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Power Transformer Loading Analysis in order to improve the Reliability of a Substation

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Abstract – *This paper presents the power transformer loading analysis in order to improve the reliability of a substation. The substation that was the location of the study was the 150/20 KV Kentungan Substation, Sleman, Yogyakarta Special Region. Power transformers are the most important electrical equipment in a substation. The power transformer functions as a provider of electrical energy that has been transmitted from the power plant to then be channeled to electricity loads. In its operational it is very important to know the capacity and capacity of power transformers in serving electric loads for decades to come, with the aim that the electric power service can take place well. Therefore, the forecasting of the power transformer is important to know in the framework of the operational planning of a good substation. The results of the study indicate that the peak load of power transformers in the period 2014 to 2016 is still in a safe level, where the maximum peak load is 93% of the total capacity of the transformer. However, it is recommended that the power transformer capacity be planned to begin to anticipate the growth of loads in the coming years.*

Keywords: *Power transformer, loading, substation, peak load*

I. Introduction

Electrical power cannot be separated from human life today where electricity has become a necessity of life that is very important in all human activities at this time [1] – [5]. Electric energy is the most important form of energy, because it not only directly welfare human life, but also is a determining factor in increasing capacity in terms of production [7] – [9]. The higher the level of welfare of a person, the higher the level of dependence on the availability of adequate and quality electrical energy [10] – [12].

Transformer is one of the most important parts in an electric power system that functions to convert power without changing the frequency of electricity, but transformers are often electrical equipment that is less noticed and not given adequate care [13]. Even transformers that have been treated are not separated from the phenomenon of failure, both thermal failure and electrical failure. If this failure continues it will cause damage (breakdown) [14] – [16]. Even though damaged transformer repairs are not easy and cannot be done in a short time. This will have an impact on a number of very large financial losses [17] – [18].

Transformers with a power capacity of 60 MVA in meeting consumer needs that run for 24 hours often transformers experience a situation where the occurrence of peak loads that occur in a number of periods of time does not necessarily affect the transformer's power capacity capable of supporting or not [19] – [20].

To find out what percentage of the transformer load increases in a period of time when the peak load can be calculated using a load factor, it can find out what percentage of load surge occurs in the transformer when peak load, and this is used as a transformer reference capacity in determining the feasibility of the transformer to operate to supply energy to the community and as a determination of whether or not the transformer can be charged with that load [21] – [22].

The purpose of this study is to determine the ability of the transformer when the peak load

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occurs, analyze changes in peak load in several periods, analyze the feasibility of the transformer in supplying energy to the load, and analyze the amount of load factor per day in one month. The benefits of this study are as information material about the feasibility of the transformer at the substation, especially the 150/20 kV Kentungan Sleman substation, and as a reference in efforts to improve and improve the quality of energy supply.

II. Literature Review

In general, the definition of an electric power system is a collection of various electrical equipment which includes generation systems, transmission systems, and distribution systems, which are interconnected and cooperate with each other so as to produce electricity for later use by customers. The flow cycle of electrical energy in the electric power system is explained in Figure 1 [23].

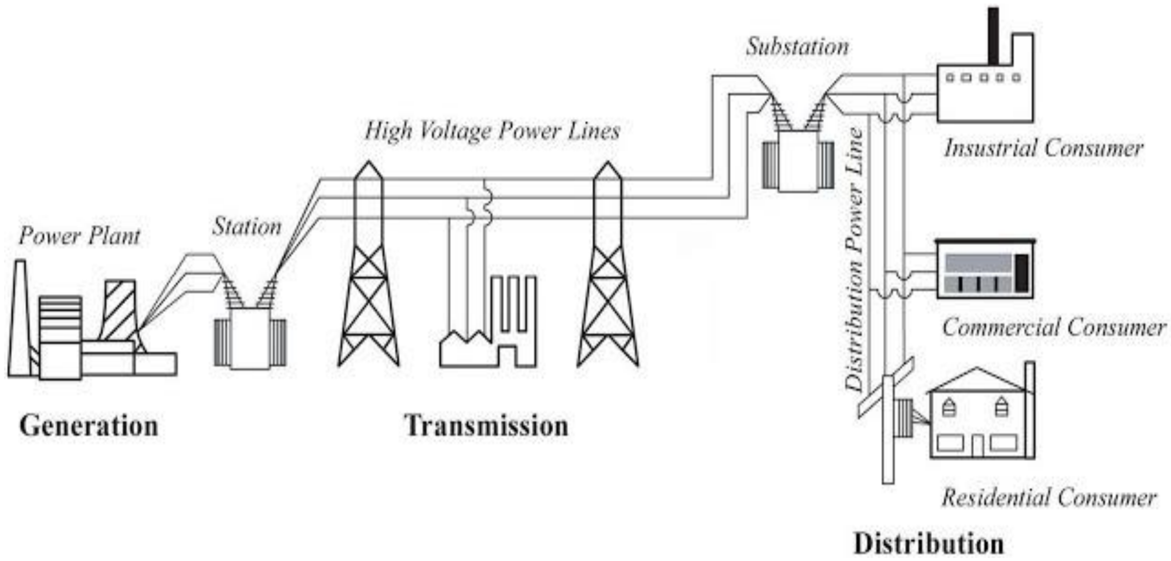

Figure 1. The main components of electrical power system

At the power plant, primary energy resources such as fossil fuels (oil, natural gas, and coal), hydro, geothermal, and nuclear are converted into electrical energy. The synchronous generator converts the mechanical energy produced on the turbine shaft into three-phase electrical energy. Through step-up transformers, this electrical energy is then sent through high-voltage transmission lines to load centers [24].

Electric power produced by large power plants with a voltage between 11 kV to 24 kV is increased by voltage by the substation with a transformer that increases the voltage to 70 kV, 154 kV, 220 kV or 500 kV then is channeled through the transmission line [25].

The purpose of raising the voltage is to minimize the loss of electrical power in the transmission line, where in this case the loss of power is proportional to the square of the current flowing (I^2R). With the same power if the value of the voltage is enlarged, then the current flowing becomes smaller so that the power loss will also be small. From the transmission line, the voltage is lowered again to 20 kV with a voltage-lowering transformer at the distribution substation, then with the voltage system the distribution of electricity is carried out by the primary distribution channel. It is from this primary distribution channel that the distribution substations take voltage to reduce the voltage with the distribution transformer being a low voltage system, namely 220/380 volts. Furthermore, it is channeled by secondary distribution channels to consumers. With this it is clear that distribution systems are an important part of the overall power system [26].

II.1. Substation

Substation is an electrical installation that consists of several electrical equipment and functions to [27]:

1. Transformation of one high-voltage electric power to another high voltage or medium voltage.
2. Measurement, supervision of operations, and security arrangements of the power system.
3. Regulating power to other substations through high voltage and distribution substations through

medium voltage feeders. According to the construction, substations can be classified as Outdoor Couple Substation and Indoor Couple Substation.

II.1.1. Outdoor Couple Substation

High voltage electrical equipment at the substation is placed outside the building or in a switchyard. Other equipment such as HV cell, control panel and relay, and DC sources are placed inside the building. This substation is usually called a conventional substation, as can be seen in Figure 2.

The advantages of outdor substations, i.e.:

a.) The construction is cheaper than the indoor substation.

b.) Isolation between equipment and between busbars using open air media thereby reducing costs for insulation media.

Figure 2. Outdoor substation

Figure 3. Indoor substation

The weakness of the outdoor substation, i.e.:

a.) Requires a large area of land.

b.) More susceptible to rain and dust (weather conditions) so that equipment is easily soiled and maintenance schedules must be carried out more frequently.

c.) Possible to experience over-voltage due to lightning strikes.

II.1.2. Indoor Couple Substation

At the indoor substation the installation of electrical equipment is placed inside the building or in a closed place. At indoor substations use gas isolation media and are called Gas Insulated Switchyard (GIS) [27].

The advantages of indoor substations are:

a.) Requires a small area.

b.) Safer against lightning and other weather effects.

c.) Less maintenance costs.

Indoor substation disadvantages are:

a.) The construction is more expensive.

b.) More insulation level.

II.1.3. Joint Pair Substation

At this substation, only the transformer is placed outside, while other equipment is inside the building.

II.1.4. Inland Substation

Substations in the ground have a characteristic similar to the inner substation, only the place is in the ground.

II.2. Substation Equipment

Equipment in a substation depends on the type of substation, function and desired level of protection. In general, a substation has the following main equipment:

1. Power Transformer

This transformer functions to channel a certain amount of power by changing the amount of voltage. The power transformer used in the substation is in the form of one 3-phase transformer or three 1-phase transformers. If a 3-phase transformer is compared to three 1 phase transformers with the same capacity, it is found that the weight of a 3-phase transformer is approximately 80% of the weight of three 1-phase transformers. The 3-phase transformer is also more profitable in terms of the foundation, wiring and space needed. The advantage of using a 1 phase transformer is that if a backup transformer is needed, then for 1 phase transformer is enough to add one 1 phase transformer only so that it becomes four 1 phase transformers, so it is very economical. However, if there are many transformers in a substation, then the 3-phase transformer is more profitable.

2. Circuit Breaker (CB)

CB is a device that can open or close a circuit both in normal working conditions and in the event of a failure. In normal working conditions CB can be operated manually or by using a remote controller, otherwise when a failure occurs CB will work automatically. CB is equipped with media to extinguish arcs, such as with air, gas, oil and so on.

3. Disconnecting Switch (DS)

DS functions to separate the electrical circuit in a situation not burdened. In general, DS cannot disconnect the current. Although he can decide on a small current, opening or closing the DS must be done after opening the CB first. To ensure that the sequence operation error does not occur, there must be an interlock between CB and DS. In its control circuit, the interlock circuit will prevent the DS from working when CB is still closed.

4. Measuring Transformer

Measuring transformers consist of current transformers and voltage transformers (or potential transformers). The current transformer functions to change the amount of current in the system to a smaller scale for the purposes of measuring current, kWh meter, and protection relay. Voltage transformers function to change the amount of voltage from high to low voltage for the purpose of indicating the voltage value on the voltmeter, as well as for measuring energy.

5. Lightning Arrester

Lightning arresters are key in coordinating the isolation of an electric power system. If there is a surge or lightning, then the arrester functions to release the electrical charge to the grounding system, and reduce the overvoltage that will affect the equipment inside the substation.

6. Self-use transformer

Self-use transformers function to meet the electrical energy needs in the substation itself, for example for lighting, air conditioning, and the need for operating other electrical equipment.

7. HV Cell 20 kV (Cubicle)

In 20 kV HV Cell there is a set of cell incoming, outgoing cells, coupled PMT cell, cell spare, and so on. 20 kV Cell Cell serves as the load center for a 20 kV distribution network, where the secondary side of the 150/20 kV transformer fills in the cell incoming in 20 kV HV Cell space, then flows the current along the bus (medium voltage rail) in the cell- cell outgoing feeder. Furthermore, from these feeders, the electric power supply will be distributed to consumers in the area according to what is handled by each feeder.

In addition to the main equipment, there is also control equipment inside the substation which consists of:

a. Main control panel

The main control panel functions to control and monitor the operation of the substation and is the controlling center of a substation. The control panel is divided into instrument panel and operation panel. In the instrument panel instruments are installed, such as ammeters and kWh meters, as well as interference indicators, from here the state of operation can be monitored. While on the operation panel installed the operating switch from CB and DS and the switch position indicator lights.

b. Relay panel

In relay panels installed safety relay, such as over current relay (OCR) and directional ground relay. The work of the relay is coordinated with CB, so that if a disturbance occurs (for example due to short circuit), the relay immediately orders CB to trip. Thus the interference will not expand and cause damage to the equipment.

In addition to the main equipment and control equipment, there is also auxiliary equipment in the substation, such as refrigerators, batteries, compressors, lighting equipment and so on. Because in the operation of the substation associated with the load sharing center, communication equipment is also needed.

II.3. Power Transformer

A transformer is an electrical device that can move and convert electrical energy from one or more electrical circuits to another electrical circuit, through a magnetic coupling and based on the induction electromagnetic principle [28]. The power transformer is widely used, both in the field of electricity and electronics. The use of a transformer in a power system allows the selection of suitable, and economical voltages for each need, such as the need for high voltage in the transmission of electric power over long distances.

In the field of electric power the use of transformers is grouped into:

1) Power transformatror
2) Transformatror distribution
3) Measuring transformatror, which consists of a current transformer and a voltage transformer.

The transformer consists of two coils (primary and secondary) that are inductive. These two coils are separated electrically but are magnetically connected through a path that has low reluctance. If the primary coil is connected to an alternating voltage source, the alternating flux will appear in the laminated core, because the coil forms a closed network, the primary current flows. As a result, there is an induction (self induction) in the primary coil and induction in the secondary coil due to the influence of induction from the primary coil or mutual induction which causes magnetic flux to emerge in the secondary coil, then flows secondary if the secondary circuit is loaded, so that the electrical energy can be transferred as a whole (magnetized).

$$E = -N\, d\Phi / dt \quad \text{Volts} \tag{1}$$

Where, E = electromotive force (emf) volts
N = number of turns
$d\Phi / dt$ = change in magnetic flux

It should be borne in mind that only alternating electrical voltage can be transformed by a transformer, whereas in the field of electronics the transformer is used as a coupling impedance between the source and the load to inhibit direct current while still conducting alternating current between the circuits. The main purpose of using a core on a transformer is to reduce magnetic circuit reluctance.

A power transformer is an electrical device that functions to deliver electrical power from a medium-voltage generator to a high-voltage transmission and to deliver power from a high-voltage transmission to a low-voltage distribution network. An example of a power transformer applied to a substation is shown in Figure 4. Power transformer components consist of iron core, coil, voltage regulation, transformer oil, bushings and conservator tank.

The iron core serves to facilitate the path of flux, which is caused by electric current through the coil. Made from thin plates of insulated iron, to reduce the heat (as iron losses) caused by Eddy Current.

The transformer core is formed from a layer of silicon iron plate which has a very thin layer of insulation on one side, which is resistant to high heat and has a low heat dispersion coefficient, with a very thin thickness to be able to reduce the smaller core losses. Arranged in such a way as to form a strong and efficient magnetic core area.

Transformer coils are some coil of insulated wire that forms a coil. The coil consists of a primary coil and a secondary coil which is isolated both from the iron core and between the coils with solid insulation such as cartons, pertinakan and others. The coil is a voltage and current transformation tool.

Figure 4. Power transformer in a substation

The regulation voltage determines the magnitude of the transformer secondary voltage variation under different load factor conditions. Regulatory voltage is the voltage ratio in the secondary terminal when it is not loaded and during full load conditions. This is taken into account because it can be used as a reference for the requirements of parallel transformer work.

Transformer regulation voltage is measured after the output terminal (secondary) is short-circuited (full load condition) and increases the voltage gradually at the input side (primary) so that the current flowing on the primary side reaches its nominal value. In this condition the nominal current magnitude flows on both sides of the winding, and the primary side voltage at that time is called the regulation voltage. Short circuit impedance consists of active and reactive components and can be expressed in Ohm units as other impedance quantities, the amount depends on the transformer's nominal capacity and voltage.

Most coils and core power transformers are immersed in transformer oil, especially large capacity power transformers, because transformer oil has the properties of insulation and transfer media, so that the transformer oil functions as a cooling and insulation media.

In a transformer there are two components that actively generate heat energy, namely iron (core) and copper (coil). If heat energy is not channeled through a cooling system it will cause iron and copper to reach high temperatures, which will damage the insulation value. As a mean for cooling, the coil and core are incorporated into a type of oil, called transformer oil. The oil has a dual function, namely cooling and insulation.

It should be stated that transformer oil must be of high quality and always be clean. Because heat energy is generated from the core or coil, the temperature of the oil will rise. This will result in changes in transformer oil. After all, in the long term various impurities will be formed which will reduce the quality of transformer oil. These things can result in the ability to cool or isolate the oil will decrease. Furthermore, it can also occur that humid air as is the case in the tropics, results in the entry of water in transformer oil.

When the temperature of the transformer oil being operated is measured, it will appear that the temperature of the oil will depend on the height of the measurement in the tank. The highest temperature will be found at around 70 to 80% of the vessel height.

Transformer oil as an insulating material as well as heat transfer media from the hot (windings and core) parts of the tank or cooling radiator has the following characteristics:

a. Specific gravity of 0.85 to 0.90 at a temperature of 13.5º C
b. Low viscosity to facilitate circulation from hot parts to cold parts, ie 100 to 10 Saybolts second at 40º C
c. Boiling point not less than 135º C
d. Freezing point is not more than -45º C
e. The breakdown voltage is not less than 30 kV per 2.5 mm or 120 kV / 1 cm
f. The expansion coefficient is 0,00065 per 1º C
g. 180º C to 190º C flash point
h. Burning point 205º C
i. Moisture to water vapor is nil

The relationship between the transformer coil to the outside network through a bushing is a conductor that is covered by an insulator, which also functions as a divider between the conductor and the transformer tank.

In general, the parts of the transformer submerged in transformer oil are in the tank. To accommodate the expansion of transformer oil, the tank is equipped with a conservator.

III. Methodology

In this research, the authors conducted a quantitative study which analyzed the loading of a 20 kV transformer at Kentungan Substation 150/20 kV, Sleman, Special Region of Yogyakarta, by looking for load factors when peak loads occur, starting from the beginning of 2014 until the end of 2016.

To analyze and process the research data, a tool is needed, one unit of computer that is installed Microsoft Office 2013 software, especially Microsoft Word, Microsoft Excel and Microsoft Power Point, and a calculator.

The research material is the data needed in research that includes:

1. Single line feeder diagram.
2. Peak load data.
3. Load factor data.

In the process of collecting this final assignment the author conducts research by direct observation to the field and retrieval of system data and library reviews that are needed, in addition to further believing the condition of the system also do question and answer with the PT. PLN (Persero).

The data needed in the data collection process are as follows:

1. Peak Load Data

This peak load data is needed to find out at what time the load spike is high enough, so that it can be calculated how many factors the load occurs.

2. Load Factor Data.

Load factor data is needed to determine the end of this research process. By getting the value of the load factor, it can be concluded how the quality of the transformer is. Whether or not the transformer is used when the peak load occurs

3. Data Processing

After the required data has been fulfilled then perform calculations and analysis. Then it will get the value of the load factor to determine the feasibility of the transformer. As for the calculation steps as follows:

a. Calculate peak load.
b. Calculate average load
c. Calculate load factor

The results of the study used the load factor calculation method by using the average peak load that occurs every day, so that the percentage of load factors that occur.

IV. Results and Discussion

This study was conducted at the 150/20 kV Kentungan Substation. Geographically, the Kentungan Substation is located on Jl. Kaliurang Km 6,5 Yogyakarta, Indonesia. Judging from the equipment, Kentungan Substation is an outdoor pair substation. The Kentungan substation has a working voltage of 150/20 kV, ie the voltage of 150 kV is the transformer primary side voltage which is lowered to 20 kV on the transformer secondary side for distribution to customers through feeder-feeders.

Kentungan Substation has two power transformers, namely Transformer II and Transformer IV, with a capacity of each 60 MVA transformer serving 14 feeders in the working area of PT. PLN (Persero) Yogyakarta Area. Transformer II serves 8 (eight) feeders, namely feeders of KTN 1, KTN 2, KTN 3, KTN 5, KTN 6, KTN 9, KTN 10 and KTN 14. While IV transformers serve 6 feeders, namely feeders KTN 4, KTN 7, KTN 8, KTN 11, KTN 12 and KTN 13.

The load factor is the ratio between the average load to its peak load over a period of time. Average load and peak load can be expressed in kilo-watts or kilo-volt-amperes.

The load factor of the power transformer at the Kentungan substation from January 2014 to December 2014 is shown in Table I and Figure 5.

Table I. Load factor of power transformer in Kentungan substation from January 2014 to December 2014

Month	Power Transformer capacity (MVA)	Peak Load (MW)	Load Factor (%)
January	60	53.7	86
February	60	50.2	91
March	60	51.1	82
April	60	52.0	86
May	60	51.1	92
June	60	51.2	90
July	60	47.6	89
August	60	51.1	91
September	60	52.8	88
October	60	52.0	86
November	60	52.0	95
December	60	53.7	90

From the calculation of the power transformer load factor on the Kentungan substation from January 2014 to December 2014, as can be seen in Table I and Figure 5, it can be concluded that the highest load factor occurred in November 2014 which was 95%.

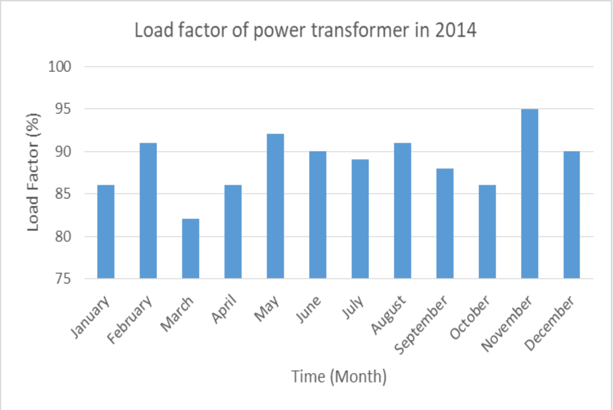

Figure 5. Load factor power transformer in Kentungan substation from January 2014 to December 2014

Then the load factor calculation was carried out in 2015. The load factor of the power transformer at the Kentungan substation from January 2015 to December 2015 is shown in Table II and Figure 6.

Table II. Load factor of power transformer in Kentungan substation from January 2015 to December 2015

Month	Power Transformer capacity (MVA)	Peak Load (MW)	Load Factor (%)
January	60	52.0	92
February	60	52.8	90
March	60	54.4	94
April	60	52.8	91
May	60	52.0	91
June	60	47.5	90
July	60	48.5	88
August	60	52.0	92
September	60	50.2	91
October	60	49.5	95
November	60	52.0	93
December	60	52.8	89

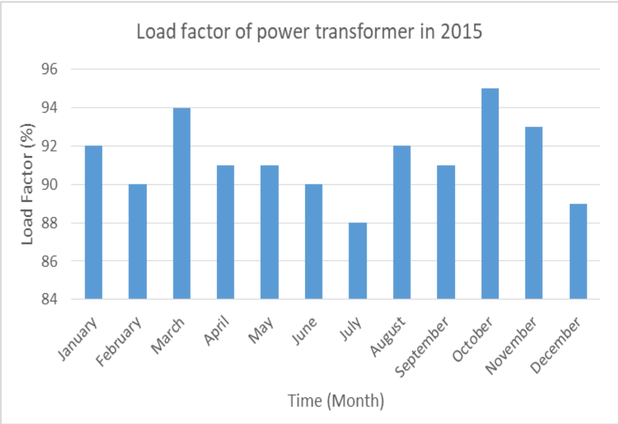

Figure 6. Load factor power transformer in Kentungan substation from January 2015 to December 2015

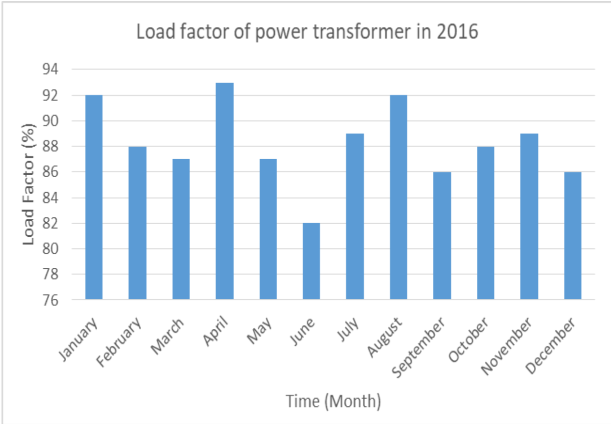

Figure 7. Load factor power transformer in Kentungan substation from January 2016 to December 2016

From the calculation of the power transformer load factor on the Kentungan substation from January 2015 to December 2015, as can be seen in Table II and Figure 6, it can be concluded that the highest load factor occurred in October 2015 which was 95%.

Then the load factor calculation was carried out in 2016. The load factor of the power transformer at the Kentungan substation from January 2016 to December 2016 is shown in Table III and Figure 7.

Table II. Load factor of power transformer in Kentungan substation from January 2016 to December 2016

Month	Power Transformer capacity (MVA)	Peak Load (MW)	Load Factor (%)
January	60	52.0	92
February	60	56.3	88
March	60	53.7	87
April	60	53.7	93
May	60	52.8	87
June	60	51.1	82
July	60	52.8	89
August	60	53.7	92
September	60	55.4	86
October	60	55.4	88
November	60	57.1	89
December	60	53.7	86

From the calculation of the power transformer load factor on the Kentungan substation from January 2016 to December 2016, as can be seen in Table III and Figure 7, it can be concluded that the highest load factor occurred in April 2016 which was 93%.

Based on the analysis, it can be seen that the lowest peak load and load factor occurred in June 2016, which was 51.1 MW and the load factor was 82%. The value of the small peak load and load factors in June 2016 in June coincided with the fasting month and Eid al-Fitr, so that the use of electricity from consumers could be said to decline.

Based on the graph in Figure 5, Figure 6, and Figure 7, it can be seen that the peak load can still be served by a power transformer, so the power transformer still meets the requirements and is still feasible to use. The state of the power transformer at Kentungan Substation is still able to anticipate the occurrence of a peak load that may occur.

V. Conclusions

Regarding the analysis, we conclude some points as the followings.

1. Based on the results of calculations for 3 years from 2014-2016, the highest load factor value was obtained in October 2015 with the highest peak load of 49.5 MW and November 2014 with the highest peak load of 52 MW at 95%.
2. The load factors that occurred in 2014 and 2015 were very high because the number of transformers in the Kentungan Substation was still 2, while in 2016 the number of

transformers at the holding substations was 3 units.

3. The magnitude of the value of the load factor obtained is 93% is very good, but if the transformer load continues to be done then the age of the transformer will be shorter. The standard for load factors according to PLN ranges from 60% - 80%.

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References

[1] Fitriyah, Q., Istardi, D. 2011. "Prediksi Beban Listrik Pulau Bali dengan Menggunakan Metode Backpropagasi". Seminar Nasional Informatika 2011 (semnasIF 2011). UPN Veteran Yogyakarta, 2 July 2011

[2] Fitzgerald, A.E. (1992). "Mesin-Mesin Listrik Edisi Keempat". Jakarta : Penerbit Erlangga.

[3] Haidaroh, A. 2013. "Pengenalan Kecerdasan Buatan (Artificial Intellegence)". Kupang : STIKOM Artha Buana.

[4] Heizer, J., Render, B. (2009). "Manajemen Operasi. Edisi 9. Terjemahan Chriswan Sungkono". Jakarta : Salemba Empat

[5] Kusumadewi, F. (2014). "Peramalan Harga Emas Menggunakan Feedforward Neural Network Dengan Algoritma Backpropagation". Yogyakarta : Universitas Negeri Yogyakarta.

[6] Laughton, M.A., Warne, D. F.. (2003). "Electrical Engineer's Reference Book 16th Edition". Great Britain : Newnes

[7] Muis, S. (2017). "Jaringan Syaraf Tiruan ; Sistem Kecerdasan Tiruan dengan Kemampuan Belajar dan Adaptasi". Yogyakarta : Teknosain.

[8] Nurkholiq, N. 2014. "Analisis Perbandingan Metode Logika Fuzzy dengan Jaringan Syaraf Tiruan Backpropagation Pada Peramalan Kebutuhan Energi Listrik Jangka Panjang di Indonesia Sampai Tahun 2022". TRANSIENT Vol. 3, No. 2, ISSN : 2302-9927 (Juni 2014), pp. 245 -251.

[9] Pratama, R. A. Anifah, L. (2016). "Peramalan Beban Listrik Jangka Panjang D.I.Yogyakarta Menggunakan Neural Network Backpropagation". Jurnal Teknik Elektro. Volume 05 Nomor 03 Tahun 2016, p.p 37-47.

[10] Purnomo, H. (2004). "Peramalan Beban Listrik Jangka Pendek dengan Menggunakan Model Jaringan Syaraf Tiruan di PT. PLN Region III Jawa Tengah dan DIY". Yogyakarta : Universitas Gadjah Mada.

[11] Purnomo, M.H., Kurniawan, A. (2006). "Supervised Neural Networks dan Aplikasinya". Yogyakarta : Graha Ilmu.

[12] Siang, J. J. (2009). "Jaringan Syaraf Tiruan dan Pemrogramannya Menggunakan MATLAB". Yogyakarta : ANDI.

[13] Syahputra, R., Soesanti, I. (2016). "Power System Stabilizer Model Using Artificial Immune System for Power System Controlling". International Journal of Applied Engineering Research (IJAER), 11(18), pp. 9269-9278.

[14] Syahputra, R. (2016). "Transmisi dan Distribusi Tenaga Listrik". Yogyakarta : LP3M UMY Yogyakarta.

[15] Syeto, G. J. (2010). "Peramalan Beban Listrik Menggunakan Jaringan Syaraf Tiruan Metode Kohonen". Surabaya : Institut Teknologi Surabaya.

[16] Tamizharasi, G dkk. 2014. "Energy Forecasting using Artificial Neural Networks". IJAREEIE Vol. 3, Issue 3. March 2014, pp. 7568-7576.

[17] Syahputra, R., Soesanti, I., Ashari, M. (2016). Performance Enhancement of Distribution Network with DG Integration Using Modified PSO Algorithm. Journal of Electrical Systems (JES), 12(1), pp. 1-19.

[18] Syahputra, R., Robandi, I., Ashari, M. (2015). Performance Improvement of Radial Distribution Network with Distributed Generation Integration Using Extended Particle Swarm Optimization Algorithm. International Review of Electrical Engineering (IREE), 10(2). pp. 293-304.

[19] Syahputra, R., Robandi, I., Ashari, M. (2014). Optimization of Distribution Network Configuration with Integration of Distributed Energy Resources Using Extended Fuzzy Multi-objective Method. International Review of Electrical Engineering (IREE), 9(3), pp. 629-639.

[20] Syahputra, R., Robandi, I., Ashari, M. (2015). Reconfiguration of Distribution Network with DER Integration Using PSO Algorithm. TELKOMNIKA, 13(3). pp. 759-766.

[21] Syahputra, R., Soesanti, I. (2016). Design of Automatic Electric Batik Stove for Batik Industry. Journal of Theoretical and Applied Information Technology (JATIT), 87(1), pp. 167-175.

[22] Soesanti, I., Syahputra, R. (2016). Batik Production Process Optimization Using Particle Swarm Optimization Method. Journal of Theoretical and Applied Information Technology (JATIT), 86(2), pp. 272-278.

[23] Syahputra, R., Robandi, I., Ashari, M. (2015). PSO Based Multi-objective Optimization for Reconfiguration of Radial Distribution Network. International Journal of Applied Engineering Research (IJAER), 10(6), pp. 14573-14586.

[24] Syahputra, R., Soesanti, I. (2016). DFIG Control Scheme of Wind Power Using ANFIS Method in Electrical Power Grid System. International Journal

of Applied Engineering Research (IJAER), 11(7), pp. 5256-5262.
[25] Syahputra, R., Soesanti, I. (2015). Power System Stabilizer model based on Fuzzy-PSO for improving power system stability. 2015 International Conference on Advanced Mechatronics, Intelligent Manufacture, and Industrial Automation (ICAMIMIA), Surabaya, 15-17 Oct. 2015 pp. 121 - 126.
[26] Syahputra, R. (2017). Distribution Network Optimization Based on Genetic Algorithm. Jurnal Teknologi, Journal of Electrical Technology UMY (JET-UMY), 1(1), pp. 1-9.
[27] Syahputra, R., Soesanti, I. (2016). Application of Green Energy for Batik Production Process. Journal of Theoretical and Applied Information Technology (JATIT), 91(2), pp. 249-256.
[28] Syahputra, R. (2016). Application of Neuro-Fuzzy Method for Prediction of Vehicle Fuel Consumption. Journal of Theoretical and Applied Information Technology (JATIT), 86(1), pp. 138-149.

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