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Power Plant Clustering in Indonesia by using k-Means

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Abstract: There are two problems in Indonesian electricity statistical report that are published by the Ministry of Energy and Mineral Resources. First, most of these reports are presented in tabular form. Second, these reports are independent and have not been related to other data, yet such as geographic and demographic data. So, these reports are still difficult to be analyzed. In this research, we proceed and analyze the Indonesian power plant installed capacity data that is published by the Ministry of Energy and Mineral Resources. This data then is combined with the demographic and geographic data. The main research is to mapping the distribution of the installed capacity of power plants based on provinces. In this research, we use k-means clustering as the basis clustering method. The analyzed data is the installed capacity of the PLN's power plants, both they are owned or rented. Based on the clustering result there are several findings in installed capacity of power plants in Indonesia. First, there are significant gap between provinces in the island of Java and provinces outside the island of Java. PLN's owned power plants dominate in Java while PLN's rented power plants dominate in outer Java. DI Yogyakarta is not only behind any provinces in the island of Java but also behind lots of provinces in Indonesia provinces in Sumatera are promising to competing East Java and Central Java.

Key words: Power plant, installed capacity, electricity, k-means clustering, Indonesia, several findings

INTRODUCTION

Indonesia is the world largest island country which its size is 1,904,569 km^2. There are more than thirteen thousand islands. This country is also very populous with over 261 million people. One big problem that occurs in Indonesia is the equality, especially in the development progress. Some area such as Java reaches very fast development while others such as Kalimantan, Sulawesi and Papua suffer from development and welfare. This condition also occurs in infrastructure sector. People in Java enjoy prominent infrastructure while people outer Java suffers from infrastructure both in quantity and quality aspects. One infrastructure that is very important to support the development is electricity. Adequate and stable electricity supply is important to support development and to attract investment.

One aspect that can be used to analyze the equality of electricity supply is the existence, capacity and distribution of the power plants. Unfortunately, works in analyzing electricity supply in Indonesia is very few. Cornot-Gandolphe studied the relationship between the Indonesia's electricity demand and the supply in the coal sector. In her research, Cornot-Gandolphe (2017) explains the plan to expand the power sector, the 35,000 MW program, the condition and prospect of the coal powered power plants in Indonesia and the coal industry and regulation in Indonesia. Adam and Sambodo (2015) have analyzed that the electrification ratio and electricity consumption per capita in Indonesia is relatively low compared with other middle income countries. They also said that Indonesia failed to provide sufficient electricity supply so that, the government must maintain and develop new electricity infrastructure (Adam and Sambodo, 2015). Unfortunately, PLN's infrastructure cannot meet this challenge to supply rapid increase in electricity demand (Adam and Sambodo, 2015). Burke and Kurniawati (2018) announced that the electricity subsidy reform in Indonesia has given PLN some breathing space to scale up its capacity (Marquardt, 2014). Marquardt (2014) found that in Indonesia, renewable energy played marginal role as source for electricity. This condition occurs because of the lack of awareness of the local representatives in developing and promoting renewable energy in Indonesia and the key obstacles in promoting the renewable energy is politics (Marquardt, 2014). Tharakan (2015) strengthened these findings by announcing that fossil fuels includes oil, coal and gas, still play the significant role in the energy mix in Indonesia. Meanwhile, renewable energy contributes <5% (Tharakan, 2015). Research that was held by World Bank also announced the inability of PLN to supply adequate electricity in Indonesia (Jayawardena, 2005). In the

electrification rate aspect, Bali got the highest one, so that, this province beaten any provinces in the island of Java (Jayawardena, 2005). In the other side, Papua got the lowest one (Jayawardena, 2005). Based on these problems, we analyze the distribution of electricity supply by clustering the installed capacity of the power plants in Indonesia. The purpose of this research is to give better analyzes and perspectives in the distribution of the installed capacity of power plants in Indonesia. This analysis is not independent only in the installed capacity aspect but also is related to the demographic and geographic aspect.

In this researcher, we use k-means clustering method as the basis method. It is because k-means clustering method is a popular method to cluster quantitative data. This method has been adopted in many fields. Nasution *et al.* (2019) introduces the extended k-means clustering method in generating similarity cluster in Indonesian ethnic languages. In his researcher, he concludes that five clusters as the best clusters of Indonesian ethnic languages (Nasution *et al.*, 2019). used improved k-means clustering in analyzing relationship in multiple social networks (Virmani *et al.*, 2017). In their researcher, they found that the ensemble k-means clustering performs 70% better than the fix value of k-means (Virmani *et al.*, 2017). Sahu *et al.* (2017) compared k-means and adaptive k-means clustering in image segmentation work. In their researcher, they proof that adaptive k-means method performs better than basic k-means does (Sahu *et al.*, 2017). Huang *et al.* (2005) used k-means type clustering in data mining application. Singh *et al.* (1996) used k-means clustering in segmenting functional MRI. The objects in this work are blood vessel and microvasculature (Singh *et al.*, 1996).

MATERIALS AND METHODS

In this researcher, installed capacity of the power plants data is taken from the book of electricity statistic number 30-2017 that was published by the Ministry of Energy and Mineral Resources of Indonesia (Anonymous, 2017). There are two tables in this book that we use. The first table is the PLN's installed capacity of power plant by type and by region (MW) 2016. The second table is the PLN's installed capacity rented by type of power plant and by region 2016 (MW). In these tables, the installed capacity is presented in mega watt (MW). The installed capacity is grouped by provinces. The installed capacity is also grouped by the type of the power plant. Besides the electricity data, we also use demographic and geographic data. This data is taken from The book of data and information of Indonesia Health Profile 2017 (Anonymous, 2018). This book is published by the Ministry of Health of Indonesia. For demographic and geographic data, we use table of resident population estimation, area size and resident density by provinces year 2017. Even this demographic data is 1 year after the electricity data, we assume that the difference between resident population in year 2016 and 2017 is not, so different so that the work will be still relevant.

In this researcher, we use basic k-means clustering. In the basic k-means clustering, the goal is grouping the population so that, the group is stable and the total distance between the member and their centroid is minimal. As a basic k-means clustering, the clustering step is as follows. At the first time, centroids are placed randomly. In this researcher, the centroids will be placed in any members' position randomly. After initial centroids location is determined, the next process is the iteration. During the iteration, each population member will be dispatched to the nearest centroid. After all members have been dispatched, the total member-centroid distance is calculated. Then, the centroids will be moved to the center of their members. Then, the iteration is repeated. The iteration stops if the minimal total member-centroid distance is reached.

RESULTS AND DISCUSSION

The k-means clustering method then is implemented into web based clustering application. This application is developed by using PHP language. The source data is stored in MySQL database system. In this researcher, we cluster five data: installed capacity of PLN's owned power plants, installed capacity of PLN's rented power plants, installed capacity of total PLN power plants, ratio between the total installed capacity and the province size and ratio between the total installed capacity and the province population. The data is grouped by provinces. There are two clustering works that are done for each data: three centroid clustering and five centroid clustering.

In the first clustering, we cluster the installed capacity of PLN's owned power plants. In this clustering, the observed data for each cluster are: total capacity, number of members, average capacity, minimum capacity, maximum capacity and list of provinces. The three centroid clustering result is shown in Table 1 while the five centroid clustering result is shown in Table 2.

Based on data in Table 1, it is shown that there is significant gap in installed capacity of PLN's owned power plant distribution in Indonesia. In the first cluster, the average installed capacity of is 276.43 MW while the

Table 1: Three centroid PLN's installed capacity of power plant clustering result

Cluster No.	Total capacity (MW)	Number of members	Average capacity (MW)	Minimum capacity (MW)	Maximum capacity (MW)	List of provinces
1	6,910.68	25	276.43	0.32	670.83	Aceh, Riau Island, Bengkulu, Jambi, South Sumatera, Bangka Belitung, DI Yogyakarta, Bali, West Kalimantan, Central Kalimantan, South Kalimantan, East Kalimantan, North Kalimantan, North Sulawesi, Gorontalo, Central Sulawesi, West Sulawesi, South Sulawesi, South East Sulawesi, West Nusatenggara, East Nusatenggara, Maluku, North Maluku, Papua, West Papua
2	7,688.21	5	1,537.64	774.81	3,068.78	North Sumatera, West Sumatera, Riau, Lampung, Central Java
3	22,493.18	4	5,623.29	3,748.40	6,309.80	Banten, DKI Jakarta, West Java, East Java

Table 2: Five centroid PLN's installed capacity of power plant clustering result

Cluster No.	Total capacity (MW)	Number of members	Average capacity (MW)	Minimum capacity (MW)	Maximum capacity (MW)	List of provinces
1	1,038.52	11	94.41	0.32	189.78	Riau Island, DI Yogyakarta, North Kalimantan, Gorontalo, Central Sulawesi, West Sulawesi, South East Sulawesi, Maluku, North Maluku, Papua, West Papua,
2	3,310.89	10	331.09	216.80	445.58	Bengkulu, Jambi, Bangka Belitung, West Kalimantan, Central Kalimantan, South Kalimantan, North Sulawesi, South Sulawesi, West Nusatenggara, East Nusatenggara,
3	4,920.95	7	702.993	626.51	809.07	Aceh, West Sumatera, Riau, South Sumatera, Lampung, Bali, East Kalimantan,
4	9,076.93	3	3,025.64	2,259.75	3,748.40	North Sumatera, DKI Jakarta, Central Java
5	18,744.78	3	6,248.26	6,164.62	6,309.80	Banten, West Java, East Java

Table 3: Three centroid PLN's installed capacity of rented power plant clustering result

Cluster No.	Total capacity (MW)	Number of members	Average capacity (MW)	Minimum capacity (MW)	Maximum capacity (MW)	List of provinces
1	86.94	12	7.25	0.000	30.82	Bengkulu, Banten, DKI Jakarta, West Java, Central Java, DI Yogyakarta, East Java, North Kalimantan, Gorontalo, West Sulawesi, North Maluku, West Papua
2	1,687.18	15	112.48	76.250	205.00	West Sumatera, Riau Island, Jambi, Bangka Belitung, Lampung, Central Kalimantan, South Kalimantan, North Sulawesi, Central Sulawesi, South Sulawesi, South East Sulawesi, West Nusatenggara, East Nusatenggara, Maluku, Papua
3	2,277.81	7	325.40	246.97	368.55	Aceh, North Sumatera, Riau, South Sumatera, Bali, West Kalimantan, East Kalimantan

average installed capacity in the second cluster is 1,537.64 MW and in the third cluster is 3,748.40 MW. It means that the gap in average installed capacity between the first cluster and other clusters is very big. In the number of member aspect, the first cluster contains 25 provinces while other provinces are distributed into other two clusters. Most of installed capacity is concentrated in the third cluster that contains only four provinces. All provinces in the third cluster are in island of Java. Meanwhile, all provinces in the first cluster except DI Yogyakarta is outer the island of Java.

Based on data in Table 2, it is shown that when five centroids are used, the installed capacity of PLN's owned power plants are distributed better. The number of members in the first cluster and the second cluster is almost equal. The number of members in the fourth cluster and in the fifth cluster is equal. By comparing with data in Table 1 and 2, the members of the third cluster comes from some members of the first cluster and some members of the third cluster in Table 1. Unfortunately, the gap in installed capacity is still high. The total capacity in the fifth cluster is approximately eighteen times the total capacity in the first cluster. The total capacity in the fifth cluster is approximately twice the total capacity in the fourth cluster which this cluster is right before the fifth cluster.

In the second clustering, we cluster the installed capacity of PLN's rented power plants. In this clustering, the observed data for each cluster are: total capacity, number of members, average capacity, minimum capacity, maximum capacity and list of provinces. The three centroid clustering result is shown in Table 3 while the five centroid clustering result is shown in Table 4.

Based on data in Table 3, the gap among clusters in the PLN's rented power plants is not, so, high. The number of members in the first cluster is almost equal to in the second cluster while the number of members in the second cluster is approximately twice higher than in the

Table 4: Five centroid PLN's installed capacity of rented power plant clustering result

Cluster No.	Total capacity (MW)	Number of members	Average capacity (MW)	Minimum capacity (MW)	Maximum capacity (MW)	List of provinces
1	86.94	12	7.25	0.000	30.82	Bengkulu, Banten, DKI Jakarta, West Java, Central Java, DI Yogyakarta, East Java, North Kalimantan, Gorontalo, West Sulawesi, North Maluku, West Papua
2	797.96	9	88.66	76.25	100.00	West Sumatera, Riau Island, Bangka Belitung, Lampung, North Sulawesi, Central Sulawesi, East Nusatenggara, Maluku, Papua
3	499.72	4	124.93	118.98	132.00	Jambi, Central Kalimantan, South Kalimantan, South East Sulawesi
4	636.47	3	212.16	184.50	246.97	West Kalimantan, South Sulawesi, West Nusatenggara
5	2,030.84	6	338.47	309.00	368.55	Aceh, North Sumatera, Riau, South Sumatera, Bali, East Kalimantan

Table 5: Three centroid PLN's installed capacity of total power plant clustering result

Cluster No.	Total capacity (MW)	Number of members	Average capacity (MW)	Minimum capacity (MW)	Maximum capacity (MW)	List of provinces
1	12,954.80	28	462.67	0.32	1,143.36	Aceh, West Sumatera, Riau, Riau Island, Bengkulu, Jambi, South Sumatera, Bangka Belitung, Lampung, DI Yogyakarta, Bali, West Kalimantan, Central Kalimantan, South Kalimantan, East Kalimantan, North Kalimantan, North Sulawesi, Gorontalo, Central Sulawesi, West Sulawesi, South Sulawesi, South East Sulawesi, West Nusatenggara, East Nusatenggara, Maluku, North Maluku, Papua, West Papua
2	9,432.50	3	3,144.17	2,615.32	3,748.40	North Sumatera, DKI Jakarta, Central Java
3	18,756.70	3	6,252.23	6,176.54	6,309.80	Banten, West Java, East Java

Table 6: Five centroid PLN's installed capacity of total power plant clustering result

Cluster No.	Total capacity (MW)	Number of members	Average capacity (MW)	Minimum capacity (MW)	Maximum capacity (MW)	List of provinces
1	171.10	5	34.22	0.32	93.22	DI Yogyakarta, North Kalimantan, West Sulawesi, North Maluku, West Papua
2	2,326.76	9	258.52	155.11	332.69	Riau Island, Bengkulu, Bangka Belitung, Gorontalo, Central Sulawesi, South East Sulawesi, East Nusatenggara, Maluku, Papua
3	5,445.59	9	605.07	426.02	909.07	West Sumatera, Jambi, Lampung, West Kalimantan, Central Kalimantan, South Kalimantan, North Sulawesi, South Sulawesi, West Nusatenggara
4	10,695.45	7	1,527.92	936.27	3,068.78	Aceh, North Sumatera, Riau, South Sumatera, Central Java, Bali, East Kalimantan
5	22,505.10	4	5,626.28	3,748.40	6,309.80	Banten, DKI Jakarta, West Java, East Java

third clusters. Unfortunately, the gap in installed capacity is different. The total capacity gap between the second cluster and the third cluster is not so wide but the average capacity in the third cluster is almost three times than in the second cluster. Unfortunately, the installed capacity gap between the first cluster and other clusters is very wide. The total installed capacity in the second cluster is approximately seventeenth times higher than in the first cluster. The average installed capacity in the second cluster is approximately sixteenth times higher than in the first cluster.

By comparing data in Table 3 and 4, it is shown that the members of the first cluster in Table 3 are also the members of the first cluster in Table 4. Meanwhile, the members of the second cluster and of the third cluster in Table 3 are distributed from the second cluster to the fifth cluster in Table 4. The interesting part in Table 4 is that all provinces in the island of Java are in the first cluster. Meanwhile, all members in the second cluster to in the fifth cluster are out of the island of Java. It can be said the private sector is more active to build power plant in the areas that are outer the island of Java rather than in the island of Java. As it is common that private sector is interested in profit and prospect, so, it also can be said that building the power plant outer the island of Java is more profitable and more prosperous rather than in the island of Java.

In the third clustering, we cluster the installed capacity of total PLN's power plants both it is owned or is rented. In this clustering, the observed data for each cluster are: total capacity, number of members, average capacity, minimum capacity, maximum capacity and list of provinces. The three centroid clustering result is shown in Table 5 while the five centroid clustering result is shown in Table 6.

Based on data in Table 5, it is shown that when the total installed capacity of power plants is clustered, the gap among clusters is narrower. Compared with result in Table 1, it is shown that the number of members in the first cluster in Table 5 is more than the number of members in the first cluster in Table 6. In Table 1, the average capacity of the first cluster is 4.92% of the average

Table 7: Three centroid total capacity to area size ratio of installed capacity of power plant clustering result

Cluster No.	Number of members	Average capacity (MW/km^2)	Minimum capacity (MW/km^2)	Maximum capacity (MW/km^2)	List of provinces
1	30	0.02	9.41×10^{-5}	0.13	Aceh, North Sumatera, West Sumatera, Riau, Riau Island, Bengkulu, Jambi, South Sumatera, Bangka Belitung, Lampung, Central Java, DI Yogyakarta, East Java, West Kalimantan, Central Kalimantan, South Kalimantan, East Kalimantan, North Kalimantan, North Sulawesi, Gorontalo, Central Sulawesi, West Sulawesi, South Sulawesi, South East Sulawesi, West Nusatenggara, East Nusatenggara, Maluku, North Maluku, Papua, West Papua
2	3	0.33	0.17	0.65	Banten, West Java, Bali
3	1	5.65	5.65	5.65	DKI Jakarta

Table 8: Five centroid total capacity to area size ratio of installed capacity of power plant clustering result

Cluster No.	Number of members	Average capacity (MW/km^2)	Minimum capacity (MW/km^2)	Maximum capacity (MW/km^2)	List of provinces
1	9	0.002	9.41×10^{-5}	0.0042	DI Yogyakarta, West Kalimantan, Central Kalimantan, North Kalimantan, Central Sulawesi, West Sulawesi, North Maluku, Papua, West Papua
2	11	0.010	0.006	0.015	Riau, Bengkulu, Jambi, South Sumatera, South Kalimantan, East Kalimantan, Gorontalo, South Sulawesi, South East Sulawesi, East Nusatenggara, Maluku
3	10	0.044	0.016	0.129	Aceh, North Sumatera, West Sumatera, Riau Island, Bangka Belitung, Lampung, Central Java, East Java, North Sulawesi, West Nusatenggara
4	3	0.333	0.169	0.653	Banten, West Java, Bali
5	1	5.645	5.645	5.645	DKI Jakarta

Table 9: Three centroid total capacity to population ratio of installed capacity of power plant clustering result

Cluster No.	Number of members	Average capacity (MW/person)	Minimum capacity (MW/person)	Maximum capacity (MW/person)	List of provinces
1	11	5.66×10^{-5}	8.51×10^{-5}	0.000102	Central Java, DI Yogyakarta, North Kalimantan, Central Sulawesi, West Sulawesi, South Sulawesi, West Nusatenggara, East Nusatenggara, North Maluku, Papua, West Papua
2	20	0.000155	0.000103	0.000233	Aceh, North Sumatera, West Sumatera, Riau, Riau Island, Bengkulu, Jambi, South Sumatera, Bangka Belitung, Lampung, West Java, East Java, Bali, West Kalimantan, Central Kalimantan, South Kalimantan, North Sulawesi, Gorontalo, South East Sulawesi, Maluku
3	3	0.000383	0.000281	0.000507	Banten, DKI Jakarta, East Kalimantan

capacity of the third cluster. Meanwhile, in Table 5, the average capacity of the first cluster is 7.40% of the average capacity of the third cluster. In Table 1, the total capacity of the first cluster is 30.72% of the total capacity of the third cluster. Meanwhile, in Table 5, the total capacity of the first cluster is 69.06% of the total capacity of the third cluster. As it is known that the most of members in the first cluster are out of the island of Java, it can be said that the contribution of the private power plant is significant in reducing power capacity gap between provinces out of island of Java and provinces in the island of Java. Based on data in Table 6, it is shown that even the gap among clusters in installed capacity of total power plant is narrower, the gap between the the third cluster and other clusters is still wide. When five centroids are used in this clustering process, the number of members in the third cluster is almost similar with the clustering process that uses three centroids. Meanwhile, the twenty eight provinces in the first cluster in Table 5 are distributed into the first cluster to the fourth cluster in Table 6. Unfortunately, when five centroids are used, it is shown that in total power plants clustering result, the average capacity between the first cluster and the fifth cluster is very wide. The average capacity of the first cluster is only 0.6% of the fifth cluster.

In the fourth clustering, we cluster the ratio of the installed capacity of total PLN's power plants (owned or is rented) to the province size. In this clustering, the observed data for each cluster are: number of members, average capacity per size, minimum capacity per size, maximum capacity per size and list of provinces. The three centroid clustering result is shown in Table 7 while the five centroid clustering result is shown in Table 8 and 9.

Based on data in Table 7, it is shown that the gap among clusters is very wide. There is only one member in the third cluster which is DKI Jakarta that is known as the center of gravity of economy in Indonesia. In the second cluster there are three provinces. By excluding Bali, both Banten and West Java are provinces with powerful industrial activities and the location of these two provinces are side by side with Jakarta. Meanwhile, the rest of provinces are grouped in the first cluster. By comparing the average capacity per area size between clusters, it is shown that the gap between the first and the

Table 10: Five centroid total capacity to population ratio of installed capacity of power plant clustering result

Cluster No.	Number of members	Average capacity (MW/person)	Minimum capacity (MW/person)	Maximum capacity (MW/person)	List of provinces
1	3	4.82×10^{-6}	8.51×10^{-8}	1.03×10^{-5}	DI Yogyakarta, North Kalimantan, West Sulawesi
2	7	7.25×10^{-5}	5.37×10^{-5}	8.96×10^{-5}	Central Java, Central Sulawesi, South Sulawesi, West Nusatenggara, East Nusatenggara, North Maluku, Papua
3	14	0.00013	0.00010	0.00016	West Sumatera, Riau Island, Bengkulu, Jambi, South Sumatera, Lampung, West Java, East Java, West Kalimantan, South Kalimantan, Gorontalo, South East Sulawesi, Maluku, West Papua
4	8	0.00021	0.00017	0.00028	Aceh, North Sumatera, Riau, Bangka Belitung, Bali, Central Kalimantan, East Kalimantan, North Sulawesi
5	2	0.00043	0.00036	0.00051	Banten, DKI Jakarta

second cluster and the third cluster is very wide. The average capacity per area size of the first cluster is only 0.35% of the third cluster. Meanwhile, the average capacity per area size of the first cluster is only 5.84% of the third cluster.

Based on data in Table 8, it is shown that the gap between the first cluster and other clusters is very wide. When the five centroids are used, there is not any change in the second cluster and the third cluster compared with the clustering result when three centroids are used. These thirty provinces in the first cluster in Table 7 are distributed into first three clusters in Table 8. Central Java and East Java are in the third cluster. Meanwhile, DI Yogyakarta is the only province in the island of Java that is in the first cluster. Meanwhile, there is not any province in Sumatera in the first cluster. It can be said that in total capacity to province size ratio, even DI Yogyakarta is in the island of Java, it is worse than any provinces in the island of Sumatera.

In the fifth clustering, we cluster the ratio of the installed capacity of total PLN's power plants (owned or is rented) to the province population. In this clustering, the observed data for each cluster are: number of members, average capacity per person, minimum capacity per person, maximum capacity per person and list of provinces. The three centroid clustering result is shown in Table 9 while the five centroid clustering result is shown in Table 10.

Based on data in Table 9, it is shown that in the total capacity to population ratio parameter, there is not any gap between provinces in the island of Java and provinces outside the island of Java. Provinces in the the island of Java are distributed in all clusters. In the third cluster, there are Banten and DKI Jakarta. In the second cluster, there are West Java and East Java. In the first cluster, there are DI Yogyakarta and Central Java. There are two interesting findings in this result. First, there is not any provinces in the island of Sumatera is in the first cluster because all of provinces in the island of Sumatera are in the second cluster. Second, East Kalimantan is in the third cluster.

Based on data in Table 10, there is dynamics in provinces distribution. In the fifth cluster, there are Banten and DKI Jakarta because East Kalimantan is moved to the fourth cluster. West Java and East Java are still in the middle cluster. Central Java is in the second cluster. Unfortunately, DI Yogyakarta is still in the first cluster which means that DI Yogkakarta is always behind any other provinces in the island of Java. There are two positive research findings. First, there is not any provinces in the island of Sumatera is in the first two clusters because these provinces are distributed into the third cluster and the fourth cluster. Second, there is not any provinces in the island of Papua is in the first cluster. Papua is in the second cluster while West Papua is in the third cluster.

CONCLUSION

Based on the explanation above, this research provides better perspective in analyzing the distribution of the installed capacity of the power plants in Indonesia. There are several research findings due to this work. PLN's owned power plants dominate the installed capacity in provinces in the island of Java. Meanwhile, private power plants dominate the installed capacity in provinces outside the island of Java. The existence of these private power plants gives significant contribution in reducing the installed capacity gap between provinces in the island of Java and provinces outside the island of Java. The installed capacity gap between DKI Jakarta and any other provinces in Indonesia is very wide so that, it should be reduced to create better equality among provinces. In all aspects in this researcher, DI Yogyakarta is always behind any other provinces in the island of Java. DI Yogyakarta is also behind most of provinces in the island of Sumatera. Many provinces in Sumatera are promising to compete with East Java and West Java.

RECOMMENDATIONS

There are many future research potentials in mapping and analyzing electricity condition in Indonesia by using

machine learning methods. Besides clustering, some machine learning methods can be used to predict the electricity condition in Indonesia that includes: supply, demand and distribution. Any deeper researches such as mapping the power plant type or electricity consumption based on the sector are also interesting, so that, it can contribute for better development in Indonesia.

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