Appendix 5-1-1 AC/DC Changeover Method of Locomotive

A neutral section will be provided in the overhead catenary system at the AC/DC junction point. Passing through it the locomotives will switch from AC to DC (or vice versa), using on-board switches. In JNR, AC/DC switching is made in accordance with the following way.

1. Operating Restrictions

(1) Trains run through the neutral section with notch off.

(2) Single pantograph is used in the AC electrified section, while double pantograph are used in the DC section.

2. Handling during Neutral Section Passing

As trains pass through the neutral section, AC/DC switching is made on-board by the engine driver in accordance with wayside signs (see Fig. 5.1.1.1).

3. Protection from Accidental Entrance

(1) Accidental entrance from DC to AC section

For a train about to enter the AC section without proper handling, primary protection is provided by automatically opening the on-board air circuit breakers as soon as the pantograph enters the neutral section and detects no-voltage. This way, no accident will occur if the train enters the AC section. Operation can thus continue normally.

If the primary protection does not work, secondary protection is provided by protective relays, which detect discharge current (on a DC lightning arrester) generated at the moment the locomotive enters the AC section. The relays then actuate the air circuit breakers, limiting the damage to the DC lightning arrester only. In this case, the damaged lightning arrester must be replaced before resuming operation.

(2) Accidental entrance from AC to DC section

If a train enters the DC section without proper handling, an AC main fuse will melt within seconds and cut off the circuit from the catenary. Operation can be resumed by following the normal procedure. The main fuse must be replaced before operating in AC section.

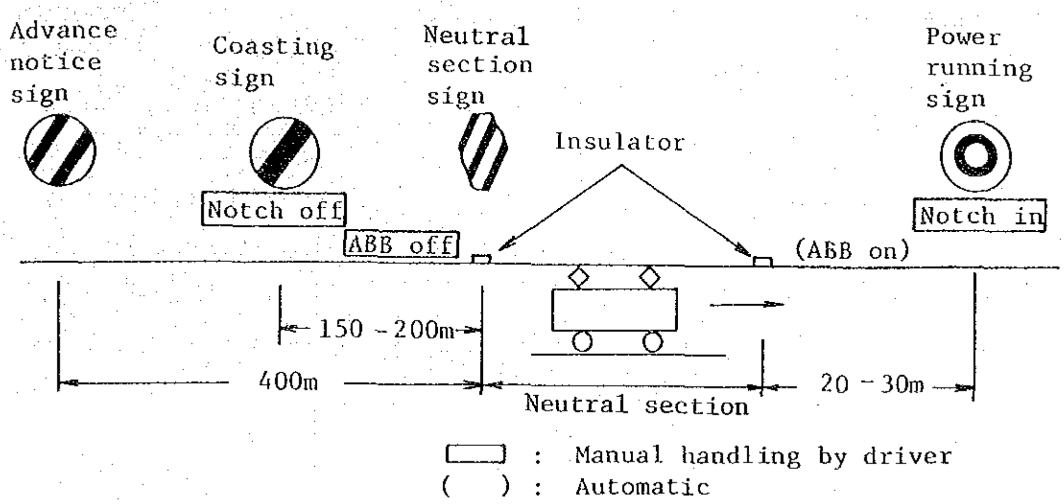


Fig. 5.1.1.1 Handling and Signs for Neutral Section

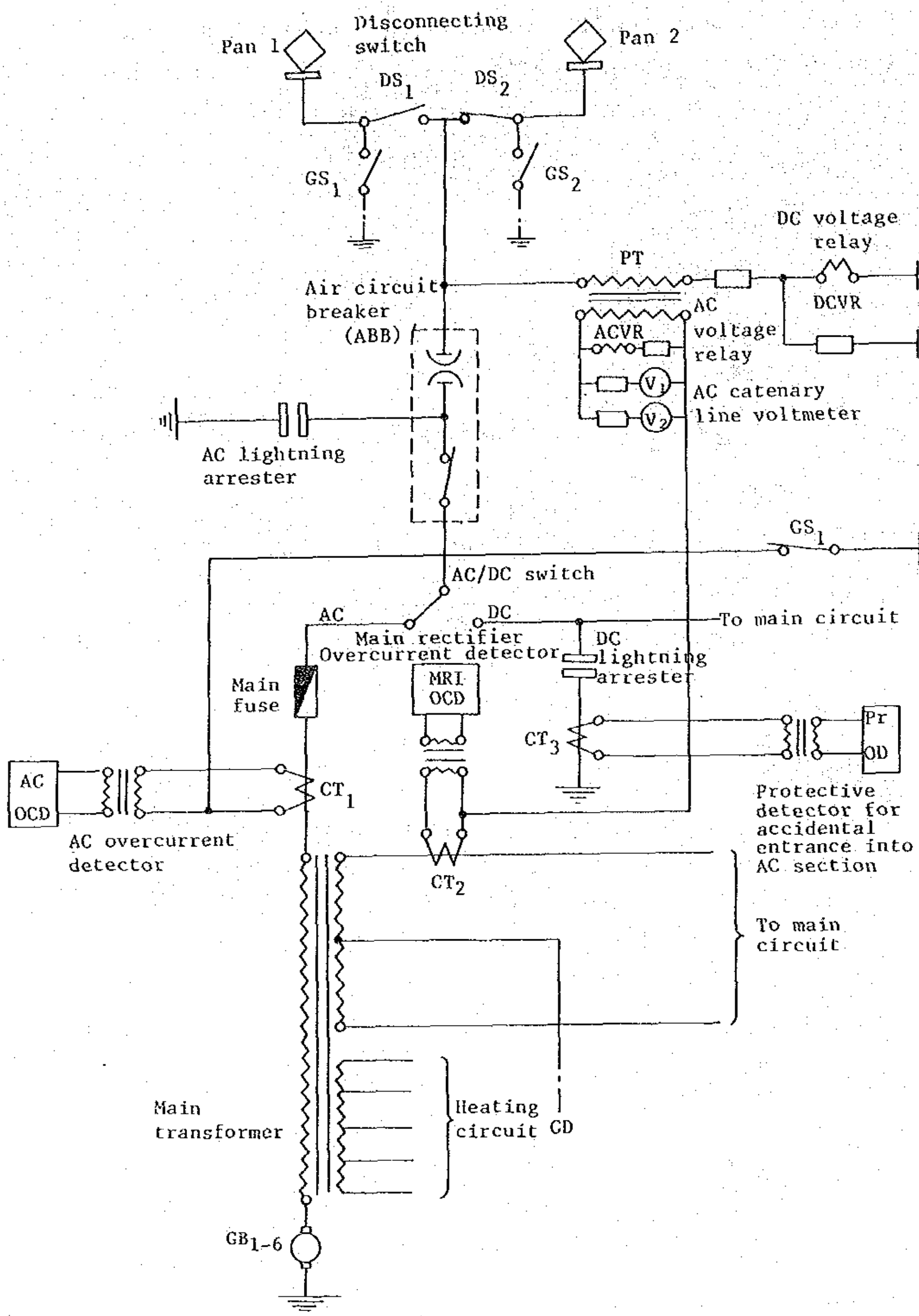


Fig. 5.1.1.2 Simplified Circuit Diagram of the AC/DC Dual-Service Locomotive (EF81)

Appendix 5-1-2 Length of the Neutral Section (in JNR)

1. Length of the neutral section installed to separate adjacent AC electrification sections with different phases

Driver of the electric locomotive must notch off when passing the neutral section to prevent contact between different AC power sources. To prevent arcing of the load current through pantograph due to mishandling of the driver, an insulated neutral section is provided in the contact wire. From test results carried out by JNR, the arc length is 3 mm/kVA. Therefore, with maximum load (2,700 kVA) applied on the electric locomotive (EF81), the arc length will be:

2,700 (kVA) x 3 (mm/kVA) = 8,100 (mm)

The neutral section length of 8 m was adopted in JNR because it is very rare that an electric locomotive will pass through the neutral section under maximum load conditions.

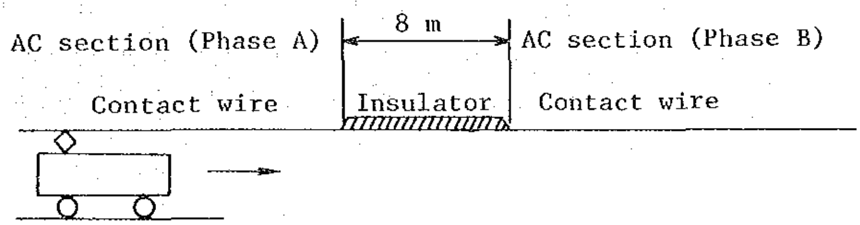


Fig. 5.1.2.1 Composition of the Neutral Section

2. Length of the neutral section to separate AC and DC sections

When the electric locomotive runs from an AC section to a DC section, the necessary length of the neutral section is calculated as follows.

Maximum arc length (8 m) + Spacing between pantographs (15.2 m) (EF81) = 23.2 m

In reality, however, the neutral section length adopted by JNR is 20 m because it is highly improbable that an electric locomotive will pass through the neutral section under maximum load conditions.

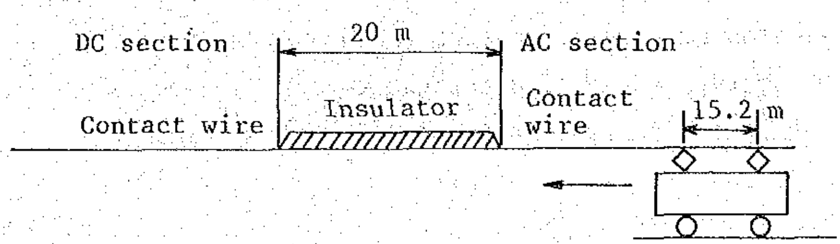


Fig. 5.1.2.2 Composition of the Neutral Section

3. Length of the neutral section to separate DC and AC sections

When the electric locomotive keeps running from DC to AC section without proper handling, the protective relay will operate and the safety measures are taken as shown in Table 5.1.2.1. For this purpose the length of the neutral section is determined long enough for the electric locomotive to remain within it until the safety measures are completed. The neutral section length is determined as shown in the following table.

Table 5.1.2.1 Neutral Section Length Based on Test Results of Electric Locomotive (EF81)

Item		Measured value	Adopted value
A	Arcing time (ms)	597	200
B	Main motor voltage drop (ms)		600
	Voltage relay operation (ms)	230	300
C	Operation of relays and auxiliary circuit breakers (ms)	106	110
	Main circuit breaker operation (ms)		100
D	Safety margin (ms)	-	100
A + B + C + D (ms)		933	1,410
Effective length for 110 km/h speed (m)		28	43
E	Spacing between pantographs (m)	15.2	
Required neutral section length (m)		43.2	58.2=60

As shown in Table 5.1.2.1, the neutral section length of 60 m is adopted.

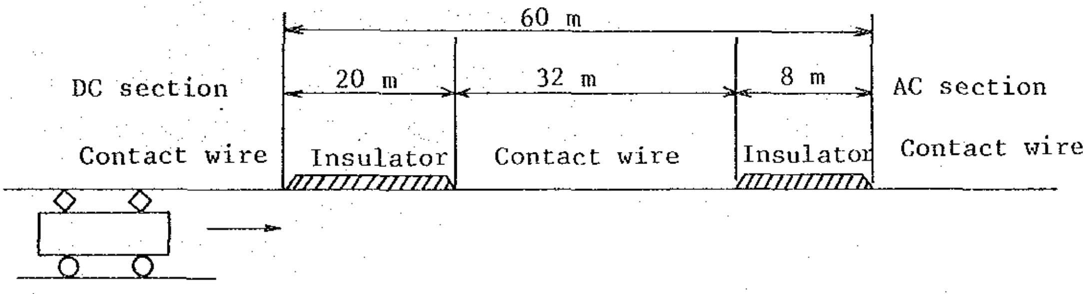


Fig. 5.1.2.3 Composition of the Neutral Section

Appendix 5-3-1 Comparison of Expenditures on Traction System Alternatives

1. Premises

The electrification of the main lines will progress at an annual rate of 100 km including the Merak Line (Merak - Serpong) which will be completed in 1997.

In JABOTABEK lines, 113.4 km will be DC electrified by 1992, the Tanahabang-Serpong section (23.3 km) in 1997.

2. Items of expenditures

Only the expenditures listed below are compared:

a. Investment

(a) Tractive units operated in the electrified lines (including JABOTABEK lines).

(b) Facilities for locomotive changing (Alternatives 1, 2, 6, and 7).

(c) Maintenance facilities for electric locomotives operated in the JABOTABEK lines (Alternatives 2, 4, 5, 7, and 8).

(d) New double tracks with AC electrification in the Manggarai-Bekasi section (Alternative 7).

(e) Converting the JABOTABEK electrification system from DC to AC (Alternative 8).

(f) New DC electrification of the Tanahabang-Serpong section (Alternatives 1, 2, 4, 5, 6, and 7).

(g) New AC electrification of the Tanahabang-Serpong section (Alternative 8).

b. Maintenance cost

Maintenance cost corresponding to the investment items in a.

c. Fuel/power cost

Fuel/power cost for train operation on the Section and the Merak line (Merak-Jakarta).

d. Residual value

The residual value of the facilities and tractive units.

3. Unit costs

(1) Tractive unit

a. Locomotives

EL (DC)	1.00	(978 million Rp.)
EL (AC)	1.30	
EL (AC/DC)	1.40	
DL	1.30	(New rolling stock)
DL	0.65	(Existing rolling stock of 10-year use)

b. Electric MU cars

EC (DC)	1.00	(638 million Rp.)
EC (AC)	1.10	
EC (AC/DC)	1.13	

(2) Converting from EC (DC) to EC (AC)

59.5 million Rp./car

(Conversion includes installation of additional circuit breakers, transformer and rectifier.)

(3) Electrification facilities (JABOTABEK lines)

AC system	255 million Rp./km
DC system	306 million Rp./km

(4) Converting electrification facilities from DC to AC (JABOTABEK lines)

225 million Rp./km

(Conversion includes new substations, sectioning post and AF installation with land acquisition, and improvement of supporting structures, signalling and telecommunications.)

(5) Facilities for locomotive changing (Tambun, Cisauk)

DL - EL (AC) 4,247 million Rp.
EL (DC) - EL (AC) 4,674 million Rp.

(Facilities include land acquisition, constructing additional sidings and lead tracks, and installing power supply changeover facilities.)

(6) New double tracks with AC electrification in the Manggarai-Bekasi section

2,920 million Rp./km

(Double tracking includes improving the Manggarai Station and constructing passenger car storage tracks at Cipinang.)

(7) Fuel/power cost

a. Passenger train

EC	730 Rp./train-km
EL	663 Rp./train-km
DL	880 Rp./train-km

b. Freight train

EL	932 Rp./train-km
DL	1,408 Rp./train-km

4. Tractive unit

(1) Main lines

Number of tractive units required for the main lines is shown in Table 5.3.1.1.

Table 5.3.1.1 Number of Tractive Units for the Main Lines

Alternative	Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1	EL [AC]	49 [49]	60 [11]	71 [11]	82 [11]	88 [6]	100 [12]	112 [12]	123 [11]	134 [11]	145 [11]
	DL	20 [20]	20 [0]	21 [1]	21 [0]	22 [1]	28 [6]	28 [0]	29 [1]	30 [1]	31 [1]
2	EL [AC]	49 [49]	60 [11]	71 [11]	82 [11]	88 [6]	100 [12]	112 [12]	123 [11]	134 [11]	145 [11]
	EL [DC]	20 [20]	20 [0]	21 [1]	21 [0]	22 [1]	28 [6]	28 [0]	29 [1]	30 [1]	31 [1]
4	EL [AC/DC]	58 [58]	68 [10]	79 [11]	91 [12]	97 [6]	114 [17]	125 [11]	136 [11]	148 [12]	160 [12]
5	EC [AC/DC]	51 [51]	61 [10]	72 [11]	84 [12]	90 [6]	107 [17]	118 [11]	129 [11]	141 [12]	153 [12]
	EL [AC/DC]	56 [56]	56 [0]	56 [0]	56 [0]	56 [0]	56 [0]	56 [0]	64 [8]	64 [0]	64 [0]
6	EC [AC]	44 [44]	54 [10]	65 [11]	76 [11]	82 [6]	95 [13]	105 [10]	116 [11]	128 [12]	139 [11]
	EL [AC]	56 [56]	56 [0]	56 [0]	56 [0]	56 [0]	56 [0]	56 [0]	64 [8]	64 [0]	64 [0]
	DL	20 [20]	20 [0]	21 [1]	21 [0]	22 [1]	28 [6]	28 [0]	29 [1]	30 [1]	31 [1]
7	EL [AC]	58 [58]	68 [10]	79 [11]	91 [12]	97 [6]	110 [13]	121 [11]	132 [11]	144 [12]	156 [12]
	DL	3 [3]	3 [0]	3 [0]	3 [0]	3 [0]	9 [6]	9 [0]	9 [0]	10 [1]	10 [0]
8	EL [AC]	58 [58]	68 [10]	79 [11]	91 [12]	97 [6]	114 [17]	125 [11]	136 [11]	148 [12]	160 [12]

Note: Figures within brackets [ ] indicate tractive unit newly introduced.

(2) JABOTABEK lines

Number of tractive units required for the JABOTABEK lines is shown in Table 5.3.1.2.

Table 5.3.1.2 Number of EMU Cars for JABOTAEK Lines

1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
336 (76)	384 (48)	432 (48)	480 (48)	532 (52)	584 (52)	632 (48)	680 (48)	728 (48)	776 (48)

Note: Figures within parentheses ( ) indicate tractive unit newly introduced.

5. Results

The annual expenditures and their net present values (NPV) are shown in Table 5.3.1.3.

Table 5.3.1.3 Annual Expenditure and NVP

(Unit: million Rp.)

		NPV	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Residual value
Alternative 1													
Investment	Tractive unit	246,494	123,646	44,615	45,889	44,615	42,065	52,263	45,889	45,889	45,889	45,889	385,299
	Ground facilities	6,507	4,249					11,387					13,769
Maintenance cost	Tractive unit	21,965	2,010	2,503	3,034	3,531	4,011	4,772	5,282	5,813	6,344	6,875	
	Ground facilities	430	38	38	38	38	38	148	148	148	148	148	
Fuel/power cost		49,421	7,416	7,549	7,685	7,823	7,964	10,071	10,257	10,446	10,649	10,839	
Total		324,817	137,359	54,705	56,646	56,007	54,078	78,641	61,576	62,296	63,030	63,751	399,068
Alternative 2													
Investment	Tractive unit	250,882	130,444	44,615	45,592	44,615	41,768	54,302	45,889	45,592	45,592	45,592	396,372
	Ground facilities	7,987	5,949					11,812					15,518
Maintenance cost	Tractive unit	18,484	1,496	1,989	2,490	2,987	3,446	4,054	4,563	5,065	5,570	6,080	
	Ground facilities	536	55	55	55	55	55	169	169	169	169	169	
Fuel/power cost		46,556	7,008	7,134	7,263	7,393	7,527	9,444	9,617	9,796	9,981	10,161	
Total		324,445	144,952	53,793	55,400	55,050	52,796	79,781	60,238	60,622	61,312	62,002	411,890
Alternative 4													
Investment	Tractive unit	249,189	127,793	44,275	45,643	47,011	41,351	56,401	45,643	45,643	47,011	47,011	404,254
	Ground facilities	2,984	1,275					7,138					7,444
Maintenance cost	Tractive unit	18,427	1,462	1,955	2,460	2,983	3,437	4,066	4,572	5,078	5,600	6,123	
	Ground facilities	211	13	13	13	13	13	84	84	84	84	84	
Fuel/power cost		46,556	7,008	7,134	7,263	7,393	7,527	9,444	9,617	9,796	9,981	10,161	
Total		317,367	137,551	53,377	55,379	57,400	52,328	77,133	59,916	60,601	62,676	63,379	411,698
Alternative 5													
Investment	Tractive unit	266,892	146,769	44,275	45,643	47,011	41,351	56,401	45,643	49,722	47,011	47,011	415,612
	Ground facilities	2,984	1,275					7,138					7,444
Maintenance cost	Tractive unit	19,572	1,653	2,146	2,651	3,174	3,629	4,257	4,763	5,311	5,834	6,357	
	Ground facilities	211	13	13	13	13	13	84	84	84	84	84	
Fuel/power cost		47,007	7,084	7,211	7,341	7,473	7,608	9,526	9,671	9,882	10,067	10,249	
Total		336,666	156,794	53,645	55,648	57,671	52,601	77,406	60,161	64,999	62,996	63,701	423,056
Altarnative 6													
Investment	Tractive unit	264,855	144,636	43,340	45,889	44,615	42,065	53,537	43,346	49,798	47,164	45,889	397,205
	Ground facilities	6,507	4,249					11,387					13,769
Maintenance cost	Tractive unit	23,184	2,226	2,707	3,238	3,731	4,215	4,988	5,468	6,042	6,590	7,117	
	Ground facilities	430	38	38	38	38	38	148	148	148	148	148	
Fuel/power cost		49,803	7,478	7,613	7,750	7,889	8,032	10,140	10,327	10,517	10,713	10,913	
Total		344,779	158,627	53,698	56,915	56,273	54,350	80,200	59,289	66,505	64,615	64,067	410,974
Alternative 7													
Investment	Tractive unit	243,666	124,283	43,340	44,615	45,889	40,790	53,537	44,615	44,615	47,164	45,889	391,460
	Ground facilities	41,456	48,014					11,387					49,461
Maintenance cost	Tractive unit	18,790	1,508	1,989	2,481	2,991	3,437	4,215	4,708	5,201	5,749	6,259	
	Ground facilities	2,833	442	442	442	442	442	589	589	589	589	589	
Fuel/power cost		47,159	7,040	7,166	7,295	7,427	7,561	9,683	9,862	10,046	10,234	10,425	
Total		353,904	181,287	52,937	54,833	56,749	52,230	79,411	59,774	60,451	63,736	63,162	440,921
Alternative 8													
Investment	Tractive unit	271,068	142,681	46,399	47,674	48,948	44,105	58,126	47,674	47,674	48,948	48,948	416,092
	Ground facilities	28,151	26,769					5,949					6,374
Maintenance cost	Tractive unit	18,765	1,449	1,963	2,490	3,030	3,510	4,160	4,687	5,218	5,753	6,297	
	Ground facilities	188	13	13	13	13	13	72	72	72	72	72	
Fuel/power cost		46,556	7,008	7,134	7,263	7,393	7,527	9,444	9,617	9,796	9,981	10,161	
Total		364,728	177,920	55,509	57,440	59,384	55,155	77,751	62,050	62,760	64,754	65,478	422,466

6. Analysis

According to Table 5.3.1.3, alternative 4 has the lowest NPV. The analysis of each item is described in the following.

(1) Investment on ground facilities

Alternatives 4 and 5, which do not require locomotive changing, are more economical in terms of initial investment by 3.0 to 4.5 billion Rp. compared with alternatives 1, 2, and 6 which require locomotive changing. Furthermore, the same amount of savings can be expected when the Merak Line is electrified in 1997.

Alternatives 7 and 8 require a large initial investment. Namely, alternative 7 requires 47 billion Rp. for the construction of new double tracks with AC electrification; and alternative 8 requires 25 billion Rp. to convert from DC to AC electrification system.

(2) Investment on tractive unit

Alternative 7 is the most economical since EL (AC) hauls most trains. It saves 3 and 5.5 billion Rp. compared to Alternative 1 and 4, respectively.

Alternative 1 which uses existing DL, can save approximately 4 billion Rp. compared with Alternatives 2 and 4.

Alternatives 5 and 6 which adopt some EC trains on the main lines are relatively expensive.

Alternative 8 requires the highest investment because of high conversion and purchasing costs of EC (AC) for the JABOTABEK lines.

(3) Maintenance cost

The maintenance cost of ground facilities is relatively small for each alternative.

Alternatives 1 and 6 which use DL, require higher tractive unit maintenance cost by about 0.5 to 0.7 billion Rp. per year compared with other alternatives.

(4) Fuel/power cost

Alternatives 1 and 6 additionally require 0.35 to 0.6 billion Rp. per year.

Appendix 6-7-1 Simulation Analysis of Track Capacity between Cikampek - Cirebon

1. Objective

Simulation analysis was conducted to estimate the extent to which track capacity between Cikampek - Cirebon can be increased through improvement of railway facilities.

2. Method

Using JNR's Diagram Planning System (DIAPS), train diagrams in the section were made for five cases of different train speed and facility conditions.

Five cases are as follows:

Case 1. <u>No change</u>

Present operating and facility conditions are maintained.

Case 2. <u>Electrification</u>

Train speed will be increased by electrification, while maintaining the present track and signalling facilities.

Case 3. <u>Automatic block (without block signals) & relay/electronic interlocking device</u>

In addition to Case 2, existing block, interlocking and signalling devices will be modernized.

Case 4. <u>Automatic block (with block signals)</u>

In addition to Case 3, block system will be upgraded to allow successive train operation between stations.

Case 5. <u>Passing track</u>

In addition to Case 4, new passing tracks will be provided at two inter-station sections which are regarded as bottlenecks to the track capacity of the whole section.

3. Basic Data

(1) <u>Stopping station and time for each train type</u>

Stopping station and time for each train type were assumed as shown in Table 6.7.1.1.

(2) <u>Train handling time for each case</u>

Train handling time at station for each of the five cases were assumed as shown in Table 6.7.1.2.

(3) <u>Standard operation time for each train type</u>

Operation time between stations was assumed for each type of train per each direction. Operation time in case 1 was taken from the present train diagram, and those in cases 2 - 5 were assumed by taking into consideration speed-up by electrification, as shown in Table 6.7.1.3.

(4) <u>Track diagram</u>

Station tracks used for train crossing and passing were determined as shown in Fig. 6.7.1.1.

Table 6.7.1.1 Stopping Time at Way Stations

(Unit: min.)

Train		Station / Train No.	CKP	TJS	PAB	PRI	PAS	CKM	PGB	CRA	HGL	CPA	CLH	SUK	KAB	TIS	TLS	JTB	KTM	KLW	AWN	BDW	CNK	CN
Passenger	Super express & express	1 - 49																						5
	Fast	101 - 149	5		2		2		2		2				2			2			2			5
	Fast	201 - 249	5				2		2		2				2	2		2			2			5
	Local	601 - 649	2	1	1	1	1	1	2	1	1	*0 (1)	1	*0 (1)	1	1	1	2	1	1	1	1	1	2
Freight	Express	BT1 - BT99	15																					10
	Local	TRS1 - TRS99	15						10									10						10

Note: * one min. after provision of passing tracks.

Table 6.7.1.2 Train Handling Time in Each Simulation Case

Simulation Case	Railway system	Time required for crossing with trains in opposite direction				Required headway between successive trains								Time required for trains departing from or arriving at the same track
						Block system without block signal				Automatic block with block signal				
		a_1	a_2	a_3	a_4	c_1	c_2	c_3	c_4	h_1	h_2	h_3	h_4	b
1	Existing system	m.s. 5:00	m.s. 1:00	m.s. 2:00	m.s. 3:00	m.s. 5:00	m.s. 5:00	m.s. 1:00	m.s. 1:00					3:00
2	Electrification	5:00	1:00	2:00	3:00	5:00	5:00	1:00	1:00					3:00
3	Automatic block (without block signal)	3:00	1:00	1:00	2:00	3:00	3:00	1:00	1:00					3:00
4	Automatic block (with block signal)	2:00	0:30	0:30	2:00					m.s. 3:00	m.s. 3:00	m.s. 3:00	m.s. 3:00	3:00
5	Additional passing tracks	2:00	0:30	0:30	2:00					3:00	3:00	3:00	3:00	3:00

Table 6.7.1.3 Net Operation Time before Electrification (bound for Cikampek)

(Passenger train)

	Express				Fast				Local			
UP	PPAO				PPBO				PPCO			
CIKAMPEK	800	930	900	1030	730	900	830	1000	730	900	830	1000
TRANJUNG	430	530	600	700	500	600	630	730	430	530	600	700
PABUARAN	500	630	600	730	430	600	530	700	430	600	530	700
PRINGKSP	500	600	630	730	530	630	700	800	530	630	700	800
PASIRBNG	500	630	600	730	430	600	530	700	430	600	530	700
CIKAUM	800	900	930	1030	830	930	1000	1100	730	830	900	1000
PEGADEN	700	830	800	930	630	800	730	900	630	800	730	900
CIPUNEGA	600	700	730	830	630	730	800	900	530	630	700	800
HAURGEUL	x	x	x	x	x	x	x	x	x	x	x	x
CIPEDANG	930	1100	1030	1200	900	1030	1000	1130	1030	1200	1130	1300
CILEGEH	x	x	x	x	x	x	x	x	x	x	x	x
SUKAMLNG	700	800	830	930	700	800	830	930	730	830	900	1000
KADOKANG	530	700	630	800	600	730	700	830	530	700	630	800
TERISI	730	830	900	1000	700	800	830	930	730	830	900	1000
TERAGASA	800	930	900	1030	830	1000	930	1100	730	900	830	1000
JATIBARN	730	830	900	1000	700	800	830	930	730	830	900	1000
KERTSEMY	700	830	800	930	700	830	800	930	630	800	730	900
KALIWEDI	700	800	830	900	730	830	900	1000	630	730	800	900
ARJAWINA	500	630	600	730	430	600	530	700	430	600	530	700
BANGODWA	430	530	600	700	430	530	600	700	430	530	600	700
CANGKRNG	630	800	730	900	630	800	730	900	530	700	630	800
CIREBON												
*	12330				12300				11930			

(Freight train)

	Express				Local			
UP	FFCS				FFDS			
CIKAMPEK	1100	1230	1200	1330	1530	1700	1630	1800
TRANJUNG	630	730	800	900	800	900	930	1030
PABUARAN	800	930	900	1030	1000	1130	1100	1230
PRINGKSP	800	900	930	1030	1000	1100	1130	1230
PASIRBNG	800	930	900	1030	1000	1130	1100	1230
CIKAUM	1200	1300	1330	1430	1600	1700	1730	1830
PEGADEN	1000	1130	1100	1230	1230	1400	1330	1500
CIPUNEGA	900	1000	1030	1130	1100	1200	1230	1330
HAURGEUL	x	x	x	x	x	x	x	x
CIPEDANG	1400	1530	1500	1630	1800	1930	1900	2030
CILEGEH	x	x	x	x	x	x	x	x
SUKAMLNG	900	1000	1030	1130	1400	1500	1530	1630
KADOKANG	800	930	900	1030	1000	1130	1100	1230
TERISI	1100	1200	1230	1330	1400	1500	1530	1630
TERAGASA	1200	1330	1300	1430	1600	1730	1700	1830
JATIBARN	1100	1200	1230	1330	1330	1430	1500	1600
KERTSEMY	1000	1130	1100	1230	1300	1430	1400	1530
KALIWEDI	1000	1100	1130	1230	1300	1400	1430	1530
ARJAWINA	700	830	800	930	900	1030	1000	1130
BANGODWA	700	800	830	930	800	900	930	1030
CANGKRNG	1000	1130	1100	1230	1300	1430	1400	1530
CIREBON								
*	18130				23430			

Table 6.7.1.4 Net Operation Time after Electrification

DOWN	(Passenger train) PPAO			(Express freight train) FFC5				(Local freight train) FFD5				
CIKAMPEK	600	730	800	830	700	800	900	930	730	900	1000	1030
TRANJUNG	330	500	500	530	400	530	500	600	400	600	530	630
PABUARAN	400	530	530	600	430	530	630	700	500	630	700	730
PRINGKSP	400	600	600	630	430	630	600	700	500	730	700	800
PASIRBNG	400	530	600	630	430	600	630	700	500	630	700	800
CIKAUM	600	730	730	800	630	830	800	900	730	930	900	1030
PEGADEN	500	700	700	730	600	700	800	830	630	800	830	900
CIPUNEGA	430	600	530	630	430	630	600	700	500	730	630	800
HAURGEUL	z	z	z	z	z	z	z	z	z	z	z	z
CIPEDANG	700	830	830	900	800	900	930	1000	830	1000	1030	1130
CILEGEH	z	z	z	z	z	z	z	z	z	z	z	z
SUKAMLNG	530	700	700	730	600	800	730	830	630	830	800	930
KADOKANG	400	530	600	630	430	600	630	700	500	630	700	800
TERISI	530	700	700	730	600	800	730	830	700	930	830	1000
TERAGASA	600	730	730	800	630	800	830	900	700	830	930	1000
JATIBARN	530	730	700	730	600	800	730	830	700	900	830	930
KERTSEMY	500	630	630	700	530	700	730	800	600	730	830	900
KALIWEDI	500	630	630	700	530	730	700	800	600	830	800	900
ARJAWINA	400	530	530	600	430	530	600	630	430	600	700	730
BANGODWA	330	500	500	530	400	530	500	600	400	630	530	700
CANGKRNG	500	630	630	700	530	630	730	800	600	730	800	830
CIREBON *	9300				10330				11300			

UP	(Passenger train) PPAO			(Express freight train) FFC5				(Local freight train) FFD5				
CIKAMPEK	600	730	800	830	700	800	900	930	730	900	1000	1030
TRANJUNG	330	500	500	530	400	530	500	600	400	600	530	630
PABUARAN	400	530	530	600	430	530	630	700	500	630	700	730
PRINGKSP	400	600	600	630	430	630	600	700	500	730	700	800
PASIRBNG	400	530	600	630	430	600	630	700	500	630	700	800
CIKAUM	600	730	730	800	630	830	800	900	730	930	900	1030
PEGADEN	500	700	700	730	600	700	800	830	630	800	830	900
CIPUNEGA	430	600	530	630	430	630	600	700	500	730	630	800
HAURGEUL	z	z	z	z	z	z	z	z	z	z	z	z
CIPEDANG	700	830	830	900	800	900	930	1000	830	1000	1030	1130
CILEGEH	z	z	z	z	z	z	z	z	z	z	z	z
SUKAMLNG	530	700	700	730	600	800	730	830	630	830	800	930
KADOKANG	400	530	600	630	430	600	630	700	500	630	700	800
TERISI	530	700	700	730	600	800	730	830	700	930	830	1000
TERAGASA	600	730	730	800	630	800	830	900	700	830	930	1000
JATIBARN	530	730	700	730	600	800	730	830	700	900	830	930
KERTSEMY	500	630	630	700	530	700	730	800	600	730	830	900
KALIWEDI	500	630	630	700	530	730	700	800	600	830	800	900
ARJAWINA	400	530	530	600	430	530	600	630	430	600	700	730
BANGODWA	330	500	500	530	400	530	500	600	400	630	530	700
CANGKRNG	500	630	630	700	530	630	730	800	600	730	800	830
CIREBON *	9300				10330				11300			

Table 6.7.1.5 Net Operation Time after Construction of Two Passing Tracks at CIPEDANG and SUKAMELUNG

DOWN	(Passenger train) PPAO				(Express freight train) FFC5				(Local freight train) FFD5			
CIKAMPEK	600	730	800	830	700	800	900	930	730	900	1000	1030
TRANJUNG	330	500	500	530	400	530	500	600	400	600	530	630
PABUARAN	400	530	530	600	430	530	630	700	500	630	700	730
PRINGKSP	400	600	600	630	430	630	600	700	500	730	700	800
PASIRBNG	400	530	600	630	430	600	630	700	500	630	700	800
CIKAUM	600	730	730	800	630	830	800	900	730	930	900	1030
PEGADEN	500	700	700	730	600	700	800	830	630	800	830	900
CIPUNEGA	430	600	600	630	500	700	630	730	530	700	630	730
HAURGEUL	330	500	530	600	400	530	600	630	430	530	600	630
CIPEDANG	400	530	500	600	400	600	530	630	430	600	530	630
CILEGEH	300	430	500	500	330	430	530	600	330	500	500	530
SUKAMLNG	300	430	400	430	300	500	430	500	330	500	430	530
KADOKANG	400	530	600	630	430	600	630	700	500	630	700	800
TERISI	530	700	700	730	600	800	730	830	700	930	830	1000
TERAGASA	600	730	730	800	630	800	830	900	700	830	930	1000
JATIBARN	530	730	700	730	600	800	730	830	700	900	830	930
KERTSEMY	500	630	630	700	530	700	730	800	600	730	830	900
KALIWEDI	500	630	630	700	530	730	700	800	600	830	800	900
ARJAWINA	400	530	530	600	430	530	600	630	430	600	700	730
BANGODWA	330	500	500	530	400	530	500	600	400	630	530	700
CANGKRNG	500	630	630	700	530	630	730	800	600	730	800	830
CIREBON												
*	9300				10330				11300			

UP	(Passenger train) PPAO				(Express freight train) FFC5				(Local freight train) FFD5			
CIKAMPEK	600	730	800	830	700	800	900	930	730	900	1000	1030
TRANJUNG	330	500	500	530	400	530	500	600	400	600	530	630
PABUARAN	400	530	530	600	430	530	630	700	500	630	700	730
PRINGKSP	400	600	600	630	430	630	600	700	500	730	700	800
PASIRBNG	400	530	600	630	430	600	630	700	500	630	700	800
CIKAUM	600	730	730	800	630	830	800	900	730	930	900	1030
PEGADEN	500	700	700	730	600	700	800	830	630	800	830	900
CIPUNEGA	430	600	600	630	500	700	630	730	530	700	630	730
HAURGEUL	330	500	530	600	400	530	600	630	430	530	600	630
CIPEDANG	400	530	500	600	400	600	530	630	430	600	530	630
CILEGEH	300	430	500	500	330	430	530	600	330	500	500	530
SUKAMLNG	300	430	400	430	300	500	430	500	330	500	430	530
KADOKANG	400	530	600	630	430	600	630	700	500	630	700	800
TERISI	530	700	700	730	600	800	730	830	700	930	830	1000
TERAGASA	600	730	730	800	630	800	830	900	700	830	930	1000
JATIBARN	530	730	700	730	600	800	730	830	700	900	830	930
KERTSEMY	500	630	630	700	530	700	730	800	600	730	830	900
KALIWEDI	500	630	630	700	530	730	700	800	600	830	800	900
ARJAWINA	400	530	530	600	430	530	600	630	430	600	700	730
BANGODWA	330	500	500	530	400	530	500	600	400	630	530	700
CANGKRNG	500	630	630	700	530	630	730	800	600	730	800	330
CIREBON												
*	9300				10330				11300			

4. Scheduling of Train Diagram

(1) All trains were assumed to be operated through the whole section.

(2) Ratio of trains by type

Trains were set up in accordance with the following ratio for each type.

a. Passenger train : Freight train = 10 : 1

b. Passenger train
   Super express/express : Fast : Local = 3 : 2 : 3.5

c. Freight train
   Express/Fast : Local = 1 : 1

(3) Operating time zone

Trains were set within the following time zones at Cikampek.

Table 6.7.1.6 Time Zone for Train Setting (at Cikampek)

Train		For Jakarta	For Cirebon
Passenger	Super express, express & fast	3°30' - 5°00' 7°00' - 12°30' 15°30' - 20°30'	6°30' - 8°00' 10°00' - 15°30' 18°30' - 23°30'
	Local	3°30' - 20°30'	6°30' - 23°30'
Freight		0°00' - 24°00'	0°00' - 24°00'

(4) Minimum headway

Minimum headway for successive train operation in Cases 4 and 5 was assumed to be 3 minutes.

(5) Construction of new passing tracks

In Case 5, new passing tracks were provided at Cipedang and Sukamelang which have no passing track at present.

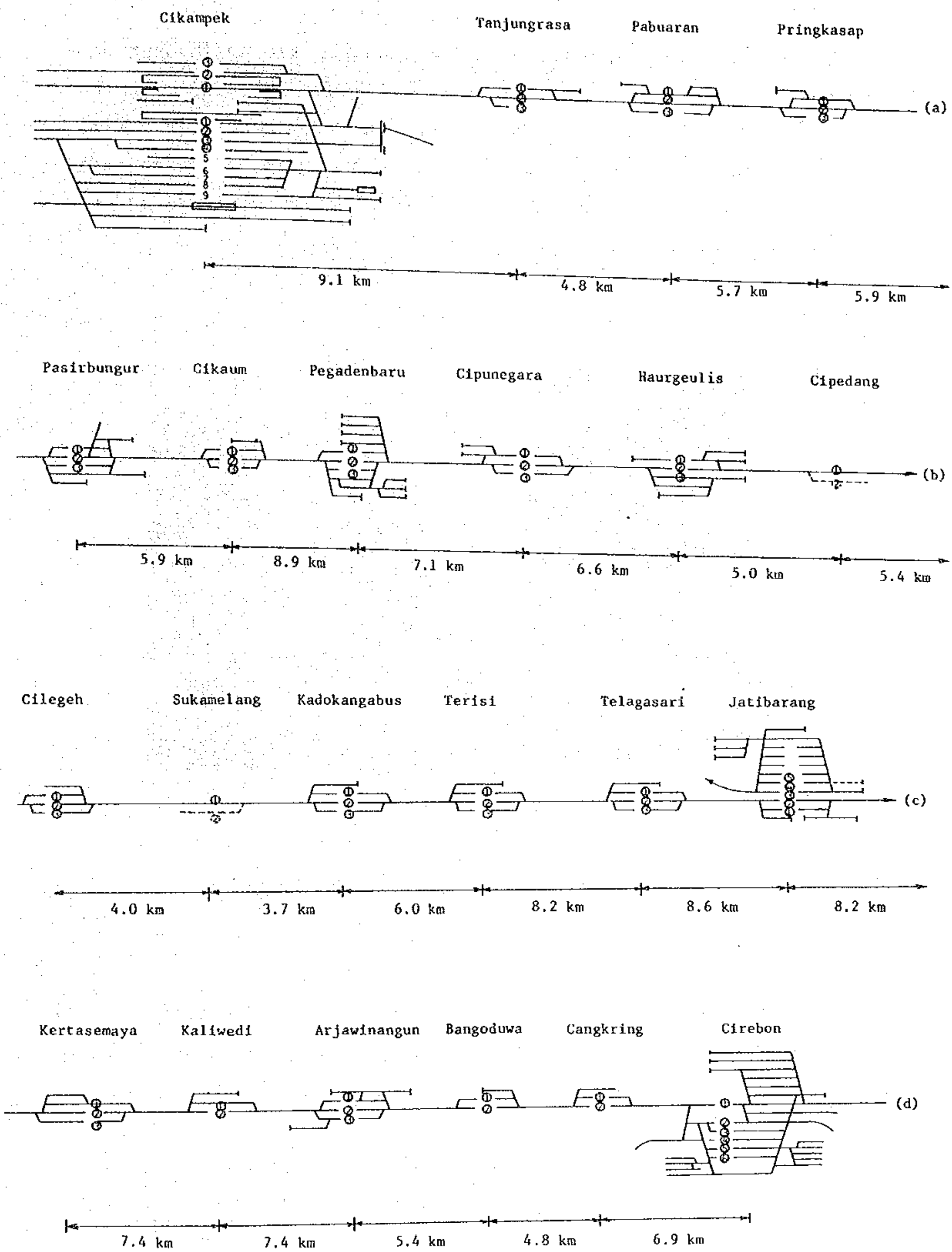


Fig. 6.7.1.1 Passing Tracks in the Cikampek - Cirebon Section Used in the Simulation

5. Simulation

After inputting the basic data, trains were set up through man-machine interaction using graphic display (Photo 6.7.1.1). In the simulation, the number of trains at the time when total slack time, which represents wasteful stopping time at stations to avoid conflict between two trains, reaches 20% of the total train hour was adopted as the practical track capacity.

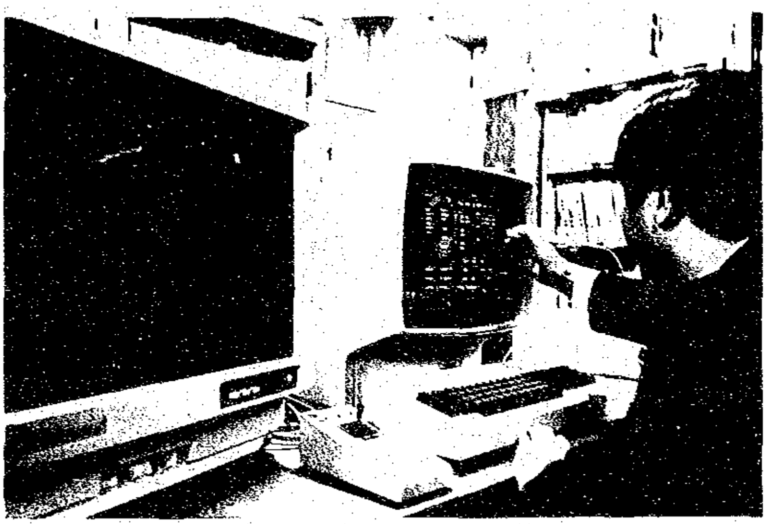


Photo 6.7.1.1 Simulation by DIAPS

6. Simulation Result

The result of the simulation is summarized in Table 6.7.1.7. Train diagrams, with the maximum number of trains set up for each of the five cases, are shown in Figs. 6.7.1.2 - 6.

Table 6.7.1.7 Result of the Simulation

Case	Total train hour (T)	Total slack time (s)	S/T(%)	Passenger train			Freight train		Track capacity
				Express	Fast	Local	Ex-press	Local	
1	Hr. Min. Sec. 193 : 38 : 30	Hr. Min. Sec. 38 : 17 : 30	19.8	20	12	22	2	2	58
2	172 : 51 : 30	34 : 25 : 30	19.9	22	14	24	4	2	66
3	205 : 7 : 30	40 : 36 : 30	19.8	26	16	30	4	2	78
4	264 : 18 : 30	52 : 4 : 00	19.7	32	22	38	4	4	100
5	304 : 52 : 00	60 : 29 : 30	19.8	36	24	43	6	4	113

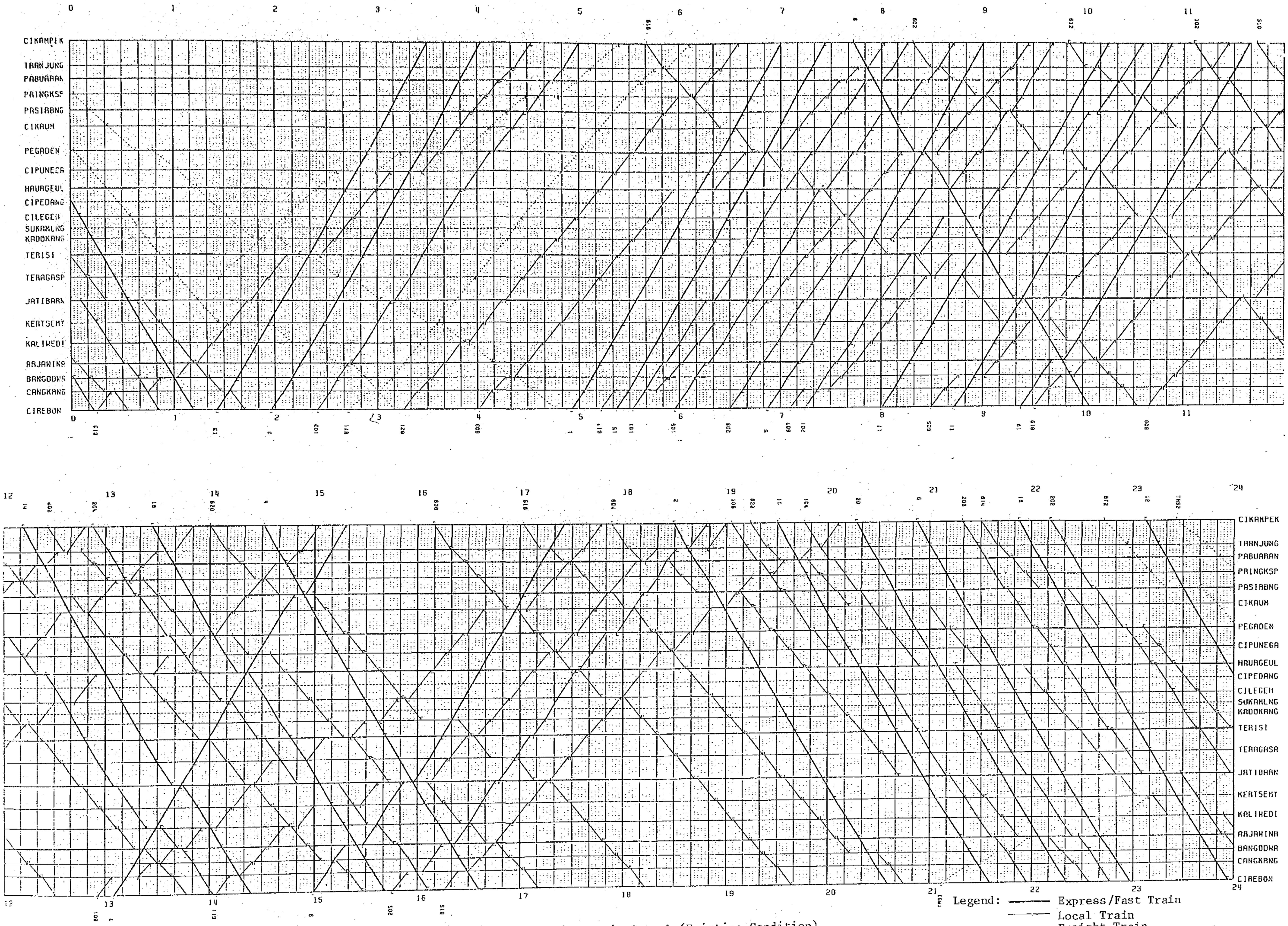


Fig. 6.7.1.2 Train Diagram in Case 1 (Existing Condition)

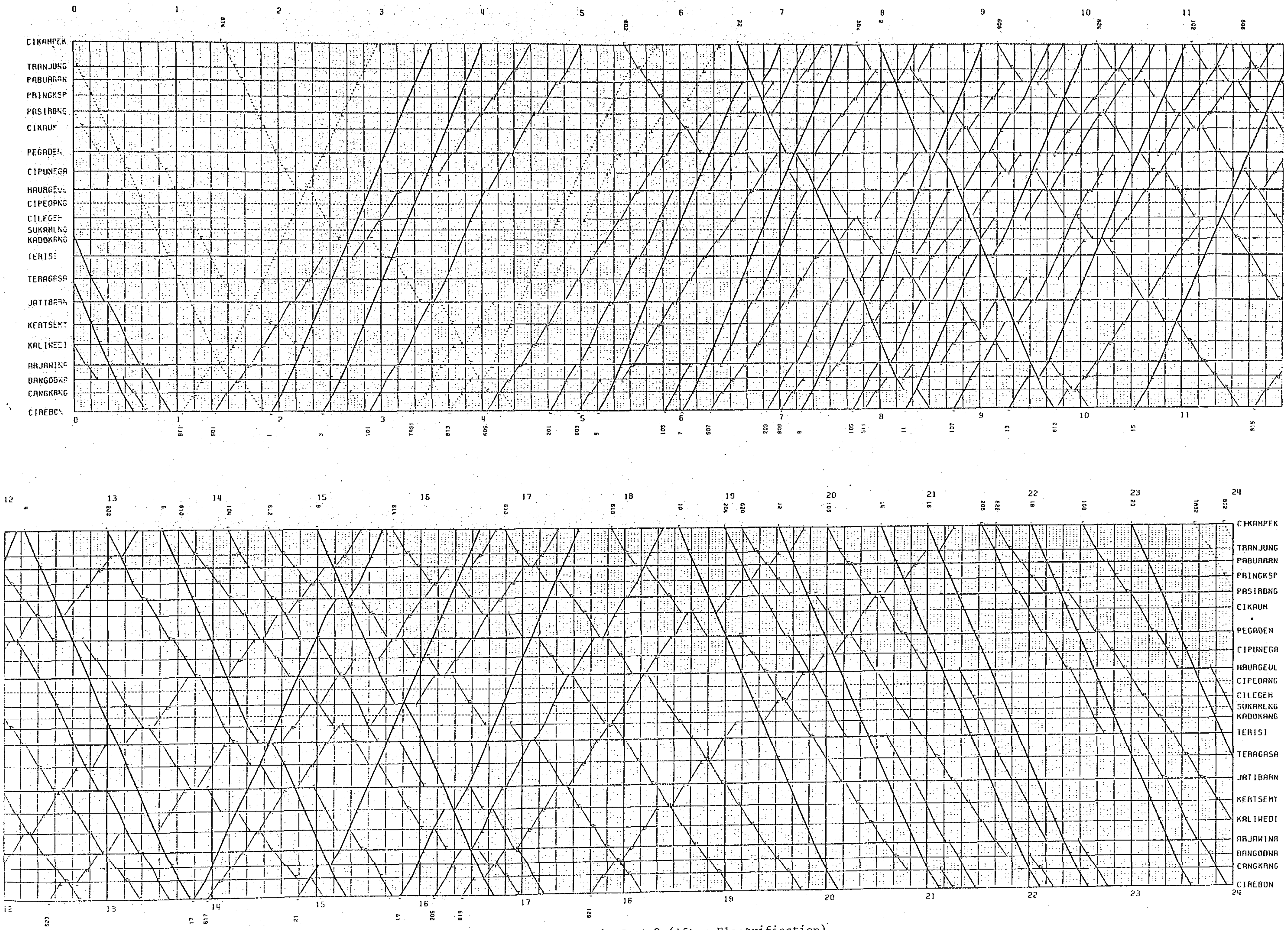


Fig. 6.7.1.3 Train Diagram in Case 2 (After Electrification)

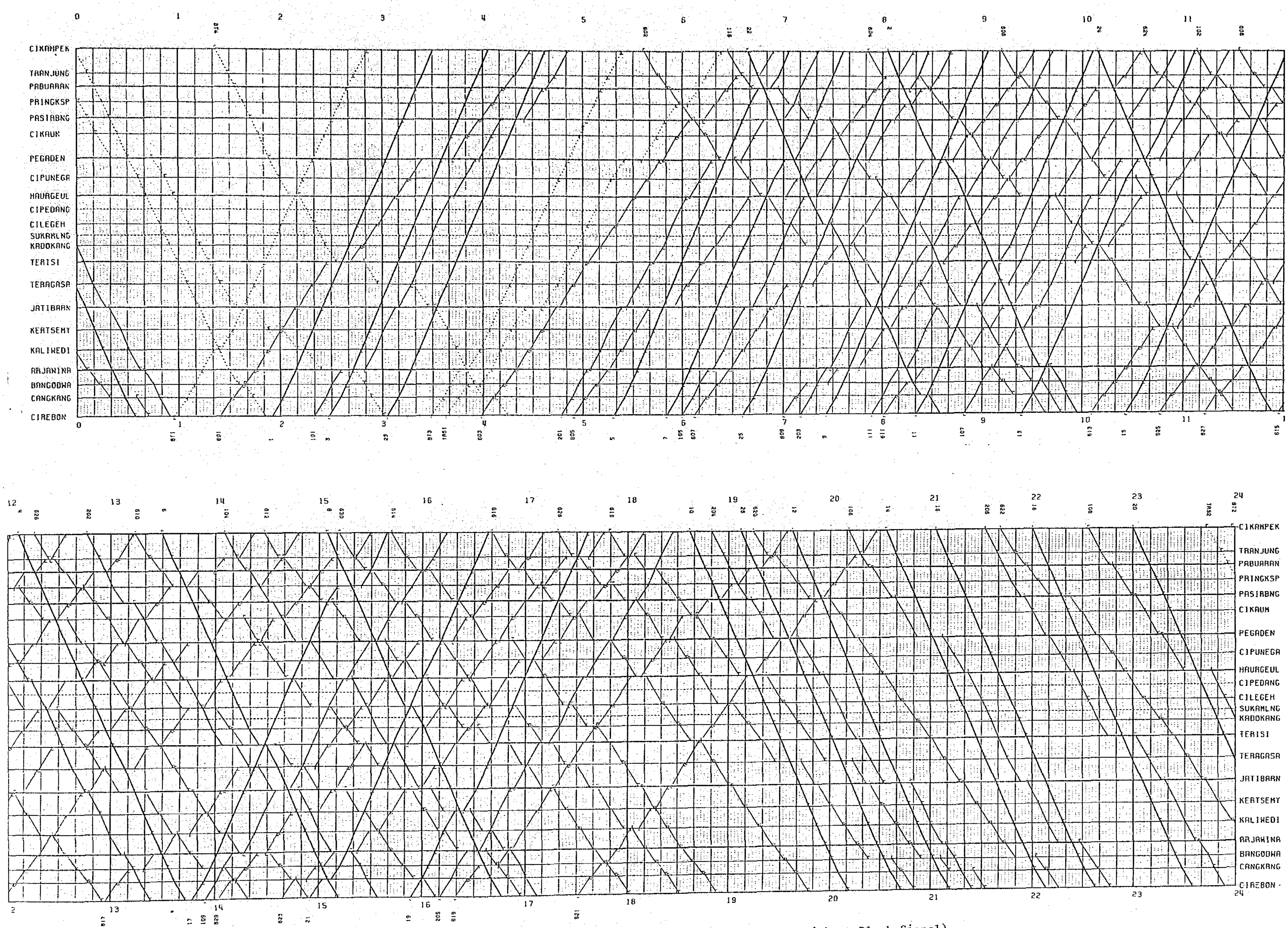
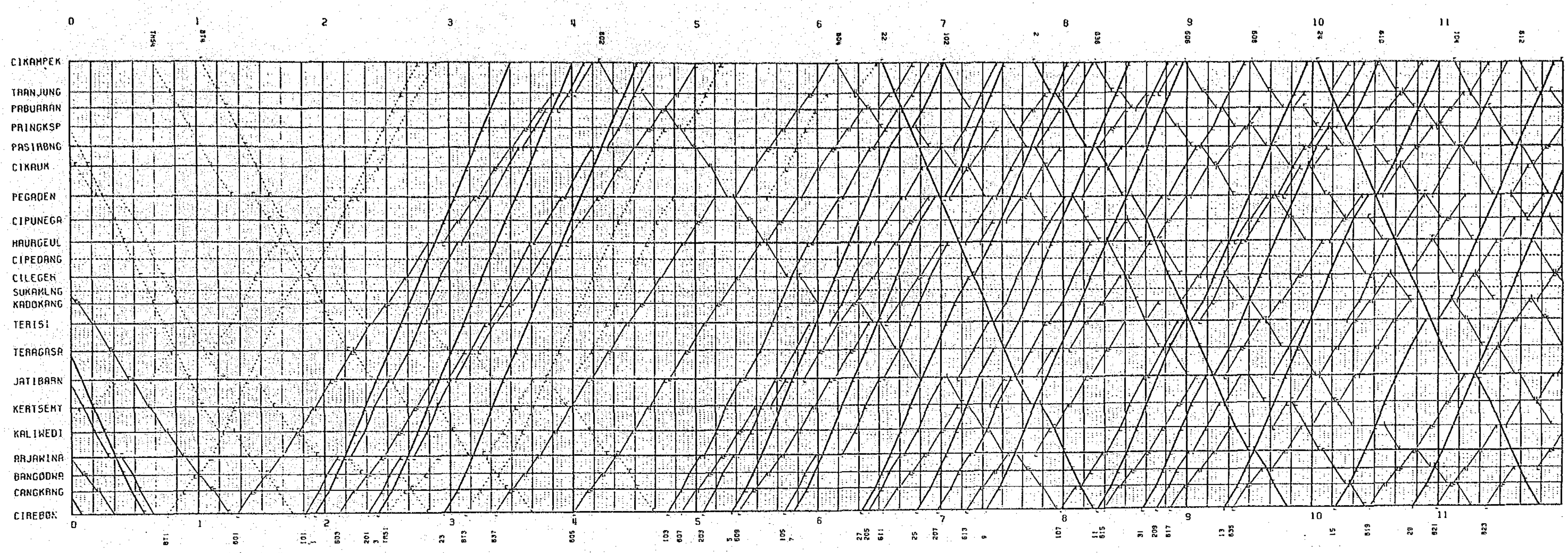


Fig. 6.7.1.4 Train Diagram in Case 3 (Electrification & Automatic Block without Block Signal)



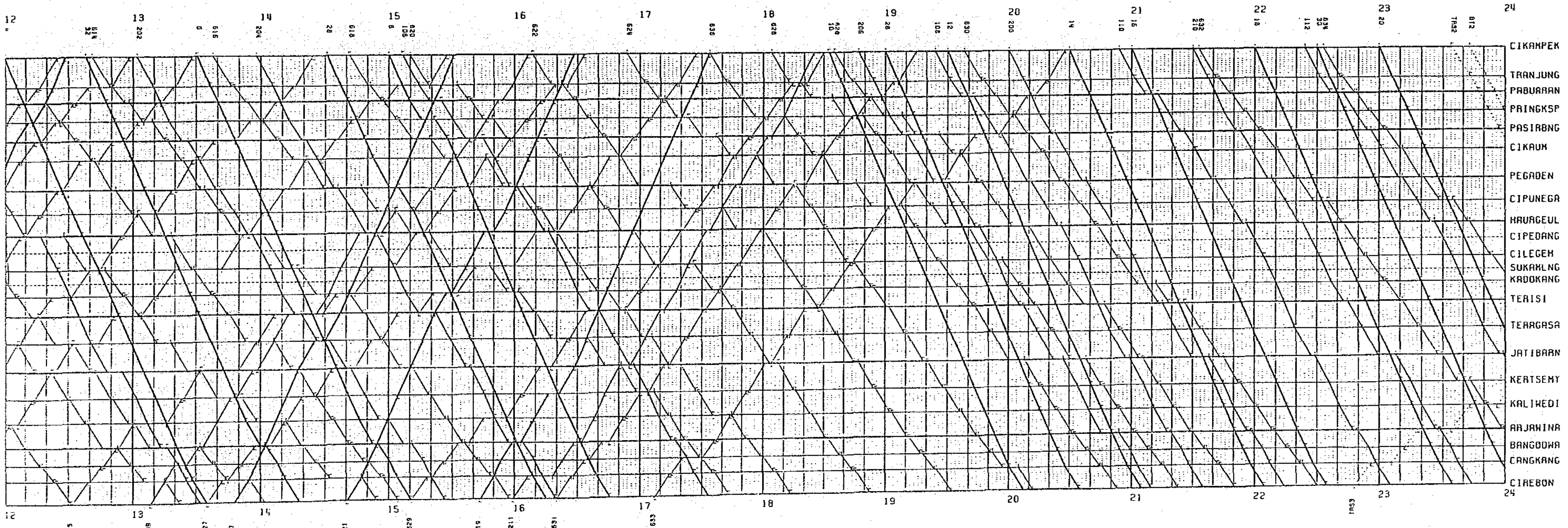


Fig. 6.7.1.5 Train Diagram in Case 4 (Electrification & Automatic Block)

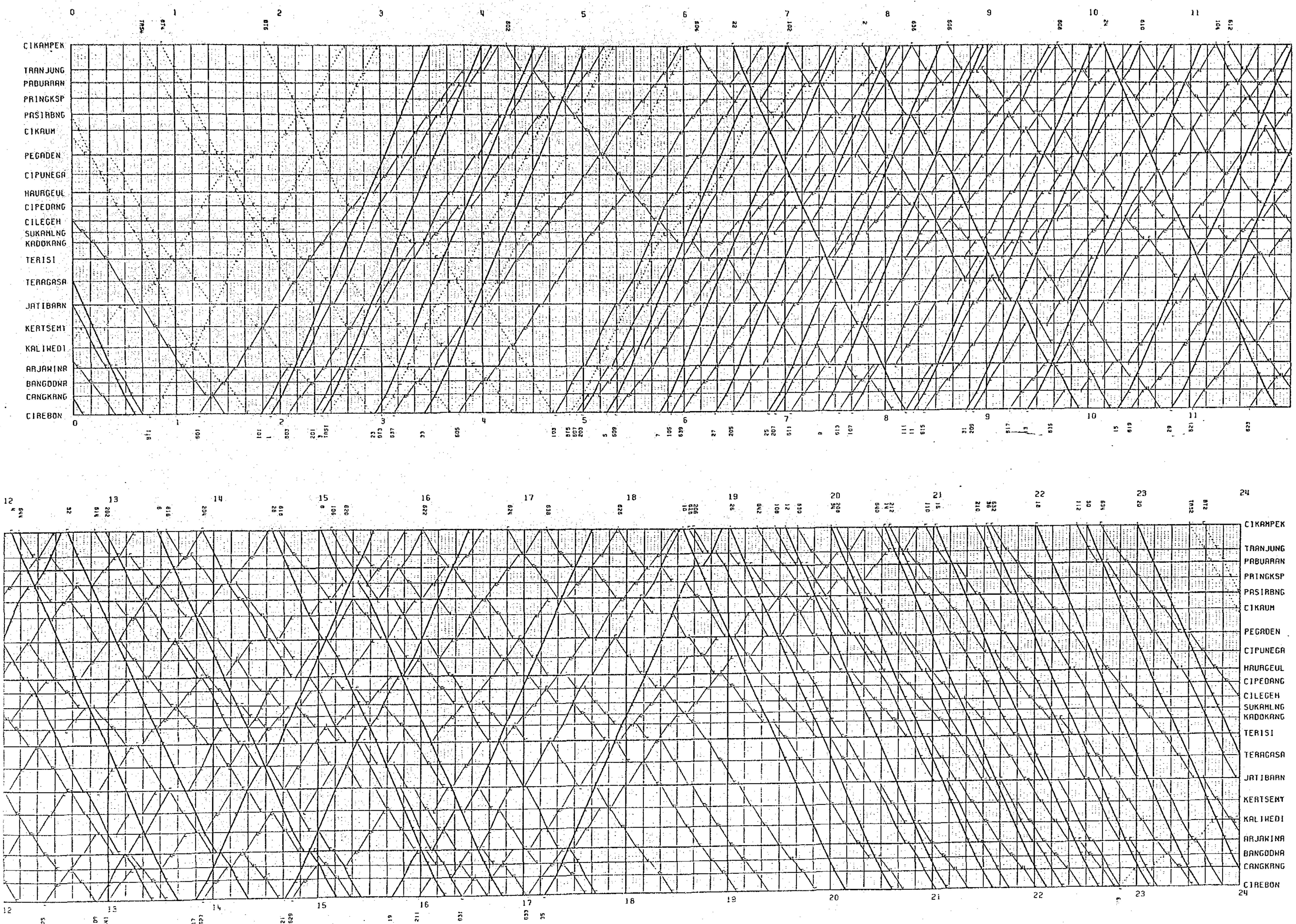


Fig. 6.7.1.6 Train Diagram in Case 5 (Electrification & Automatic Block & Additional Passing Stations)

7. The Outline of the Simulation

(1) Processing of the Simulation

a. A planner schedules a train in consideration of the tentative plan. He inputs the following processing conditions of a train, the train number, the origin station, the departure time at the origin, the destination station, the arrival time at the destination, taking into account station yards, rolling stock rostering and driving crew scheduling.

b. The computer calculates the arrival and departure time of the train at every way station with conditions given in the step a. and basic data of net operation time, stopping way station and the stopping time etc. which are input in advance.

c. When the processing of the step b. are completed, the computer displays the operation diagram of the train on the CRT graphic display device.

d. Then, the planner makes decision whether he is satisfied with the computer output or not. If satisfied, he returns to the step a. to set up the next train. If not satisfied, he will input the alternative condition and order the computer to start the calculation.

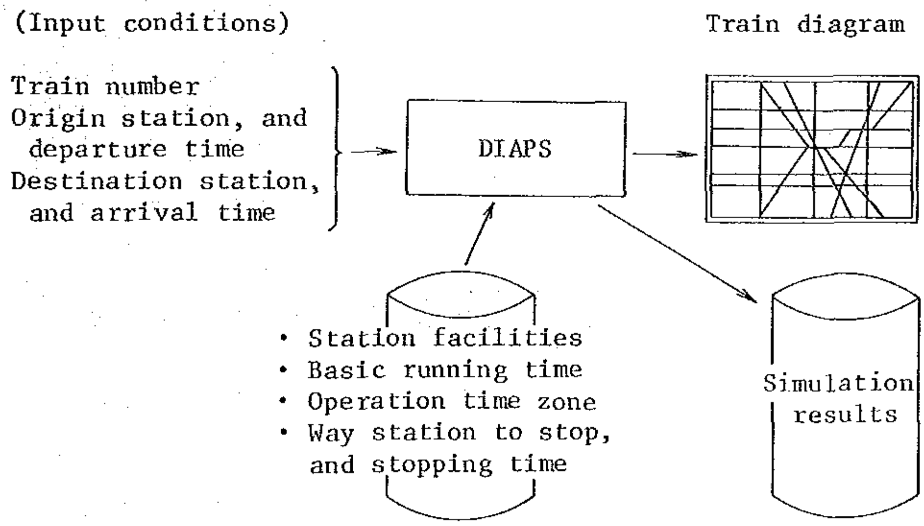


Fig. 6.7.1.7 Processing in DIAPS

(2) System configulation

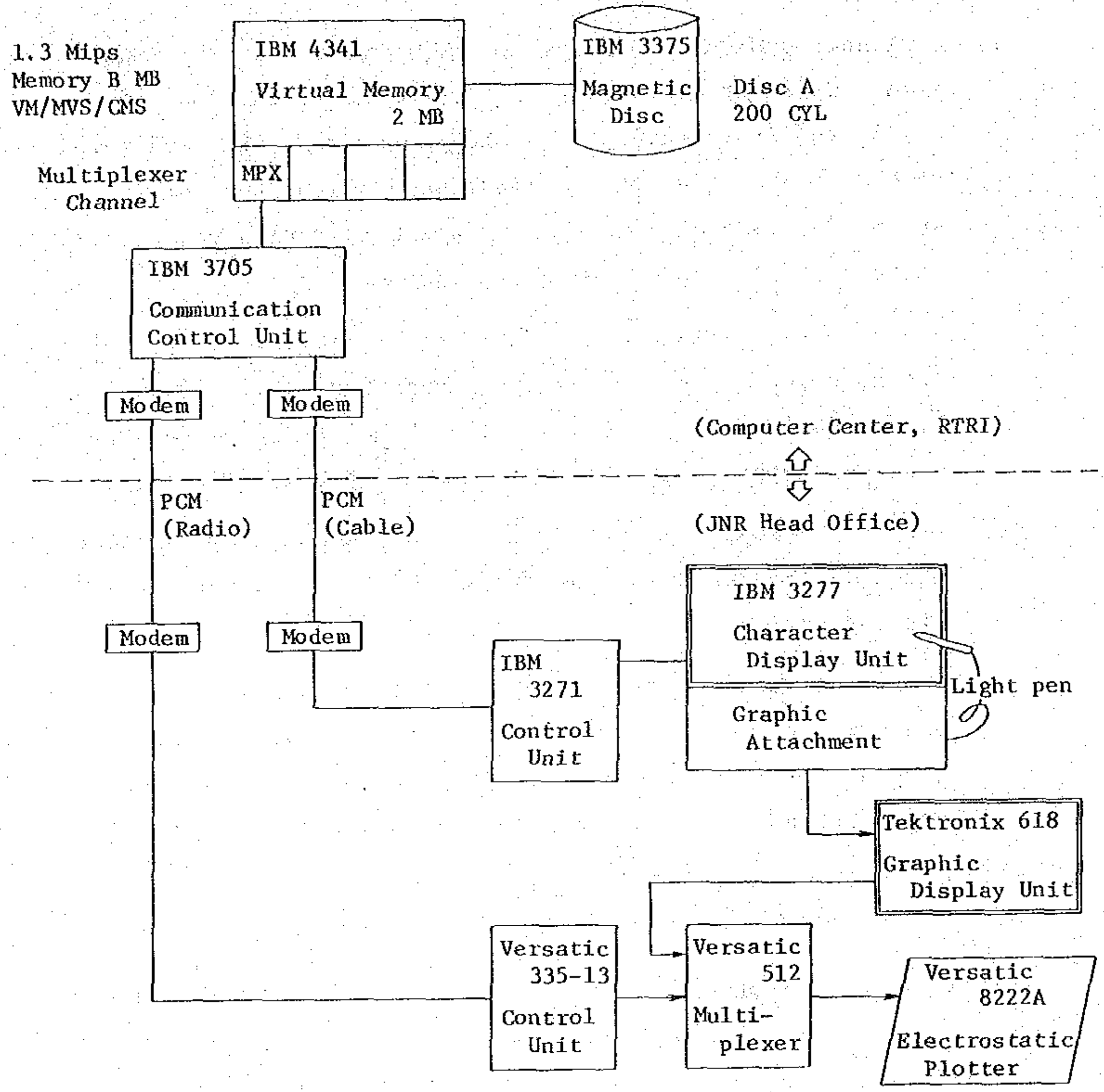


Fig. 6.7.1.8 Devices Configulation

Appendix 6-7-2 Transportation Plan Based on the Maximum Speed of 120 km/hr

1. Introduction

During discussions on the Interim Report, the Indonesian side requested to prepare a plan based on the maximum design speed of 120 km/h.

It is assumed that all technical problems are identified and solved. Specifically, wheel-rail dynamics need careful attention and may necessitate new light-weight car and truck design and more stringent maintenance standards, inspection and maintenance of rolling stock and tracks.

Electric locomotives and fixed installations in this report would meet the requirements of 120 km/h, but signaling, highway level crossing, and possibly turnouts in stations might need further investigation. In this context, the experience of the Japanese National Railways would be of value.

2. Operation Time

Operation time, including the operational margin but excluding the stopping time and the passing time, is calculated by assuming the following conditions:

(1) The grades and curves of the railway are unchanged.

(2) The train types are super-express and express.

(3) The speed when passing through stations will be limited to 70 km/h.

(4) In the Jakarta-Bekasi section, the trains will operate via the Eastern Line, and the operation time is unchanged.

The calculation results are shown in Tables 6.7.2.1 to 6.7.2.6.

Table 6.7.2.1 Operation Time of Super-express Trains in the Jakarta-Surabaya Section (Northern Line)

Station	Distance between stations (km)	Operation time (minutes) 120 km/h (A)	Operation time (minutes) 100 km/h (B)	Difference (B - A)
Jakarta				
	27.290 (Via Eastern Line)	39.5	39.5	0
(Bekasi)				
	192.616	124.0	134.0	10.0
Cirebon				
	75.863	48.5	53.5	5.0
Tegal				
	60.130	39.5	42.5	3.0
Pekalongan				
	87.980	65.5	67.0	1.5
Semarang				
	139.107	91.0	97.5	6.5
Cepu				
	36.058	25.0	26.0	1.0
Bojonegoro				
	104.802	70.0	74.0	4.0
Surabaya				
Total	723.846	503.0 (8h 23m)	534.0 (8h 54m)	31.0

Note: The train does not stop at stations enclosed in parenthesis.

Table 6.7.2.2 Operation Time of Super-express Trains in the Jakarta-Surabaya Section (Southern Line)

Station	Distance between stations (km)	Operation time (minutes)		Difference (B - A)
		120 km/h (A)	100 km/h (B)	
Jakarta				
	27.290	39.5	39.5	0
(Bekasi)				
	192.616	124.0	134.0	10.0
Cirebon				
	130.787	93.0	96.5	3.5
Purwokerto				
	166.885	115.5	120.5	5.0
Yogyakarta				
	59.238	43.5	46.5	3.0
Solo				
	96.937	60.5	66.0	5.5
Madiun				
	68.895	44.5	49.5	5.0
Kertosono				
	87.109	60.0	65.5	5.5
Surabaya				
Total	829.757	580.5 (9h 40m 30s)	618.0 (10h 18m)	37.5

Table 6.7.2.3 Operation Time of Express Trains in the Jakarta-Surabaya Section (Northern Line)

Station	Distance between stations (km)	Operation time (minutes)		Difference (B - A)
		120 km/h (A)	100 km/h (B)	
Jakarta				
	27.290	39.5	39.5	0
(Bekasi)				
	57.455	38.0	40.5	2.5
Cikampek				
	95.113	62.0	67.0	5.0
Jatibarang				
	40.048	27.5	29.5	2.0
Cirebon				
	75.863	48.5	53.5	5.0
Tegal				
	60.130	39.5	42.5	3.0
Pekalongan				
	69.791	53.0	54.5	1.5
Kaliwungu				
	18.189	14.0	14.0	0
Semarang				
	60.309	39.5	43.0	3.5
Ganbringan				
	78.798	53.5	56.0	2.5
Cepu				
	36.058	25.0	26.0	1.0
Bojonegoro				
	104.802	70.0	74.0	4.0
Surabaya				
Total	723.846	510.0 (8h 30m)	540.0 (9h 0m)	30.0

Table 6.7.2.4 Operation Time of Express Trains in the Jakarta-Surabaya Section (Southern Line)

Station	Distance between stations (km)	Operation time (minutes)		Difference (B - A)
		120 km/h (A)	100 km/h (B)	
Jakarta				
	27.290 (Via Eastern Line)	39.5	39.5	0
(Bekasi)				
	57.455	38.0	40.5	2.5
Cikampek				
	95.113	62.0	67.0	5.0
Jatibarang				
	40.048	27.5	29.5	2.0
Cirebon				
	130.787	93.0	96.5	3.5
Purwokerto				
	27.167	20.5	21.0	0.5
Kroya				
	47.956	34.0	36.5	2.5
Kebumen				
	28.113	20.5	21.5	1.0
Kutoarjo				
	63.649	46.0	47.0	1.0
Yogyakarta				
	28.570	21.0	22.5	1.5
Klaten				
	30.668	24.5	26.0	1.5
Solo				
	28.959	19.5	20.0	0.5
Sragen				
	67.978	43.0	48.0	5.0
Madiun				
	68.895	44.5	49.5	5.0
Kertosono				
	39.530	27.5	30.0	2.5
Mojokerto				
	47.579	34.5	37.5	3.0
Surabaya				
Total	829.757	595.5 (9h 55m 30s)	632.5 (10h 32m 30s)	37.0

Table 6.7.2.5 Operation Time of Super-express Trains in the Jakarta-Bandung Section

Station	Distance between stations (km)	Operation time (minutes)		Difference (B - A)
		120 km/h (A)	100 km/h (B)	
Jakarta				
	27.290	39.5	39.5	0
(Bekasi)				
	57.455	36.0	41.0	5.0
(Cikampek)				
	89.727	89.5	91.0	1.5
Bandung				
Total	174.472	165.0 (2h 45m)	171.5 (2h 51m 30s)	6.5

Note: The train does not stop at the stations enclosed in parenthesis.

Table 6.7.2.6 Operation Time of Express Trains in the Jakarta-Bandung Section

Station	Distance between stations (km)	Operation time (minutes)		Difference (B - A)
		120 km/h (A)	100 km/h (B)	
Jakarta				
	27.290	39.5	39.5	0
(Bekasi)				
	57.455	38.0	43.0	5.0
(Cikampek)				
	75.065	80.0	81.0	1.0
Padalarang				
	14.662	13.0	13.5	0.5
Bandung				
Total	174.472	170.5 (2h 55m 30s)	177.0 (2h 57m)	6.5

3. Travelling Time

The travelling time is calculated by adding the stopping time and the passing time to operation time with the following conditions:

(1) The super-express trains and the express trains stop at the stations shown in Tables 6.7.2.1 to 6.7.2.6.

(2) The stopping time is 2 minutes for super-express trains at all stations, and 3 minutes at major stations and 2 minutes at other stations for express trains.

(3) The time loss for crossing at each major section is calculated by assuming the number of trains as of 1992.
(Figs. 6.3.1 to 6.3.3 of this Report).

(4) Super-express trains stop only for crossing another super-express.

The results of the calculations are shown in Tables 6.7.2.7 to 6.7.2.12.

The results are discussed in the following.

(1) The difference between the operation time and the travelling time is approximately 60 minutes for super-express trains and more than 100 minutes for express trains in the Jakarta-Surabaya section. The difference is attributable to the more frequent stops for passing and regular stopping. In the Jakarta-Bandung section the difference is of the order of 5 minutes because there are less trains and less stations to stop at.

Table 6.7.2.7 Travelling Time from Jakarta
(Northern Line, super-express)

Destination	Travelling time (hr: min. sec.)		Difference
	120 km/h (A)	100 km/h (B)	(B - A) min.
Cirebon	3:06.00 (186.0 min.)	3:17.30 (197.5 min.)	11.5
Semarang	5:53.30 (353.5)	6:14.00 (374.0)	20.5
Surabaya	9:14.30 (554.5)	9:47.30 (587.5)	33.0

Table 6.7.2.8 Travelling Time from Jakarta
(Southern Line, super-express)

Destination	Travelling time (hr: min. sec.)		Difference
	120 km/h (A)	100 km/h (B)	(B - A) min.
Cirebon	3:06.00 (186.0 min.)	3:17.30 (197.5 min.)	11.5
Yogyakarta	6:59.30 (419.5)	7:20.00 (440.0)	21.0
Madiun	8:52.30 (532.5)	9:22.30 (562.5)	30.0
Surabaya	10:46.00 (646.0)	11:27.00 (687.0)	41.0

Table 6.7.2.9 Travelling Time from Jakarta
(Northern Line, express)

Destination	Travelling time (hr: min. sec.)		Difference
	120 km/h (A)	100 km/h (B)	(B - A) min.
Cirebon	3:14.00 (194.0 min.)	3:25.00 (205.0 min.)	11.0
Semarang	6:29.30 (389.5)	6:51.00 (411.0)	21.5
Surabaya	10:16.00 (616.0)	10:50.00 (650.0)	34.0

Table 6.7.2.10 Travelling Time from Jakarta
(Southern Line, express)

Destination	Travelling time (hr: min. sec.)		Difference
	120 km/h (A)	100 km/h (B)	(B - A) min.
Cirebon	3:14.00 (194.0 min.)	3:25.00 (205.0 min.)	11.0
Yogyakarta	7:41.30 (461.5)	8:02.30 (482.5)	21.0
Madiun	9:50.30 (590.5)	10:20.30 (620.5)	30.0
Surabaya	11:54.30 (714.5)	12:36.30 (756.5)	42.0

Table 6.7.2.11 Travelling Time of Super-express in the Jakarta-Bandung Section

Section	Travelling time (hr: min. sec.)		Difference (B - A) min.
	120 km/h (A)	100 km/h (B)	
Jakarta - Bandung	2:50.00 (170.0 min.)	2:56.30 (176.5)	6.5

Table 6.7.2.12 Travelling Time of Express in the Jakarta-Bandung Section

Section	Travelling time (hr: min. sec.)		Difference (B - A) min.
	120 km/h (A)	100 km/h (B)	
Jakarta - Bandung	3:03.00 (183.0 min.)	3:09.30 (189.5)	6.5

(2) The travelling time of the 120 km/h trains is compared with that of current trains in the next table.

Table 6.7.2.13 Travelling Time Differences

(hr: min. sec.)

Section	Current train (1985)		Maximum speed (km/h)		Time reduced		
	Train name	Travelling time (A)	120 (B)	100 (C)	A - B	A - C	C - B
Jakarta-Surabaya (Northern Line)	Mutiara Utara	14:05.00	9:14.30	9:47.30	4:50.30	4:17.30	33.00
Jakarta-Surabaya (Southern Line)	Bima	15:05.00	10:46.00	11:27.00	4:19.00	3:38.00	41.00
Jakarta-Bandung	Parahiyangan	3:15.00	2:50.00	2:56.30	25.00	19.00	6.30

4. Train Speed and Operation Pattern

Figs. 6.7.2.1 - 6.7.2.5 show the operation pattern of passenger trains using travelling times prepared above.

The figure shows the relation between travelling time and round-trip frequency assuming the effective time zones of 5 a.m. to 10 p.m. Time required at terminal station is assumed to be approximately 3 hours, consisting of deadheading time to the depot, cleaning time, water supply time, inspection time, etc.

The relation between travelling time and operation pattern is shown in Table 6.7.2.14. From the table, 14 trains (marked with "o") can make round-trip within the effective time zone at a maximum speed of 120 km/h, compared with current 9 trains, enabling round-trip for 5 trains, i.e., 3 Jakarta - Surabaya trains, 1 Jakarta - Yogyakarta train and 1 Jakarta - Semarang train.

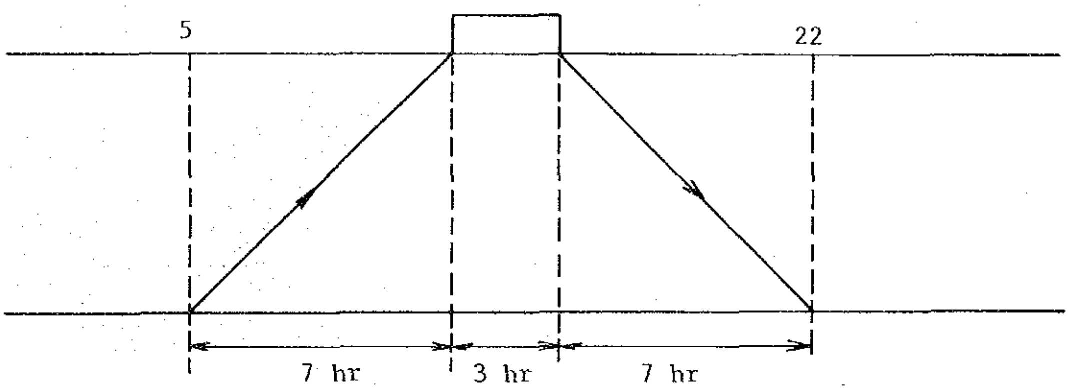


Fig. 6.7.2.1 Operation Pattern (1) (Daytime trains, 1 round-trip)

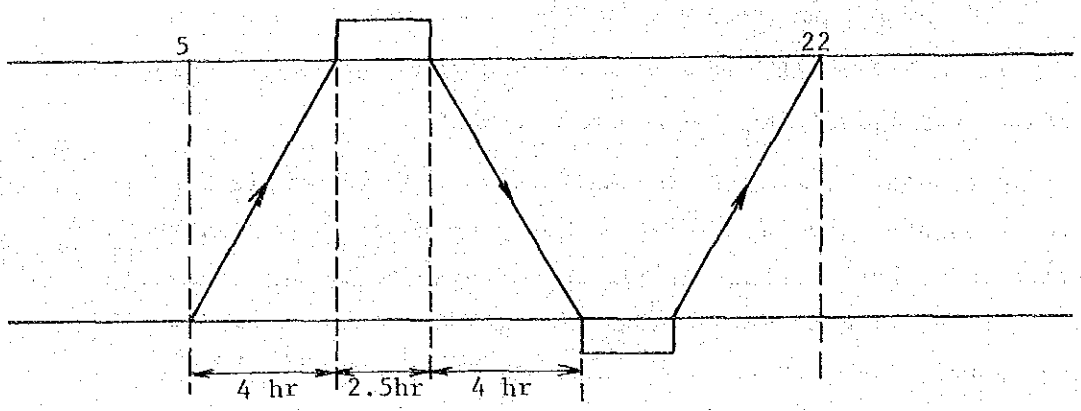


Fig. 6.7.2.2 Operation Pattern (2) (Daytime trains, 1.5 round-trips)

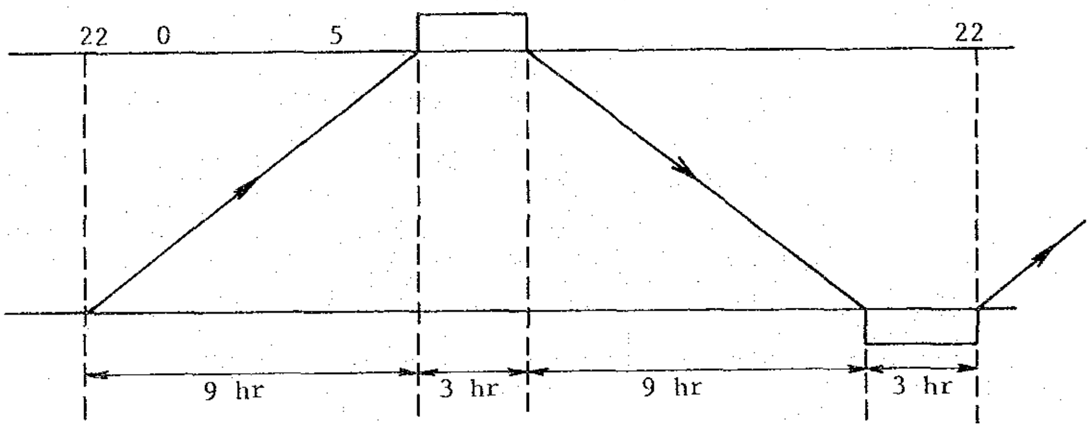
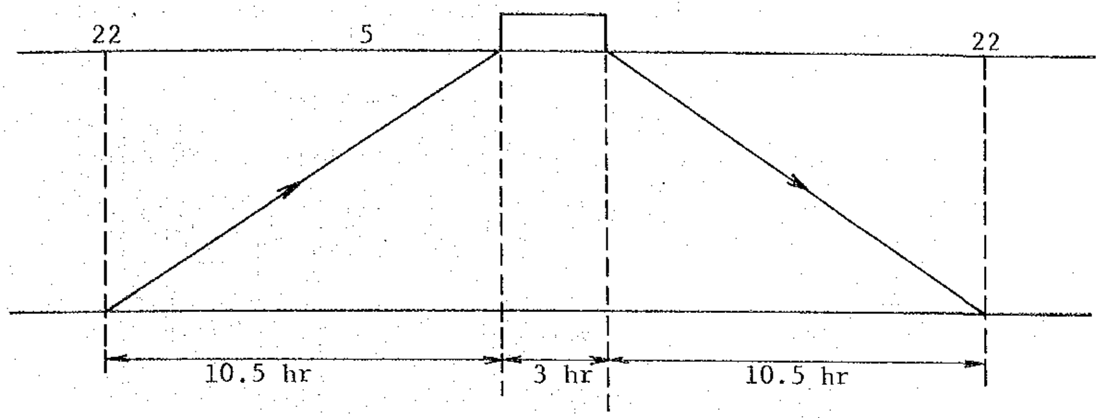
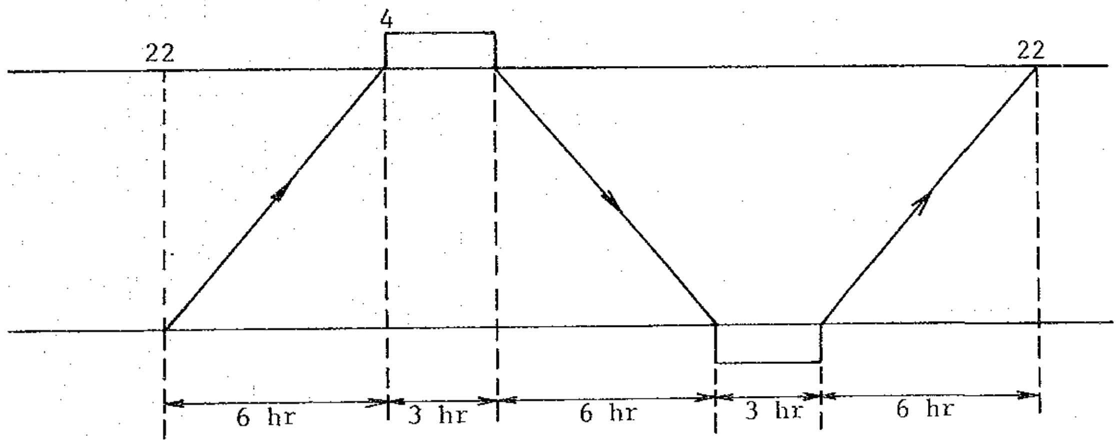


Fig. 6.7.2.3 Operation Pattern (3) (Combination of night and daytime trains (A), 1 round-trip)



Note: This pattern cannot be used repeatedly because it does not afford time for cleaning and the like. It can be used, however, for other trains after 5 o'clock of the next day.

Fig. 6.7.2.4 Operation Pattern (4) (Combination of night and daytime trains (B), 1 round-trip)



Note: The arriving time of the night train is not within the effective time zone.

Fig. 6.7.2.5 Operation Pattern (5) (Combination of night and daytime trains, 1.5 round-trips)

Table 6.7.2.14 Train Operation Section and Passenger Train Operation Pattern

Max. train speed	Train operation section	Super-express train travelling time (hr:min. (sec)	Operation pattern				
			(1)	(2)	(3)	(4)	(5)
120 km/h operation	Jak - Cn	3:06	o	o	×	×	×
	Jak - Sm	5:53.30	o	×	o	o	o
	Jak-Sb (Northern Line)	9:14.30	×	×	* o	o	×
	Jak - Yk	6:59.30	o	×	o	o	×
	Jak - Sb (Southern Line)	10:46	×	×	×	o	×
	Jak - Bd	2:50	o	o	×	×	×
Current trains	Jak - Cn	4:00	o	o	×	×	×
	Jak - Sm	7:15	o	×	o	o	×
	Jak - Sb (Northern Line)	14:05	×	×	×	×	×
	Jak - Yk	10:00	×	×	o	o	×
	Jak - Sb (Southern Line)	15:05	×	×	×	×	×
	Jak - Bd	3:15	o	o	×	×	×

Note: * The required time at the terminal station becomes a little shorter than 3 hours.

5. Effect of 120 km/h Operation

(1) Increase in traffic demand

As mentioned before, travelling time, substantially reduced compared with the current trains as a result of the 120 km/h operation, will increase railway traffic demand.

(2) Improvement in rolling stock utilization

When the travelling time is shortened, the running distance per day increases. Since the locomotives can be commonly used, the reduction in travelling time directly improves the utilization efficiency.

It must be remembered, however, that passenger cars are normally used in a fixed composition, so the utilization efficiency varies with the possible number of round trips in an effective time zone.

(3) Number of passenger train set-ups and cars

The number of passenger cars required in 1992, excluding those for local trains, is shown in Table 6.7.2.15 for each maximum speed cases.

Their total numbers are 634, 654 and 884 for 120 km/h, 100 km/h and current speed, respectively. Upgrading from the current speed to 120 km/h yields a savings of 250 cars or 28.3%.

Table 6.7.2.15 Passenger Cars Required for Each Maximum Speed in 1992

Train type	Section		Number of trains	Number of train set-ups (including stand-by)		
				120 km/h	100 km/h	Current speed
Super-express train	Jakarta - Surabaya (Northern Line)		2	2	2	3
	Jakarta - Samarang		4	2	2	3
	Jakarta - Cirebon		6	2	2	3
	Jakarta - Surabaya (Southern Line)		2	2	3	3
	Jakarta - Madiun		2	2	2	3
	Jakarta - Yogyakarta		8	5	5	5
	Jakarta-Bandung		10	4	4	4
	Sub-total	Number of set-ups	-	19	20	24
		Number of passenger cars	-	174	184	224
Express & Fast trains	Jakarta - Surabaya (Northern Line)		2	2	2	3
	Jakarta - Semarang		12	8	8	8
	Jakarta - Cirebon		18	6	6	8
	Jakarta - Surabaya (Southern) Line)		4	5	5	6
	Jakarta - Madiun		4	3	3	5
	Jakarta - Yogyakarta		18	11	11	22
	Semarang - Surabaya		2	2	2	2
	Yogyakarta - Surabaya		4	2	2	3
	Mediun - Surabaya		14	3	4	4
	Jakarta - Bandung		12	4	4	5
	Sub-total	Number of set-ups	-	46	47	66
		Number of passenger cars	-	460	470	660
Total number of passenger cars			-	634	654	884

Notes: 1. The number of passenger train set-ups is obtained from the passenger train operation pattern in Figs. 6.7.2.1 — 6.7.2.5.

2. The train make-up will be 6 cars for super-express in Jakarta - Bandung section and 10 cars for others.

Appendix 7-1-1 Protection System of T-branch Transmission Line

In general, π-branch system is used for transmission lines. However, T-branch system is becoming popular even in 275 kV systems in Japan in view of construction cost saving with the same protection level.

Table 7.1.1.1 shows main and back-up protection systems for multi-terminal transmission lines in Japan.

Some typical protection systems are outlined in the following.

(1) Current differential carrier relaying system

This is a new reliable system using a microwave system. This system detects fault in the transmission line by comparing momentary value of influent and effluent currents at each terminal of the system. As the system requires costly information system, it is applied mostly for arterial transmission lines.

(2) Pilot wire relaying system

This system uses exclusive communication line called pilot wire between each terminal, and detects fault comparing the current condition at each terminal.

This system is mostly used in short-distance transmission line up to approximately 20 km.

(3) Distance-direction comparison relaying system

This system detects fault by means of directional distance relays that monitor both directions of the transmission line at each terminal, and by comparing the results of the relays via transmission lines.

This system is relatively economical because it uses power line carrier system to transmit information between the terminals. It must be remembered however, that, depending on the system configuration, it may be unable to provide sufficient protection.

Table 7.1.1.1 Main and Back-up Protection Systems of Transmission Lines

Application		Fault / Number of terminals	2: Short-circuit	2: Ground fault	3 or more: Short-circuit	3 or more: Ground fault	Remarks
275 kV - 187 kV		Main protection	Pure phase comparison relaying system, directional control phase comparison relaying system, distance directional comparison relaying system, pilot wire relaying system.		Current differential (FM, PCM) relaying system, pure phase comparison relay system, distance directional comparison relay system, pilot wire relay system.		(1) In general, there is a maximum of three terminals. (2) When there are three terminals, the application of the phase comparison relaying system and distance directional comparison relaying system should be examined with care. (3) The pilot wire relaying system is advantageous for short-distance transmission lines (Approximately 20 km). (4) In general, the main protection is duplicated.
		Back-up protection	Distance directional relaying system		Same as left		
High-resistance grounding system under 154 kV	Ordinary transmission line	Main protection	Distance directional comparison relaying system Pilot wire relaying system	Power directional comparison relaying system Pilot wire relaying system	Current differential (FM, PCM) relaying system Distance directional comparison relaying system Pilot wire relaying system	Current differential (FM, PCM) relaying system Power directional comparison relaying system Pilot wire relaying system	(1) When there are three terminals, the application of the distance directional comparison relaying system and power directional comparison relaying system should be examined with care. (2) The zero-phase-sequence circulating current shall be examined in connection with the ground fault main protection of transmission lines with multiple circuits laid in parallel. (3) The pilot wire relaying system is applicable to short-distance transmission lines.
		Back-up protection	Directional distance relaying system	Ground fault directional relaying system or overvoltage relaying system	Same as left		
	Other transmission lines	Main protection	Balance relaying system (SSR)	Balance relaying system (SGR)	Same as left		(1) The balance relaying system should not be provided for a single circuit. (2) The overcurrent system for back-up protection is applicable mainly to the 22 kV system. (3) When the transmission line distance is short, the balance relaying system should be examined with care.
		Back-up protection system	Directional distance relaying system or overvoltage relaying system	Ground fault relaying system or overvoltage relaying system	Same as left		

Appendix 7-1-2 Selection of the Power-Receiving System at Substations

In general, the conditions below must be fulfilled in the selection of a substation power-receiving system for an electric railway.

a. The power supply system must have a sufficient short-circuit capacity so that influences to the system caused by the electric railway load are within the permissible level required by the electric power company.

b. The power supply system should be highly reliable with little outage and voltage fluctuation.

c. The power-receiving system should be economical.

d. The power-receiving system should have good maintainability.

The above requirements for each substation are examined in the following.

(1) Kosambi substation

As for the influence on the power source mentioned in a, the maximum instantaneous value of the voltage unbalance rate surpasses the limit of PLN (2%) when a single-phase transformer with 70 kV power reception is used. (Refer to Table 7.1.6.1). Therefore, a 150 kV power-receiving system should be adopted when single-phase transformer is used.

The voltage unbalance rate limit of PLN is not surpassed when a V- or Scott-connection transformer is adopted with 70 kV power reception, so 70 kV power reception becomes possible.

As for the reliability mentioned in b, the 150 kV alternative is more advantageous, as shown in Table 7.1.3.

As for the economy mentioned in c, there is practically no difference between 150 kV single-phase power reception with a single-phase transformer facility and the 70 kV 3-phase power reception with a V-connection transformer facility, but the 70 kV power reception with a Scott-connection transformer facility alternative is rather expensive.

As for the ease of maintenance mentioned in d, there is practically no difference between the various alternatives.

Therefore, the 150 kV single-phase power reception, which is the alternative with the highest reliability, will be adopted because it satisfies the limit mentioned in a and there is practically no difference in maintenance or economy among the alternatives.

(2) Arjawinangun substation

As for the influence on the power source, the calculated value as of 1992 (Table 7.1.6.1) for both 70 kV and 150 kV are within the limit even when a single-phase transformer is used. When a single-phase transformer is used with 70 kV power reception, however, the instantaneous value of the voltage unbalance rate approaches the limit of 2% (1.68%); furthermore, when the Northern Line is double-tracked or when the section beyond Cirebon is electrified, it has the risk of surpassing 2%. Therefore, 70 kV cannot be regarded as sufficient when a single-phase transformer is used.

When a V- or Scott-connection transformer with 70 kV is used, the risk of surpassing the limit is negligible, so the 70 kV power reception scheme becomes possible.

As for the reliability, the 150 kV alternative is more advantageous, as shown in Table 7.1.3 of the Report.

As for the economy, there is practically no difference between 150 kV single-phase power reception with a single-phase transformer facility and 70 kV 3-phase power reception with a V-connection transformer facility, and the 70 kV power reception with a Scott-connection transformer facility is rather expensive.

As for maintenance, there is practically no difference between each alternative.

Therefore, the 150 kV single-phase power reception, which has the highest reliability, will be adopted because it satisfies the limit mentioned in 1) not only at the present time but also in the future, and there is practically no difference in economy and maintenance compared with other alternatives.

(3) Padalarang substation

There is no problem with requirement a, because the influences on PLN system is under the permissible value for both 70 kV and 150 kV systems, as shown in Table 7.1.6.1.

In connection with requirement b, the 150 kV system is more reliable than the 70 kV system, as shown in Table 5.1.3. In the Padalarang Substation of the PLN, both 150 kV and 70 kV bus bars in compound are interconnected by a 150/70 kV transformer. Furthermore, the 70 kV bus bars are interconnected with Puruwakarta and Cigareleng substations.

From above reasons, the 70 kV bus bars have high reliability with practically no difference from those of 150 kV.

As for requirement c, the construction cost of the 70 kV power receiving facilities is approximately 180 million RP. (13%) cheaper than those of 150 kV.

There is practically no difference for requirement d.

In view of the above consideration, the 70 kV power-receiving system will be adopted because it meets the PLN requirements, has practically no difference in maintainability and reliability, and is cheaper in construction cost.

Table 7.1.2.1 summarizes the above study results.

Table 7.1.2.1 Selection of Power Supply System

Substation	Voltage	Tr. type	Capacity	Economy	Reliability	Maintenance	Selection	Remarks
Kosambi Baru	70 kV	1P	×	–	Δ	o		Construction cost 70 kV(V) ≒ 150 kV(1p)
		V	o	o				
		T		Δ				
	150 kV	1P	o	o	o	o	o	
		V		Δ				
		T						
Arjawinan-gun	70 kV	1P	×	–	Δ	o		Construction cost 70 kV(V) ≒ 150 kV(1p)
		V	o	o				
		T		Δ				
	150 kV	1P	o	o	o	o	o	
		V		Δ				
		T						
Padalarang	70 kV	1P	o	o	o	o	o	Construction cost 70 kV(1p) <150 kV(1p) Cost difference about 180×10^6 Rp.
		V		Δ				
		T						
	150 kV	1P	o	Δ	o	o		
		V						
		T						

Legend: o Better Δ Good × Not good. Transformer type; 1P: Single-phase V:V-connected T: Scott-connecte

Note: Construction cost 1p < V <T

Appendix 7-1-3 Calculation of Voltage Drop

1. Calculating line impedance

The line impedance is calculated for simple catenary and direct suspension sections as follows.

(1) Self-impedance and mutual impedance

The self-impedance and the mutual impedance are calculated by computer for the conditions below by using the Carson-Polazek equation.

a. Conditions

(a) Ground conductivity	0.01 s/m (Value given by the Master Plan)
(b) Frequency	50 Hz
(c) Rail	R14 (The most popular rail used in PJKA)
(d) Pole mounting	As shown in Figs. 9.2.7 and 9.2.8 of the Report.

b. Results

Calculation results of self-impedance and mutual impedance are shown in Table 7.1.3.1 and Table 7.1.3.2, respectively.

Table 7.1.3.1 Self-impedance

(Ohm/km)

Self-impedance	Direct suspension	Simple catenary
Overhead line (Z_T)	0.2084 + j0.7657	0.2027 + j0.7286
Feeder (Z_F)	0.3439 + j0.7644	0.3439 + j0.7644

Table 7.1.3.2 Mutual Impedance

(Ohm/km)

Mutual impedance	Direct suspension	Simple catenary
Between T-F(Z_{TF})	0.0486 + j0.3444	0.0486 + j0.3444

(2) Line impedance

The line impedance is calculated by the simplified equation below, and the results are shown in Table 7.1.3.3.

$$Z = 1/4\ (Z_T + Z_F - 2Z_{TF})$$

Table 7.1.3.3 Line Impedance

(Ohm/km)

Direct suspension	0.114 + j0.210
Simple catenary	0.112 + j0.201

2. Calculation of power source and transformer impedances

The power source and transformer impedances of each substation are calculated using the equations below.

(1) Equations

a. Power supply impedance

$$Z_0 = \frac{E^2 \times 2}{P_S}$$

where:

Z_0: Power supply impedance (Ohm)

E : Feeding voltage (V)

P_S: Power source short-circuit capacity (VA)

b. Transformer impedance

$$Z_T = \frac{10E^2 \times (\%Z)}{P_T}$$

where:

Z_T: Transformer impedance (Ohm)

%Z: Transformer percent impedance (%)

P_T: Transformer capacity (kVA)

E : Feeding voltage (kV)

(2) Results

The calculation conditions and the results are shown in Table 7.1.3.4.

Table 7.1.3.4 Power Source and Transformer Impedances

Substation	Feeding voltage (kV)	Short-circuit capacity of power source (MVA)	Trans-former capacity (kVA)	Trans-former percent impedance (%)	Power source impedance (Ohm)	Trans-former impedance (Ohm)
Kosambi	25	2,798	20,000	15	j0.4470	j4.6875
Arja-winangun		1,000	15,000	10	j0.7500	j4.1670
Padalarang		1,315	5,000	10	j0.9506	j6.2500

3. Calculation of voltage drop

(1) Conditions

a. Line impedance

Shown in Table 7.1.3.3.

b. Power source and transformer impedances

Shown in Table 7.1.3.4.

c. Leakage impedance of the first autotransformer

j0.45 (Ohm)

d. Power factor

cos θ = 0.8

e. Traction current

Start	150(A)
Powering	100(A)
Coasting	0(A)

f. Train interval (normal conditions)

Cikampek - Cirebon	8 (km)
Cikampek - Bandung	20 (km)
Bekasi - Cikampek	12.5 (km) (for each single line)

g. Feeding voltage

maximum	27.5 (kV)
Minimum (Instantaneous)	17.5 (kV)

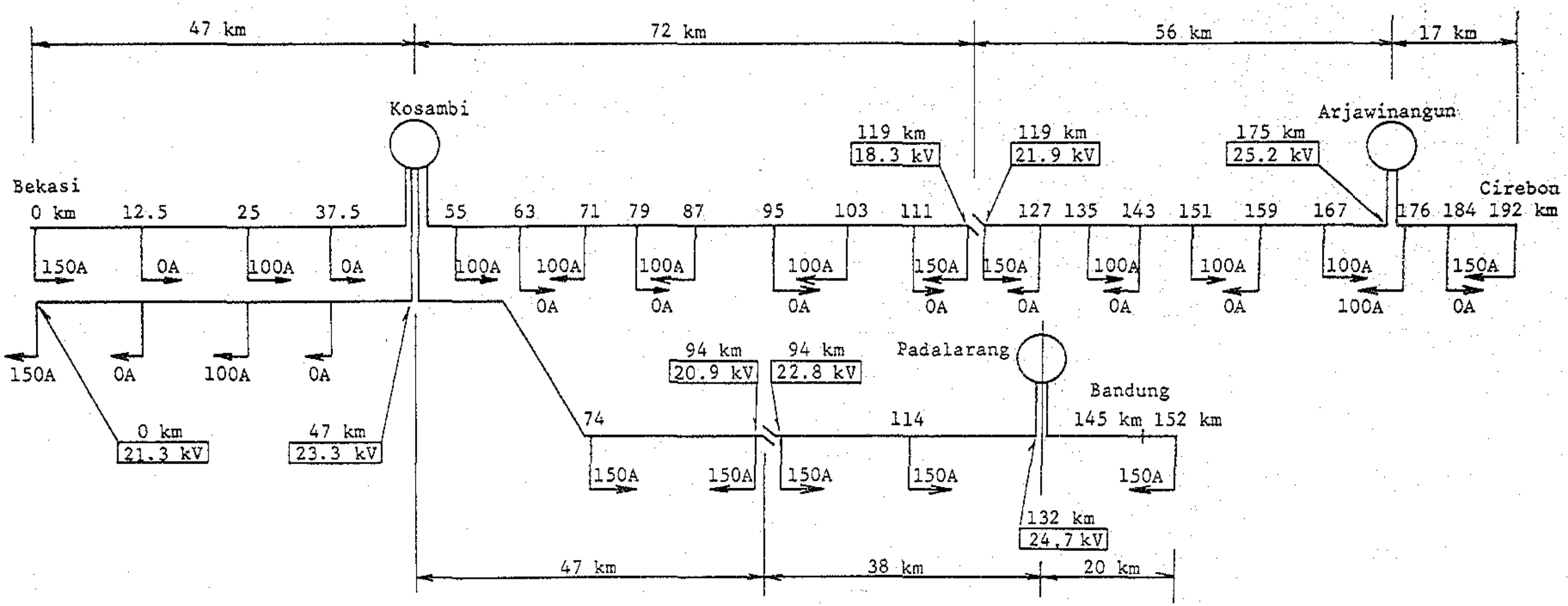
(2) Results

Each line is examined for the conditions which may cause the minimum voltage.
Figs. 7.1.3.1 to 7.1.3.3 show train positions, traction currents, and feeding line voltages.

a. Normal feeding
(See Fig. 7.1.3.1)

b. Kosambi substation outage
When the Kosambi substation is out, the Arjawinangun substation will feed up to Kosambi, and the Padalarang substation up to Bekasi.
(See Fig. 7.1.3.2)

c. Arjawinangun substation outage
When the Arjawinangun substation is out, the Kosambi substation will feed up to Cirebon.
(See Fig. 7.1.3.3)



0 km / 150A : Indicates train position and direction. The figure above the line indicates the kilometers with Bekasi as 0 km, and the figure with the arrow indicates the load current.

0 km / 20.7 kV : The figure in the rectangle indicates the feeding voltage. The figure above the rectangle indicates the kilometers with Bekasi as 0 km.

Fig. 7.1.3.1 Normal Condition

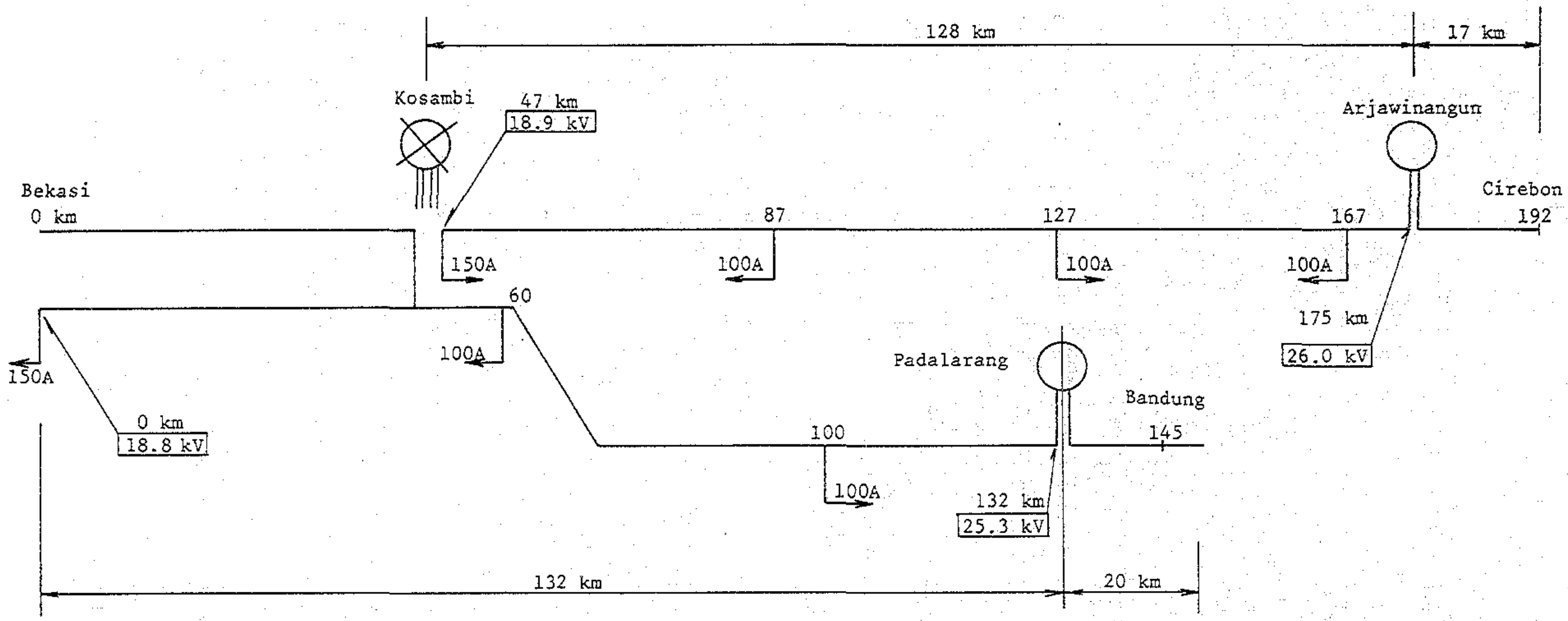


Fig. 7.1.3.2 Kosambi SS outage

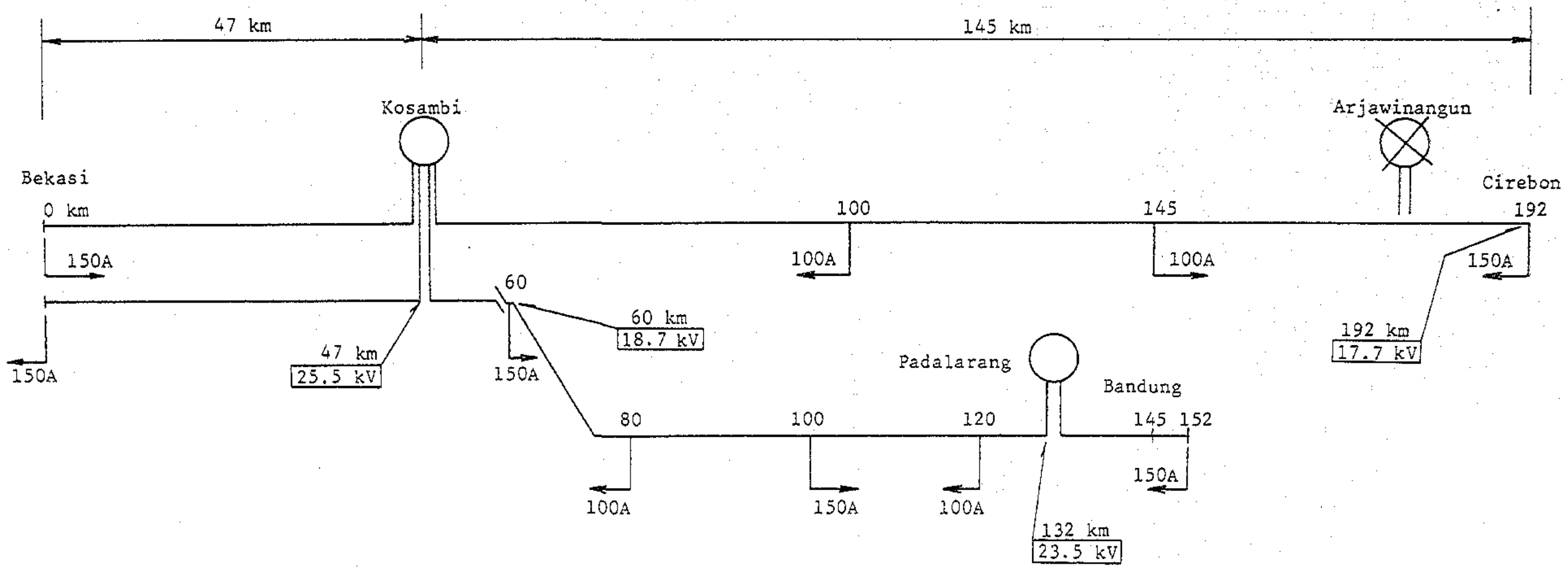


Fig. 7.1.3.3 Arjawinangun SS outage

Appendix 7-1-4 Calculation of Electric Power Consumption

Electric power consumption is the basic data for designing electric facilities, and is calculated from train operation, track conditions, etc. The electric power consumption determines the capacity of the facilities and provides data for calculating the influence on the PLN system.

The electric power consumption is calculated in the following.

(1) Calculation equations

The electric power consumption is calculated by the equations below, in terms of one hour average electric power and instantaneous maximum electric power.

a. One hour average electric power (P_a (kw))

P_a = (Number of trains (train/hour)) x (Train-kilometers (km)) x (Train weight (t)) x (Electric power consumption rate [kwh/t-km]) x (Gradient factor) x (Factor for auxiliary equipment) (1)

b. Instantaneous maximum electric power (P_p x (kw))

$$P_p = P_a + C\sqrt{P_a} \quad (2)$$

C is a constant, and the value below is used for 25 kV AC.

$$C = 6.94\sqrt{I_{tm}}$$

I_{tm}: Maximum traction current of a train (A)

(2) Electric power consumption rate

The electric power consumption rate varies according to train operation conditions such as train performance, maximum speed, schedule speed, as well as distance between stations, gradient.

The electric power consumption rate adopted in this calculation is the value used in the Japanese railway line similar to the section. (See Table 7.1.4.1)

Table 7.1.4.1 Electric Power Consumption Rate (kwh/1000t-km)

Train type / Gradient	Passenger train		Freight train	
	Express	Local	Express	Local
Level	19	31	11	16

(3) Gradient factor

The gradient factor used in this calculation is shown in Table 7.1.4.2.

Table 7.1.4.2 Gradient Factor of Electric Locomotive

Gradient (o/oo)	-10	-5	0	5	10	15	20
Gradient factor	0.4	0.6	1.0	1.5	2.0	2.5	3.5

(4) Calculation conditions

The conditions used in this calculation are shown in Table 7.1.4.3.

Table 7.1.4.3 Conditions for Calculating Electric Power Consumption

Section	Jakarta - Cirebon		Jakarta - Bandung			
Substation	Kosambi	Arjawinangun	Kosambi		Padalarang	
Gradient (‰)	0	0	0	15	0	15
Feeding distance (km)	119	73	83	11	19	38
Passenger train weight	470 t		Same as the left			
Freight train weight	100 t		670 t			
Number of trains (train/day)	Super express 24 Express 52 Fast 6 Local 6 Freight 12		Super express 10 Express 2 Fast 10 Local 10 Freight 8			
Power factor	COSΘ = 0.8					
Factor for auxiliary equipment	1.1					

(5) Calculation results

a. One hour average electric power

One hour average electric power calculated using equation (1) is shown in Table 7.1.4.4.

Table 7.1.4.4 One Hour Average Electric Power

Substation		Jakarta - Cirebon	Jakarta - Bandung	Total
Kosambi	(kW)	9,700	3,300	13,000
	(kVA)	12,200	4,100	16,300
Arjawinangun	(kW)	5,000	-	5,000
	(kVA)	6,300	-	6,300
Padalarang	(kW)	-	2,200	2,200
	(kVA)	-	2,800	2,800
Total	(kW)	-	-	20,200
	(kVA)	-	-	25,400

b. Instantaneous maximum electric power

Instantaneous maximum electric power calculated by equation (2) is shown in Table 7.1.4.5.

Table 7.1.4.5 Instantaneous Maximum Electric Power

Substation	Instantaneous maximum value (kVA)
Kosambi	27,100
Arjawinangun	13,700
Padalarang	7,800

Appendix 7-1-5 Determination of the Feeding Transformer Capacity

The feeding transformer capacity is determined according to the same standards as those of JNR. Its continuous rating should surpass the one hour average electric power. Furthermore 1/2.5 of the instantaneous maximum electric power should be under its continuous rating.

Electric power consumption at each substation calculated in Appendix 7-1-4 are shown in Table 7.1.5.1.

Table 7.1.5.1 Electric Power Consumption at Each Substation

Substation	One hour average electric power (kVA)	Instantaneous maximum electric power (kVA)	Instantaneous maximum electric power/2.5 (kVA)
Kosambi	16,300	27,100	10,840
Arjawinangun	6,300	13,700	5,480
Padalarang	2,800	7,800	3,120

The feeding transformer capacity (kVA) should be determined considering the future increase in railway traffic.

(1) Kosambi substation

From the above calculation, the feeding transformer capacity required at present is 17 MVA, and 20 MVA is adopted.

(2) Arjawinangun substation

The capacity is determined as follows by doubling the calculated value to cope with double tracking between Cikampek and Cirebon, and extension of electrification.

6,300 x 2 = 12,600 (kVA)   15 MVA

(3) Padalarang substation

The calculated value is 4 MVA, but the main transformer capacity of 5 MVA is adopted considering future load increases.

Appendix 7-1-6 Calculating Voltage Unbalance and Fluctuation

1. Equation for calculating unbalance rate

The equation for calculating the unbalance rate differs according to the transformer connection.

(1) Single-phase transformer

$$U = (P_L/P_S) \times 100$$

where:

U : Unbalance rate (%)

P_L: Load power (kVA)

P_S: Short-circuit capacity of the source (kVA)

(2) V-connection transformer

$$U = (\sqrt{P_A^2 + P_B^2 - P_A \cdot P_B} / P_S) \times 100$$

where:

P_A, P_B: Load of each phase (kVA)

(3) Scott-connection transformer

$$U = (|P_T - P_M| / P_S) \times 100$$

where:

P_T, P_M: Load of each phase (kVA)

2. Equation for calculating voltage fluctuation

The equation for calculating the voltage fluctuation rate differs according to the transformer connection.

(1) Single-phase transformer

$$V_F = 2P_D/P_S \times \sin\theta \times 100$$

where:

V_F: Voltage fluctuation rate (%)

P_D: Load power fluctuation (kVA)

θ : Power factor angle (rad)

(2) V-connection transformer

$$V_F = (2P_{AD}/PS \times \sin\theta + P_{BD}/PS \times \sin(\theta - \frac{\pi}{3})) \times 100$$

where:

P_{AD}, P_{BD}: Load fluctuation of each phase (kVA)

(3) Scott-connection transformer

$$V_F = (3\ P_{TD}/PS \times \sin(\theta + \frac{\pi}{6}) + P_{MD}/PS \times \sin(\theta - \frac{\pi}{3})) \times 100$$

where:

P_{TD}, P_{MD}: Load fluctuation of each phase (kVA)

3. Calculation conditions

(1) The worst unbalance condition, assuming maximum load for one phase and zero load for the other phases, is adopted for calculating the maximum unbalance of V-connection and Scott-connection transformers.

(2) In calculation of fluctuation rate, power factor $\cos\theta = 0.8$ is assumed.

(3) Voltage fluctuation at the substation is mainly caused by rapid changes in the current due to train starting and/or stopping. This calculation assumes that the maximum change of current of 150 A occurs when one train switches off from full notch.

(4) The load values are given by the calculation of electric power consumption (Tables 7.1.4.4 and 7.1.4.5).

(5) The short-circuit capacity of the systems is given by PLN (see Table 7.1.2).

(6) The permissible unbalance and voltage fluctuation rates are given by PLN (see Table 7.1.1).

(7) The PLN limitation value corresponding to "continuous" is applied to one hour average unbalance rate limit, and the value corresponding to "less than one hour" is applied to the instantaneous unbalance rate limit.

(8) According to the transportation plan, more than four trains per hour are assumed to start/stop in the service area of one substation. Therefore, the PLN voltage fluctuation rate limit of "more than four times in an hour" is applied.

4. Calculation results

The calculation results in 1992 are shown in Table 7.1.6.1.

Table 7.1.6.1 Estimation of Unbalance and Fluctuation Rates (1992)

Nama of substation	Voltage (kV)	Short-circuit capacity (MVA)	Maximum average value in an hour					Instantanious maximum value					Load difference (kVA)	Voltage fluctuation (%)
			Load (kVA)			Trans-former type	Voltage unbalance (%)	Load (kVA)			Trans-former type	Voltage unbalance (%)		
			Total	Up	Down			Total	Up	Down				
Kosambi baru	150	2,798	16,300	6,800	9,500	1ϕ	0.58	27,100	13,800	17,800	1ϕ	0.96	3,750	0.16
						V	0.49				V	0.64		0.16
						T	0.09				T	0.64		0.21
	70	1,148				1ϕ	1.41				1ϕ	2.34		0.39
						V	1.19				V	1.56		0.39
						T	0.22				T	1.56		0.51
Arja-winangun	150	1,000*	6,300	4,800	1,500	1ϕ	0.62	13,700	11,400	5,100	1ϕ	1.37		0.45
						V	0.56				V	1.13		0.45
						T	0.33				T	1.13		0.60
	70	814				1ϕ	0.76				1ϕ	1.68		0.55
						V	0.68				V	1.39		0.55
						T	0.41				T	1.39		0.74
Padalarang	150	3,561	2,800	2,000	800	1ϕ	0.07	7,800	6,300	3,300	1ϕ	0.21		0.13
						V	0.07				V	0.17		0.13
						T	0.03				T	0.17		0.17
	70	1,315				1ϕ	0.20				1ϕ	0.58		0.34
						V	0.18				V	0.47		0.34
						T	0.09				T	0.47		0.45

Notes: 1. Permissible characteristics of PLN applied to this plan.

Voltage unbalance rate 1.5% (continuous)
2.0% (less than an hour)
Voltage fluctuation rate 1.5% (more than four times in an hour)

2. The voltage fluctuation caused by train start and stop is supposed to occur more than four times in an hour.

3. About calculation method, see Appendix 7-1-4, 7-1-5, and 7-1-6.

Legend: IP: Single-phase, V: V-connected, T: Scott-connected.
*: Supposed value
UP: To Jakarta Down: To Cirebon/Bandung

Appendix 7-3-1 Characteristics of 80 Hz Track Circuit

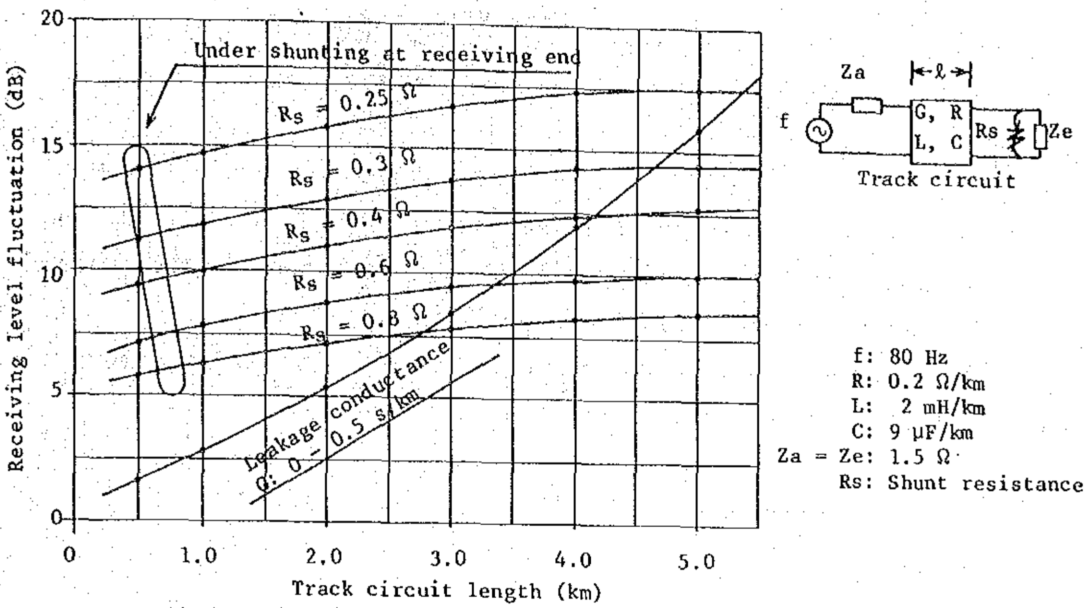


Fig. 7.3.1.1 Receiving Level

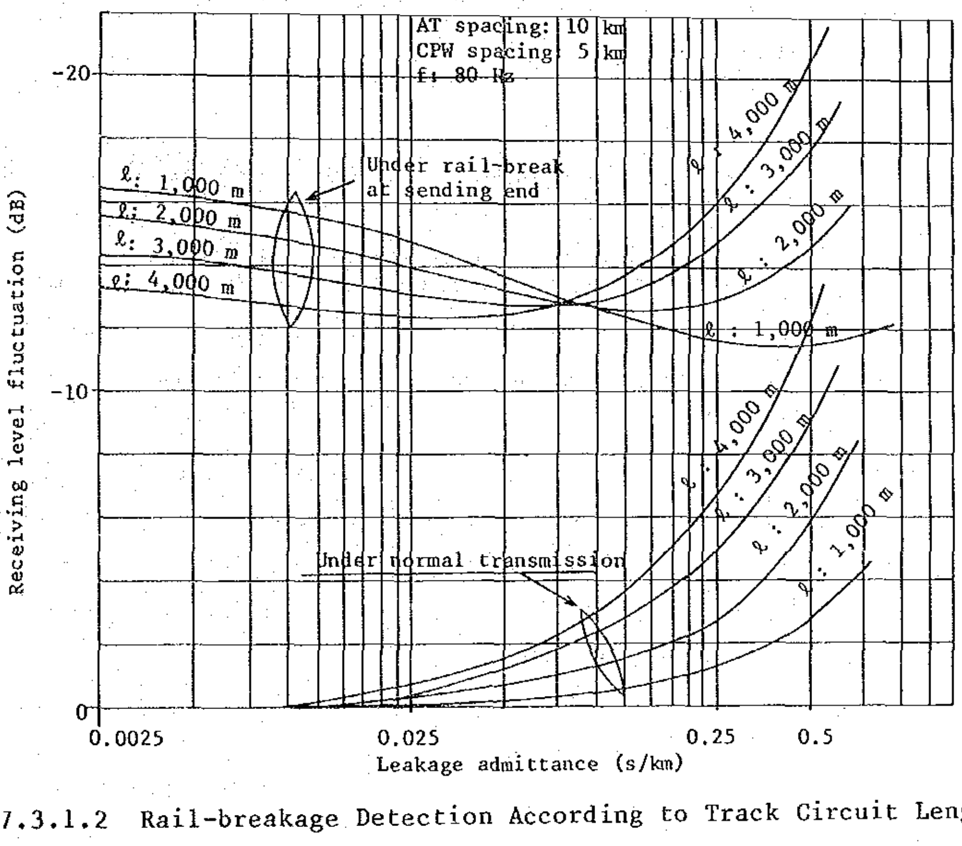


Fig. 7.3.1.2 Rail-breakage Detection According to Track Circuit Length

Appendix 7-3-2 Interference in Track Circuits Caused by VVVF Motive Unit

1. 80 Hz Code Track Circuit

According to the results of measurements conducted in Japan, the 80 Hz component in the return current of the VVVF motive unit, whose inverter current is 480 A, is 0.4 to 0.5 A.

In this project, inverter current is 1,110 A. Therefore, return current is assumed to contain the 80 Hz component as follows:

$$0.5 \times \frac{1,110}{480} \text{ A} = 1.16 \text{ A}$$

Assuming that the maximum unbalance rate of the track circuit is 10%, the 80 Hz component that will get mixed in the signal current and flow into the track relay will be approximately 60 mA according to the following calculation:

$$\frac{1}{2} \times 1.16 \text{ A} \times 0.10 = 0.058 \fallingdotseq 58 \text{ mA}$$

It is concluded that the 80 Hz track circuit is able to cope with the interference caused by the VVVF locomotive because it can operate stably for 80 Hz interference current up to 0.2 A, as shown in Table 7.3.2.1.

Furthermore, even when the track circuit unbalance rate exceeds 10% due to an unexpected rail break and the like and a large 80 Hz VVVF unbalance current flows into the track circuit, there is no risk of the track relay energized at the fail-out side because the train is detected by means of a coded current.

The basic performance of the 80 Hz AC code track circuit system is shown in Table 7.3.2.1 for reference.

2. DC Track Circuit

DC Track Circuit is free from interference caused by VVVF motive unit because its return current does not contain DC component.

The basic performance of the DC track circuit system is shown in Table 7.3.2.2 for reference.

Table 7.3.2.1 Main Performance of 80 Hz AC Code Track Circuit System

a) Track circuit conditions		
i) Applicable electrification system	:	AC electrified section
ii) Location	:	Double-rail
iii) Leakage conductance variation	:	0 to 0.5 s/km
iv) Control length and shunt sensitivity	:	20 to 2,000 m, min. 0.8 Ω 2,000 to 4,000 m, min. 0.35 Ω
v) Signal aspect	:	Two-position indication
vi) Rail-break detection	:	Possible
vii) Interference-resistivity	:	50 Hz 40 A, 80 Hz 0.2 A
viii) Maximum traction current	:	AC 400 A
ix) Cable length from track to device	:	Control cable, 1,000 m to 3,000 m
b) Climatic conditions		
i) Temperature range	:	-30 to +70°C
ii) Humidity	:	Max. 95%
iii) Power supply	:	DC 24 V ±10%
c) Impedance bond	:	1 mH, 200 A/rail

d) Transmitter

i) Modulation	:	Square wave amplitude modulation
ii) Carrier frequency	:	80 Hz
iii) Modulation frequency	:	2.5 Hz (150 code), 4.0 Hz (240 code) (max. 5 codes)
iv) Transmitting output	:	Max. 40 VA RMS
v) Load impedance	:	600 Ω
vi) Power consumption	:	Normal 50 W, shunting Max. 72 W

e) Receiver

i) Demodulation	:	Envelope detection
ii) Input impedance	:	600 Ω
iii) Minimum working level	:	15 dBm
iv) Band-pass filter attenuation	:	80 ± 4 Hz max. 6 dB, 80 ± 20 Hz min. 40 dB
v) Power consumption	:	Max. 3.5 W
vi) Track relay	:	7.5 V, 600 Ω, 4FB

Table 7.3.2.2 Main Performance of DC Track Circuit System

a) Track circuit conditions		
i) Applicable electrification system	:	AC electrified section
ii) Location	:	Single-rail within stations
iii) Leakage conductance variation	:	0 - 0.5 s/km
iv) Control length	:	1,000 m
v) Train shunt sensitivity	:	Min. 0.8 Ω
vi) Signal aspect	:	2-aspect
vii) Rail-brake detection	:	Possible (on signal rail side only)
viii) Maximum traction current	:	400 A
ix) Cable length from track to device	:	Sending cable max. 2 Ω, 500 m Receiving cable max. 3.2 Ω, 500 m
b) Climatic conditions		
i) Temperature range	:	-30 - +70°C
ii) Humidity	:	Max. 95%
c) Track relay		
i) Type	:	Polarized gravity-drop type
ii) Coil resistance	:	0.3 Ω
iii) Rated current	:	2.0 A
iv) Minimum working current	:	1.3 A
v) Releasing current	:	0.8 A
vi) Drop-away pick up ratio	:	Min. 0.6
vii) Overcurrent characteristics	:	2.8 A continuously

viii)	Working/releasing time	:	0.4 sec. with relay only 0.6 sec. with 3.2 Ω external resistance
ix)	Number of contacts	:	4FB

Appendix 7-4-1 Electrostatic Induction in Communication Line

Fig. 7.4.1.1 shows the relationship between electrostatically induced voltage (Vs)/current (Is) on the communication line and the distance (b) between the track center and the communication line. This graph indicates that, when a communication line is installed on the electrification feeder line side, electrostatic induction is greater in double track than single track and in the simple feeding system than the AT feeding system.

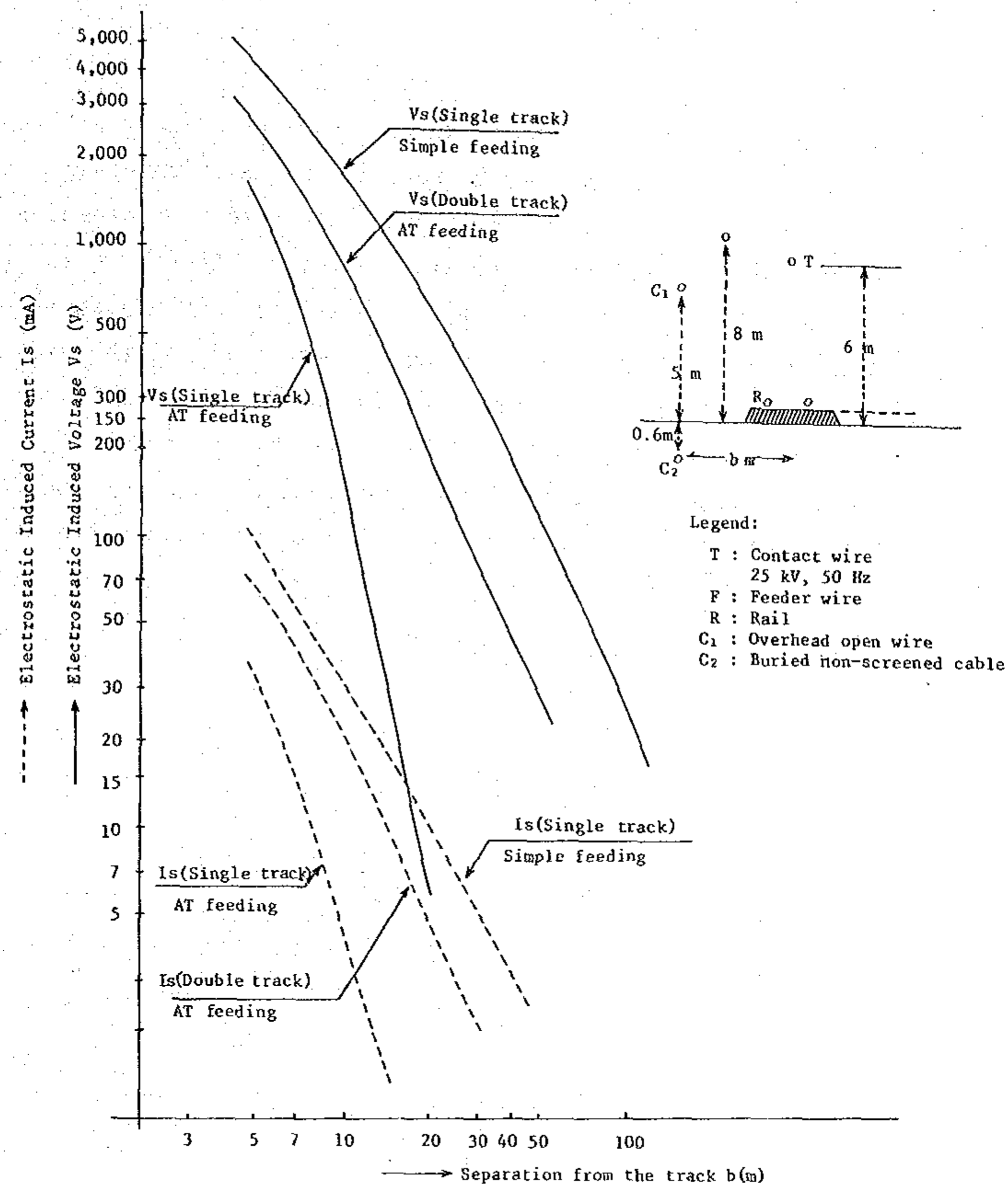


Fig. 7.4.1.1 Electrostatic Induction in the Communication Line

Appendix 7-4-2 Electromagnetic Induction in Communication Line

When a communication line is installed on the side of the track opposite the feeder line, electromagnetic induction voltage induced in it will be greater in single track than double track due to the screening effects of rail. The AT feeding system will reduce the inductive interference as shown in Fig. 7.4.2.1; the inductive voltage (50 Hz) in a 10 km long communication line is reduced to approximately 26% of the simple feeding system, while noise voltage (800 Hz) decreases to 30%. However, the diminishing effect decreases considerably as a result of the screening effects of rails and feeder lines when the distance between the communication line and the track center becomes approximately less than 30 m.

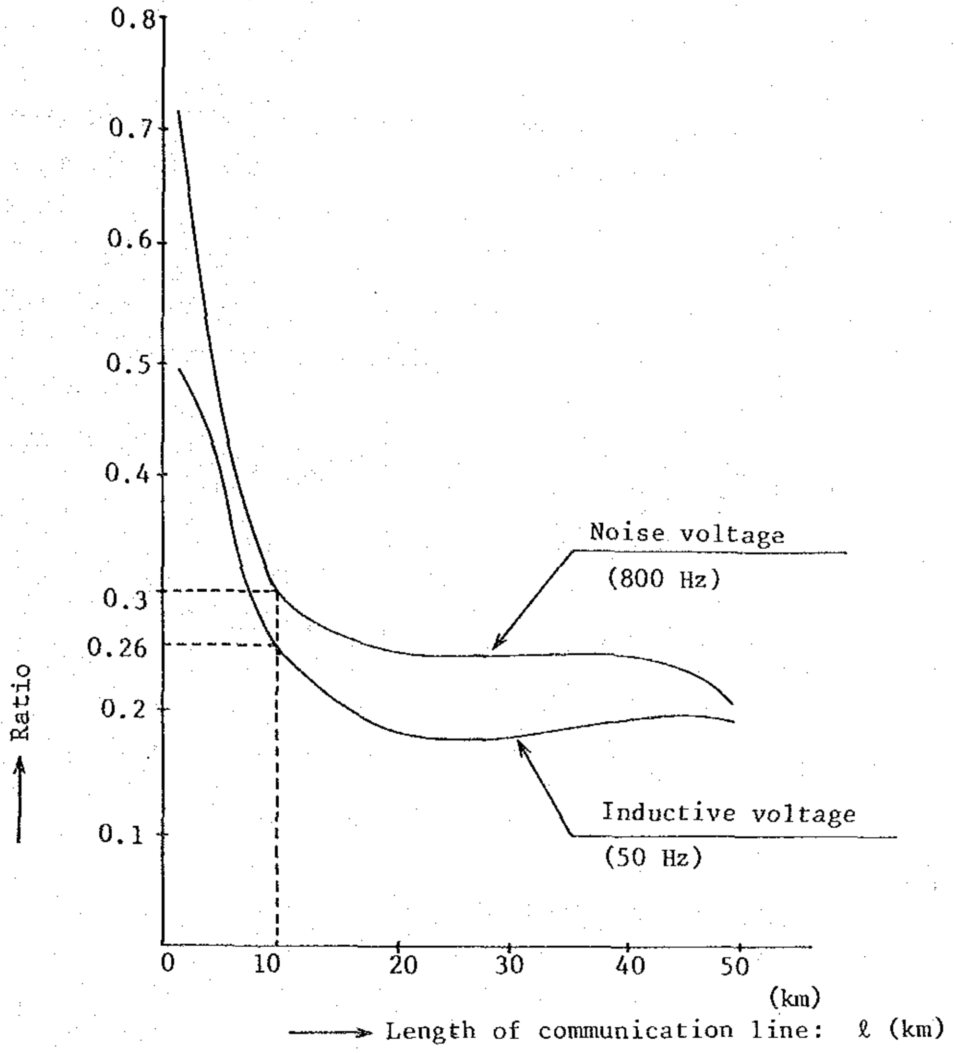


Fig. 7.4.2.1 Ratio of Inductive Interference by AT Feeding System Compared with Simple Feeding System (In case separation between communication line and track is approximately more than 30 m)

Appendix 7-4-3 Screening Factor of Communication Cable in the Project

The screening factor of the buried communication cable required to keep inductive interference within the allowable values is estimated using Appendix 7-4-2 and Fig. 7.4.3.1, as follows.

Table 7.4.3.1 Screening Factor of the Cable to Decrease Electromagnetic Inductive Interference

Screening Factor / Frequency (Hz) / Feeding system	K_P	K_J
Frequency (Hz)	50	800
Simple	0.9	0.06
AT	–	Less than 0.21

The estimation was conducted with the following assumptions.

Traction current : Ip = 100 A

Equivalent noise current : Jp = 3 A

Parallel length of communication line: P = 10 km

Separation between center of track and communication line : b = 4 m

In case of the Simple feeding system, the screening factors Kp (at 50 Hz), K_J (at 800 Hz) required for burried cable are obtained from the Fig. 7.4.3.1.

In case of the AT feeding system, the screening factor is estimated taking into consideration the induction reducing effect of the AT feeding system given in Fig. 7.4.2.1.

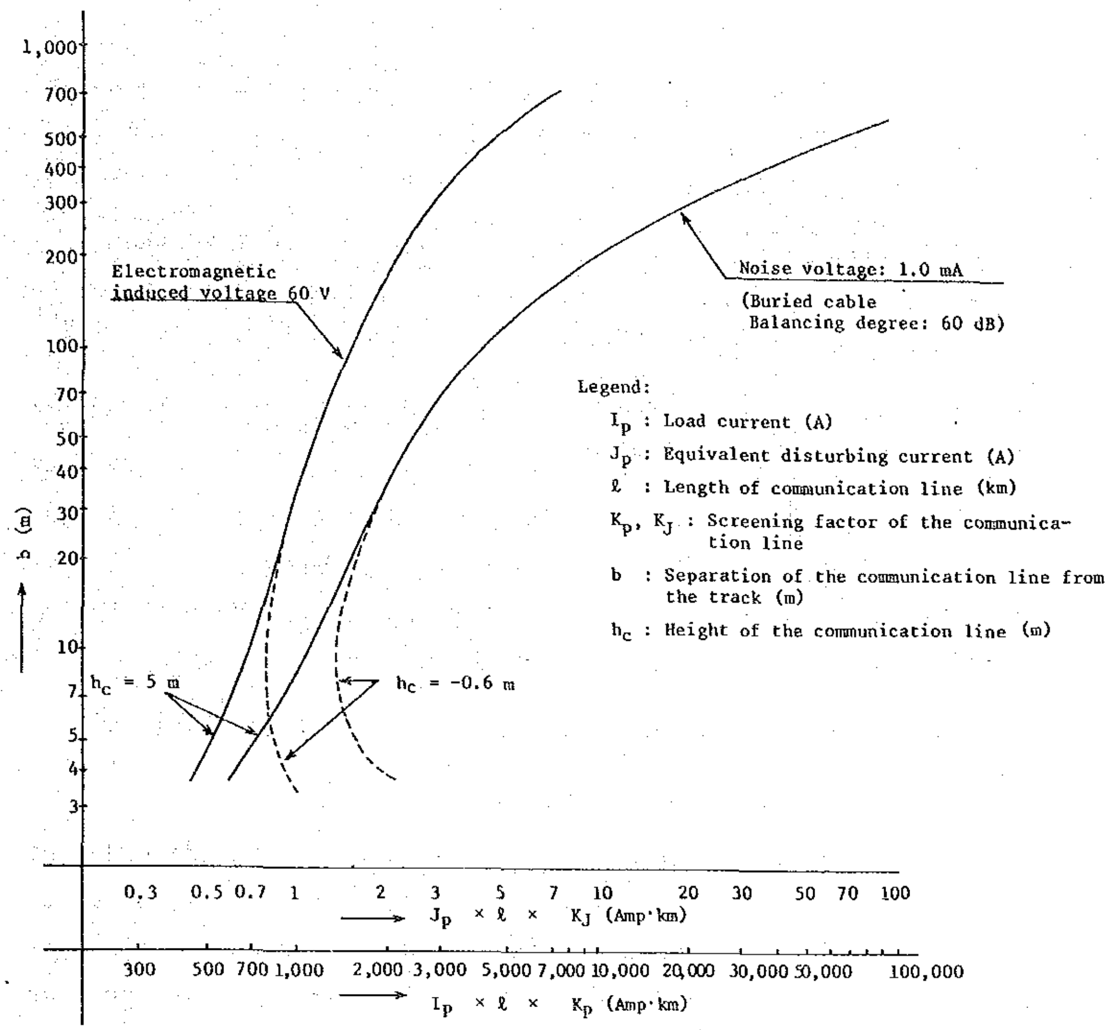


Fig. 7.4.3.1 Electromagnetic Voltage Induced in the Communication Line (Simple Feeding System, Double Track)

Appendix 8-1-1 Axle Load Reduction

The hauling capacity of the locomotive is determined in terms of the adhesive tractive force, which is calculated by multiplying the adhesive coefficient with the axle load.

Therefore, it is desirable to use the maximum axle load when starting because it requires a large tractive force, and to reduce the axle load at high-speeds to minimize the adverse shock on the track.

The variable-axle-load type electric locomotive presently used by JNR is described in the following.

The locomotive has the B-2-B axle arrangement and can change the driving axle load of the two bogies by changing that of the trailing bogie by controlling its air spring. This system has two effects.

(1) The axle load can be changed in three steps (16 t, 15 t, and 14 t) according to the permissible axle load of the railway line.

(2) When starting the train, an additional axle load of the order of 1 ton is applied over the permissible value of the railway line to increase hauling capacity, and at high-speeds the axle load is reduced under the permissible value to minimize the influence on the track.

Appendix 8-1-2 Tractive Force of the Locomotive on Steep Grade Sections

Fig. 8.1.2.1 shows the adhesion coefficient required by hauling load when starting on slope. Assuming that the maximum coefficient of adhesion of a VVVF locomotive is 35%, it can be seen from Fig. 8.1.2.1 that for single heading the maximum load with 25‰ grade is 530 tons, and 350 tons with 40‰ grade.

For double heading, the same type of locomotive can handle a maximum hauling load of 1000 tons with 25‰ and 700 tons with 40‰ . Between Padaralang and Ciajur, there is a succession of various grade sections ranging 25 to 40‰ , and there are some curves with radius of 200 m. The train resistance C at a curve section with radius of R meters is given by the expression C = 600/R kg/ton. Accordingly in a curve with a radius of 200 m, the train resistance becomes C = 3 kg/ton, which is equivalent to the train resistance in a section with 3‰ grade. So, it is concluded from Fig. 8.1.2.1 that it will be possible to haul up to 660 tons with double heading.

Likewise, in the Bandung-Banjar section the maximum gradient is 25 ‰ and the minimum radius is 200 m, so the train resistance becomes equivalent to 28‰ gradient. Accordingly, it will be possible to operate trains with approximately 480 tons hauling load for single heading and 980 tons for double heading.

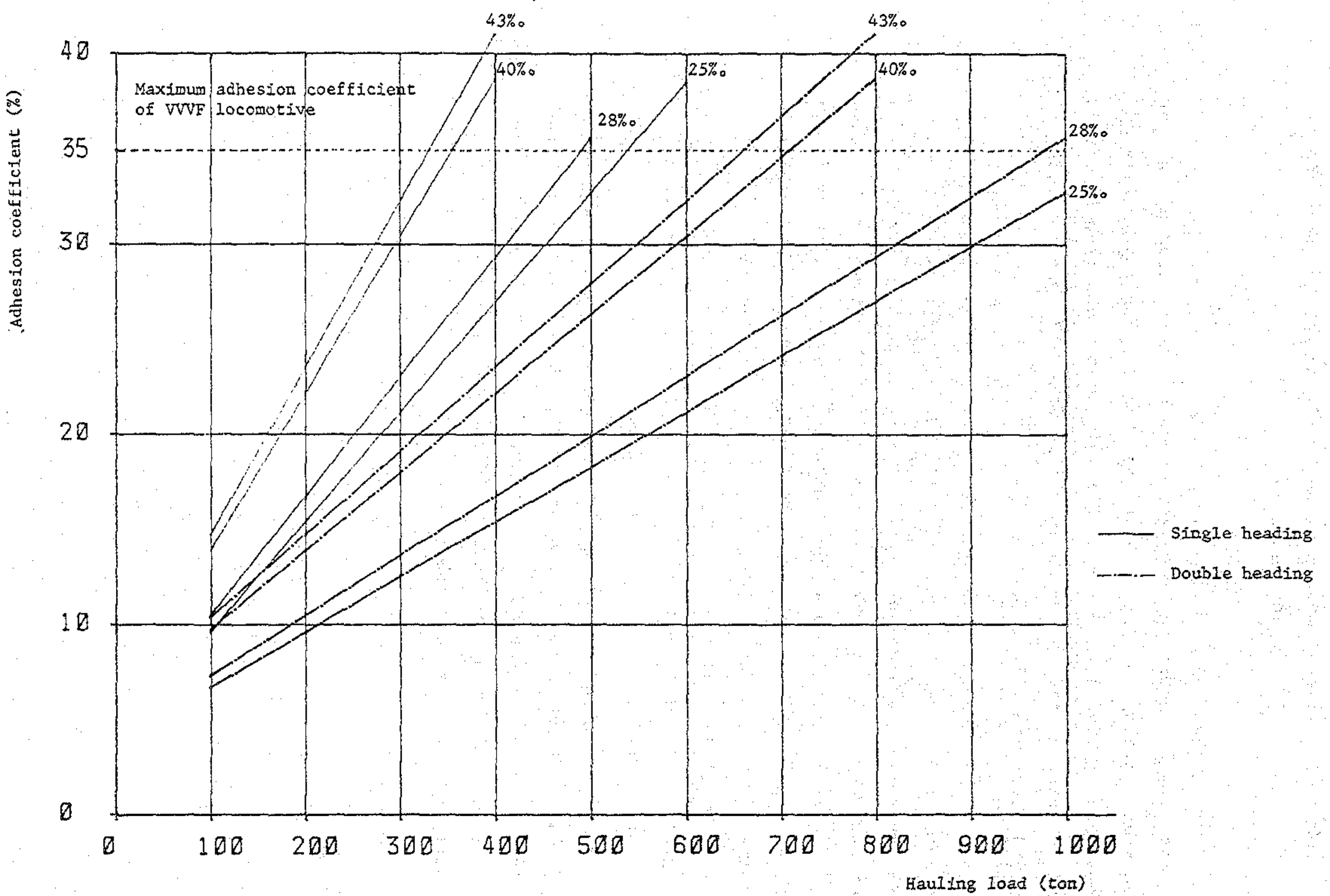


Fig. 8.1.2.1 Minimum Adhesion Coefficient Required at Starting on Grade (At axle load 15 tons)

Appendix 8-1-3 Comparison of the Motor-Bogie Suspension and Driving System of Electric Locomotives

1. Nose Suspension System

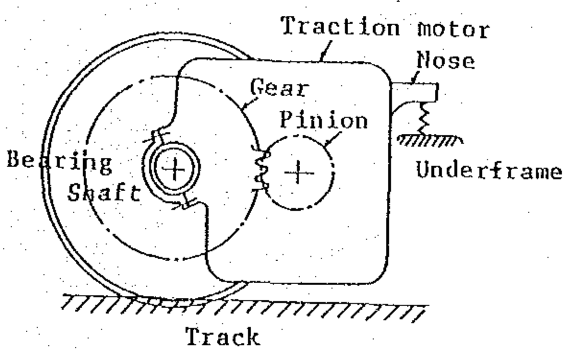


Fig. 8.1.3.1 Nose Suspension System

In this system one end of the traction motor rests on the axle via bearings, and the other end rests on the bogie frame via the nose, as shown in Fig. 8.1.3.1. The gear mounted on the axle is directly meshed with the pinion mounted on the armature end.

This sytem exerts some adverse shock on the track because half of the traction motor weight is unsprung weight supported by the axle.

Since the maximum speed of an electric locomotive hauled train is limited to not more than 110 km/h in JNR, majority of electric locomotive are equipped with this system.

2. Mono-motor Bogie System

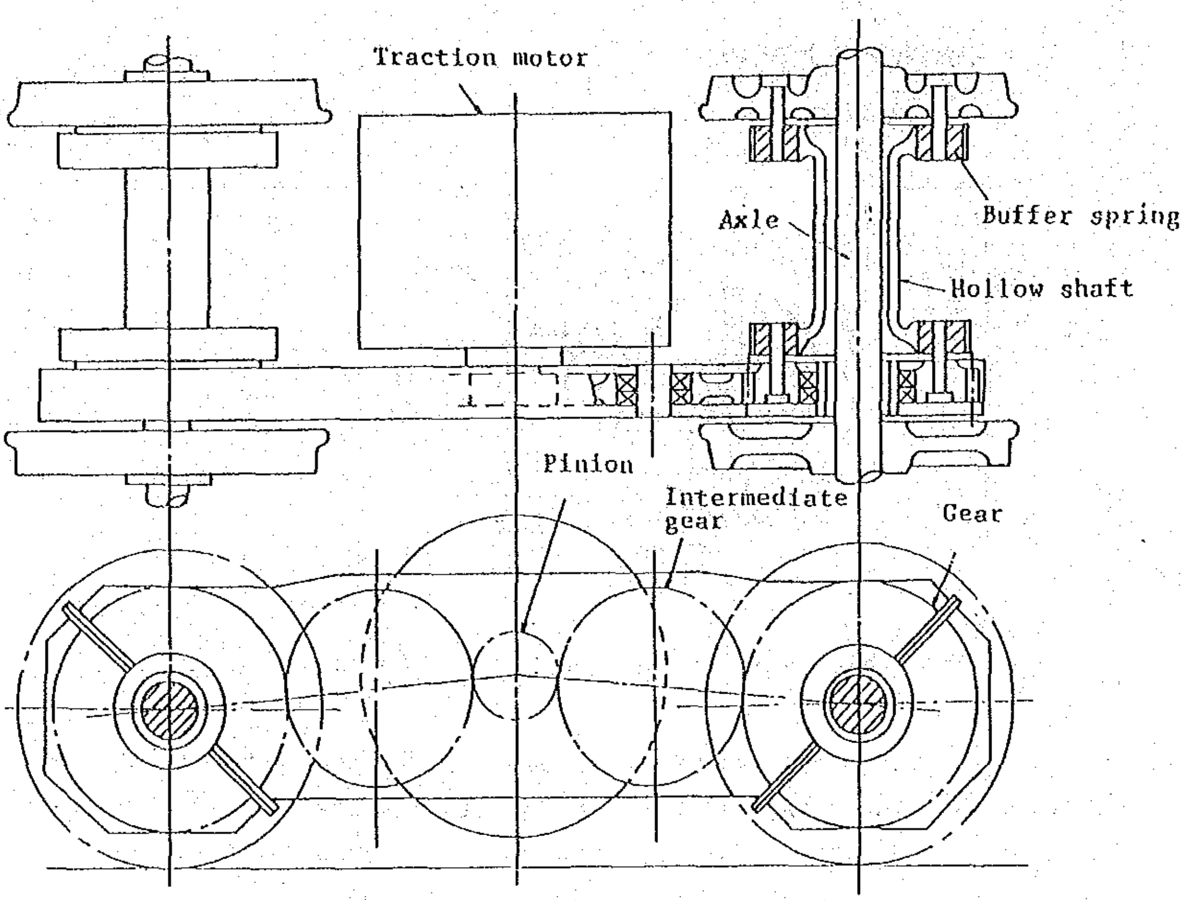


Fig. 8.1.3.2 Mono-motor Bogie System

In this system the traction motor is mounted at the center of the bogie, and the rotary power is transmitted to the axle by meshing the pinion of the traction motor with the gear via two sets of intermediate gears, as shown in Fig. 8.1.3.2.

This system is suited for high-speed rolling stock because the traction motor is a sprung weight.

It must be remembered however, that the power transmission mechanism becomes rather complicated compared with other systems, being prone to maintenance troubles.

Only a type, EF80, is equipped with this power transmission system in JNR. But, due to the maintenance problems, this system is not employed by other types.

3. Quill Driving System

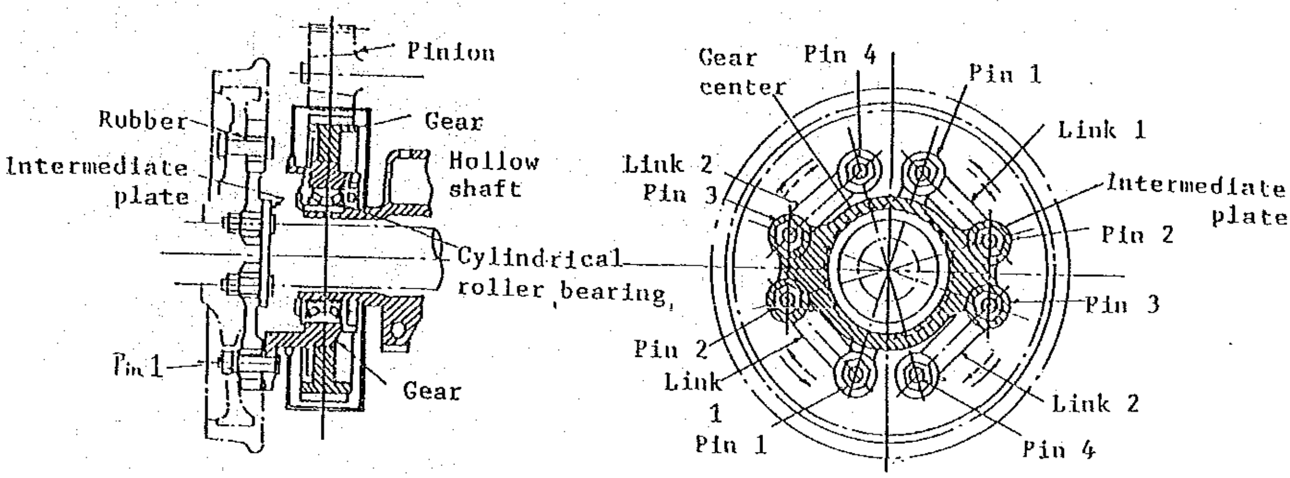


Fig. 8.1.3.3 Quill Driving System

One end of the traction motor rests on the bogie via the nose, and the other end rests on a hollow shaft which encircles the axle. The hollow shaft is fixed on the bogie frame. The gear rests on the hollow shaft via roller bearings. Torque of the traction motor is transmitted via the pinion to the gear, and transmitted from the pin 1 mounted on the gear to the pin 2 via link 1. It is transmitted to the pin 3 mounted on the intermediate plate and to the wheel via link 2.

Therefore, the entire traction motor is sprung weight, and this system is suited for high-speed operation. Furthermore, it is advantageous from the maintenance standpoint as well.

This driving system is adopted on ED60, ED71, and EF66 type locomotives in JNR and is working satisfactorily.

As a result of the above comparative study, adoption of this system is preferable from the standpoints of influence on the track at high-speed operation (120 km/h) in the future and maintenance.

Appendix 9-1-1 Headroom for the AC Electrification

1. Insulation Clearance

Insulation clearances for the proposed electrified section were determined with reference to the study results in the Master Plan, as follows:

Clearance	The project (mm)	UIC (mm)
Standard	-	270
Minimum	200	220
Instantaneous approach	150	170

2. Construction Gauge

Sufficient insulation clearance should be provided between AC overhead equipment and track structures. Required headrooms were determined for the insulation clearances as follows:

(1) Horizontal clearance for pantograph (L)

a. Pantograph length: 1,760 mm; b. Horizontal car vibration: 200 mm; C. Instantaneous insulation clearance: 150 mm; d. Tolerance: 140 mm

$$L = a + 2b + 2c + d = 2{,}600 \text{ mm}$$

(2) Overhead clearance for pantograph (h)

a. Dynamic uplift of contact wire: 100 mm; b. Instantaneous insulation clearance: 150 mm

$$h = a + b = 250 \text{ mm}$$

(3) Horizontal clearance for catenary line (P)

a. Catenary deviation: 300 mm; b. Insulation clearance: 200 mm; c. Tolerance: 100 mm

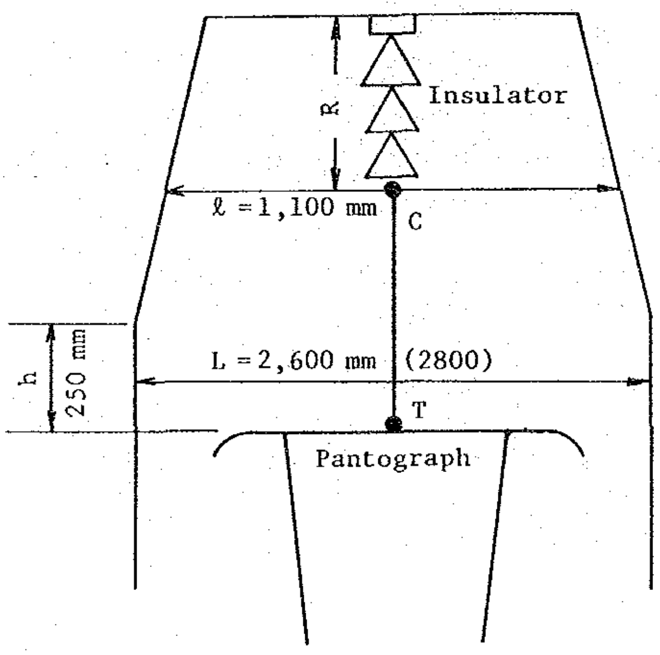
$$P = 2a + 2b + c = 1,100 \text{ mm}$$

(4) Overhead clearance for catenary line (R)

a. Insulation clearance: 200 mm; b. Catenary supporting fixture: 500 mm

$$R > b > a$$

The above clearances are shown in Fig. 9.1.1.1.
For AC electrification, the existing PJKA construction gauge needs to be modified to allow the above insulation clearances. If the horizontal clearances still cannot be obtained after modification, the width of pantograph may be shortened, the pantograph's horns may be insulated or the spacing of the supporting structures on the overhead line equipment may be reduced.



Legend:
( ): in case of tilting railway car
R ≧ 500 mm

Fig. 9.1.1.1 Headroom Requirements

Appendix 9-2-1 Protective Measures for Overhead Line Equipment

a. The protective wire will be installed on the supporting pole/mast for the overhead line equipment at a shielding angle less than 45° (in consideration of the shielding effect against lightening).

b. The protective wire will be supported by one suspension insulator (on fixed beams in the station yard or at places where more than five steel masts are installed consecutively).

c. Metallic parts such as insulator fastening band, cross-arm and beam will be interconnected by grounding conductors and then connected to the protective wire.

d. The protective wire will be grounded either directly or through rail as shown in Table 9.2.1.1.

Table 9.2.1.1 Grounding of Protective Wire

Section	Place	Grounding method			
		Grounding to rail		Direct grounding	
		Direct	Through impedance bond	Spacing (m)	Grounding resistance (X)
Bekasi - Cirebon	Inter-station	-	AT point & Inter-AT point	200	30 or less
	Station	-	-	200	30 or less
Cikampek - Kiara-condong	Inter-station	Every 200 m	-	-	-
	Station		Both ends of station yard	200	30 or less