Power Supply Planning Study on Electric Train Island North Java Tracking

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Abstract— **Problems in the circuit of electric train track north of the island of Java is how to determine with certainty the installed capacity of electric power supply for electric train set of the above. For the evaluation used for the calculation of power distribution systems for electrical networks such electric train. The final result shows that the electric train power required for a network system 4359 kWdengan phase 25 kV, 50 Hz from traksinya substations, so that the installed power capacity at traction substations amounted to 15.6 MW. Power is distributed to substations PLN (Persero) through three-phase transmission lines of 150 kV, 50 Hz, while the capacity of substations is assumed to be equal to 44 MVA.**

Keywords— **electric train, electric power distribution system**

I. INTRODUCTION

Transportation system in Java that every day more and more dense the number of vehicles, the use of electric train as the main transportation should be considered. With the utilization of technological sophistication of high-speed electric train will replace diesel trains in use today, and as the initial project will serve the route Surabaya-Jakarta via Semarang and Cirebon by the same route. Electric Rail train will be supplied from the transmission network of PLN Limited Co. situated around the North Island of Java, namely between Surabaya to Jakarta. With the existence of electric train, it is expected that problems in the field of transport can be eliminated, and also stimulate thoughts for others to find alternative power source can be utilized in all aspects of life. (Aliansyah, 2000)

Electric train is one of the many types of vehicles driven by electric motors. Electric motors that drive this train is put under the deck of the train, because train consists of motor coaches, which have motor cars at the bottom of the deck and trailer coach that is the carriage of goods. Dimensions of the electric motor that is used is limited by the capacity of the room below deck and all other control equipment labored under the deck except for the serving operator. Thus the dimensions should be small electric motors with power yng big enough. (Aliansyah, 2000). 500 kV network (etc) stretched across the northern part of Java Island, connecting Suralaya, Gandul, south of Bandung, Ungaran, Krian, and Paiton. 150 kV network spread from the west end to the eastern tip of Java,. All networks are connected to each other in accordance with levels and is associated also with all the generators in Java. Along with the development of networks of PLN Limited Co.that there is a good number of channels and power then it was likely a whole will be supplied by a network of 150 kV. (Hatrivianto, 1998) KRL operation described in three phase induction motors that receive power supply from PLN Limited Co, the electric power supply system with 500 kV or 150 kV network etc. Target of this research was to study the supply of electric power supply for electric train Surabaya-Jakarta.

II. MATERIALS AND METHODS RESEARCH

2.1 Materials Research

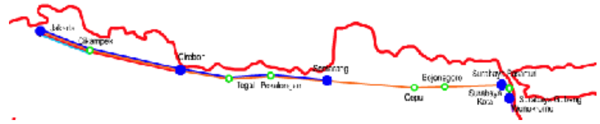


Figure 2.1 Railway Northern Cross P. Java (Source: Statistical Department of Transportation, Jakarta, 1998, recycled)

Electrical systems for power distribution between the Surabaya-Jakarta is divided into three regions supplying electricity that is: Zone A between Surabaya - Semarang, a distance of 220 km Zone B between Semarang - Cirebon, a distance of 230 km Zone C between Cirebon - Jakarta, a distance of 300 km Main substation Kereta Api Indonesia Ltd. Co. will later be placed in four cities, namely: (1) Singapore, (2), Semarang, (3) Cirebon, and (4) Jakarta. To assist in the distribution of electric power in each and every zone will be placed substations, substation circuit Kereta Api Indonesia (KAI) Ltd. Co, a distance of 100 km, because the charging system will use the current system of alternating current (AC) single phase auto-transformer, which allows for the placement of substations, substation circuit ± 100 km. According Diatmoko (2003)). Substation circuit Kereta Api Indonesia (KAI) Ltd. Co.will also be placed above the three zones: zone A in Cepu, zone B in Tegal or Pekalongan, and zone C at the optimum result.

2.2. Methods Research

2.2.1 How It Works, Distribution System Of Sub Station Of PLN Ltd Co. To A Rationing System (flow top)

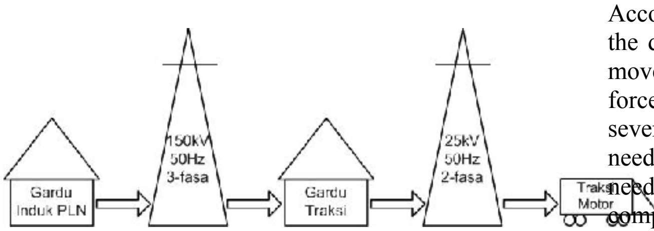


Figure 2.2 Distribution System Electrical Power Network Against KRL

Electric power distribution facilities for electric railway electrification generally consist of substations (GIs), transmission lines, power lines, traction substations (subtation), the flow system (contact wire), and rail. In general, the supply system for rationing system of alternating current (AC) power flow is as follows. Three-phase electric power from substations PT. PLN (Persero) is channeled to the traction substations through high voltage transmission lines (150 kV, 50Hz). In traction substations, electric power is converted into single-phase electric power (using a three-phase transformer circuit scott) with suitable voltage is 25 kV electrification needs. Of traction substations, electric power is channeled to the rationing system (flow up) and then later move the electric trains. Flows back to the traction substations with intermediate rail.

2.2.2 How It Works Electrification System Of Rationing System To The Traction Motor

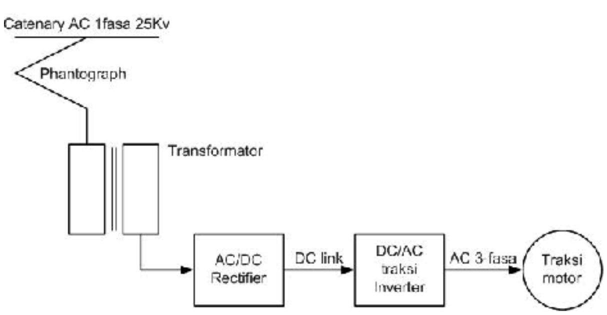


Figure 2.3 Schematic Electrical Traction Electrification System

Voltage alternating current (AC) single-phase 25 kV of the catenary system is channeled to the transformer through panthograph. Further on down voltage transformer as needed rectifire, from here the voltage alternating current (AC) single phase voltage is converted to Direct Current (DC). Furthermore, the DC voltage converted into a three-phase voltage via an inverter, so it can move a three-phase AC motor.

2.3 Phase Calculation

According Sudibya (2000), attraction force generated by the driving unit is the force required by the railway to move the unit pnggerak and the whole train. Tensile force required to move the train can be divided into several components, among others: (a) The components needed to provide acceleration (b) The components needed to overcome the resistance (resistance) train. (c) components needed to overcome the slope (gradient). (d) The components needed to overcome the corner.

III. RESULTS AND DISCUSSION

Total Weight 3.1 Calculation KRL AC

The size of the inside of each compartment KRL AC can be seen as Figure 3.1

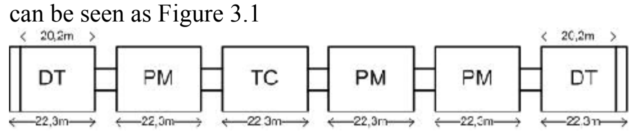


Figure 3.1 Size Inner Comparment KRL AC

Based on images 3.1, the total weight of KRL AC at normal capacity can be calculated as in Table 3.1 by using the provisions sebgai trader:

a. Seat size for one person: 0.43 m²

b. The size of the place stood for 1m ²: 2 passengers

c. The average weight per person: 60 kg

Table 3.1 Weight KRL AC

Couch Type	DT	PM	TC	PM	PM	PM	Jumlah
The carriage Area (m²)	60,6	64,8	64,8	64,8	64,8	60,6	380,40
Seating capacity(persons)	48	54	54	54	54	48	312
Seating Area (m²)	20,64	23,22	23,22	23,22	23,22	20,64	
Place Standing Area (m²)	39,96	41,58	41,58	41,58	41,58	39,96	246,24
Standing capacity (persons)	80	83	83	83	83	80	492
Passenger capacity (persons)	128	137	137	137	137	128	804
Passenger load (kg)	7680	8220	8220	8220	8220	7680	48.240
Empty Weight (kg)	32.000	39.000	39.000	39.000	39.000	32.000	213.000
Empty Weight (kg)	261.240kg + 2 the rail road engineer KRL (120 kg) = 261.360kg						

Source: PT. KAI (Persero), Manggarai Sector Section of Electric Circuits section (lla)

Total load (W) = load load passengers + driver + 2 people
= 48 240 + 213 000 + 120 = 261 360 kg = 261.360 tons

3.2 Power Flow Calculation Results

Power flow calculation to be performed in accordance with Figure 2.2 which refers to:
1. Supply the power needed by the traction motor
2. Power capacity of traction substations

3.2.1 The Power Supplies Required By The Traction Motor

3.2.1.1 Operation Of The Motor Torque On The Condition Remains

According Sudibya (2000), at fixed torque region operation, to generate torque remained the input current at a fixed price. Fixed operating areas will expire at the speed of the motor speed above the branches.

1 Calculating Motor Speed Translation

In the circumstances still need to know the torque-speed electric trains on the voltage and frequency on the condition of the branches, then it can be obtained :

$$n_S = \frac{120f}{P} = \frac{120x80}{4} = 2400rpm$$

From the calculation of unknown spin at 2400 rpm statornya, where as the known data of motor rotor speed of 2345 rpm, then for the slip can be calculated:

$$s = \frac{n_s - n_r}{n_s} x100\% = \frac{2400-2345}{2400} x100\% = 2.29\%$$

From the above calculation we can count how many actual translational speed of the KRL, when the motor is run at a speed rating, which is equal to the speed of the motor rotor speed; ($n_m = n_r = 2345Rpm$), using equations substitution :

$$V = \frac{n_m x6x3.14xD}{ex100} = \frac{1659x6x3.14x0.86}{6.12x100} = 61.36km/jam$$

With : D = 0,86 m ; $e = \frac{153}{25} = 612$ (gear ratio) ; n_m = 1659 rpm

2 Calculate The Required Torque Large KRL

The steps being undertaken to estimate the amount of torque required to move the electric trains operating in the region remains, namely to calculate the forces acting on the KRL when being accelerated, using the translational speed of KRL (61.36 km / h). While the forces in effect at the KRL in a state of accelerated among others:

a. Style To Cope With The Acceleration

Fa = W x a ; With : W = 261.360 kg ; $a = 0,8 m / s^2$

Fa = 261.360 x 0,8 = 209,10 kN

b.The Force To Overcome Resistance

Fr = (6.3765 x W) + 2064+ (0.13734 x W x V + (0.63068 x V^2)

With : Fr = Force to overcome resistance (Newton); W = 261.360 tons (total weight of the KRL)

V = 61.36 km / h (speed KRL)

Thus obtained:

Fr = (6.3765 x 261.360) + 2064 + (0.13734 x 261.360 x 61.36) + (0.63068 x 61.36^2) =8.3076 kN

c. The Force To Overcome The Curvature Or Bend

To calculate the amount of force to overcome the curvature of the path can we assume to be traversed by the KRL are included on the bend with the curvature of 150 m, then the magnitude of the force to overcome the bend is as follows: $Fc = \frac{700}{R} xWxg$

By: Fr = Force to bend mengtasi (Newton) ; R = radius of curvature (m)

W = Total weight of the KRL (261.360 tons); g = force of gravity (9.8 m / s ²)

Are obtained :

$$Fc = \frac{700}{R} xWxg = \frac{700}{150} x261.360x9.8 = 11952,864N = 11.95kN$$

So that the tensile force Ft is required by the KRL were as follows : $Ft = Fa + Fr + Fc$

By : Ft = tensile force (Newton) ; Fa = 209.10 kN ; Fr = 5.374 kN ; Fc = 11.95 kN

Are obtained : Ft = 209.10 + 5.374 + 11.95 = 226.424 kN

KRL much power is needed for the total tensile force = 226.424 kN at a speed of 30 km / h is:

$$Pt = \frac{FtxV}{3600} = \frac{226.424x61.36}{3600} = 3859.27kW$$

In one set of electric trains there were 12 motor traction, so that each wheel power driven spindle motor is as follows : $Pw = \frac{Pt}{jumlah\_motor}$

By : Pw = power at the wheel of KRL ; Pt = 3859.27 kW (total power KRL)

Thus obtained : $Pw = \frac{3859\ .27}{12}$ = 321.60 kW

KRL rotation speed of the motor at a speed of translation which is when the speed of 61.36 km / h is as follows : $n_m = \frac{V \times e \times 100}{6 \times \pi \times D}$

Jadi untuk menggerakan KRL dengan kecepatan 61.30km/h, dimana dalam 1 set KRL terdapat 12 poros roda yang digerakan oleh motor maka torsi yang dibutuhkan adalah :

$T_{total} = 12 \times Tw = 12 \times 8019$ = 96.228 N.m

By: n_m = Rotation of the motor (rpm) ; V= 61.36 km / h = translational velocity

E = $\frac{153}{25}$ = 6.12 (gear ratio) ; D = KRL wheel diameter (0.85 m)

It is obtained :

$n_m = \frac{61.36x6.12x100}{6x\pi x0.85} = 2344.98rpm$ = 2344.98 rpm

So that the torque is used on each wheel axle speed electric trains on the V = 61.36 km / h is:

$$Tw = \frac{Pw \times 60 \times e}{2 \times \pi \times n_m}$$

By : Tw = Torque wheels ; n_m = 2344.98 rpm (motor rotation) ; $e = \frac{153}{25} = 6.12$ (gear ratio)

Thus obtained : diperoleh

$:Tw = \frac{Pw \times 60 \times e}{2 \times \pi \times n_m} = \frac{321.60 \times 60 \times 6{,}12}{2 \times \pi \times 2344.98}$ = 8019 Nm

So to move the electric trains with speed 61.30km / h, where in one set of electric trains have wheels that pivot 12 movable by the motor torque required is :

$T_{total} = 12 \times Tw = 12 \times 8019$ = 96.228 N.m

3 Calculating Absorbed From Network Power

In calculating the power absorbed from the network by the KRL is as follows:

a. Gear Box Calculate Input Power (P_{i-gb})

Power output at the gear box (P_{o-gb}) = power wheel (P_W)

Then : $P_{1-gb} = \frac{P_{o-gb}}{\eta_{gb}}$ By : P_{o-gb} = 321.60 kW and η_{gb} = 0.97 Then : $P_{i-gb} = \frac{321.60}{0.97}$ = 331.54 kW

Power losses in the gear box : $P_{i-gb} - P_{o-gb}$ = 331.54 - 321.60 = 10 kW

b. Calculate The Motor Input Power (P_{i-m})

Gearbox input power (P_{i-gb}) = power output of the motor (P_{o-m}) : $P_{i-m} = \frac{P_{o-m}}{\eta_m}$

By : P_{o-m} = 331.54 kW; then obtained :

$P_{i-m} = \frac{331.54}{0.97}$ = 341.79 kW

So that the motor power losses = $P_{i-m} - P_{o-m}$ = 341.79 - 331.54 = 10.25 kW

While the torque generated on the motor shaft is :

$$T_{motor} = \frac{P_{o-m}x60}{2.\pi.n_m} = \frac{331.54x60}{2.\pi.2344.98} = 1350.79 \text{ Nm}$$

By : T_{motor} = Motor shaft torque (Nm); P_{o-m} = 331.54 motor output power (kW) ; n_m= 2344.98 rpm

Motor input power with the inverter output power. An inverter unit to serve four pieces so that the traction motors on inverter input power is :

$$P_{i-inv} = \frac{P_{o-inv}x4}{\eta_{inv}} = \frac{341.79x4}{0.97} = 1409.44 \text{ kW}$$

By: P_{i-inv} = Inverter input power (kW); P_{o-inv} = power output of the inverter (kW); η_{inv} = inverter efficiency

So that power losses in the inverter are: P_{i-inv} - P_{o-inv} = 1409.44-(341.79 x 4) = 42.28 kW

Same input power inverter with output power at the chopper line. One set of inverter supplied by a chopper line, so the chopper input power on line is :

$$P_{i-chop} = \frac{P_{o-chopp}}{\eta_{chopp}} = \frac{1409.44}{0.97} = 1453.03kW$$

By : $P_{i-chopp}$ = Chopper input power (kW) ; $P_{o-chopp}$ = 1453.03; chopper output power (kW) ;

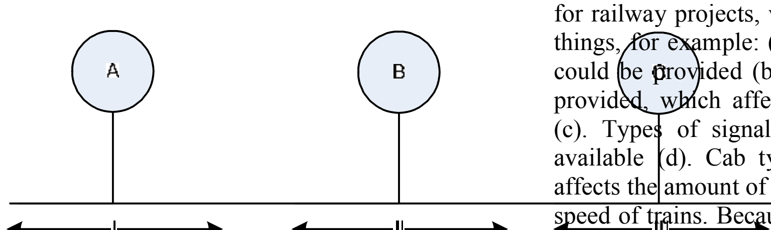
η_{chopp} = Efficiency chopper

The importance of the power losses in the chopper line is : $P_{i\text{-}chopp}$ - $P_{o\text{-}chopp}$ = 1453.03-1409.44 = 43.59 kW
Power absorbed from the same network with the power line input on the chopper, because there are a set of three-line chopper KRL, the KRL absorbed power from the network are:
$P_{i\text{-}KRL}$= 3 x $P_{i\text{-}chop}$ = 3 x 1453.03 = 4359.09 kW. from the data mentioned above, can be calculated the amount of current consumption per train :

$$I = \frac{P}{V} = \frac{4359.09kW}{25kV} = 174 Ampere$$

3.2.2 Selection Alternating Current Electrification Systems Turn One-Phase 25 kV
From the above calculation, the absorbed power from the electric train network of 4359.09 kW. From Figure 2.2, and pay attention to the table Heavy KRL AC, the distribution channels that will be applied 25 kV single phase with a frequency of 50 Hz with a maximum distance of 50.263km so far. This system requires a transformer along 50 263 km, the transformer here functioned to reduce the voltage drop across the network. From Figure 2.1 for each route traversed by electric train, then the transformer needs to zone A 4 fruits, 4 fruit zone B and zone C 6 fruit.

3.2.3 Calculation Of Traction Substation Installed Capacity
3.2.3.1 Imposition Of Traction Substations
Traction substations generally bear the burden of moving electric trains arrive at the half distance of traction substations for traction substation next to both sides. More detail can be seen in Figure 3.2



II.

Figure 3.2 Schematic Distance Traction Substation

In Figure 3.2 above, the electric trains that move region I is supplied by the traction substation A, in region II were supplied by the traction substation B, and in regions III disupali by C. traction substations Then to determine the power capacity of a traction substation required data as follows:
(1). Operating voltage (2). Density trains per day between the two substations traction (3). the distance between the two traction substations (4). The average speed of trains between the two traction substations (5). power consumption / flow-per-train
For points 2, 3, and 4 can be summarized as the number of trains that simultaneously consume power between the two substations traction (n). OR

$$n = \frac{kepada\tan - KRLxjarak}{kecepa\tan ratarata}$$

As shown in Figure 2.1 is shown, the Zone A between Surabaya – Semarang a distance of 220 KM, THE ZONE B between Semarang – Cirebon a distance of 230 km, and the Zone C between Cirebon – Jakarta, a distance of of 300 km So you can retrieve the average distance between traction substations is 250 km. When the density of trains between the two substations to 16 trains per day and average train speed is 120 km / h, then $n = \frac{16/24 jamx250km}{120km/jam}$ N = 1 (SATU) KERETA.
Thus there is a train that consume power traction substations between A and B. From the above calculation reveals: (-) Supply system: 25 kV, 50 Hz, 1 phase, (-) absorbed power train of the network: 4359.09 kW.
From the data mentioned above, can be calculated the amount of current consumption PER TRAIN ;

$$I = \frac{P}{V} = \frac{4359.09kW}{25kV} = 174 \text{ AMPERE}$$

3.2.3.2 CALCULATION OF TRACTION SUBSTATION CAPACITY
Due to inherent difficulties in estimating the density of train future the data used in this calculation the density of the train while now. This is because it involves various aspects of highly complex and interrelated with each other.
Those aspects include: (1). Estimated number of railway enthusiasts in the future, (2). Number of funds available for railway projects, which ultimately determines many things, for example: (a). The number of train units that could be provided (b). Railway conditions that can be provided, which affects the travel time from the train (c). Types of signaling and traffic arrangements are available (d). Cab types that can be provided which affects the amount of power consumption and maximum speed of trains. Because of the things mentioned above, as reference will be calculated based on the data capacity of traction substations train diwaktu current density with the assumption that the power consumption of each train 4359.09 kW or 174 A. If electrification carried out in 2005 and at the beginning, traction substation capacity is prepared to serve the load for 20 years, ie until 2025. then in 2025, the number of railway traction substation shall be served by it, using the formula: $Kt = Ks + Ks \{ (1 + i)^t - 1 \}$
By : Kt = Number of trains in year t ; Ks = number of trains now
i = Increase in passengers per train per year ; t = year term
Based on data from PERUMKA that the increase in the number of passengers per year is 5 %, then in 2025 based on the formula above, the traction substations

should serve as many train loads : $Kt = 1 + 1 \{ (1 + 0.05)^{20} - 1) = 3$ trains : Total Expense = 3 x 174 A = 522 A
And magnitude of total electric power absorbed by the train is = 25 kV x 522 A = 13 MW
So for the planning of electrification, traction substations must have the capacity for
Capacity = ((13 MW x 20%) + 13 MW) = (2.6 kW + 13 MW) = 15.6 MW
With: 20% is reserve power for abnormal conditions

IV.CONCLUSION

From the obtained results and discussion that requires electric traction power equal to 4359.09 kW, for which the necessary electrical power networks with voltage systems Alternative Current (AC) 25 kV single phase with a frequency of 50 Hz. For that traction substation shall have a capacity of 156 MW, which is served by the transmission line voltage system with Alternative Current (AC) three phase 150 kV with a frequency of 50 Hz, thus it can be assumed that the supply of power from substations PT. PLN (Persero) amounting to 44 MVA 150/20 kV distribution system (according to table).

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