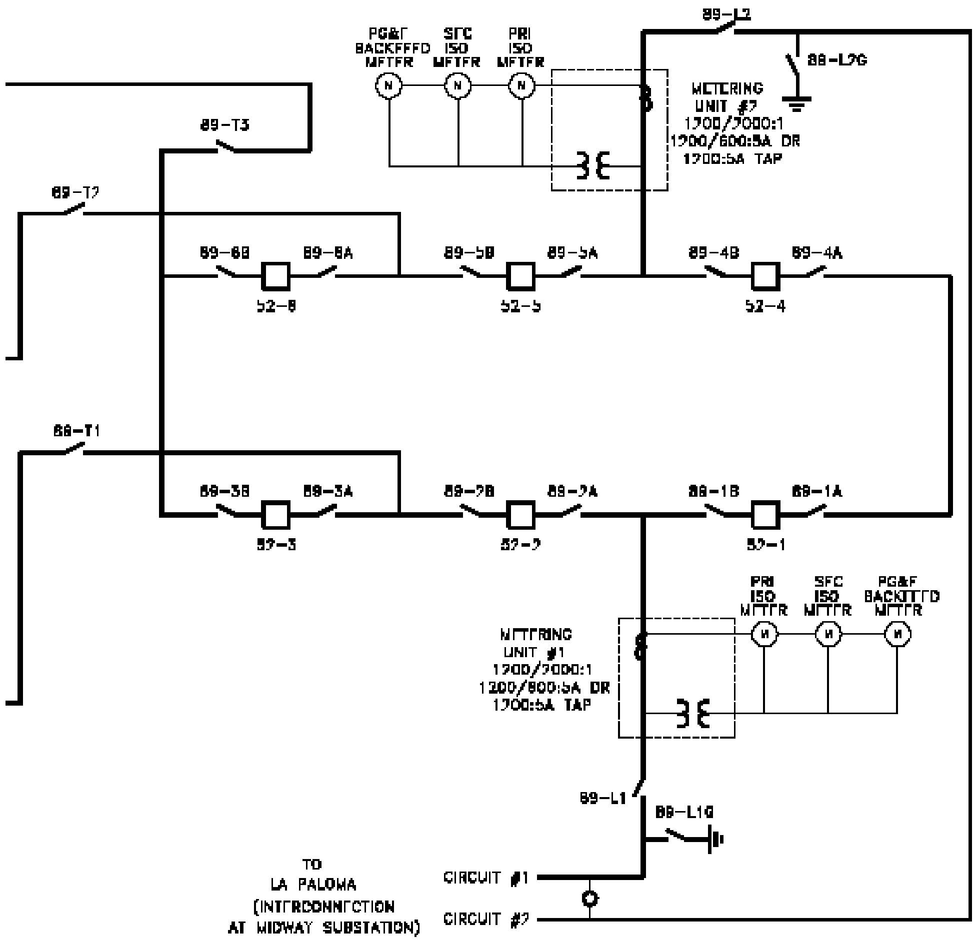
- Metering Net Compensated Output
  - CTs and PTs are bigger
  - Need three each (Form 9S)
  - With two lines out of substation it's difficult to calculate LLC
  - Operations cannot “see” Aux loads
  - Difficult to meter back-feed when unit is down

Substation Metering

Design:

- Metering Net Compensated Output
  - CTs and PTs are bigger
  - Need three each (Form 9S)
  - Operations cannot “see” Aux loads
  - Difficult to meter back-feed when unit is down
  - Only need two meter installations
  - LLC is easy to do

Substation Metering



Substation Metering

Design:

- Back-feed Metering
  - Aux-Loads
  - Start-Up Power
  - Accuracy
- Meter and CT Location
  - Burden

Substation Metering

Design:

- Equipment
- Determined by Metering Point and Load/Generation
  - CTs 1200/5
  - PTs 2000/1
  - Necessary Certifications

Grid Operations

Grid Operations

Substation Metering

Design:

- Users of Data
  - Utility
  - Independent Operator
  - Scheduling Coordinator/Marketer

Substation Metering

Design:

- Protocols
  - MV 90
  - Modbus/DNP
  - Displays
  - Security
- Displays
- Security

Control and Protection

Objectives

- Introduce Philosophies of Control and Protection
- Identify Types of Protection Systems and Relay Selection Criteria
- Review Key Design Considerations and Application Problems

Basic Functions of a Protection System

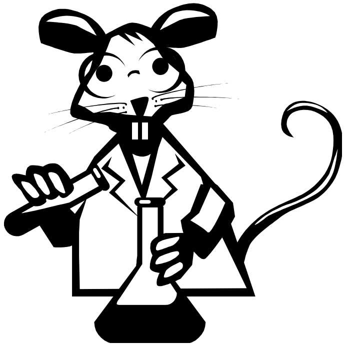
- Ensure Safe and Reliable Power System Operation
- Mostly achieved through design
- System functions incorrectly or fault occurs
- What are the causes?

Causes for faults and improper operations

- Lightening and Rain

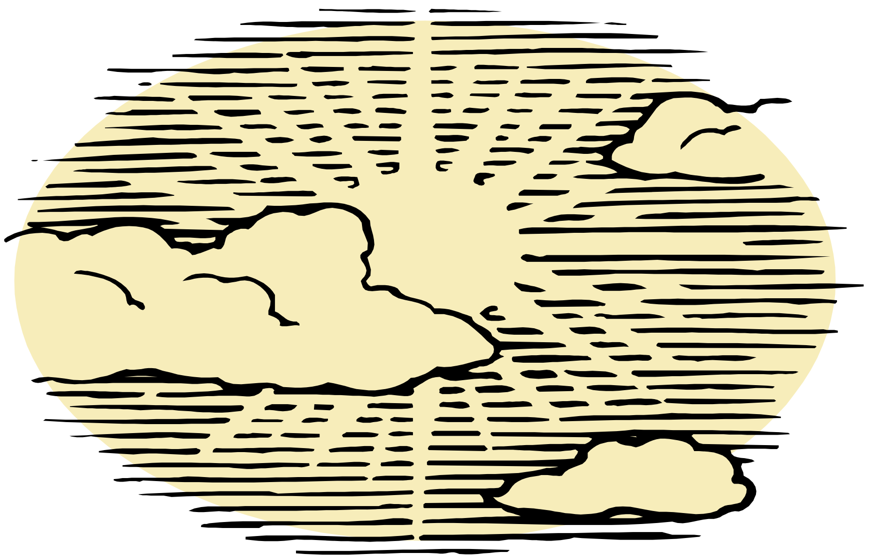
Causes for faults and improper operations

- Animals



Causes for faults and improper operations

- Dust
- Heat
- Environment

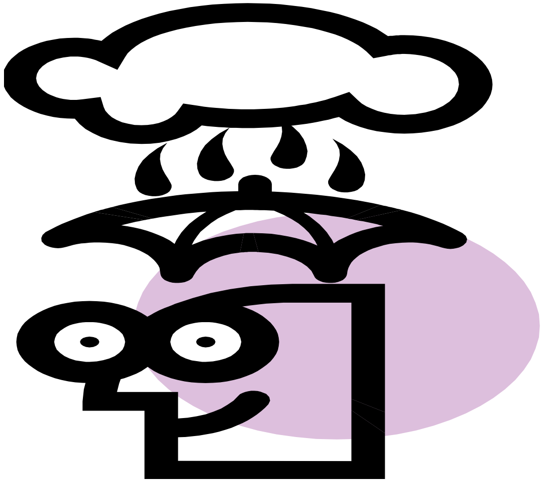


Causes for faults and improper operations

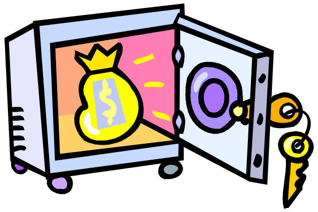
- Age
- Human Errors

What is Protection?

- Insurance against such causes



How Good Your Protection or Insurance Is



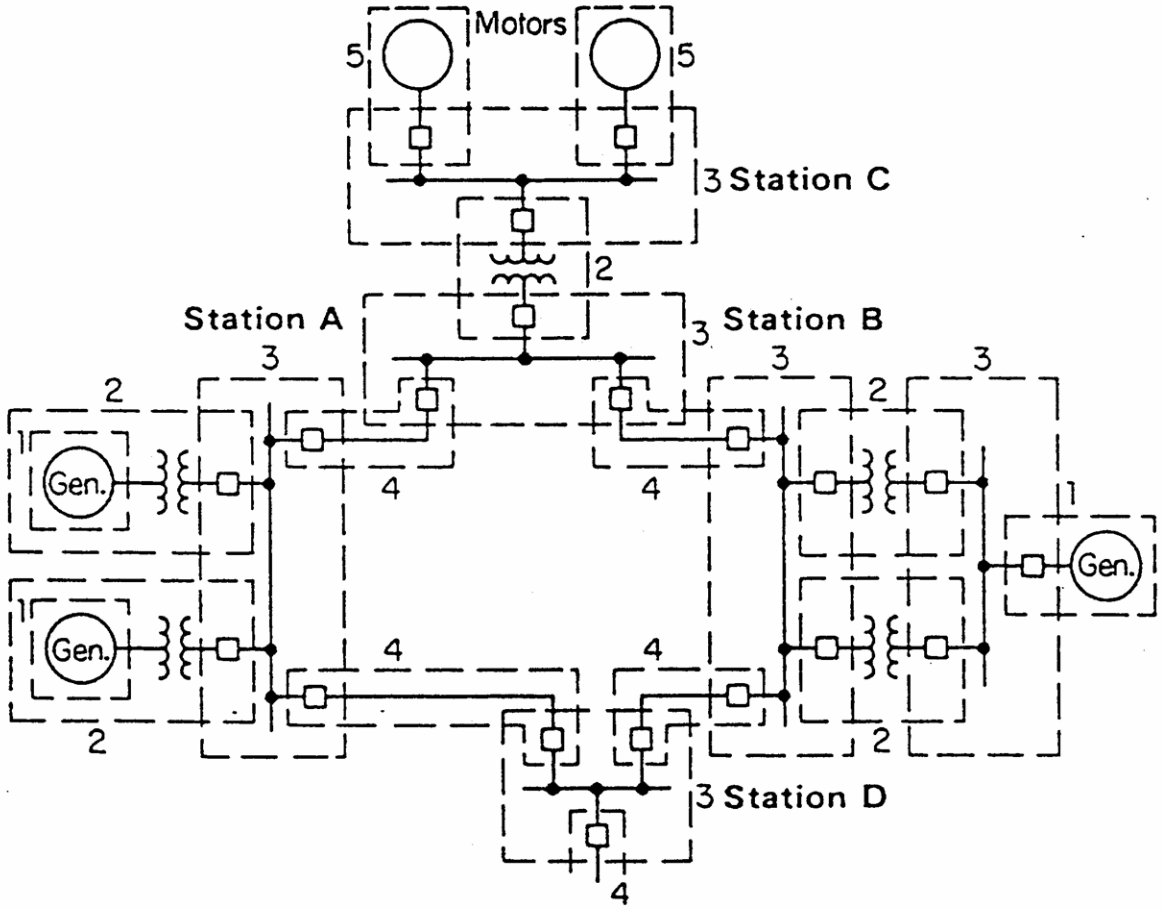
- Reliability (Dependability + Security)

- Selectivity
- Speed
- Simplicity
- Economy

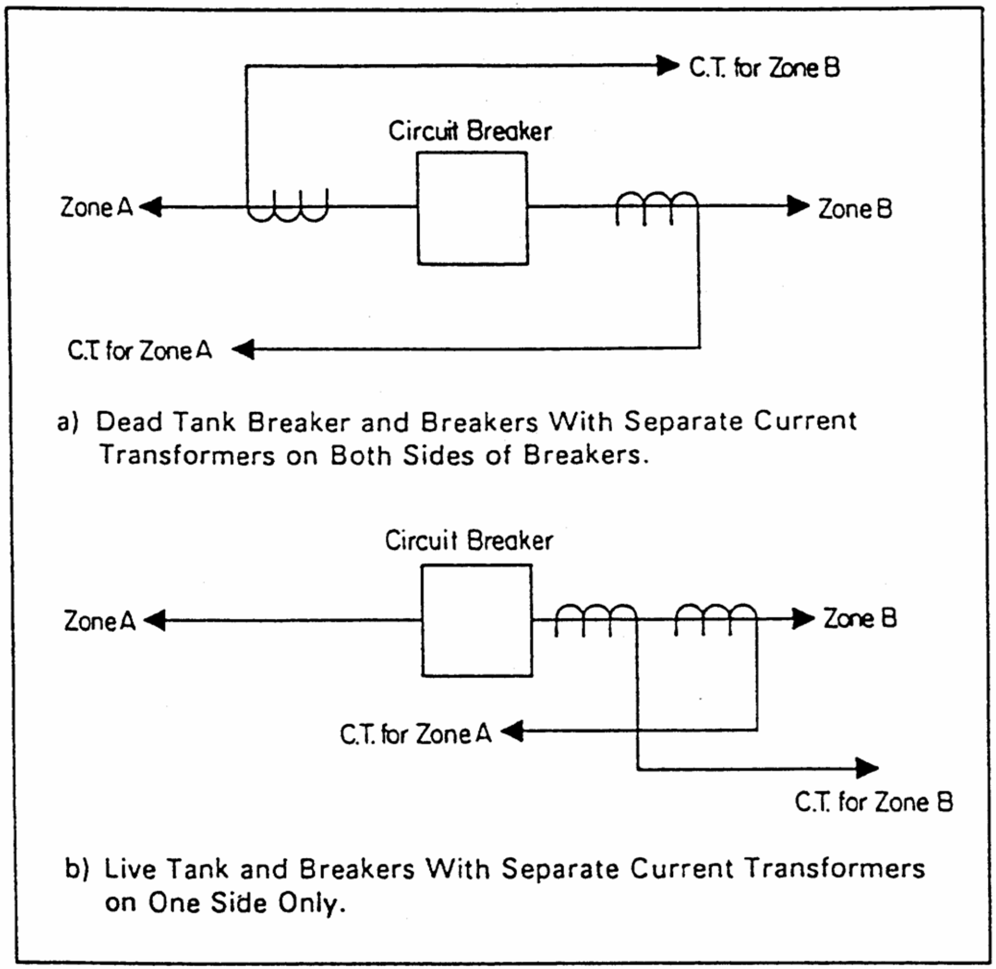
Zones of Protection or Coverage Area

- Circuit Breakers (or other) Provide Demarcation Point
- Usually Defined with Development of the One-Line Diagram
- Define which System Components must be Removed from Service for a Given Fault Condition
- Should Overlap

A Typical System and Its Zones of Protection



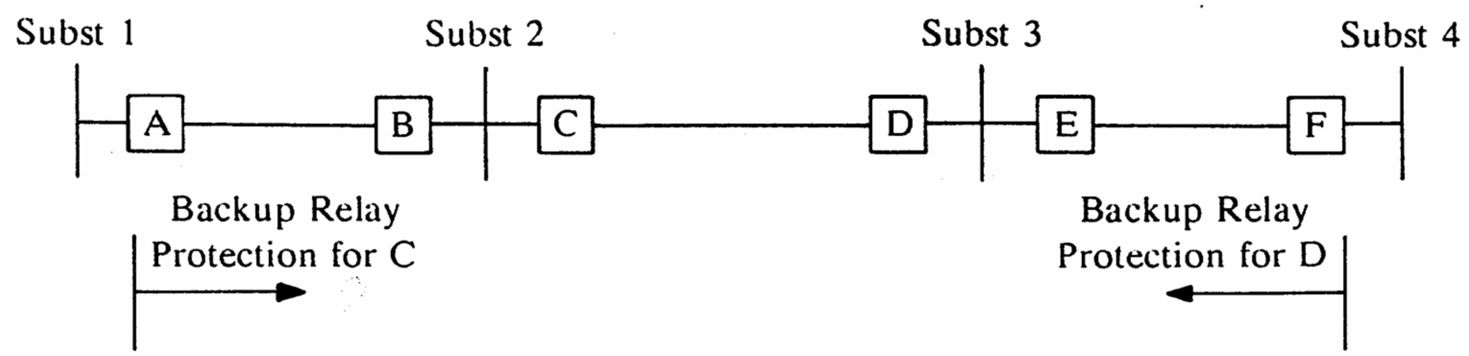
Principle of Overlapping Protection Around a Circuit Breaker



Levels of Protection

- Primary - First Line of Protection
- Secondary – Second Line of Protection
- Backup - Different relays in a different location with different zones of protection to back-up failure of the primary or secondary relaying system
- Follow the principle of Single Failure

How Backup Relays Operate For a Simple System



Applying Protective Relaying

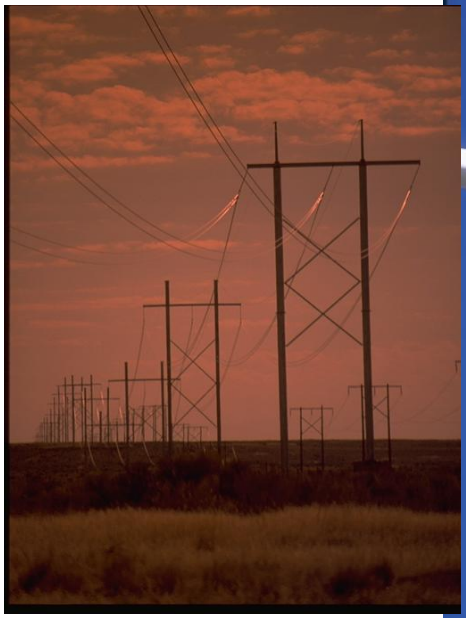
- System Configuration
- Existing System Protection
- Existing Operating Procedure and Practices
- Degree of Protection Required
- Fault Study
- Maximum Load Current, CT Ratios
- Potential Device Location and Connection
- Line Impedance Data
- Breaker Data

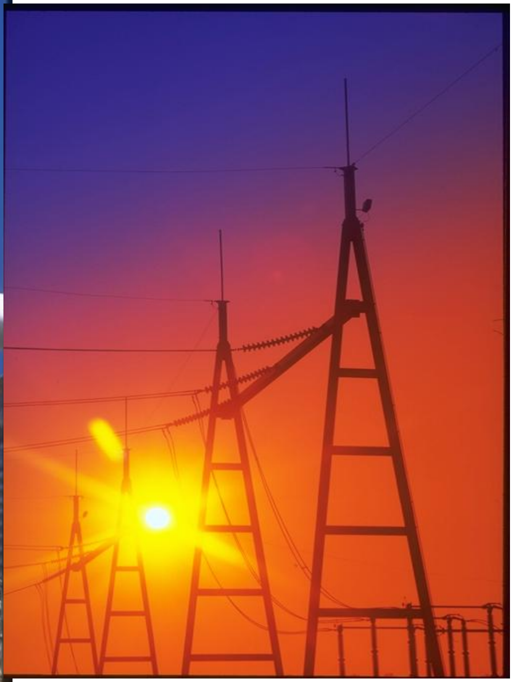
Measuring Quantities

- Current (I)
- Voltage (V)
- Frequency (f) and Rate of Change of frequency or (df/dt)
- Impedance (Z)
- Power (P, Q)
- Flux Density (V/f)
- Phase Angle (Ø)

Components for Protection

- Line, Bus, Transformer, Reactor, Cap Bank, Breaker





Normal Operation and Fault Conditions

- Normal Operation: Low Value of Current, Nominal Voltage and Frequency
- Fault Condition: Current Increases, Voltage Drop, Change in Power Frequency and Presence of High Frequency Noise
- Tools Available: Change in Current, Drop in Voltage, Change in Power Frequency
- Ignore: High Frequency Noise which is Unpredictable

Types of Measuring Relays

- Current Only: Overcurrent Instantaneous or Time Delayed (50/51)
- Voltage Only: Under Voltage and/or Overvoltage (27/59)
- Current from Two Sources: Current Differential (87T, 87G)
- Voltage from Two Sources: Voltage Differential(87V)
- Current and Voltage: Impedance (21), Directional OC (67)
- Voltage and Frequency: Over-flux (24)
- Carrier or Pilot Wire Protection (85)
- Current and Time Delay: Breaker Failure (50/62)

Types of Protection

ANSI DEVICE NUMBERS

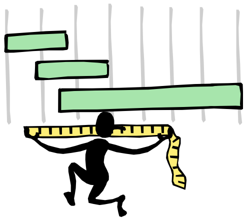
No.	DESCRIPTION
2	Time-delay
21	Distance
25	Synchronism-check
27	Undervoltage
30	Annunciator
32	Directional power
37	Undercurrent or underpower
38	Bearing
40	Field
46	Reverse-phase
47	Phase-sequence voltage
49	Thermal
50	Instantaneous overcurrent
51	AC time overcurrent
59	Overvoltage
60	Voltage balance
63	Pressure
64	Apparatus ground
67	AC directional overcurrent
68	Blocking
69	Permissive
74	Alarm
76	DC overcurrent
78	Out-of-step
79	AC reclosing
81	Frequency
85	Carrier or pilot-wire
86	Lock out
87	Differential
94	Tripping

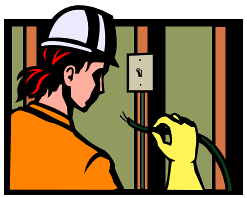
Relay Selection Criteria

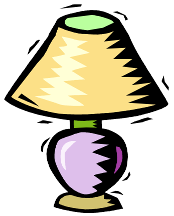
- Existing Relay Population
- Client Preference
- Functions Required
- Past Experience
- Maintenance and Spare Parts
- Training
- User Friendliness

Types of Relays and Other Components

- Measuring Relay
- Timers
- Auxiliary Relays
- Switches
- Indicating Lamps

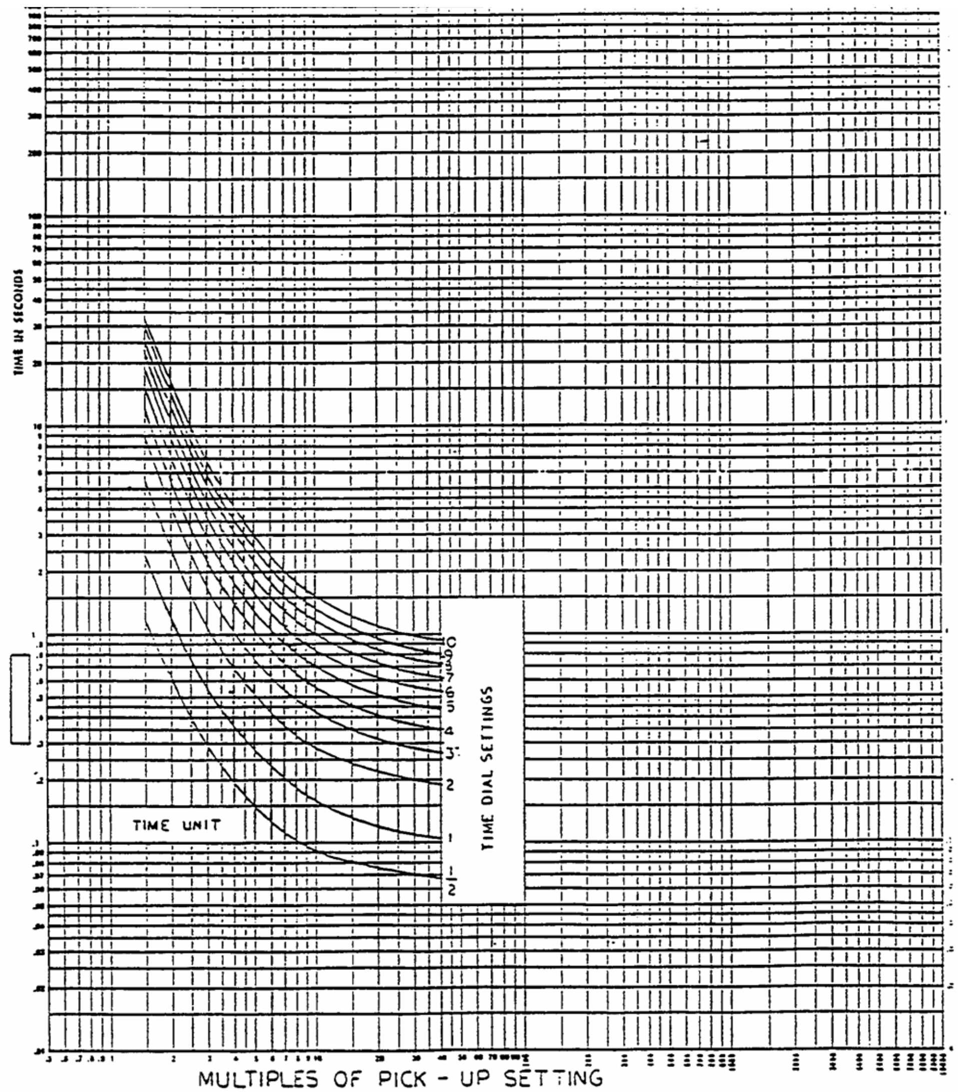




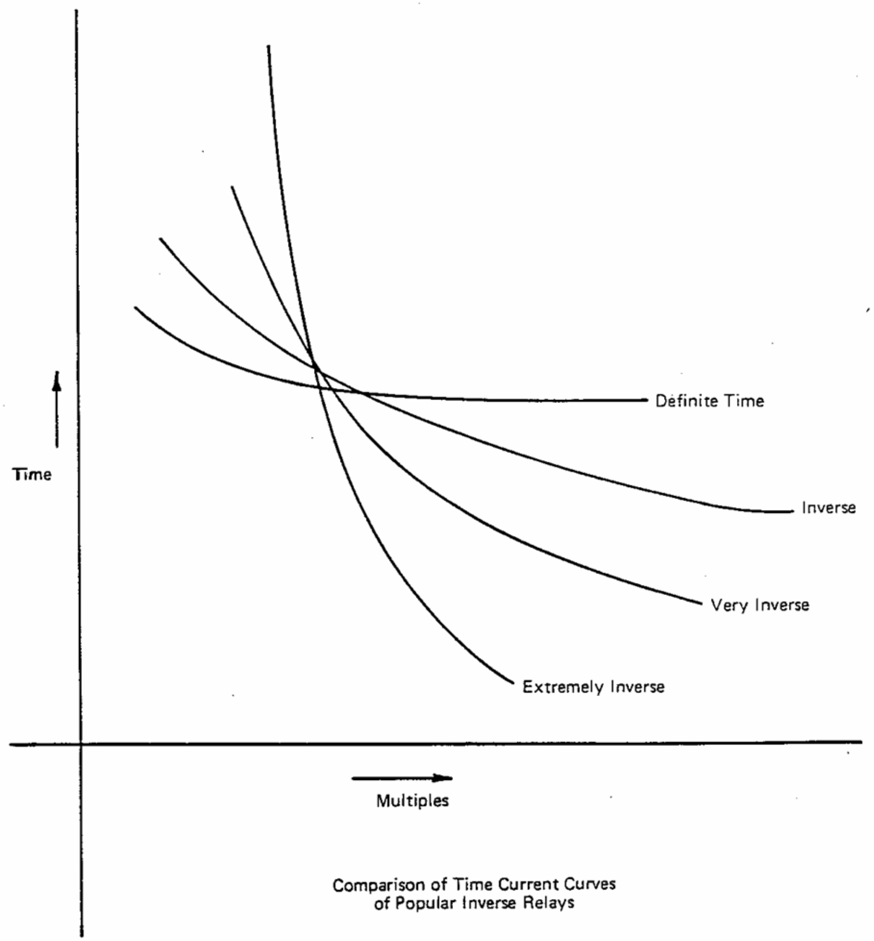


Over Current Relay

- Detects Increase in Current value
- Relay Operation Instantaneously or Time Delayed
- Different Ways to Achieve Time Delay
- Fixed Time Delay
- Inverse time delay are pre-selected time-current functions (Definite Time, Inverse, Very inverse, Extremely Inverse, etc.)
- CO, IT, KC-2, SEL 351

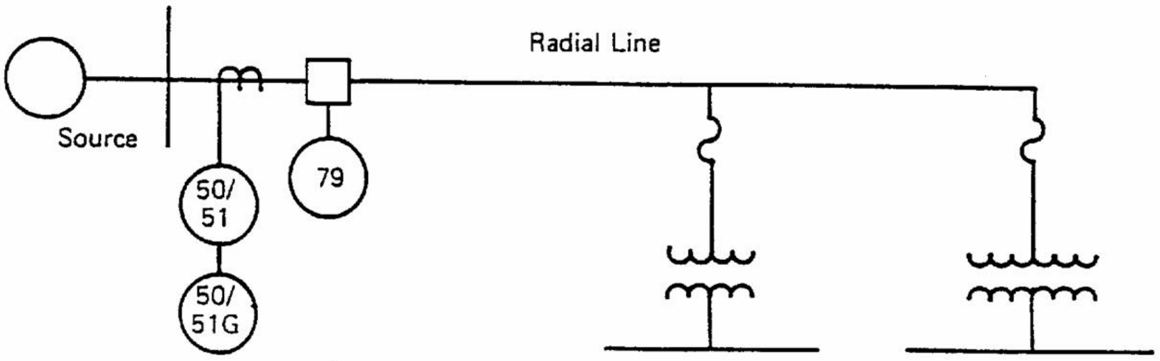

TIME IN SECONDS
TIME UNIT
TIME DIAL SETTINGS
10
9
8
7
6
5
4
3
2
1
1/2
MULTIPLES OF PICK - UP SETTING

Typical Time-Current Characteristics of Overcurrent Relays



Comparison of Time Current Curves
of Popular Inverse Relays

Simple Overcurrent Relay Application



69 kV and Below

1. Recloser
2. Overcurrent Relays/Breaker

Depends On

1. Fault Magnitudes
2. Load Current

Above 69 kV

Overcurrent/Breaker

Application Considerations of Overcurrent Relays

- Most commonly used for thermal protection of radial distribution feeders and transformers
- Must be coordinated with “down stream” protection - this may cause difficulty when many levels of relaying are used
- May be applied on the phase conductors and/or neutral conductors

Application Considerations of Overcurrent Relays (continued)

- Will operate on fault currents in either direction and zones of protection may not be well-defined
- Potentials are not required for correct operation of the relays and therefore PTs are not needed.
- Relatively simple to apply in most cases but difficult to coordinate

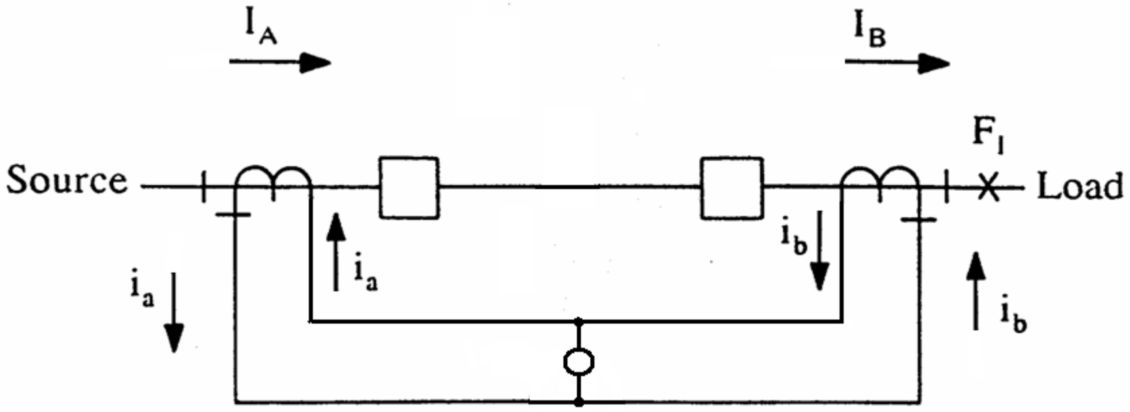
Over/Undervoltage Protection (59/27)

- Similar to overcurrent relays except that voltage is the operating quantity
- May have both instantaneous and time functions
- Typically used with initiation of system configuration changes such as adding or removing shunt capacitor banks or reactors
- Often used with synchronism checking (25) and automatic reclosing (79) schemes
- Also may be used to detect faults on ungrounded systems
- BE1-59, BE1-27

Current Differential Relay (87)

- Current from Two sources
- Measure the Difference in Current
- Basic principle: the vector sum of all current entering a device must be equal to zero unless there is a fault within the device or protected zone
- Used for Transformer, Generator, Bus, Reactor etc.
- Also used for Transmission Line with Special Arrangement of Communication
- SEL 387, SEL 587, CA-16, HU

Simple Application



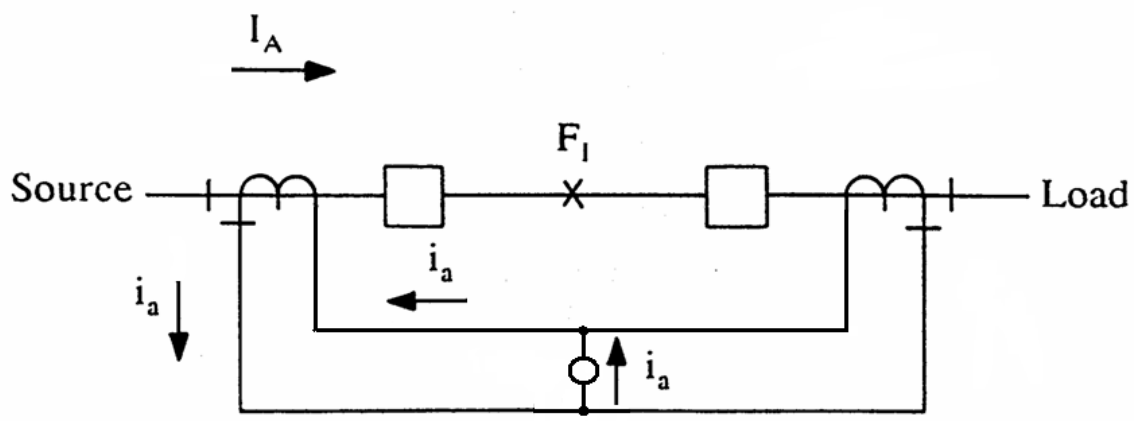
Normal

$I_A = I_B$

$i_a = i_b$

$\Delta i = O$

Simple Application



<u>Fault</u>

$I_A = I_{F1} \qquad I_B = O$

$i_a = i_{F1} \qquad i_b = O$

$\Delta i = i_{F1}$

Application Considerations for Differential Relays

- All CTs used in a differential protection scheme should have the same over all CT ratios
- Similar CT saturation characteristics is preferred
- Operation at highest CT tap is Desired
- Differential relaying is susceptible to misoperation for through faults due to CT saturation
  - CT secondary burden should be kept to a minimum to avoid CT saturation
- Differential relays should have dedicated CTs

Application Considerations of High Impedance Bus Differential Relays (continued)

- CT switching is not possible
- Provides pre-defined protection zones
- Very simple to apply
- Should be used in conjunction with lockout relays
- In case of Transformer special care shall be taken for phase angle matching on two sides of the windings
- More complex when there are three windings for the transformer or other special transformers

Low Impedance Bus Differential Relays

- Overcomes the application limitations of High Impedance Scheme
- Not simple to apply
- Different CT ratio and characteristic is possible
- System is replicated at lower current level and it is dynamic

Voltage Differential Relay

- Mainly used for Capacitor Bank protection
- Compare voltage across the one of the capacitor can and bus PT
- Difference in voltage indicates a fault in the capacitor unit
- SEL -287

Directional Overcurrent Protection (67)

- Directional Overcurrent Relay may have both Instantaneous and Time Overcurrent characteristics, but has an additional voltage or current element to provide directional reference for the relay

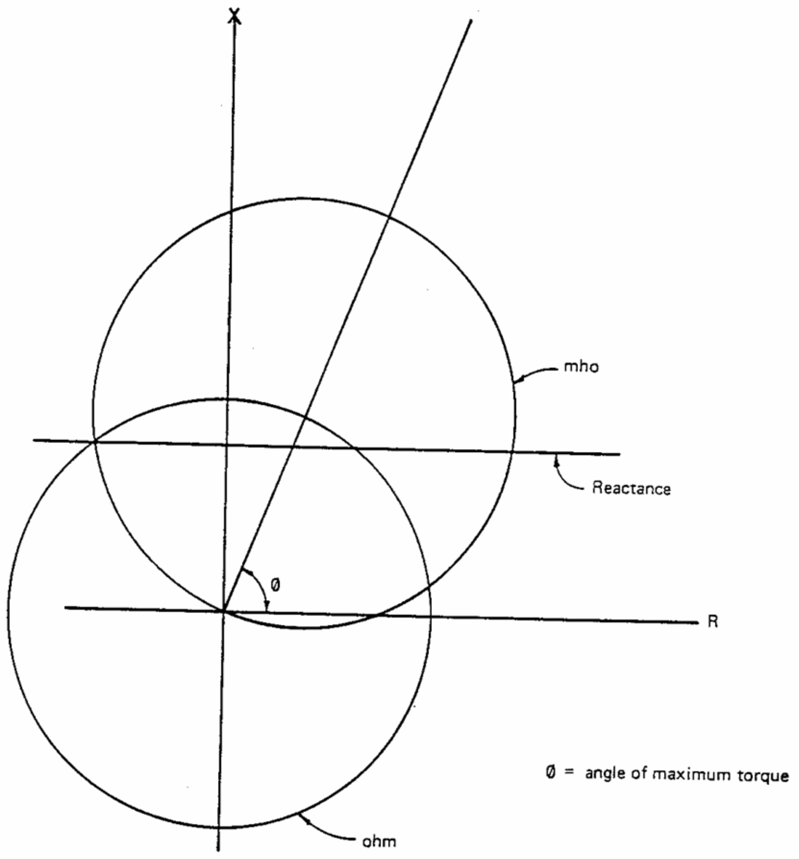
Application Considerations of Directional Overcurrent Relays

- Most commonly used for ground fault protection on looped transmission line systems
- As with nondirectional overcurrent relays, must be coordinated with “down stream” protection - this may cause difficulty when many levels of relaying are used
- Provide more defined zones of protection than nondirectional overcurrent relays
- Require additional voltage or current connections for directional reference

Step Distance (Impedance) Protection (21)

- Uses both current and voltage as the operating quantities and therefore has directional capabilities
- Operates on the value defined by the ratio between voltage and current or Z
  - under fault conditions, the voltage decreases and the current increases (Z=V/I)
- Zone 1 setting is about 80% of the line length or Z

Mho Characteristic of a Typical Distance Relay



Electromechanical Characteristics of Popular Distance Relays

Application Considerations of Step Distance Protection

- Most common relay scheme used for transmission line protection
- Requires both voltage and current connections
- May not be effective protection for short transmission lines where the fault current is relatively similar in magnitude for both close in faults and faults at the end of the line
- May be susceptible to misoperations for power swings on long transmission lines
- May be subject to misoperations due to mutual coupling on parallel transmission lines

Piloted Relaying Schemes

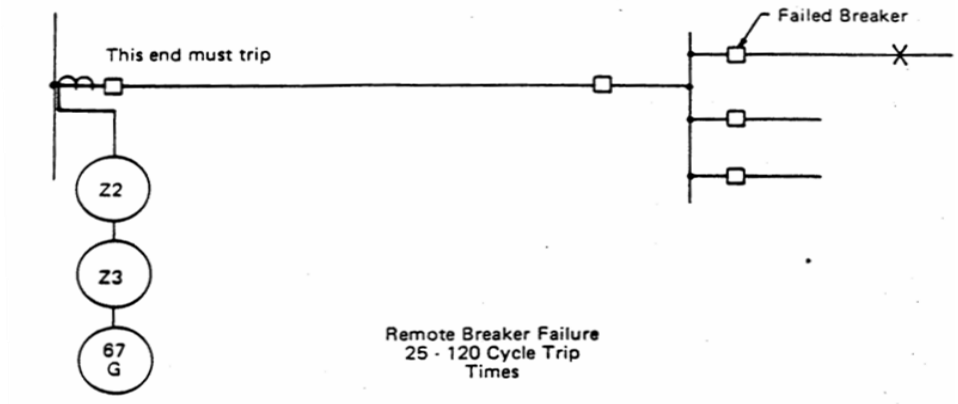
- Piloted relay schemes include communication channels between the transmission line terminals
- Commonly used channels are leased telephone lines, PLC, microwave or fiber optics)

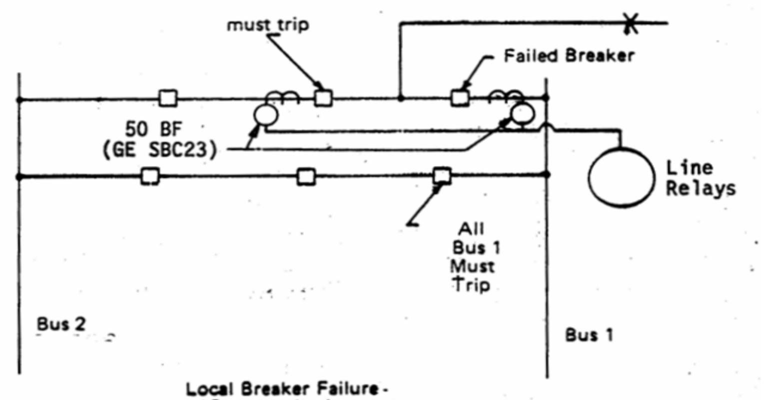
- Common types
  - Permissive Overreaching Transferred Tripping (POTT)
  - Permissive Underreaching Transferred Tripping (PUTT)
  - Direct Underreaching Transferred Tripping (DUTT)
  - Directional Comparison Blocking (DCB)
  - Directional Comparison Unblocking (DCU)
  - Phase Comparison
  - Line Differential

Breaker Failure Protection (50BF)

- Remote breaker failure schemes are typically applied at lower voltages - included as part of backup relaying design
- Usually has time delay of the order of 25-120 cycles
- Local breaker failure schemes are typically applied at higher voltages where fault clearing times are more critical
- Usually time delay is of the order of 10-15 cycles

Breaker Failure Protection (50BF)





Transformer Categories

- Transformers are subdivided into four categories

  I - 5 to 500kVA single phase, 15 to 500kVA three phase

  II - 501 to 1667kVA single phase, 501 to 5000kVA three phase

  III - 1668 to 10,000kVA single phase, 5001 to 30,000kVA three phase

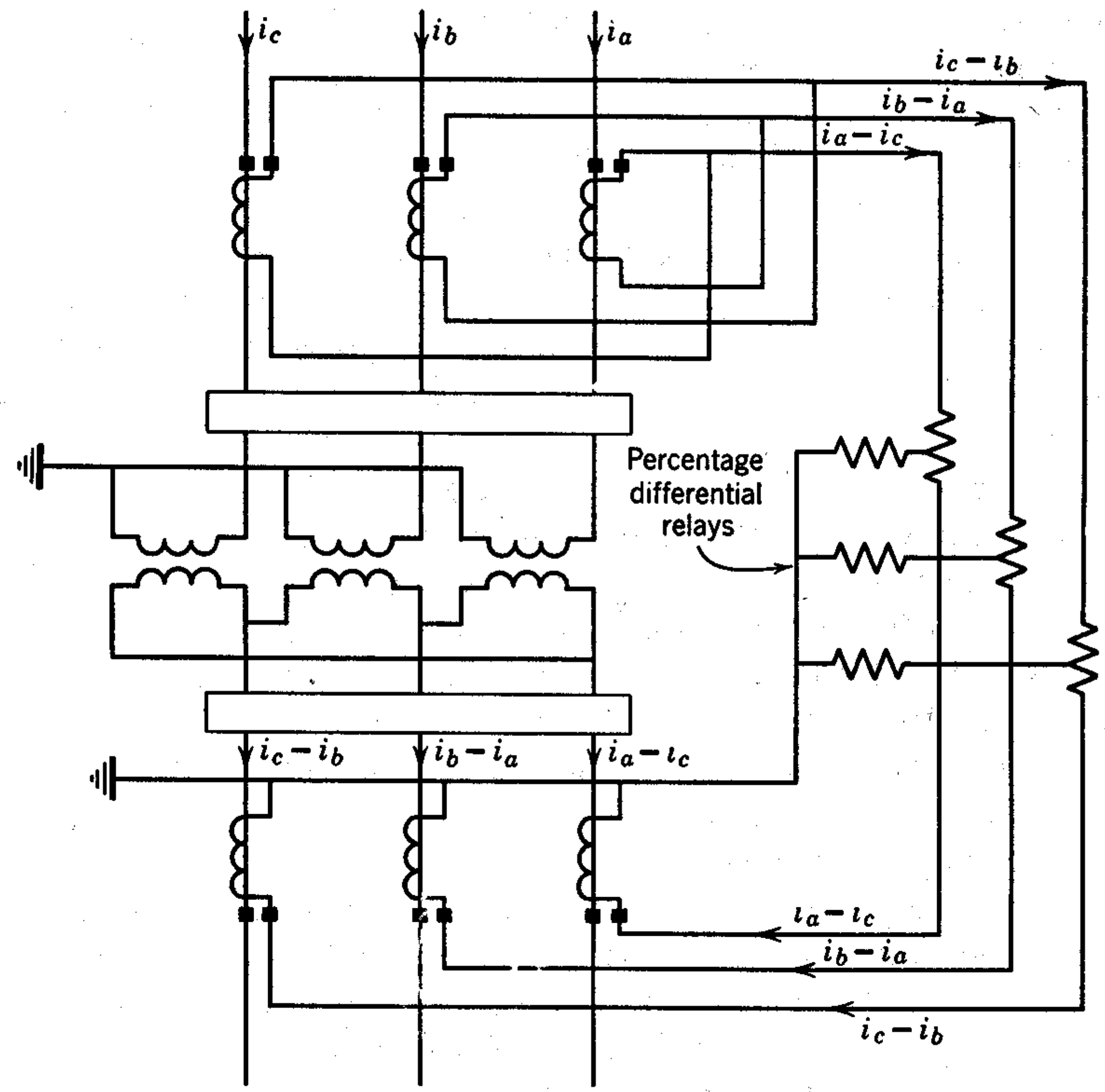
  IV - Above 10,000kVA single phase, above 30,000kVA three phase

Transformer Protection

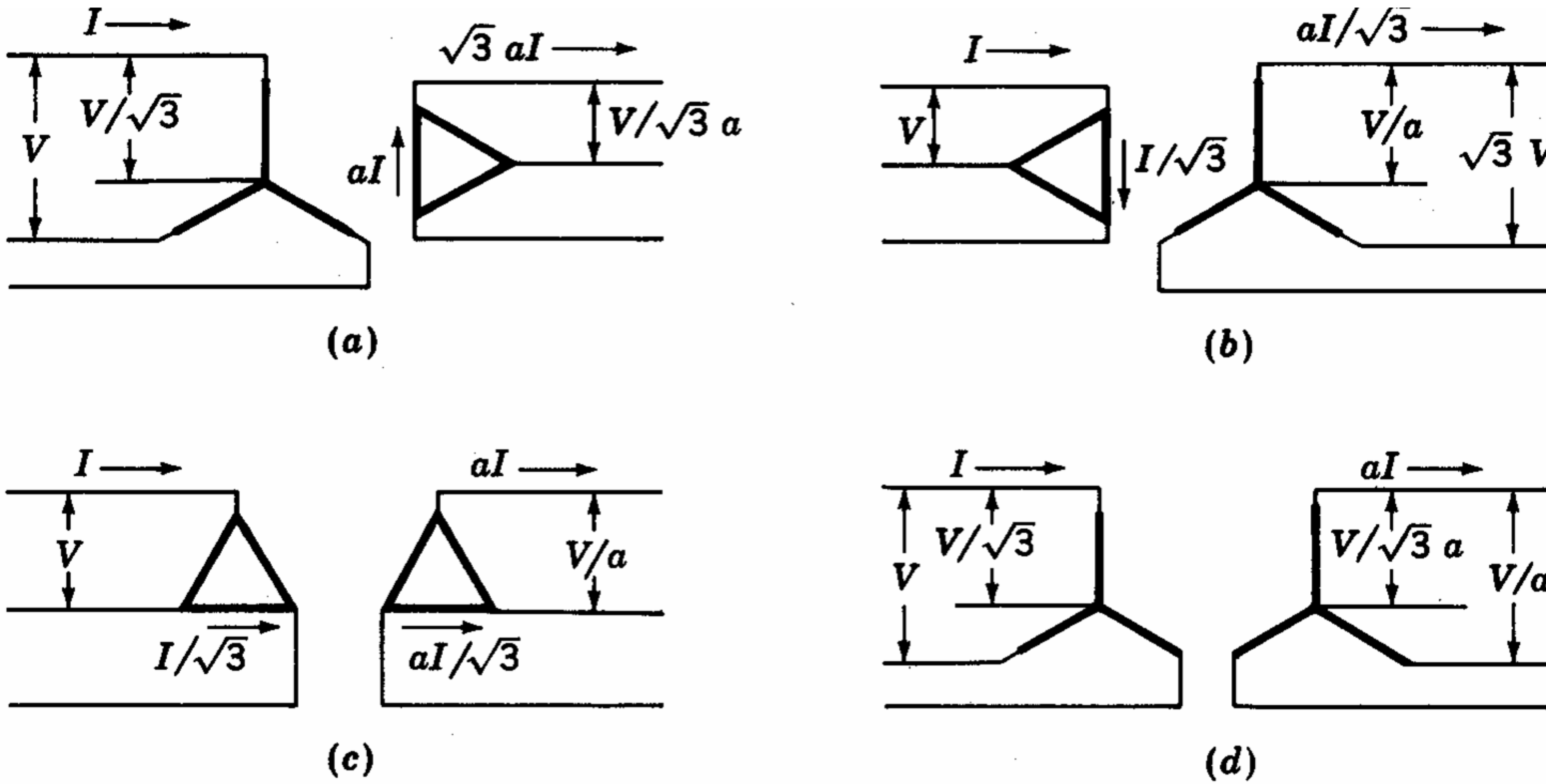
- Transformers must be protected from overheating that may be caused from overloading or through fault
- $I^2t = K$
- Thermal protection of transformers may be provided by overcurrent relays or fuses
- Current differential protection is used for internal faults

Considerations for Application of Transformer Thermal Protection

- Category I and II transformers are commonly protected with fuse elements
- Protection of Category III and IV transformers may include differential protection and overcurrent relays as backup protection
- Special attention should be given to magnetizing inrush coordination, phase angle and current magnitude



Completed connections for percentage-differential relaying for two-winding transformer.



I
V/√3
V
√3 aI
aI
V/√3 a
(a)
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V
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aI/√3
V/a
√3 V/
(b)
I
V
I/√3
aI
V/a
aI/√3
(c)
I
V/√3
V
aI
V/√3 a
V/a
(d)

Remember

- Protection is Art and there is no one specific correct solution

- Linda, insert your photo from Denver airport here please.