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THE ANALYSIS OF THE POWER QUALITY OF THE TRANSFORMER BHT03 OF MULTIPURPOSE RESEARCH REACTOR G.A. SIWABESSY DURING THE 30 MW OPERATION

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ABSTRACT

THE ANALYSIS OF THE POWER QUALITY OF THE TRANSFORMER BHT03 OF MULTIPURPOSE RESEARCH REACTOR G.A. SIWABESSY DURING THE 30 MW OPERATION. Age of Multipurpose Reactor G. A. Siwabessy (RSG GAS) is 30 years old. Aging is a problem to be controlled. The power supply on component is always expected to have good quality. RSG-GAS electricity is supplied from State Electricity Company through a transformer, one of which is a BHT03 transformer. Measurements have been made on the low voltage side of BHT03 RSG-GAS transformer. Measurements were made to obtain the RSG GAS power feasibility data. The purpose of this research is to know the quality of power transformer BHT03 RSG-GAS at 30 MW reactor operation. The method used is direct measurement using Power Quality Analyzer (PQA) 3197. The result of the measurement analysis shows that on the operation of 30 MW, there is a flow of current at neutral phase of 61 A. From the calculation result of imbalance of electric current in BHT03 transformer By 1.98%. The power factor is very good with the lowest value 0.92 and the highest 0.95, the average of 0.94. The power quality of the transformer BHT03 is eligible because the General Electrical Installation Requirement (PUIL) states that the electrical imbalance is less than 20%.

Keywords: power quality, transformer, 30 MW operation, electric current, imbalance

ABSTRAK

ANALISIS KUALITAS DAYA TRANSFORMATOR LISTRIK BHT03 REAKTOR SERBA GUNA G.A. SIWABESSY SAAT OPERASI REAKTOR 30 MW. *Usia Reaktor Serba Guna G. A. Siwabessy (RSG GAS) sudah 30 tahun. Penuaan merupakan masalah yang harus dikontrol. Pasokan listrik pada komponen senantiasa diharapkan memiliki kualitas yang baik. Listrik RSG-GAS dipasok dari Perusahaan Listrik Negara melalui transformator, salah satunya adalah transformator BHT03. Telah dilakukan pengukuran pada sisi tegangan rendah transformator BHT03 RSG-GAS. Pengukuran dilakukan guna mendapatkan data kelayakan daya listrik RSG GAS. Tujuan penelitian ini adalah untuk mengetahui kulitas daya listrik transformator BHT03 RSG-GAS pada saat operasi reaktor 30 MW. Metode yang digunakan adalah pengukuran langsung dengan menggunakan alat ukur Power Quality Analyzer (PQA) 3197. Hasil analisis dari pengukuran menunjukkan bahwa pada pengoperasian 30 MW ini, terdapat aliran arus pada fasa netral sebesar 61 A. Dari hasil analisis perhitungan ketidakseimbangan arus listrik pada transformator BHT03 sebesar 1,98%. Faktor daya listrik sangat baik dengan nilai terendah 0,92 dan tertingi 0,95 dengan rata-rata sebesar 0,94. Kualitas daya listrik pada transformator BHT03 memenuhi syarat karena Persyaratan Umum Instalasi Listrik (PUIL) menyatakan bahwa ketidakseimbangan listrik adalah kurang dari 20%.*

Kata kunci: kualitas daya, transformator, operasi 30MW, arus listrik, ketidakseimbangan

INTRODUCTION

To ensure that the reactor can be operated safely, continuous inspections and evaluations are required. At present, many of the components malfunction and faults may due to the supply power problems, the aging components and the effect of environments. Toovercome these operating problems, the power quality analysis is required to understand the supply stabilities and disturbances [2]. This power quality analysis is necessary to prevent the possibility of future unintended consequences which in turn jeopardize the safety of the reactor[3].

RSG GAS electricity is supplied from the PLN (State Electricity Company) through 3 transformers, i.e. namely BHT01, BHT02 and BHT03. Each transformer (BHT01, BHT02, BHT03) has a capacity of 1600 kVA, 20 kV / 400 VAC [4]. Electrical loads distribution may be initially balanced, however due to the unsynchronized starting time of each electrical equipment during operation from the start up to shutdown of reactor sometimes causing asymmetrical voltage and current (known also as a load imbalance) which affect the quality of line supply in general. Load imbalance between each phase causing the neutral current flows [5] which in turn also harm the electrical components. It means that it is very important to understand the produced power quality of transformers during a full mode operation of the RSG-GAS from start-up to shutdown with the nominal power [6].

Considering this challenges, therefore, the purpose of this study was to analyze the power quality of the electric power transformer of the RSG-GAS during reactor operation 30 MW. To achieve the above objective, a power quality analysis was carried out using a direct measurement method with a Power Analyzer Equipment. Measurements were made on the low voltage side of the High Voltage Transformer BHT03 as one of transformer in RSG-GAS. Data was recorded from the beginning of operation, up to 30 MW nominal power, until the reactor is shut down. The acquired data was then analyzed to indicate the various characteristics of power quality problems as well as to indicate the baseline quality data for future assessments.

Based on this analysis, it is expected that this paper play a significant role as the rationale for the periodical safety analysis report document which must be submitted mid of 2017 to describe the capacity of electrical equipment in maintaining the safe operation of RSG-GAS. In addition, the analysis is also beneficial for the maintenance and the operation of the RSG-GAS, as well as for the aging management program in RSG GAS.

THEORY

The Power Transformer is passive electrical devices that transform electric power from high voltage to low voltage or vice versa with the primary coil and the secondary coil by using the principle of electromagnetic induction at the same frequency [7]. The Primary and secondary coils were woundon a ferromagnetic core. Generally there are three types of connection in the three-phase transformer, the star connection (Y), delta connection (Δ) and the zig-zag connection. The three-phase winding both for the primary side and secondary side can be combined in the form of a star-star (YY), star-delta (Y-Δ), deta-star (Δ-Y) and delta-delta (Δ- Δ) connections [8].

RSG-GAS reactor building is supplied by three (3) unit of transformers 3 (three) phases, i.e. BHT01, BHT02 and BHT03 with a capacity of 1600 kVA, 20 kV / 400V [4]. The function of the transformers, BHT01, BHT02 and BHT03 is to decrease the high voltage supply of PLN 20 kV to low voltage at 400 VAC. This type of connection of the primary and secondary coils is delta - star (Δ-Y) respectively.

For the primary - secondary connection Δ - Y, the voltage wire (V_{LP}) to the primary wire equal to the primary phase voltage ($V_{LP} = V_{phP}$), and the phase voltage secondary side (V_{phS}) as well as primary and secondary voltage ratio as in equation 1 and 2 [8]. The connection diagram of Δ - Y is shown in Figure 1.

$$V_{LS} = V_{phS}\sqrt{3} \tag{1}$$

$$\frac{V_{LP}}{V_{LS}} = \frac{V_{phP}}{V_{phS}\sqrt{3}} = \frac{a}{\sqrt{3}} \tag{2}$$

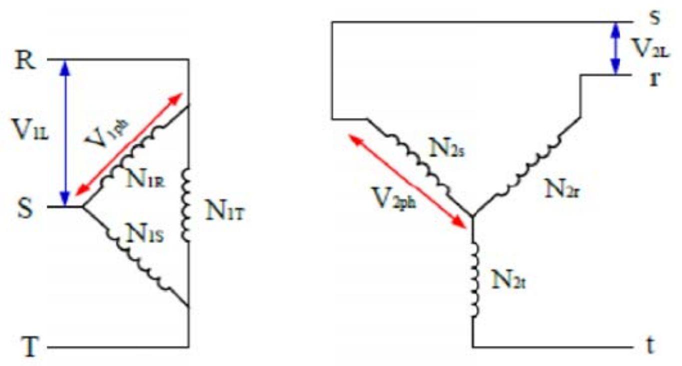

Figure 1. The three phase transformer circuit with the connection of Δ-Y [3]

The calculated power transformer (P) from the high-voltage side (primary) point of view can be expressed as the equation 3. In this case V is the primary voltage across the transformer in a units of Volt (V) and I is the grid current in units Ampere (A). Thus, the full-load current of transformer can be calculated by Equation 4 [5].

$$P = V \quad I \quad \sqrt{3} \tag{3}$$

$$I_{FL} = \frac{P}{V\sqrt{3}} \tag{4}$$

To analyze the condition of the transformer can be done by calculating the balance of the load. A transformer is considered to be in a balanced load state when the three vectors of electric current or electric voltage has a similar magnitude and separated with an angle of 120^0 each other. If one or both of these conditions is not met, then the transformer is called under an unbalanced load state. In the balanced condition, the current of R, S, T (I_R, I_S, I_T) produce a vector such as in Figure 2a, where the sum of three vectors will be 0 (zero). However the unbalanced condition will produce an electric current values, i.e. neutral current (I_N) as shown in Figure 2b. The more unbalance voltage or current occurs, the greater the value of I_N. To obtain a percentage value of loading ($\%_{load}$), the average current ($I_{average}$) is divided by the full electric current (I_{FL}). The average current is obtained by summing the absolute value of I_R, I_S, I_T divided by 3 as shown in Equation 5 and 6, so that the active power (P_{active}) of transformer can be calculated by equation 7.

a. balanced condition

b. unbalanced condition

Figure 2. The balanced vector of electric current

$$I_{average} = \frac{I_R + I_S + I_T}{3} \tag{5}$$

$$\text{Percentage of loading } (\%_{load}) = \frac{I_{average}}{I_{FL}} \, x\, 100\% \quad (6)$$

$$P_{active} = P \cos\varphi \quad (7)$$

Power quality has a variety of problems in the different phenomena [9]. Power quality is determined by the quality of current, voltage, frequency, harmonics, power loss, cos φ, grounding and the balanced system. These problems can also be identified using quality of power measurements [9]

METHODOLOGY

In order to achieve the objectives of this study, the methodology used was to perform direct power quality measurements on the transformer BHT03 RSG G.A. Siwabessy as given in Figure 3 and the data in Table 1. This research employs *Power Quality Analyzer* (PQA) 3197, *flexible clamp on sensor* 9667 for the electric current measurement and differential voltage probe for the voltage measurement busbar of phase R, S and T. The equipment capable of measure both current and voltage with the maximum range of voltage 600.0 V AC, and current 500.0 mA to 5.000 kA AC. The measurement data is then analyzed to identify and determine the quality of power based on the related indication.

Table 1 and 2 shows one of the transformer specification in RSG GAS, BHT03 RSG-GAS and the load of the transformer for the train C.

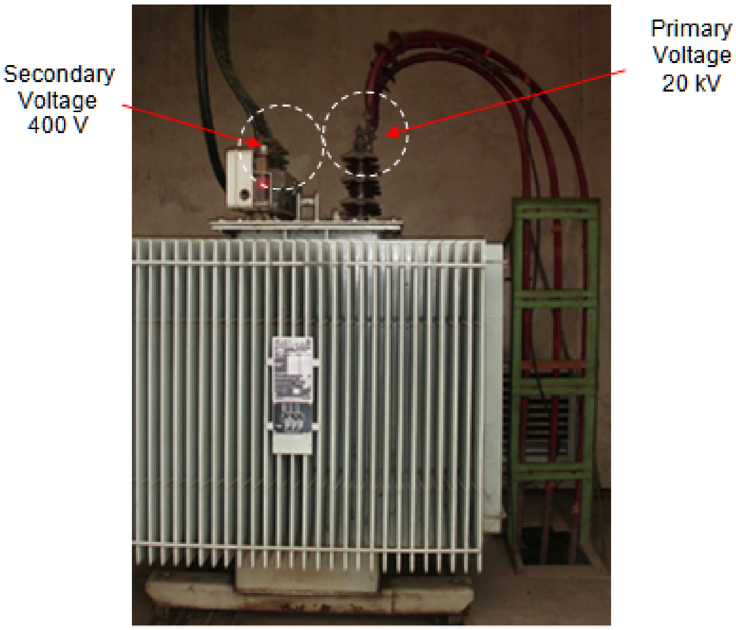

Figure 3. The oil-cooled type Transformer BHT03 RSG-GAS

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Table 1. Transformer Specification BHT03 RSG-GAS [11]

Parameters		**Specifications**
Type of Transformer		3 phase; 50 Hz
Cooling type		oil-cooledDIALA-B
Years		1992
Standard Compliance		76/SPLN-50IEC Standard
Short Circuit Voltage		6 %
The Temperature increase (^oC)		Oil: 53 ^oC Winding : 58 ^oC
Basil Isolation Level		125 kV
Weight		Oil : 850 kg Total : 3,750 kg
	Primary	**Secondary**
Nominal Power (kVA)	1,600 (kVA)	1,600 (kVA)
Connection type	Delta	Star N5
Nominal Voltage (volt)	20 (kV)	400 (volt)
Current Nominal (amp)	46.2 (A)	2,309.5 (A)

Table 2. Load of the BHT03 transformer Train C

Name	**Power (kVA)**
Main Busbar I BHC	580.53
Main Busbar II BHF	588.62
Emergency Busbar BNC	270.13
Total Connected Load Transformator BHT03	1,439.28

RESULTS AND DISCUSSION

Full load current flowing in the secondary connection of the transformer can be calculated using equation 4. Based on the data in Table 1, by using the nominal power of 1,600 kVA and nominal voltage 400 V, the full load current (I_{FL}) will be at 2,309.47 A. Based on the measurement data processing with the power quality analyzer, it is obtained an average value of electric current in phase R, S, and T as given in Table 3. Then, using the equation (5), the average current for three phase load is about 965.97 A. The obtained percentage of load by using equations 6 is around 41.83%.

Table 3. The average value of electric current for the transformer phase R,S, and T at the reactor power 30 MW

Description	Phase R	Phase S	Phase T	Neutral Phase
	(I)	(I)	(I)	(I)
Minimum	870.00	915.00	898.00	-
Maximum.	1,087.00	1.143,00	1,152.00	61.00
Average (A)	937.29	987.35	973.27	-

The measurement of power factor ($\cos\varphi$) shows a fluctuated values, betweenthe maximum of 0.95 and minimum 0.92.The fluctuations in the power factor measurement is shown in Figure 4.

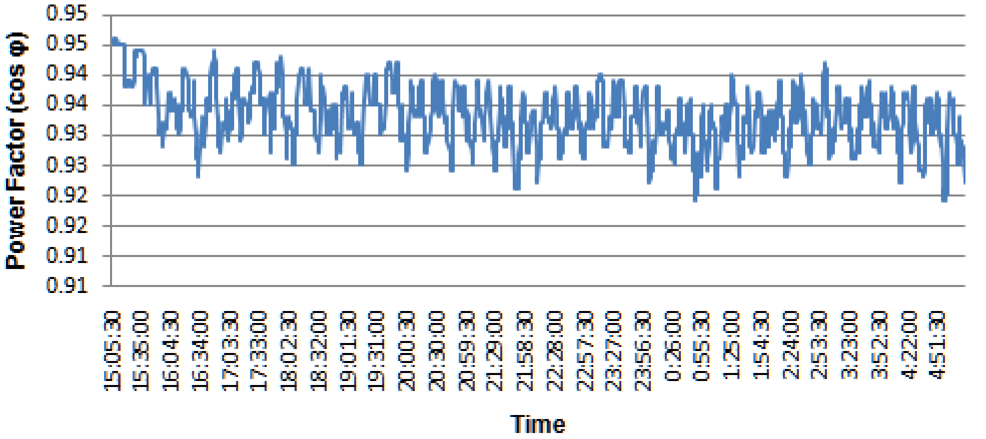

Figure 4. The fluctuation of cos φ of the transformer BHT03 during the 30 MW operation

The average value of cos φ in Figure 4 is 0.94. It means that the measured power factor have is quite good for the operation and maintenance RSG-GAS. The high power factor will reduce an extra monthly charges payment possibilities from PLN, reduce the possibility of voltage drop, decrease the power system loses and improve the capacity of carrying more loads in the existing circuit. Based on the equation 7, the can be obtained active power transformer BHT03 during reactor operation of 30 MW at around 1,504 kW.

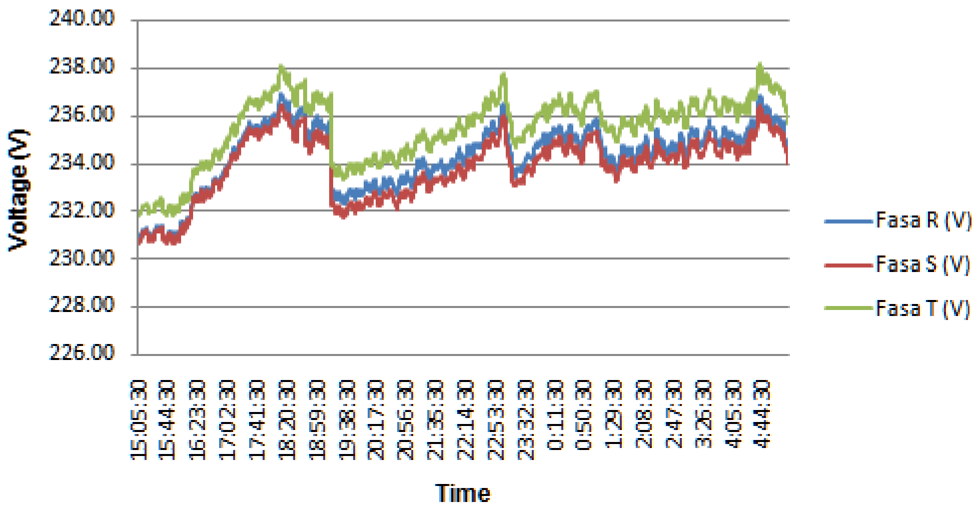

Figure 5. Electrical voltage of transformer BHT03 during the 30 MW operation.

In addition of cos φ, for the reactor operation 30 MW, electric voltage and electric current was also measured. Figure 5 shows the measurement results of BHT03 power supply voltage. Figure 5 shows that the operation mode of 30 MW of RSG-GAS from start-to shutdown was not affect to the electrical voltage supply as shown by a small voltage drop during the whole operation. Furthermore, for the electric current measurements, it was revealed neutral phase values as shown in Figure 6. The purple line indicates the current neutral phase flowing. The maximum value of the measured neutral phase current is around 61 A.

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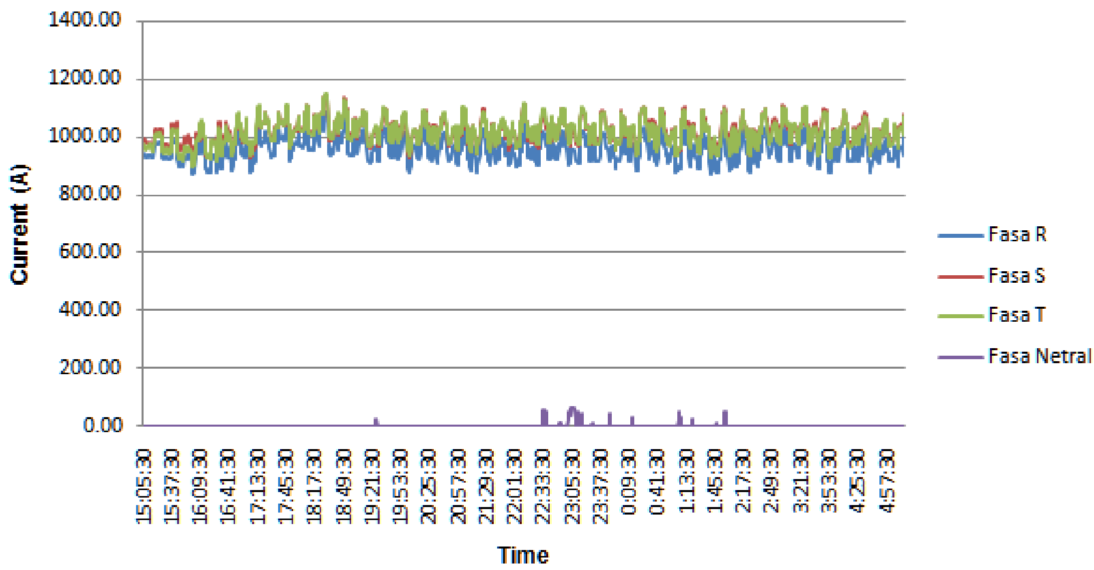

Figure 6. The electric current of BHT03 transformer during the reactor 30 MW operations

The neutral phase is certainly evident in the sine graph of the results of the measurements in Fig. 7. If all the conditions of the R, S, and Weigh phases are on the sine graph only the 3 sine line drawings, the sine line of phase R (green), the S phase (Red color) and phase T (blue). The sinus line (gray color) will coincide with the axis. It will be because of the fact that there is a neutral phase of 61 A then the image of the sine graph on the screen will be identified in Fig. 7.

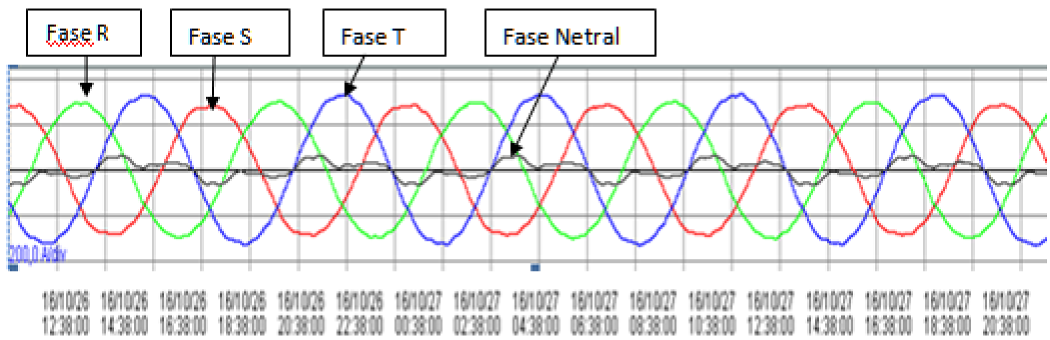

Figure 7. Sine phase graphs R, S, and T, the result of PQA transformer BHT03

The existence of a neutral phase currents indicate that there are three phases of the electrical current phase or of transformer which does not form an angle of 120^{o}, or imbalance load. By comparing each phase of current to the average current value, the detected current instability in the phase R, S and T is 0.97, 1.02 and at 1.01 respectively. The average value of the electric load current imbalance is around 1.98%. According to the General Requirements Electrical Installation in Indonesia (PUIL) the load imbalance must be under 20% [10]. It means that the load imbalance of BHT03 transformer is very small so and can be ignored.

CONCLUSION

The results of electrical power quality measurements on the RSH-GAS transformer BHT03 showed the highest average power factor value of 0.95 and the lowest 0.92 with an average of 0.94. Power factor value is quite good. On the measurement of electric current obtained there is a flow that flows into neutral that indicates the state of the load is not balanced. After calculation, the percentage of BHT03 transformer imbalance is 1,98%. BHT03 transformer unbalance percentage values still qualify from General Electrical Installation Requirements (PUIL) where load unbalance is not feasible if it exceeds 20%.

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DISKUSI/TANYA JAWAB

1. PERTANYAAN: R. Arum Rijanti (PKSEN–BATAN))

- Pada Gambar 6 dalam arah sumbu-x (time) di bagian paling bawah terdapat garis-garis. Tolong jelaskan tentang hal tersebut!
- Berapa besar fluktuasi tegangan listrik pada waktu reactor beroperasi hingga 30 MWth? Apakah kualitas listriknya masih layak?

JAWABAN: Abdul Hafid (PTKRN - BATAN)

- *Garis-garis sinyal di Gambar 6 pada bagian bawah tersebut menunjukkan bahwa terdapat fasa netral pada arus listrik yang mengalir.*
- *Besar fluktuasi tegangan listrik pada prinsipnya tidak tergantung pada besar daya operasi reaktor. Pada waktu pengukuran yang dilakukan, setelah dihitung dan dianalisis diperoleh besar fluktuasi tegangan listrik rata-rata 0,21 %. Nilai ini masih tergolong baik dan layak berdasarkan Persyaratan UmumInstalasi Listrik (PUIL), 2000.*