

The 4th International Conference on Electrical Engineering and Informatics (ICEEI 2013)

Power Evaluation of Jakarta DC Railway Substation to Meet 1.2 Million Passengers per Day

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Abstract

Jakarta is a metropolitan city that continues to strive to develop the capacity of its mass transport as other large cities in the world, primarily the development of the rail-based transportation. Indonesia Railway Company (PT Kereta Api (Persero)) had forecasted that there will be 1.2 million passengers per day on Jakarta in 2019. To meet these targets, it is necessary to adequate the infrastructure planning, especially the capacity of the DC substations which supply the electric power to the trains. This paper will demonstrate the strategy used to determine the point of placement of new DC substation and/or existing DC substation upgrades throughout the Jakarta area from 2013 to 2019. The current railway timetable and the future pattern of railway operation plan are used to predict the possibilities of peak load spots along the track.

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Selection and peer-review under responsibility of the Faculty of Information Science & Technology, Universiti Kebangsaan Malaysia.

Keywords: Railway timetable, Jakarta, DC substation, 1500 kV, headway

1. Introduction

Jakarta as the central government of Indonesia continues to grow with its numerous problems. The complexity occurred on the various aspects bring the impact to the railroad mass transportation mean. As a good example, Tokyo has a network and well-organized modern infrastructure with an average distance of 1.5 km between the stations, with an easy access to the other stations and serves almost all of the community center. Stations serve not

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only just as a place to embark or disembark the passengers, but they have become a community center to meet their needs. As for Jakarta, the average number of passenger per day in 2012 reached 412,000 people. In fact, it is still quite far from the big cities having more than one million passengers per day. However, the Indonesia Railway Company - PT Kereta Api (Persero) – has done the estimation which states that in 2019, the amount of passenger will reach 1.2 million. This situation should be well anticipated [1].

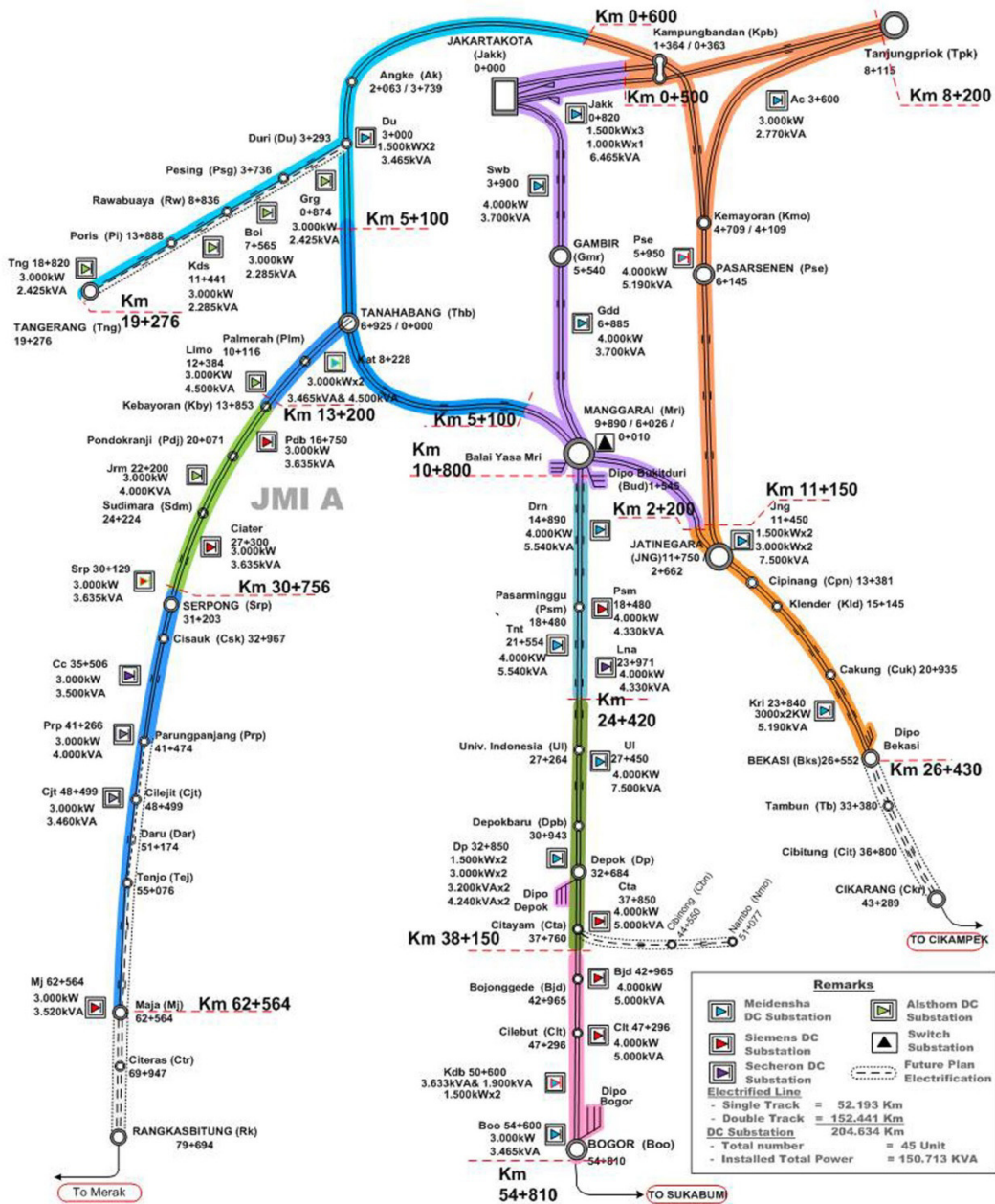


Fig. 1. Map of electric train electrification on Jakarta

The electric train system in Jakarta is using the DC 1500 V as the operating voltage. The map of the electric train system can be seen in the Fig. 1. The government is targeting the optimization of facilities and infrastructures so that by 2019, the electric trains will be able to transport 1.2 million passengers every day. Thus, there will be an addition of the number of trains that operate on a daily basis on every track, also the addition of train car sets which has an impact to higher power consumption. Therefore, it is necessary to evaluate the DC substations in order to meet the targets of 1.2 million passengers. Power upgrades as well as new DC substation installations are observed based on a safe operating voltage considering also the growth in passenger numbers in railway timetable.

2. Equivalent circuit of Jakarta DC railway catenary system

The distribution of the electric power to the traction unit is done using catenary system hanging on poles along the railroad. Most of the catenary systems in Jakarta railway are simple catenary single trolley wire type such as shown in Fig.2.



Fig. 2. Simple catenary single trolley wire

The overhead wires consist of trolley wire, messenger wire, and feeder wire connected in parallel which has the equivalent resistance is 0.0476 ohm/km. As for the rail, the resistance is 0.02398 ohm/km. The equivalent resistance R_L is sum of R_{ovh} and R_{rail} . Resistance values will affect the magnitude of the voltage drop in the system. The minimum voltage allowed to receive by electric train is defined by Indonesia Railway Company, i.e. $V_{min} \geq 4/5 V_n$ (1200V). Then the maximum power that can be received by the train is calculated by using Eq. (1) [2].

$$P = \frac{4V_n^2}{25R_L} \tag{1}$$

For a single DC substation by using Eq.1, the maximum power can received by the trains as a function of the train distance from a substation as shown in Fig.3.

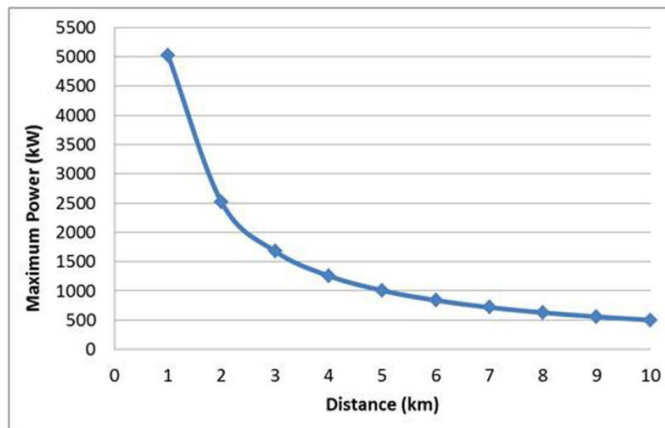


Fig. 3. Maximum power for $V \geq 4/5 V_n$ (1200V) criterion

If the electric train receives the power from two adjacent DC substations, in the worst case scenario where the position of electric train exactly in the middle (Fig.4), the DC substations will deliver the same amount of power.

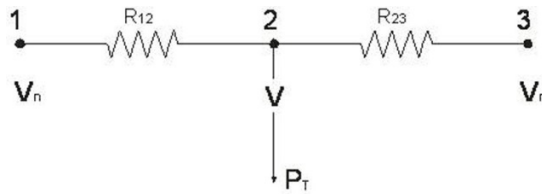


Fig. 4. Electric train supplied by two adjacent DC substations.

In the Jakarta and its surrounding areas (Jakarta, Bogor, Depok, Tangerang, and Bekasi – **Jabodetabek**), where the maximum distance between two adjacent DC substations is roughly 10 km, the maximum power that can be transferred to the train as a function of distance can be shown in Fig. 5.

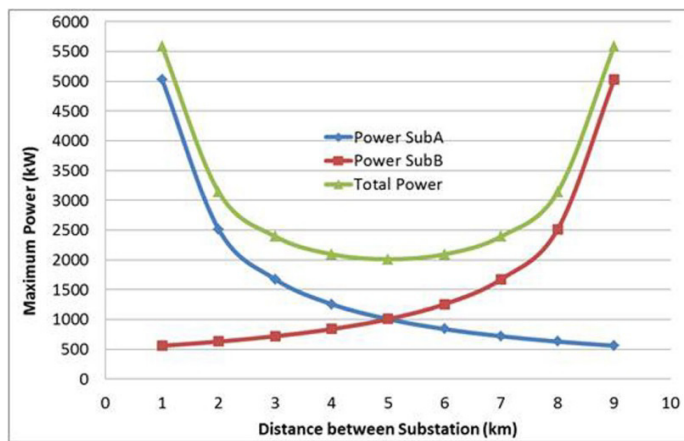


Fig. 5. Maximum power for two 10 km-separated substations

As an information, in the year of 2012, the nominal power of train set unit is 3,9 MW (8 cars) and in the 2015 will become 5 MW (10 cars). To satisfy this condition, the distance among DC substations should be less than or equal to 4 km. Therefore the maximum power is shown as in Fig. 6.

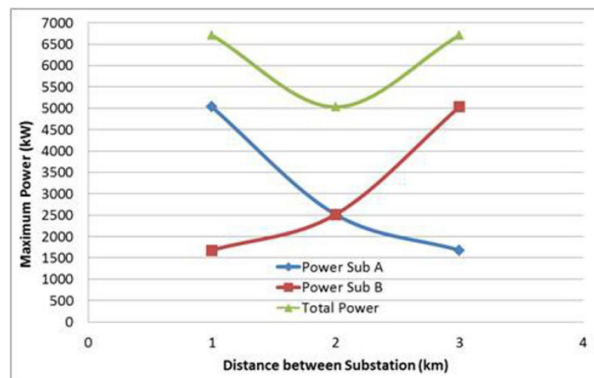


Fig. 6. Maximum power for two 4 km-separated substations

3. Railway timetable

To calculate the position of a train at a time accurately, including its speed and acceleration, it is necessary to use railway timetable. Railway time table is the schedule of the train journey that includes the operating time for passenger to embark or disembark at the train station. This timetable also includes the stop time of trains due to the tracks cross. In addition, the railway timetable will provide information about the track type whether is single track or double track. It can also be used to predict the peak electrical loads along the track, so the addition and/or upgrade of DC substation is possible to do. As an example, the railway timetable of Duri-Tangerang corridors (small part of the **Jabodetabek** area) year 2013 is shown in Fig.7 [3].

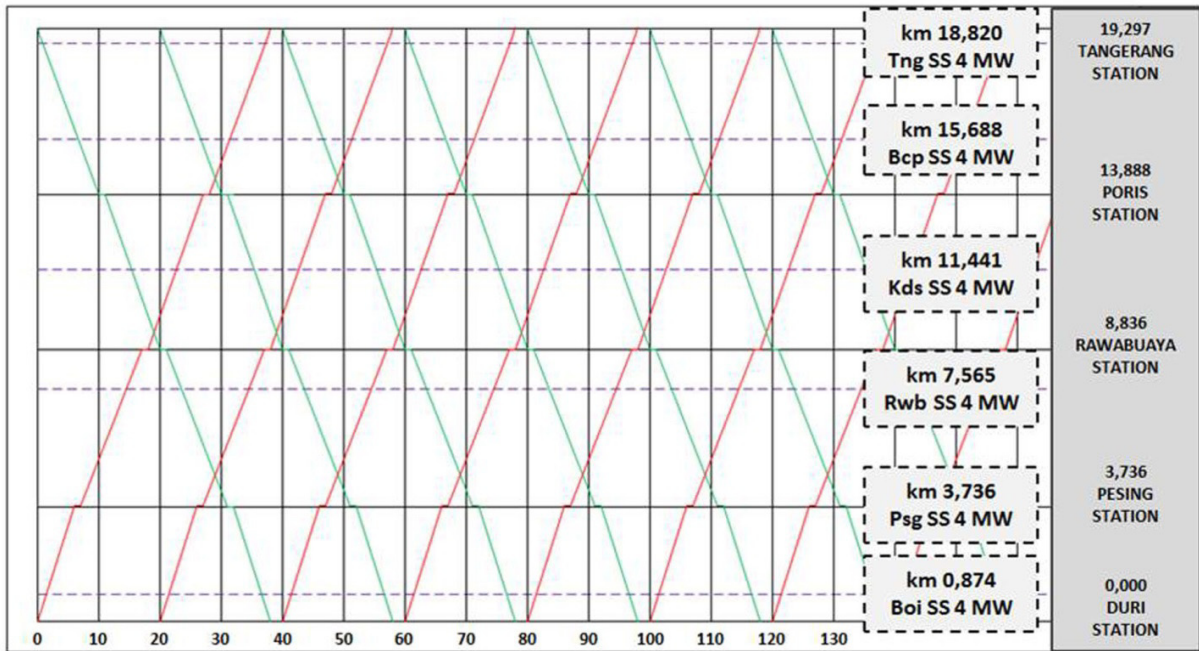


Fig. 7. The planned railway timetable of Duri-Tangerang corridors in year 2013

The x-axis represents the time of the train trip in minutes and the y-axis is the distance of a train trip in kilometers. The red line shows the train departing from Duri to Tangerang Station, while the green line shows the train departing from Tangerang to Duri station. On the right side, there are names of the stations and their distances along the tracks, while the boxes with a dotted line on the right side are the existing DC substations since year 2012. The pattern of train trip in 2013 as in Fig. 7 is based on the pattern in the year 2011 issued by the Director General of Railways, the Ministry of Transportation, Republic of Indonesia, while the train headway can be adjusted with the long-term plan of railway operation strategy. It can be seen that in Fig.7, the train headway in 2013 is 20 minutes. This number will continue to decline every year as the number of passenger increases.

4. Railway timetable prediction of Jakarta year 2019

As discussed earlier that the train headway will continue to decrease every year, meaning that there is increment of train frequency passing the tracks. Fig.8 shows the predicted conditions of Duri-Tangerang corridor in 2019 where the train headway has decreased to 8 minutes. Such prediction method will be used to determine the placement of the new substation and / or upgrade the existing substation.

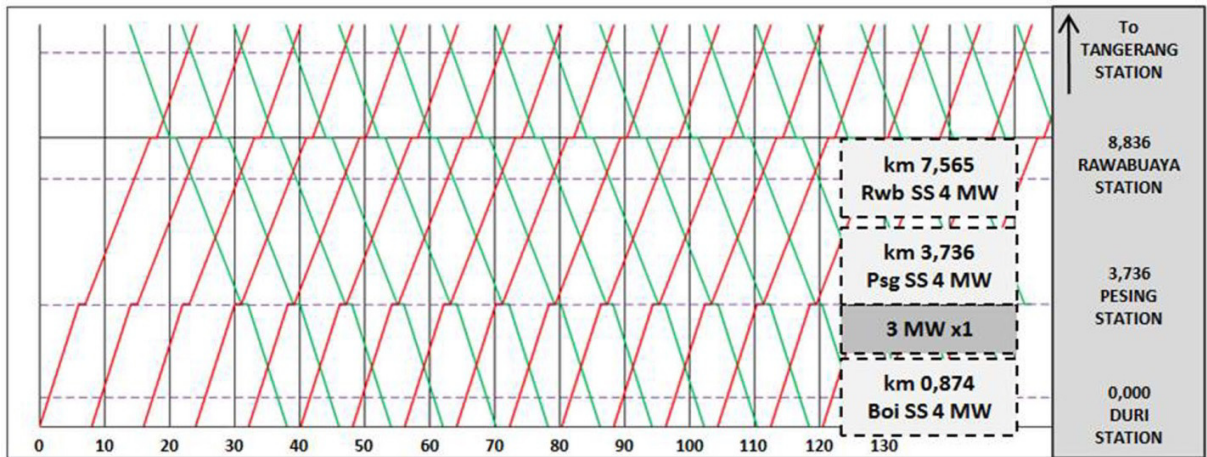


Fig. 8. The railway timetable of Duri-Tangerang corridors year 2019

5. Discussion and analysis

The placement of new substation position and / or upgrades will be prioritized to solve the following issues:

5.1 Peak load point (near station)

Based on the study, the highest load throughout the track is founded at the stations, because this is the place which allows two trains start simultaneously as will happen frequently in Duri – Tangerang corridor (according fig. 8). This will happen for the first time in the year 2016 at Pesing station. Since then, the addition of DC substation with 3-MW capacity is performed at the Pesing station. These events continue to occur until 2019 as shown in fig.8.

5.2 Crossing point between two trains (between station)

A cross between two trains can also be considered as the second peak load, due to power supply required for both trains at the crossing point. The case is identified at the Tanahabang-Citeras corridor in 2019 (see fig.9), where there is a cross happening between Tenjo and Cilejit station. The situation will also get worse when two trains at Cilejit and one train at Tenjo start simultaneously at the time of the crossing occurs.

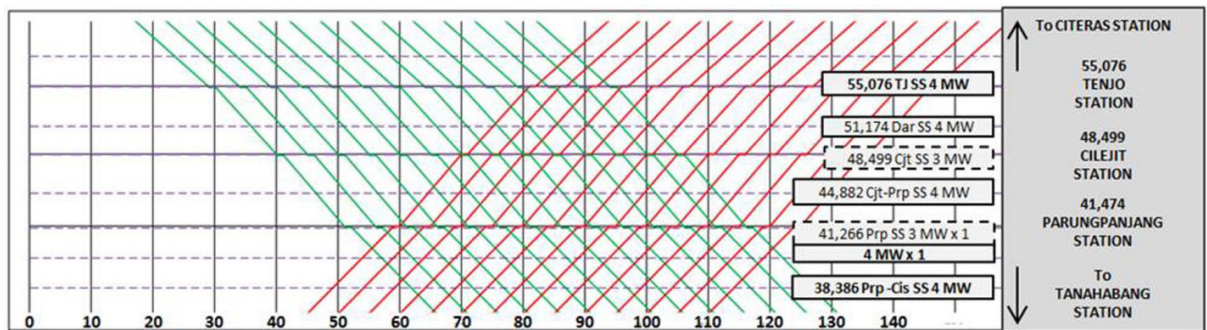


Fig. 9. The railway timetable of Tanahabang-Citeras corridors year 2019

If the DC substation in Cilejit (Cjt SS) must supply two trains at the Cilejit station and the DC substation at Tenjo (TNJ SS) must supply the trains at Tenjo station, then the two trains which crossing at Daru will experience a lack of power supply. Therefore, it is necessary to added 4 MW DC substations in Daru (Dar SS).

5.3 Reducing the voltage drop across the catenary system

Voltage drop is one of the most important technical factors to consider in determining the placement of a new substation [4]. Bekasi-Jatinegara is the corridor having the longest distance between substations (about 12 km in the year 2012, see Fig.1). Based on [5], such distance is still in the economic category especially for the 1500 V system. However, in Jabodetabek area, this condition has already caused the low voltage received by train, even lower than the standard value. It is important to give a serious attention to this voltage drop in order to have a longer lifetime for the semiconductor based components due to higher current [6]. To keep the voltage higher than 1200V, the maximum distance between two substations should be maximum at 4 km.

6. Conclusion

The Indonesia Railway Company predicts that there will be 1.2 million train passengers per day in 2019 at Jakarta. To anticipate this situation, it is necessary to have a good infrastructure readiness, such as the DC substations. This paper presented a strategy for laying a DC substation by considering long-term development of train operation patterns. The operation pattern is then used to predict the future railway timetable. Through the railway timetable, the peak load points such as simultaneous start or train crossing event can be found. This method is very suitable to determine the placement of new substations and / or upgrade existing substations.

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