Analysis of Electric Power Consumption on Business and Economic Executive Class Trains at PT KAI (Persero) UPT Depo Train Class B Medan

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Abstract

Maintenance or well-scheduled maintenance of Passenger trains, including maintenance and overcoming train air conditioning problems, maintenance of lights and other comfort support equipment such as LCD TVs and fans, PT Kereta Api Indonesia formed the Facilities Maintenance Division, in this case the Passenger Train Depot owned by each Operating Region (DAOP). the purpose of this research is to analyze the power consumption on passenger trains so that it can be done for the generating system to be assembled with a maximum amount. In this study, calculations were made about the total power consumption that must be borne by passenger trains, measuring daily loads in each class of trains, knowing the power consumption capacity factor according to the amount of load borne by the train. From the results of measurements and calculations carried out, the executive class train generator has a capacity of 500kVA, has a nominal current of 759.68A. The maximum demand of all load components installed in one executive class carriage is 17.93kW, 29.471kVA, and 61.844A and the maximum demand of all load components installed in one executive class restoration carriage is 15.86kW, 26.504kVA, and 48.356A, Translated with DeepLcom (free version). The business class train generator with a capacity of 150kVA with a nominal current of the business class generator generator is 227.9A, the maximum requirement of all installed load components in one business class carriage is 2.45kW, 3.532kVA, and 16.055A. The maximum requirements of all load components installed in one business and economy class restoration car are 1.141kW, 1.823kVA, and 8.283A. For the capacity of the economy class train generator with a capacity of 50kVA, the nominal current of the executive class generator is 75.96A, the maximum requirement of all installed load components in one economy class carriage is 0.856kW, 1.351kVA, and 6.141A.Translated with DeepL.com (free version)

Keywords: ***Electric Power Consumption of Executive Business and Economy Class Passenger Trains***

Introduction

Competition between modes of transportation is getting tighter, of course, it will affect the quality of service provided to customers who use transportation services. Each transportation company will compete to provide the best service to gain customers and a wider market share. The level of customer satisfaction is a top priority that becomes a benchmark for the success of every company, including PT Kereta Api Indonesia. For maintenance activities and maintenance of train facilities are usually carried out on a monthly, 3-monthly and semesterly schedule

This of course must be supported by the quality of human resources who are competent in their fields and a well-scheduled maintenance system or maintenance of Passenger trains, including maintenance and overcoming train air conditioning problems, maintenance of lights and other comfort support equipment such as LCD TVs and fans, PT Kereta Api Indonesia formed the Facilities Maintenance Division, in this case the passenger train depot owned by each Operating Region (DAOP) spread across Jawa and Sumatra.

On the basis of the above conditions, the purpose of this study is to analyze the power consumption on passenger trains so that it can be done for the generation system to be assembled with a maximum amount. This will be very useful when there is an extraordinary surge in passengers. In this study, calculations are made about the total power consumption that must be borne by passenger trains, measuring daily loads in each class of trains, knowing the power consumption capacity factor according to the amount of load borne by passenger trains.

Literature Review

Power is the energy expended to make an effort. In an electric power system, power is the amount of energy used to do work or effort. Electrical power is usually expressed in units of Watt or Horsepower (HP), Horsepower is a unit of electrical power where 1 HP is equivalent to 746 Watts or l bft/second. While Watt is a unit of electrical power where 1 Watt has a power equivalent to the power generated by multiplying a current of 1 Ampere and a voltage of 1 Volt. Power is expressed in P, Voltage is expressed in V and Current is expressed in I, so that the amount of power is stated.

S = V x I (1)

P = Volt x Ampere x Cos θ (2)

Where:

P = Power (Watt)

V = Voltage (Volt)

I = Current (Ampere)

CosΘ = Day factor

Then the total load components in one executive, business, and economy class train set were calculated

2.1 Power Factor

The use of electrical energy with a low power factor has a disadvantage because the value of reactive power (Q) is large enough to cause a greater need for apparent power (S) to meet the needs of active power (P). In other words, to meet the same active power needs, a larger power supply (S) is needed. To reduce these losses, it is necessary to improve the power factor to approach the ideal value of power factor = 1, usually improved to reach 0.95-0.98. In this study, the desired improvement in the power factor after the capacitor is installed is 0.98, so the following calculations are needed.

$$Q_1 = P.\tan\theta_1 \quad (3)$$

$$Q_2 = P.\tan\theta \quad (4)$$

$$Q_c = Q_1 - Q_2 \quad (3)$$

$$X_c = \frac{V_2}{Q_c} \tag{4}$$

$$C = \frac{1}{2.\pi.f.X_c} \tag{5}$$

Where:
Q_1 = Reactive power before installing capacitors
Q_2 = Reactive power after capacitor installation
Q_c = Output power of the capacitor
Θ_1 = Original phase angle
Θ_2 = Desired angle ($\cos^{-1}$ 0,98=11,48°)
P = Active power
X_c = Capacitive reactance
C = The size of the capacitor to be installed

2.2 Generation Generator Capacity

In determining the safety rating of the generator output according to PUIL 2000 article 5.6.1.2.3 which contains "Generators that work at 65 V or less and run by a separate motor, can be considered to have been protected by an overcurrent protection device that secures the motor, if this protection device works if the generator generates no more than 150 percent of the rated current at full load. The overcurrent of the generator used 150% as a multiplying factor of the nominal current (In) of the generator. The safety used is MCCB because MCCB has a large current rating and can be set according to needs. MCCB as a safety from short circuit current and overload current. MCCB used must be in accordance with the voltage rating of the generator, then the MCCB used in accordance with the voltage rating of the generator can be calculated with the following equation

$$I_n\, Genset = \frac{Generator\ Power\ (kVA)}{\sqrt{3}\, x\, V_{L-L}} \tag{6}$$

So

$$F_{Capacity} = \frac{\text{Average load}}{\text{Maximum capacity}} \tag{7}$$

Research Methodology

3.1 Train Daily Load

The power generator car is connected to other passenger cars using a Junction Box, which has 4 colors: red (R), yellow (S), blue (T), and black (neutral). There are 4 Junction Boxes per carriage that function to distribute current to the train cars to turn on air conditioners, TV sockets, exhaust fans, fans, lighting systems, and motto lights. The maximum current measurement in the executive, business and economy class train sets is carried out in the generator car. The configuration of the executive class train set has 1 locomotive, 7 K1 cars, 1 KM, and 1 BP.

Figure 1. Executive Class Circuit Configuration

The business class train has 1 locomotive, 8 K2 cars, and 1 KMP2

Figure 2. Business Class Suite Configuration

The economy class train has 1 locomotive, 10 K3 cars, and 1 KMP3

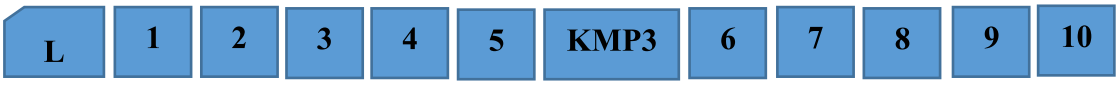

Figure 3. Economy Class Suite Configuration

The daily train load is the average load borne by the generating set in one day (24 hours). The measured current is obtained from the train generator current display and then recorded every hour while the train is traveling. The BP generator for the executive class is located in the KM car, the business class generator is located in the KMP2 car, and the economy class generator is located in the KMP3 car.

3.2 Maximum Quota of Carriages

Empirically, the maximum number of wagons that can be supplied by the generating wagon based on the nominal current data of the generator set and the maximum load current of each wagon can be calculated

$$N = \frac{I_N - I_{Max}KM}{I_{Max}K} \tag{8}$$

Where:

I_n = Nominal current of generator set
I_{Max} KM = Maximum flow of one restoration carriage
I_{max} K = Maximum flow of one passenger car

The nominal current (In) is the maximum current of the generator capacity used in the generator car. Executive class Argo trains use generators with a capacity of 500kVA, business class trains use generators with a capacity of 150kVA, and economy class trains use generators with a capacity of 50kVA

The maximum current of a restoration car (Imax KM) is the maximum current calculated from one restoration car. Executive class restoration wagons have the KM wagon code, while for business and economy classes with the KMP code

The maximum current of a passenger wagon (Imax K) is the maximum current calculated from all load components in one passenger wagon. For executive class with code K1, business class K2, and economy class K3

3.3 Executive Class Passenger Train Maximum Requirement

The load components in one executive class passenger train include: TL lamps, luggage lamps, reading lamps, exhaust fans, air conditioners, televisions or LCDs, motto lamps, and power sockets. The total maximum demand for one carriage can be seen in the table below:

Table 1. Maximum Demand For Executive Class Passenger Trains

Load	Voltage (V)	PF Cos Θ	Total Load	Power (W)	Total Power		Current
					W	VA	Ampere
20W TL lamp	220	0,42	30 units	20	600	1428,57	6,493
Trunk Light	220	0,42	28 units	40	392	933,33	4,242
Reading Lights	220	0,8	50 units	45	150	187,5	0,852
Exhaust Fan	220	0,8	2 units	18	36	45	0,204
AC	220	0,6	2 units	7150	14300	23830	36,205
Television	220	0,75	2 units	100	200	266,66	1,212
Motto Lights	220	1	10 units	14	140	140	0,636
Contact Stops	220	0,8	50 units		2112	2640	12
Total Installed					**17930**	**29471,1**	**61,844**

The maximum demand of all installed load components in one executive class carriage is 17.93kW, 29.471kVA, and 61.844A.

3.4 Maximum Requirement of Business Class Passenger Trains

The load components in one business class passenger car include: 20W and 40W TL lamps, exhaust fans, ceiling fans, motto lamps, and power sockets. The total maximum demand for one carriage can be seen in the table below.

Table 2. Maximum Demand For Business Class Passenger Trains

Load	Voltage (V)	PF Cos ϴ	Total Load	Power (W)	Total Power		Current
					W	VA	Ampere
20W TL lamp	220	0,4 2	4 Units	20	80	190,47	0,865
40W TL lamp	220	0,4 2	9 Units	40	360	857,14	3,896
Ceiling Fan	220	0,8	8 Units	45	108	450	2,045
Exhaust Fan	220	0,8	6 Units	18	104	135	0,613
Motto Lights	220	1	10 Units	14	104	140	0,636
Contact Stops	220	0,8	32 Units		8	1760	8
Total Installed					2456	3532,6 1	16,055

The maximum demand of all installed load components in one business class carriage is 2.45kW, 3.532kVA, and 16.055A.

3.5 Maximum Requirement of Economy Class Passenger Train

The load components in one economy passenger train include: 20W and 40W TL lamps, box fans, exhaust fans, and motto lamps. The total maximum demand for one economy carriage can be seen in the table below.

Table 3 Maximum demand for economy class passenger trains

Load	Voltage (V)	PF Cos ϴ	Total Load	Power (W)	Total Power		Curren t
					W	VA	Ampere
20W TL lamp	220	0,42	4	20	80	190,47	0,865
40W TL lamp	220	0,42	5	40	200	476,19	2,164
Box Fan	220	0,8	8	41	328	410	1,863
Exhaust Fan	220	0,8	6	18	108	135	,613
Motto Lights	220	1	10	14	140	140	0,636
Total Installed					**856**	**1351,6**	**6,141**

The maximum demand of all installed load components in one economy class carriage is 0.856kW, 1.351kVA, and 6.141A.

3.6 Maximum KM Carriage Requirement (Executive Class Restoration Room)

The load components in one executive class restoration car include: 20W and 40W TL lamps, exhaust fan, LCD, air conditioner, dispenser, refrigerator, and watchword lamp. The total maximum demand for one executive carriage can be seen in the table below

Table 3. Maximum Requirement of KM Carriages (Executive Class Restoration Room)

Load	**Voltage (V)**	**PF Cos Ɵ**	**Total Load**	**Power (W)**	**Total Power**		**Current**
					W	VA	Ampere
20W TL lamp	220	0,42	3 Units	20	60	142,8	0,649
40W TL lamp	220	0,42	11 Units	40	440	1047,62	4,761
Television	220	0,75	1 Units	100	100	133,33	0,606
Dispenser	220	0,6	2 Units	250	500	833,33	3,787
Refrigerator	220	0,87	2 Units	115	230	264,36	1,201
Exhaust Fan	220	0,8	5 Units	18	90	112,5	0,511
AC	380	0,6	2 Units	7150	14300	23830	36,205
Motto Lights	220	1	10 Units	14	140	140	0,636
Total Installed					**15860**	**26504**	**48,356**

The maximum demand of all load components installed in one executive class restoration carriage is 15.86kW, 26.504kVA, and 48.356A.

3.7 Maximum KMP Carriage Requirement (Business Class Restoration Room)

The load components in one business and economy class restoration car include: 20W TL lamps, exhaust fans, box fans, and motto lamps. The total maximum demand for one executive car can be seen in the table below

Table 4. Maximum KMP Carriage Requirements (Business Class Restoration Room)

Load	**Voltage (V)**	**PF Cos Ɵ**	**Total Load**	**Power (W)**	**Total Power**		**Current**
					W	VA	Ampere
20W TL lamp	220	0,42	15 Unit	20	300	714,28	3,246
Refrigerator	220	0,87	1 Units	115	115	132,18	0,6
Dispenser	220	0,6	1 Units	250	250	416,66	1,893
Exhaust Fan	220	0,8	5 Units	18	90	112,5	0,511
Box Fan	220	0,8	6 Units	41	246	307,5	1,397
Motto Lights	220	1	10 Units	14	140	140	0,636
Total Installed					**1141**	**1823,12**	**8,283**

The maximum requirements of all installed load components in one business and economy class restoration car are 1,141kW, 1,823kVA, and 8,283A.

Results and Discussion

4.1 Generating Genset Capacity

Executive class train generators with a capacity of 500kVA, have a nominal current of

$$I_n = \frac{\text{Generator Power}(kVA)}{\sqrt{3}xV_{L-L}} = \frac{500\,kVA}{\sqrt{3}x380V} = 0{,}759{,}68A$$

The nominal current of the executive class generator is 759.68A. While the business class train generator with a capacity of 150kVA, has the following nominal current

$$I_n = \frac{\text{Generator Power}(kVA)}{\sqrt{3}xV_{L-L}} = \frac{150\,kVA}{\sqrt{3}x380V} = 0{,}2279\,kA = 227{,}9A$$

The nominal current of the business class generator is 227.9A. For the capacity of the economy class train generator with a capacity of 50kVA, it has the following nominal current

$$I_n = \frac{\text{Generator Power}(kVA)}{\sqrt{3}xV_{L-L}} = \frac{50\,kVA}{\sqrt{3}x380V} = 0{,}7596\,kA = 75{,}96A$$

The nominal current of the executive class generator is 75.96A

4.2 Maximum Number of Carriages

4.2.1 Number of Executive Class Train Carriages

The Medan - Rantau Parapat Round Trip train with a departure schedule of 05.00 has a normal train set of 9 cars. The series consists of 7 passenger cars, 1 dining or restoration car, and 1 generator baggage car. The total load installed or connected in a series of Muria Executive Train is

$$P_{Total} = (\text{Number of wagons x Total Power K1}) + \text{Total Power KM}$$

$$= (7\,x\,17{,}93kW) + 15{,}86\,kW = 141{,}37kW$$

$$S_{Total} = (7\,x\,29{,}47\,kVA) + 26{,}5\,kVA = 232{,}79kVA$$

$$I_{Total} = (7\,x\,61{,}84A) + 48{,}356A = 481{,}23A$$

$$Cos\,\varphi = \frac{P}{S} = \frac{141{,}37}{232{,}79} = 0{,}61$$

Then the maximum number of passenger cars that can still be supplied by the generator car is

$$N = \frac{I_n - I_{Max}\,KM}{I_{Max}K1} = \frac{759{,}68 - 48{,}35}{61{,}84} = 11{,}5$$

Based on calculations using the equation above, the maximum number of passenger cars that can still be supplied by executive class generator cars is 11.5 cars, rounded up to 11 passenger cars

4.2.2 Number of Business Class Train Carriages

The business class train from Medan to Rantau Parapat with a departure schedule of 011.00 has a normal train set of 9 cars. The train consists of 8 passenger cars and 1 dining car or restoration plant. The total load installed or connected in one train set is

$$P_{Total} = (\text{Number of cars x Total power of K2}) + \text{Total power of KMP2}$$

$$= (8\,x\,2{,}45kW) + 1{,}14\,kW = 20{,}74kW$$

$$S_{Total} = (8\,x\,3{,}35\,kVA) + 1{,}823\,kVA = 30{,}06kVA$$

$$I_{Total} = (8\,x\,16{,}05A) + 8{,}283A = 136{,}683A$$

$$Cos\,\varphi = \frac{P}{S} = \frac{20{,}74}{30{,}06} = 0{,}69$$

The maximum number of cars that can still be supplied by the business class generator with a nominal generator load current (KMP2) of 227.9 A, the maximum current of one restoration car (KMP2) of 8.283 A, and the maximum current of one business class passenger car is 16.05 A. So that it can be calculated

$$N = \frac{I_n - I_{Max}\,KMP2}{I_{Max}K2} = \frac{227{,}9 - 8{,}283}{16{,}05} = 13{,}68$$

The maximum number of passenger cars that can still be supplied by business class generator cars is 13.68 cars, rounded up to 13 passenger cars.

4.2.3 Number of Economy Carriages

The economy class train to Rantau Parapat Medan with a departure time of 15.00 has a normal train set of 11 cars. The series consists of 10 passenger carriages and 1 dining carriage or restoration plant. The total load installed or connected in one series of economy class trains is

$$P_{Total} = (\text{Number of gebong x Total K3 Power}) + \text{Total KMP3 Power}$$
$$= (10\,x\,856W) + 1141W = 9{,}701kW$$
$$S_{Total} = (10\,x\,1351{,}66VA) + 1823{,}12VA = 15{,}323kVA$$
$$I_{Total} = (10\,x\,6{,}14A) + 3{,}283A = 69{,}683A$$
$$Cos\varphi = \frac{P}{S} = \frac{9{,}701}{15{,}323} = 0{,}63$$

The maximum number of cars that can still be supplied by the economy class generator with a nominal load current of the KMP3 generator set of 75.96 A, the maximum current of one restoration car (KMP3) is 8.283 A, and the maximum current of one economy class passenger car is 6.14 A. So that it can be calculated

$$N = \frac{I_n - I_{Max}\,KMP3}{I_{Max}K3} = \frac{75{,}96 - 8{,}283}{6{,}14} = 11{,}02$$

The maximum number of passenger cars that can still be supplied by economy class generator cars is 11.02 cars, rounded up to 11 passenger cars.

Conclusion

From the results that have been calculated in this study, it can be concluded as follow:

1. The maximum demand of all load components installed in one executive class carriage is 17.93kW, 29.471kVA, and 61.844A. Meanwhile, the maximum demand of all load components installed in one executive class restoration car is 15.86kW, 26.504kVA, and 48.356A. The executive class train generator has a capacity of 500kVA, has a nominal current of 759.68
2. The maximum demand of all installed load components in a single business class car is 2.45kW, 3.532kVA, and 16.055A. The maximum requirements of all load components installed in one business and economy class restoration car are 1.141kW, 1.823kVA, and 8.283A. Meanwhile, the business class train generator with a capacity of 150kVA with the nominal current of the business class generator is 227.9A
3. The maximum demand of all load components installed in an economy class car is 0.856kW, 1.351kVA, and 6.141A. For the capacity of the economy class train generator with a capacity of 50kVA, the nominal current of the executive class generator is 75.96A

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