REPUBLIC OF INDONESIA

MINISTRY OF COMMUNICATIONS
DIRECTORATE GENERAL OF LAND TRANSPORT
AND INLAND WATERWAYS

TENDER DOCUMENTS
FOR
NEW RAILWAY LINE FOR CENGKARENG AIRPORT
CONSTRUCTION PROJECT

STRUCTURAL CALCULATION SHEETS

PACKGE III ELECTRICAL WORK

AUGUST 1984

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

INDEX

No.

C

§ 1 SUBSTATIONS

1 VOLTAGE DROP CALCULATION OF FEEDING CIRCUITS

1-1 Calculation of Installation Intervals of Susbstations

(1) Parallel Feeding

When the distance between substations is L(km), the average distance between trains is d (km), the maximum current of the train in the center of line is Im (A), the current of other train is i(A) and the line resistance is R (Ω/km), the permissible voltage drop ΔV shall be calculated as follows;

$$\Delta V = \frac{LR}{4}\left\{\frac{i}{2}\left(\frac{L}{d}-1\right)+Im\right\}$$

But the operation condition of the new line is esteemed that the schedule speed shall be 60 km/h and the headway shall be 10 minutes in the future.

Therefore the average train intervals shall be 10 km.

On the other hand, the total length of the new line shall be about 20 km, and the maximum voltage drop shall arise at the center between cengkareng and Jakarta Kota, taking the system down of Kapuk substation into consideration.

Here, $i = 0$ in above formula

$$\text{From} \quad \Delta V = \frac{L R I_m}{4}$$

$$L = \frac{4 \times \Delta V}{I_m R}$$

Here $\Delta V = 400\,V$

$I_m = 1{,}970\,A$

$R = 0.042\ \Omega/km$ (Double Feeders)

Therefore $L = 19.3\ km$

Taking the system down of Kapuk substation into consideration, L will be 9.6 km.

(2) <u>One Direction Feeding</u>

When the distance between the substation and the end of feeding line is L (km), the maximum current is I_m and the line resistance is R (Ω/km), The permissible voltage drop ΔV shall be calculated as follows;

$$\Delta V = I_m \cdot L \cdot R$$

Therefore $L = \frac{\Delta V}{Im\,R}$

Here $\Delta V = 400V$

$R = 0.062\ \Omega/km$ (Single Feeder)

$Im = 2{,}070$ (A), as the total of the starting current of the train (1.970A) and the power for the mounted auxiliary loads in staying train (100A)

Therefore $L = 3.1$ km

1-2 Voltage Drop Calculation of Feeding Circuits

The calculated results of voltage drop under each condition are as shown in Table 1. In each case, the feeding voltages satisfy the allowable minimum voltage 1100V or more. The DC bus circuit voltage in SS will be 1523 V due to the following reason:

The DC bus voltage E in SS will be calculated using the following formula.

$$E = Ed \{ 1 + \varepsilon (1 - \frac{I}{Id}) \}$$

Here. Ed : DC rating voltage 1500 V

ε : Voltage regulation of transformer 6 %

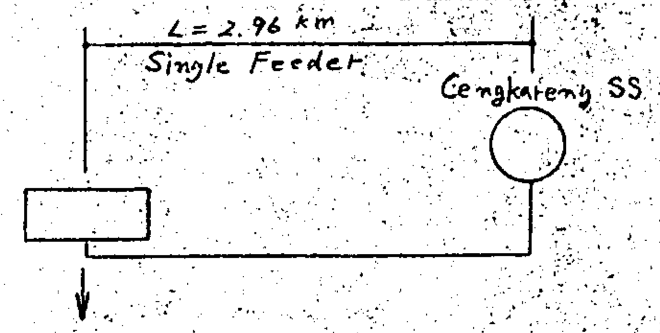
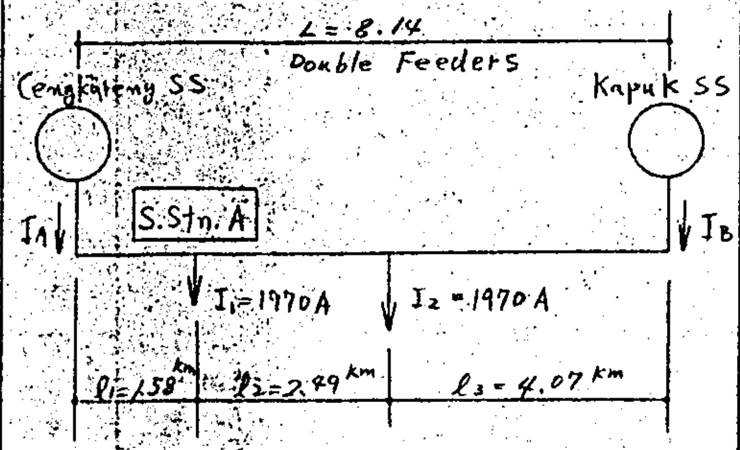
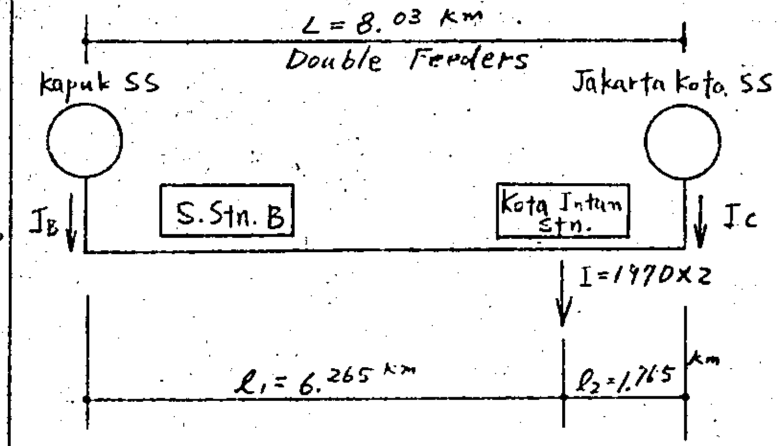
Id : Rating current of rectifier 2000 A

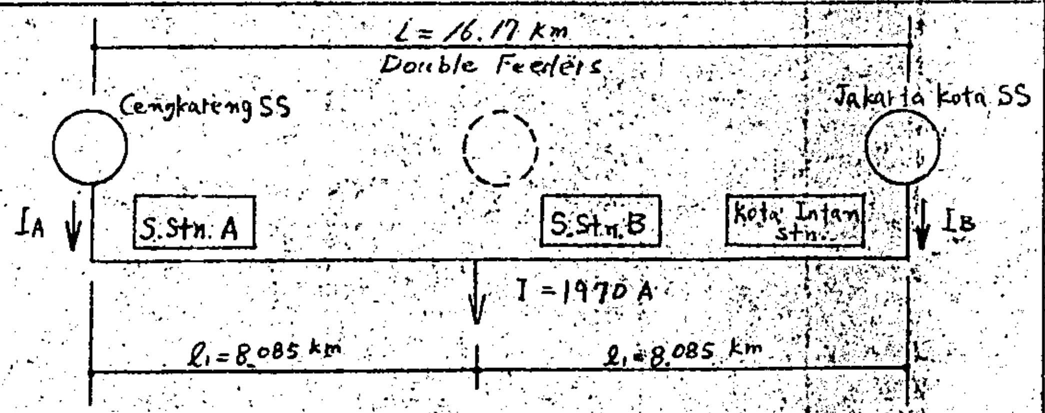
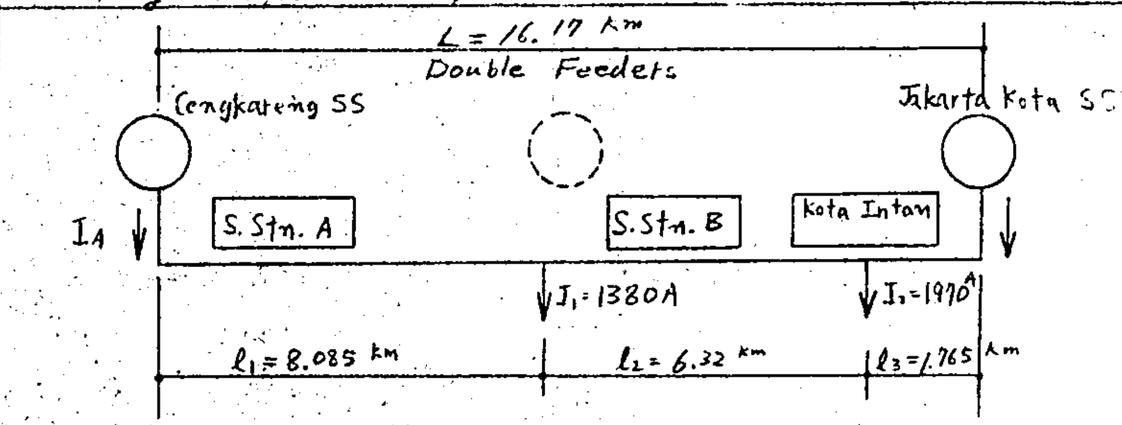
I : Load current

When the load current in SS is 1970 A,

$$E = 1523 \text{ V}$$

Table 1 Calculation of Voltage Drop

Condition		Headway : 10 min. 8 car train Resistance of Feeding Circuit: R=0.062 (Ω/km)(Single Feeder) R=0.042 (Ω/km)(Double Feeder) Leaking Current Ratio : 30% Max. Current: I=1970 A		
Normal Feeding		Starting at JIAC Stn.	Starting at S.Stn A and the center of both SS	Simultaneous Starting of 2 trains at kota Intan Stn.
	Estimated Load	 $I = 1970 + 100 = 2070$ A	 $I_B = \frac{1}{L}\{(l_1+l_2)I_2 + l_1 I_1\} = 1367$ A	 $I_C = \frac{l_1}{L} I = 3074$ A
	Calculation	$e = I \cdot L \cdot R = 380$ V	$e = I_B \cdot l_3 \cdot R = 234$ V	$e = I_C \cdot l_2 \cdot R = 288$ V
	Feeder Voltage (v)	1523 − 380 = 1143 (V)	1523 − 234 = 1289 (V)	1523 − 288 = 1295 V

Expanded Feeding		Starting at the center of both SS	Starting at Kota Intan, Powering at the center of both SS
	Estimated Load	 $I_A = I/2 = 985$ A	 $I_A = \frac{1}{L}\{(l_2+l_3)I_1 + l_3 I_2\} = 905$
	Calculation	$e = I_A \cdot l_1 \cdot R = 334$ (V)	$e = I_A l_1 R = 307$ V
	Feeding Voltage (v)	1523 − 334 = 1189 (V)	1523 − 307 = 1216 (V)

2 CALCULATION OF RECTIFIER CAPACITY IN EACH SUBSTATION

The capacity of rectifier will be required to satisfy both of one hour maximum load Y and momentary over load Z of train load.

2-1 One Hour Maximum Load Y

One hour maximum load is calculated as follows:

$$Y = n_1 \times \frac{60}{h} L \times K \times z + \alpha \cdot n_2 \times \frac{60}{h} \times \frac{L}{S} \times z$$

Here n_1 : Number of cars in one train

h : Head way

L : Share distance

K : Rate of power consumption of train — 35 kwh/1000t-km

α : Power for air conditioner

n_2 : Number of air conditioned car in one train

2M2T — 1 car

4M4T — 2 car

S : Schedule speed — 40~60 km/h

2-2 Momentary Overload Z

The momentary overload Z will be required to satisfy the following formula (1) and (2). The formula (2) means the capacity which enables 2 trains in front of SS to start simultaneously.

$$Z_1 = Y + C\sqrt{Y} \qquad (1)$$

$$Z_2 = I_m \times 2 \times 1.5^{KV} \qquad (2)$$

Here Y: One hour maximum load

C: $1.7\sqrt{I_m}$

I_m: Maximum current of train

Formula (1) is gained from the actual results of JNR, and has a better conformity to the more close headway load.

Comparing Z_1 with Z_2, there is a following tendency.

Headway close $Z_1 > Z_2$

Headway not close $Z_1 < Z_2$

2 - 3 Overload Capacity of Rectifier

The ratio between one hour maximum load and momentary overload is about 300 % in Japan. From this result the overload capacity of rectifier is specified as 300 %, 1 minute.

From the formula (1)

$$Z_1 / Y = 1 + C \frac{1}{\sqrt{Y}}$$

I_m = 1970 A (total of starting current 1890 A and air conditioning load 80A)

$$Z/Y = 1 + 75.5/\sqrt{Y}$$

It is as shown in Fig. 1

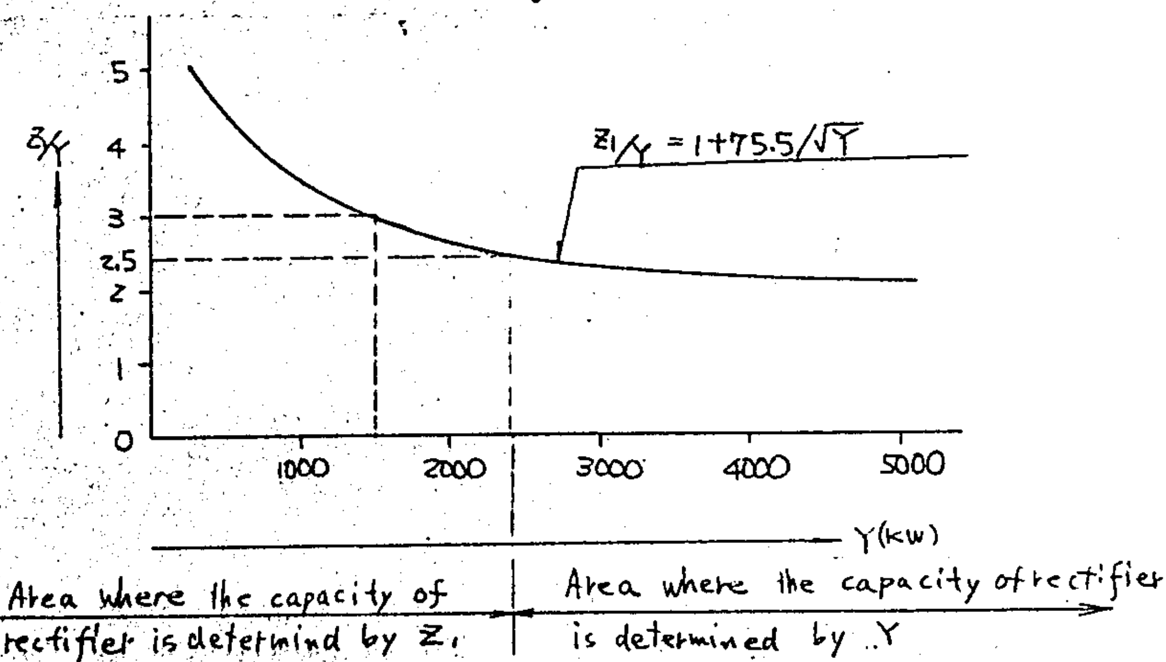


Fig. 1 Relation between Z_1 and Y

Generally speaking the value of Z_1/r is 300 % or less in the close overhead line which has a bigger one hour maximum load compared with a momentary overload. -

2-4 Calculation of rectifier capacity

The rectifier capacity P will be determined as follows, considering the safety for overload capacity, namely 250 % of overload capacity, and spare factor α (25%).

When $Z/Y > 2.5$ $\qquad P = \frac{Z}{2.5} \times \alpha$

When $Z/Y < 2.5$ $\qquad P = Y$

Y has an overload capacity of 150%, 2 hours, therefore the spare factor for Y will be not considered.

Considering the above mentioned conditions, the capacity of the rectifier in each substation is calculated in 3 cases; the normal operation, the system down of Kapuk substation and the system down of Duri substation in Western line. The results are as shown in Table 2, 3 and 4.

Air conditioned cars will be operated between JIAC. Stn. and Jatinegara, and the capacity of rectifiers will include the load for them.

(1) Cengkareng Substation

The ratio between one hour maximum load and momentary overload is 2.5 or more in Cengkareng line, due to the relatively long headway. Therefore the main factor to determine the capacity of rectifier is a momentary overload.

Momentary overloads become maximum in the simultaneous starting of trains, and are 2955 kw in 2M2T and 5910 kw in 4M4T.

In Central line, 8-car operation is planned now, therefore in Cengkaren line, 8-car operation will be started in near future from the point of train management. Then the unit capacity of rectifier in Cengkareng should be 3000 kw.

If the overload capacity of rectifier take 500%, the unit capacity would become smaller. But in Jakarta Kota SS, Z/Y is less than 2.5, as mentioned later. Therefore the unit capacity of rectifier should be 3000 kw, class S, considering the exchangeability of units and the unification of the rating.

(2) Kapuk Substation

The unit capacity of rectifier should be 3000 kW, class S, determined by the momentary overload, same as that of Cengkareng SS.

(3) Jakarta Kota Substation

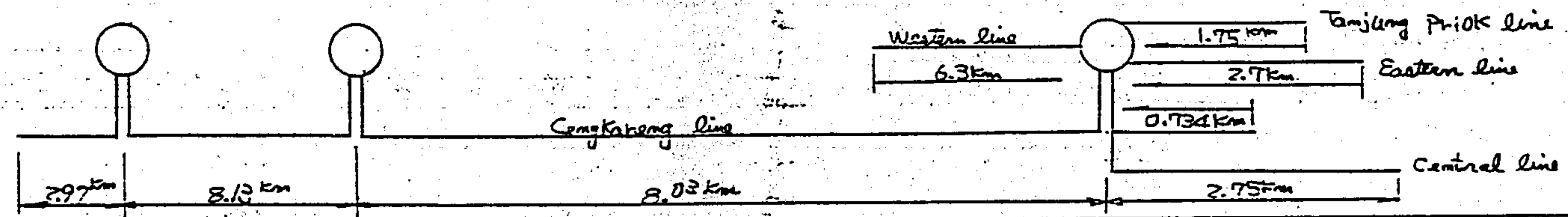
In Jakarta Kota SS, Z/Y will be about 3.0 in the first stage, and will become less than 2.5 in accordance with the increase of load. The installing capacity of rectifier in Jakarta Kota SS will be determined by one hour maximum load, and required to be 3000 kW in the first stage.

It is planned in Western line electrification project that 2 sets of 1500 kW rectifier will be installed in Jakarta Kota SS. But Jakarta Kota SS is an important substation, situated in the load center, supplying power for each line.

Then another 3000 kW rectifier will be installed as standby unit, considering the future increase of load. In future the exchange of 1500 kW rectifier for 3000 kW rectifier will be required in accordance with the increase of load in each line.

Table 2 Capacity of Substations

In normal operation

	Cengkareng			Kapuk			Jakarta Kota														
	~1997	~2006	2007~	~1997	~2006	2007~	~1997	——				~2006	——				2007~	——			
	Single track		Double track	Single track		Double track	Single track	Double track				Single track	Double track				Double track				
	Cengkareng line						Cengkareng line	Western line	Eastern line	Tanjung Priok line	Central line	Cengkareng line	Western line	Eastern line	Tanjung Priok line	Central line	Cengkareng line	Western line	Eastern line	Tanjung Priok line	Central line
Net work																					
Share Distance L(km)	7.035			8.08			4.749	3.15	2.7	1.75	2.75	4.749	3.15	2.7	1.75	2.75	4.749	3.15	2.7	1.75	2.75
Number of Cars in One Train m(car)	4	8	8	4	8	8	4	8	4	4	8	8	8	8	8	8	8	8	8	8	8
Head way h(minute)	20	20	10	20	20	10	20	6	20	20	20	20	6	6	6	6	10	6	6	6	6
K (kw$h$/car km)	1.51						1.51	1.78				1.51	1.78				1.51	1.78			
One hour maximum Load Y (kw)	297	594	1188	341	683	1365	215	897	115	74	285	430	897	769	498	948	860	897	769	498	948
							total	1586				total	3542				total	3972			
Momentary overload Z (kw) ① by	2955	5910	5910	2955	5910	5910	5910					5910					5910				
Momentary overload Z (kw) ② by	1216	2433	3789	1326	2655	4153	4591					8033					8727				
Z/Y	9.9	9.9	5.0	8.7	8.7	4.3	3.7					2.3					2.2				
Y≥(Z/2.5) x 1.25	1478	2955	2955	1478	2955	2955	2955					3542					3972				
unit capacity (kw)	3000	3000	3000	3000	3000	3000	1500		3000			3000					3000				
Number of Units	1 (1)	1(1)	1(1)	1	1	1	2		(1)			2 (1)					2 (1)				

Note

One hour maximum Load Y

$$Y = m_1 \times \frac{60}{h} \times L \times K \times 2 + \alpha m_2 \frac{60}{h} \times \frac{L}{S} \times 2$$

α: Power for air conditioning 60 kw/car

m_2: Number of air conditioned cars in one train

2M2T $m_2 = 1$, 4M4T $m_2 = 2$.

S: Schedule speed 40~60 km/h

Momentary overload

① Simultaneous start of two cars

$Z = I_m \times 2 \times 1.5^{KV}$

2M2T $I_m = 945A + \frac{\alpha}{1.5^{KV}} \times m_2 \doteqdot 985A$

4M4T $I_m = 1890A + \frac{\alpha}{1.5^{KV}} \times m_2 \doteqdot 1970A$

② According to the statistical results

$Z = Y + C\sqrt{Y}$

$C = 1.7\sqrt{I_m}$

The number in ( ) indicates standby unit.

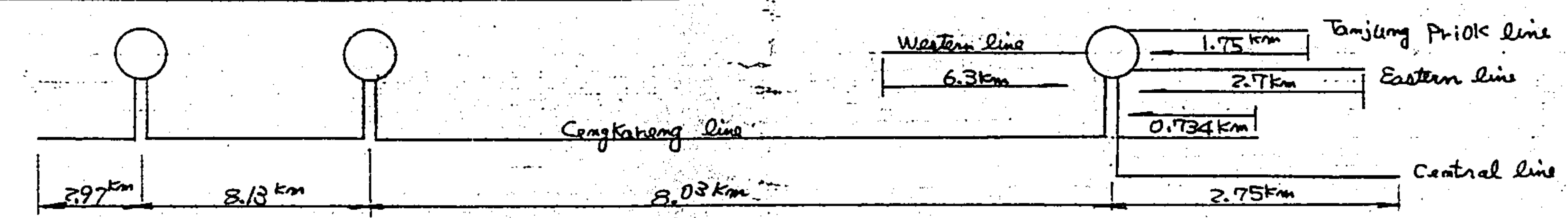
Air conditioned cars will be operated in Cengkareng line and Central line.

Table 3 Capacity of Substations

In Kapuk substation system down

	Cengkareng			Kapuk			Jakarta Kota														
	~1997	~2006	2007~	~1997	~2006	2007~	~1997	—				~2006	—				2007~	—			
	Single track		Double track	Single track		Double track	Single track	Double track				Single track	Double track				Double track				
	Cengkareng line						Cengkareng line	Western line	Eastern line	Tanjung Priok line	Central line	Cengkareng line	Western line	Eastern line	Tanjung Priok line	Central line	Cengkareng line	Western line	Eastern line	Tanjung Priok line	Central line

Net work



Share Distance L(km)	11.1						8.764	3.15	2.7	1.75	2.75	8.764	3.15	2.7	1.75	2.75	8.764	3.15	2.7	1.75	2.75
Number of Cars in One Train n_i (car)	4	8	8				4	8	4	4	8	8	8	8	8	8	8	8	8	8	8
Headway h (minute)	20	20	10				20	6	20	20	20	20	6	6	6	6	10	6	6	6	6
K (kWh/car km)	1.51						1.51	1.78				1.51	1.78				1.51	1.78			
One hour maximum Load Y (kW)	469	937	1874				397	897	115	74	285	794	897	769	498	948	1587	897	769	498	948
							total 1768					total 3906					total 4699				
Momentary overload Z (kW) ① by	2955	5910	5910				5910					5910					5910				
Momentary overload Z (kW) ② by	1624	3247	5140				4941					8622					9871				
Z/Y	6.3	6.3	3.2				3.3					2.2					2.1				
Y or (Z/2.5) x 1.25	1478	2955	2955				2955					3906					4699				
unit capacity (kW)	3000	3000	3000				1500		3000			3000					3000				
Number of Units	1(1)	1(1)	1(1)				2		(1)			2 (1)					2 (1)				

Note

One hour maximum Load Y

$Y = n_1 \times \frac{60}{h} \times L \times K \times 2 + \alpha n_2 \frac{60}{h} \times \frac{L}{S} \times 2$

S: Schedule speed 40~60 km/h

α: Power for air conditioning 60 kW/car

n_2: Number of air conditioned cars in one train

2M2T — $n_2 = 1$, 4M4T — $n_2 = 2$

Momentary overload

① Simultaneous start of two cars

$Z = I_m \times 2 \times 1.5\,kV$

2M2T $I_m = 945^A + \frac{\alpha}{1.5\,kV} \times n_2 = 985A$

4M4T $I_m = 1890^A + \frac{\alpha}{1.5\,kV} \times n_2 = 1970A$

② According to the statistical results

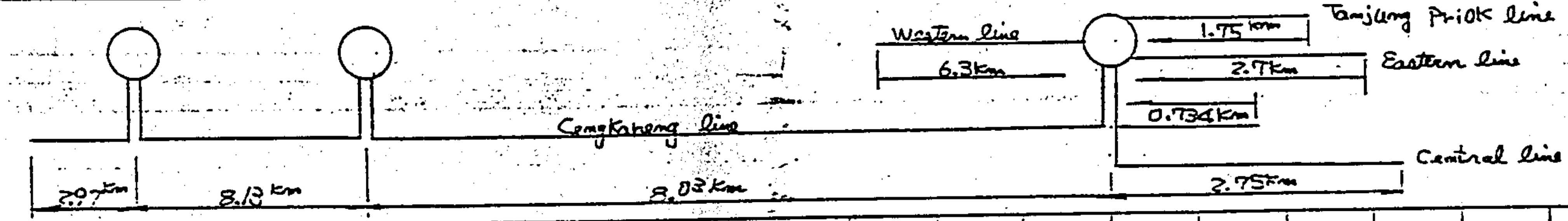
$Z = Y + c\sqrt{Y}$

$C = 1.7\sqrt{I_m}$

The number in ( ) indicates standby unit.

Air conditioned cars will be operated in Cengkareng line and Central line.

Table 4 Capacity of Substations In Duri Substation (Western line) system down

	Cengkareng			Kapuk			Jakarta Kota														
	~1997	~2006	2007~	~1997	~2006	2007~	~1997	—				~2006	—				2007~	—			
	Single track		Double track	Single track		Double track	Single track	Double track				Single track	Double track				Double track				
	Cengkareng line						Cengkareng line	Western line	Eastern line	Tanjung Priok line	Central line	Cengkareng line	Western line	Eastern line	Tanjung Priok line	Central line	Cengkareng line	Western line	Eastern line	Tanjung Priok line	Central line
Net work																					
Stane Distance L(km)	7.035			8.08			4.749	6.3	2.7	1.75	2.75	4.749	6.3	2.7	1.75	2.75	4.749	6.3	2.7	1.75	2.75
Number of Cars in One Train n(car)	4	8	8	4	8	8	4	8	4	4	8	8	8	8	8	8	8	8	8	8	8
Head way h(minute)	20	20	10	20	20	10	20	6	20	20	20	20	6	6	6	6	10	6	6	6	6
K (kwh/car km)	1.51						1.51	1.78				1.51	1.78				1.51	1.78			
One hour maximum Load Y (kw)	297	594	1188	341	683	1365	215	1794	115	74	285	430	1794	769	498	948	860	1794	769	498	948
							total	2483				total	4439				total	4869			
Momentary overload Z (kw) ① by	2955	5910	5910	2955	5910	5910	5910					5910					5910				
Momentary overload Z (kw) ② by	1216	2433	3789	1326	2655	4153	6243					9466					10134				
Z/Y	9.9	9.9	5.0	8.7	8.7	4.3	2.5					2.1					2.1				
Y≈(Z/2.5) x 1.25	1478	2955	2955	1478	2955	2955	2955					4439					4869				
unit capacity (kw)	3000	3000	3000	3000	3000	3000	1500			3000		3000					3000				
Number of Units	1(1)	1(1)	1(1)	1	1	1	2			(1)		2 (1)					2 (1)				

Note

One hour maximum Load Y

$Y = n_1 \times \frac{60}{h} \times L \times K \times 2 + \alpha n_2 \frac{60}{h} \times \frac{L \times 2}{S}$

α : Power for air conditioning 60 kw/car

n_2 : Number of air conditioned cars in one train

2M2T — $n_2 = 1$. 4M4T $n_2 = 2$

S : Schedule speed 40~60 km/h

Momentary overload

① Simultaneous start of two cars

$Z = I_m \times 2 \times 1.5^{KV}$

2M2T $I_m = 945A + \frac{\alpha}{1.5^{KV}} \times n_2 = 985A$

4M4T $I_m = 1890A + \frac{\alpha}{1.5^{KV}} \times n_2 = 1970A$

② According to the statistical results

$Z = Y + C\sqrt{Y}$

$C = 1.7\sqrt{I_m}$

The number in ( ) indicates standby unit.

Air conditioned cars will be operated in Cengkareng line and Central line.

3 CALCULATION ON POWER RECEIVING NETWORK

3-1 Cengkareng Substation

(1) Distribution Network

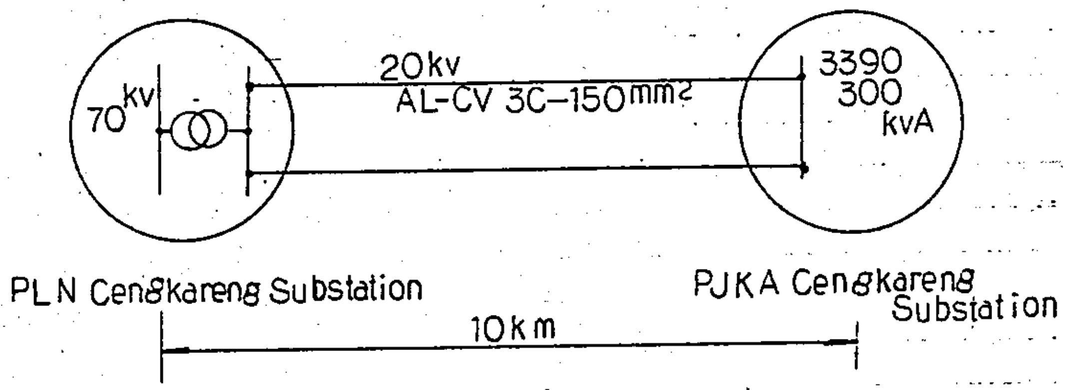


Fig. 2 Distribution Network

(2) 3-phase Short Circuit Capacity of 70 kV Bus

MAX. 2673 MVA (Data from PLN in 1982)

MIN. 2096 MVA (〃)

Converting it into % Z

MAX. 0.38 % (on the base of 10 MVA)

MIN. 0.48 % (〃)

(3) The Capacities and % Z of 70 kV/20 kV Transformers

Capacity 60 MVA (on the arrangement with PLN)

% Z 13 %

Number One set

Converting it into % Z

$$13\% \times \frac{10\ MVA}{60\ MVA} = 2.17\%$$

(4) % Z of 20kV Transmission Line

On the calculation of the short circuit capacity, usually the reactance alone shall be used.

$X_L = 0.1\ \Omega/km$ (on the arragement with PLN)

Converting it into % Z (on the base of 10MVA)

$$\%X_L = \frac{P\,MVA\ \ X_L\,\Omega}{E^2\,(kV)} \times 100$$

then

$\%X_L = 0.25\ (\%/km)$

(5) % Z upto the Power Receiving Point of Cengkareng Substation of PJKA

MAX. $0.38 + 2.17 + 0.25 \times 10^{km} = 5.05\%$

MIN. $0.48 + 2.17 + 0.25 \times 10^{km} = 5.15\%$

(6) 3-phase Short Circuit Capacity in the Power Receiving Point of Cengkareng Substation of PJKA

$$Ps = \frac{100}{\%Z} \times 10{,}000$$

then

MAX. 198 MVA

MIN. 194 MVA

(7) Voltage Regulation

Assuming the Ero as the terminal voltage at the power receiving point, the voltage regulation % Reg shall be calculated as follows ;

$$\% Reg = \frac{20^{kV}\sqrt{3} - Ero}{Ero} \times 100\ (\%)$$

here

$$Ero = \frac{20^{kV}}{\sqrt{3}} - I \cdot L\ (R \cos\varphi + X_L \sin\varphi)$$

I : Load current

L : Distance between PLN substation and Cengkareng substation of PJKA. = 10 km

R : Resistance of 20kV distribution line = 0.26 (Ω/km) (Refer to 3-6)

X_L : Reactance of 20kV distribution line = 0.1 (Ω/km)

$\cos\varphi$: Power factor 0.8

$\sin\varphi$: Reactive factor 0.6

The load current shall be as follows, considering the fluctuating load.

$$I \doteqdot \frac{3390^{kVA} \times 1.5 + 300^{kVA}}{\sqrt{3} \times 20^{kV}}$$

$$= 155 A$$

therefore

$$\% Reg \doteqdot 3.7\ \%$$

3-2 Kapuk Substation

(1) Distribution Network

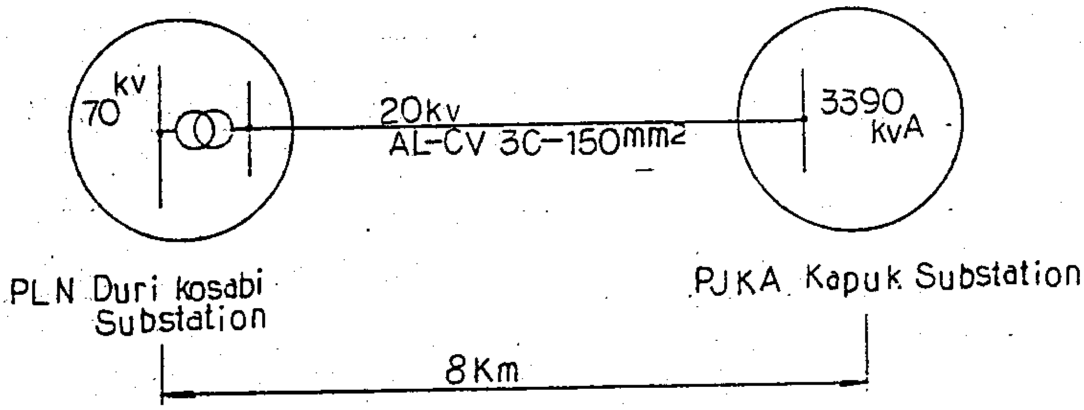


Fig. 3 Distribution Network

(2) 3-phase Short Circuit Capacity of 70 kV Bus

MAX. 3160 MVA (Data from PLN in 1982)

MIN. 2463 MVA (〃)

Converting it into % Z

MAX. 0.31 % (on the base of 10 MVA)

MIN. 0.40 % (〃)

(3) The capacities and % Z of 70kV/20kV Transformers

Capacity 60 MVA (on the arrangement with PLN)

% Z 13 %

Number One set

Converting it into % Z

$$13\% \times \frac{10\ MVA}{60\ MVA} = 2.17\%$$

(4) %Z of 20kV Transmission Line

Using the same method as in Cengkareng Substation

$\% X_L = 0.25$ (%/km)

(5) %Z upto the Power Receiving Point of Kapuk Substation of PJKA

MAX. $0.31 + 2.17 + 0.25 \times 8^{km} = 4.48\%$

MIN. $0.40 + 2.17 + 0.25 \times 8^{km} = 4.57\%$

(6) 3-phase Short Circuit Capacity in the Power Receiving Point of kapuk Substation of PJKA

$$Ps = \frac{100}{\% Z} \times 10{,}000$$

then

MAX. 223 MVA

MIN. 219 MVA

(7) Voltage Regulation

Using the same method as in Cengkareng Substation

2.8 % is gained.

3 - 3 Jakarta kota Substation

(1) Distribution Network

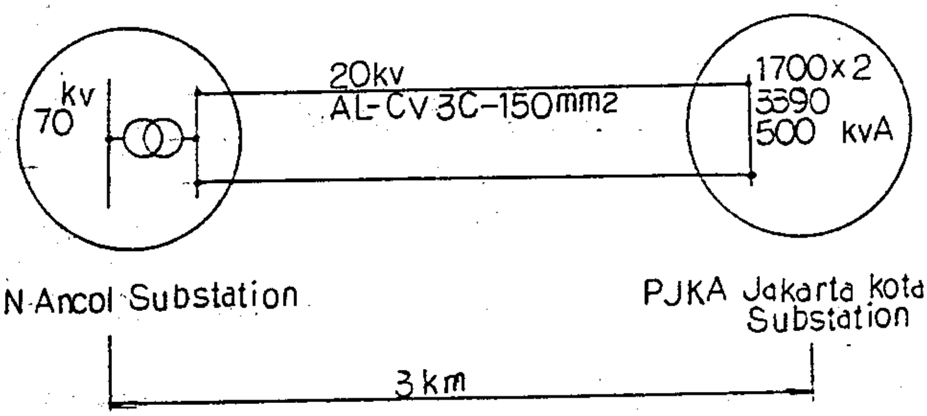


Fig. 4 Distribution Network

(2) 3-phase Short Circuit Capacity of 70kV Bus

MAX. 1251 MVA (Data from PLN in 1982)

MIN. 1203 MVA (〃)

Converting it into %Z

MAX. 0.80 % (on the base of 10MVA)

MIN. 0.83 % (〃)

(3) The capacities and %Z of 70kV/20kV Transformers

Capacity 60MVA (on the arrangement with PLN)

%Z 13 %

Number Two sets

Converting it into %Z

$$13\% \times \frac{10MVA}{60MVA \times 2} = 1.08\%$$

(4) <u>%Z of 20 kV Transmission Line</u>

Using the same method as in Cengkareng Substation

$\%X_L = 0.25$ (%/km)

(5) <u>%Z upto the Power Receiving Point of Jakarta Kota Substation of PJKA</u>

MAX. $0.80 + 1.08 + 0.25 \times 3^{km} = 2.63\%$

MIN. $0.83 + 1.08 + 0.25 \times 3^{km} = 2.66\%$

(6) <u>3-phase Short Circuit Capacity in the Power Receiving Point of Jakarta Kota Substation of PJKA</u>

$$P_s = \frac{100}{\%Z} \times 10.000$$

then

MAX. 380 MVA

MIN. 376 MVA

(7) <u>Voltage Regulation</u>

Using the same method as in Cengkareng Substation

2.2 % is gained.

3-4 Interrupting Capacity of Circuit Breakers for Power Receiving

The interrupting capacity of circuit breakers shall be the same capacity in these three substations, considering of exchangeability. Therefore the calculation of 3-phase short circuit currents shall be made for Jakarta kota substation, which shall have the maximum 3-phase short circuit capacity, as follows.

$$I_S = \frac{380\ MVA}{\sqrt{3} \times 20 KV} = 11\ KA$$

The interrupting capacity of the circuit breakers shall be 25 KA, considering of the increase of the power source capacity of PLN network in the future.

3-5 Selection of Power Receiving Cable Sizes

The study shall be made on the condition that the same cable size shall be adopted for these three substations.

The short circuit capacity of CV cable shall be calculated as follows, on the conditions that the basic temperature is 90° and the maximum momentary allowable temperature is 230°C.

$$I_s = 134 \frac{S}{\sqrt{t}}$$

Here

S : Cable size (mm²)

t : fault continuing time

Assuming t = 1.0 sec.

S = 82 mm²

Taking the increase of the power source capacity of PLN in the future into the consideration, 22KV CV single-core 150 mm² cables shall be adopted. The continuous allowable current rating of this cables is 335A, and the load current in Jakarta kota substation is 210A.

3-6 Line Constant of Cable

The resistance and inductance of 22 kV Al CV cable 3-core 150 mm² (aluminium conductor cross-linked polyethylene insulated polyvinyl chroride sheathed cables) between PLN SS and PLN Switch House, shall be calculated in this section. A composition of 22 kV Al CV 3-core 150 mm² in JAPAN is shown in Fig. 5.

(1) Resistance

The resistance of conductor in temperature T_1 shall be calculated as follows:

$$R = R_{20}\{1 + \alpha(T_1 - 20)\}$$

Here R_{20} : resistance at conductor temperature 20°C, 0.201 (Ω/km)

α : temperature coefficient 0.00403 (1/°C)

The allowable continuous temperature rise of CV cable is 90°C, therefore we can get a following value, putting 90 in T_1 of the above formula.

$$R = 0.26 \quad (\Omega/km)$$

In the data from PLN, R is 0.2 Ω/km. This value seems to be the value at conductor temperature 20°C.

(2) Inductance

The inductance of cable is calculated using the following formula. Here the inductance means the self and mutual inductance per each phase.

$$L = (2 \ln \frac{2S}{d} + X_0) \times 10^{-1} \; (mH/km)$$

Here X_0 : 0.5

S : interval between each conductor center (mm)

d : outer diameter of conductor (mm)

From Fig. 5

$S = 7 \times 2 + 14.7 = 28.7$ mm

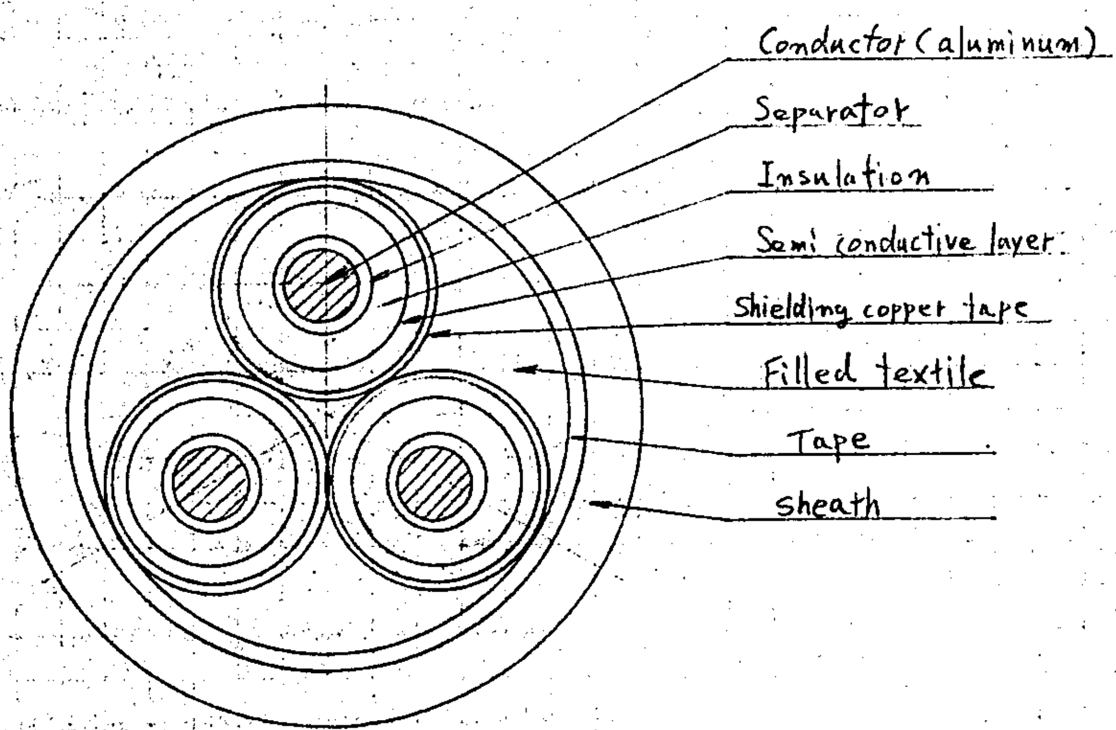
$d = 14.7$ mm

Then $L = 0.322$ (mH/km)

Therefore impedance Z is as follows:

$$Z = WL = 2\pi f L = 2 \times \pi \times 50 \times 0.322^{mH/km}$$

$$= 0.10 \quad (\Omega/km)$$



Outer diameter of conductor 14.7 mm

Insulation thickness 7.0 mm

Fig. 5 Composition of 22 kV AL CV 3-core 150 mm^2

In the data from PLN., Z is 0.1 Ω/km. Therefore the cables provided by PLN, seems to be the almost same composition as that of Fig. 5.

Therefore this cable has enough capacity for the load current.

4 CALCULATON ON FEEDING CIRCUITS

4-1 Protection with Linked Breaking Device (hereinafter called : LBD)

The protection area for the feeding circuits shall be shortened to the center between the substations with LBD, and the sensitiveness of the detection of the faults shall be improved.

For one example, to the long distance of feeding circuit between Cengkareng and kapuk substation a calculation shall be made.

The fault current ΔI, which flows into Cengkareng substation as shown in Fig. 6, shall be calculated as follows, but the fault shall be an arc fault.

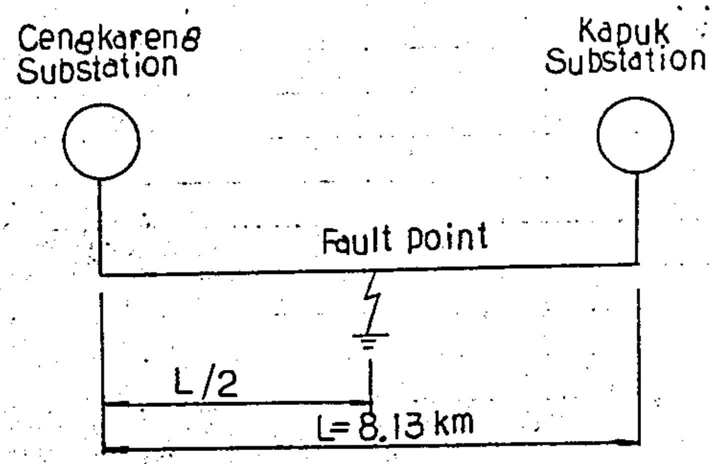


Fig 6

$$\Delta I = \frac{1500 - Ea}{Ro_1 + \frac{1}{2} r\ell + 2Ra}$$

Here ;

Ea : arc fault voltage = 300 V

Ro_1 : internal resistance of Cengkareng substation = 0.0525 Ω

r : resistance of feeding circuit (double feeders) = 0.042 Ω/km

ℓ : distance between substations = 8.13 km

Ra : resistance at arc fault point (at feeder branch intervals of 250 meters) = 0.05 Ω

Therefore ΔI = 3710 A

As the value of ΔI in the train shall be 1000 A (4M4T), this value is within protection area.

Here the values of Ea and Ra comes from Japanese National Railways' actual results.

4-2 Protection with 50F

As for 50F, the calculation shall be made for the JIAC side of Cengkareng substation. The fault shall be arc fault.

The fault current ΔI, which flows into Cengkareng substation as shown in Fig. 7, shall be calculated as follows;

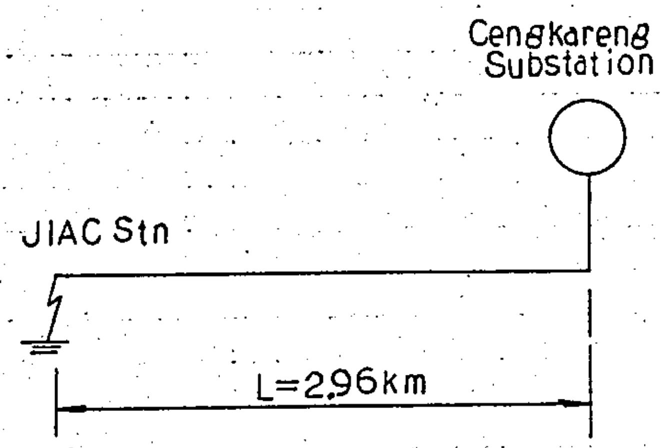


Fig 7

$$\Delta I = \frac{1500 - E_a}{R_{01} + r\ell + R_a}$$

Here;

E_a : arc fault voltage = 300V

R_{01} : internal resistance of Cengkareng substation = 0.0525 Ω

r : resistance of feeding circuit (single feeder) = 0.062 Ω/km

ℓ : distance between substations

= 2.96 km

Ra : resistance at arc fault point

(at feeder branch intervals of 250 meters)

= 0.05 Ω

Therefore ΔI = 4196 A

As the value of ΔI in the train shall be 1000A (4M4T), this value is within protection area. Here the values of Ea and Ra cames from Japanese National Railways' actual results.

8.2 SUPPORTING STRUCTURE FOR OVERHEAD CONTACT SYSTEM

* Refer to the structural calculation sheets of Package I (11 of 11).

calculation sheets ; package III : electrical work