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Distribution Transformer Synchronization Simulation and Implementation with Dyn5 and Dyn11 Vector Groups using the MATLAB Simulink and TTR Test

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A B S T R A C T

Nowadays, the quality of electrical energy really needs to be improved especially for industrial purposes that require a good level of reliability in the distribution of electrical energy. Maintenance of distribution transformers is routinely carried out to ensure that the quality of electrical energy produced is in accordance with standards. This maintenance is done using the customer's load from the distribution transformer to the mobile substation transformer, that can be done using synchronization. This synchronization requires the same distribution transformer vector groups, otherwise it will produce non-standard output. The aim of this research is to determine the vector groups effect on parallel transformer installation system, the method to overcome the synchronous problem of different vector groups based on simulating and testing the synchronization of a 20 / 0.4 kV distribution transformer with the Dyn5 and Dyn11 vector groups. The results obtained from this research are two transformers that have different vector groups can be synchronized with an abnormal connection (changing the position of the secondary terminal cable connection and the primary terminal cable) so that it will produce the same voltage phase. This will abnormal treatment of distribution transformers maintenance that do not have a back-up transformer with the same vector group still can use the different vector group transformers.

INTRODUCTION

The National Energy Policy in Indonesia as stated in the Regulation of the Minister of Energy and Mineral Resources Number 18 of 2019 concerning the Quality Level of Electricity Distribution Services by PT. PLN, the regulation aims to provide electrical energy and maintain the continuity of its distribution. Nowadays, the quality of electrical energy needs to be improved along with the increasing use of electrical energy in everyday life, especially for industrial purposes that require a good level of reliability in the distribution of electrical energy. The most basic problems in the distribution of electric power are the quality, continuity and availability of electric power services to customers. One way to maintain continuity is to synchronize the transformer. In maintaining the quality of distribution of electrical energy by reducing blackouts caused by repair, maintenance or damage to transformers by synchronizing transformers both in the PLN area and in the area of private companies [1].

A transformer is an electrical device that can convert or transfer alternating electrical energy (AC) from one voltage level to another due to the performance of magnetic coupling with the basic principle of electromagnetics [2],[3],[4]. In a 3-phase transformer there is a connection group called a vector groups, namely the winding relationship between the high-voltage winding and the low-voltage winding that can affect the phase angle shift [5],[6]. This angular shift is also called transformer clock.

In Indonesia, for distribution transformers, there are generally four types of transformer groups based on their vector groups and neutral points [7]. In the installation of a three-phase transformer can be installed in parallel with two or more transformer units, it is said to work in parallel or synchronous if both the secondary side and the primary side are connected to serve the same load [8]. There are several factors that require this parallel system, including: Load growth, increased service reliability, transportation limitations and production limitations.

In industrial environments that have large electrical power and loads, parallel transformer systems are often used to simplify maintenance and to increase electrical energy in the future [9]. In these companies, if there is a disturbance or damage to one of the parallelized transformers, it will reduce the capacity of the electric power to be distributed, so that it can reduce production results due to not being able to run production machines optimally, then the alternative is to replace the transformer with how to rent or buy a transformer that has almost the same technical data, as for the obstacles in the field, often the available transformers have a different group vector or transformer clock with the transformer installed so that the handling of blackouts takes longer due to the assumption that they cannot be

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synchronized, so replacement is needed as soon as possible by synchronizing existing transformers with due regard to other synchronous requirements [10]–[13].

For the PLN environment, a parallel system is carried out to minimize blackouts due to maintenance or additional power capacity to be supplied [14]–[16], for example for substation or transformer maintenance activities, it is required to do blackouts for the safety of workers and the unit itself. due to blackouts, losses are not only experienced by customers, but also distribution network operators due to loss of potential electrical energy sold [6], it is necessary to transfer the load to minimize these losses by using a Mobile Substation Unit (UGB). Case in point at PT. PLN (Persero) ULP Rayon Belanti, Padang City experienced several problems, one of which was an overload and an unbalanced load, so to overcome this problem, an increase in the capacity of the distribution transformer was carried out as a means of distributing electricity, so to increase the power needed, one solution was by adding a Mobile Substation Transformer (Portable Transformer) which is connected in parallel with the operating distribution transformer [17]. And another example is the implementation of the installation of Mobile Substation Units at PT PLN (Persero) Tanjung Priok Area in distribution substation maintenance activities, the SAIDI value has been improved by 2.51 hours/customer/year or the saved kWh is 14493.89 kWh with a value of rupiah that can be calculated. saved Rp 21,266,595 [18]. In the load transfer or synchronous process, technical problems are often encountered, namely the transformer to be synchronized has a different group vector, for example the installed transformer is Dyn11 or Dyn1 while the transformer in the Moving Substation Unit has a group vector of Dyn5, so special treatment is needed so that the transformer can be synchronized. and no damage occurs due to the difference in the transformer clock which will cause a large excitation current and will have an impact on damage to the synchronized unit.

The desired final achievement of the transformer synchronization system is to parallelize two or more transformers, so that when a transfer or load sharing occurs, there is no blackout in the existing electricity network for consumers or the public and there is no short circuit in the parallel transformer system [19]. This research focusses to synchronize Dyn5 and Dyn11 distribution transformer to get the same vector groups using special terminal connection. It can help the maintenance transformer industry to provide the more easily synchronize transformers that have different vector groups

METHOD

A transformer is an electrical device that can convert or transfer alternating electrical energy (AC) from one voltage level to another based on the principle of electromagnetic induction (EMF Induction) that occurs between 2 (two) or more inductors (coils), but does not change the input source frequency or transformer output frequency[20]. The transformer can only work on alternating current (AC). In general, transformers are divided into 2 (two) types, namely step-up transformers and step-down transformers [21].

A transformer has a vector group, whether it is a single-phase or three-phase transformer and vector diagram is a vector that describes the relationship between magnetic flux, voltage and current flowing in a circuit. Affecting the values of the connections in a vector depends on the nature of the load, the impedance of the primary and secondary windings and the transformer losses. Three-phase transformer, has a coil connection on the primary side and secondary side, the connection is like wye, delta and zigzag. For the combination of primary and secondary coil connections in general, namely: Wye-wye (Y-y), Wye - delta (Y-d), Delta - wye (D-y), Delta - delta (D-d), Delta - zigzag (D-z), and Wye - zigzag (Y-z).

According to IEC 60076-1, the vector group notation is HV-LV respectively. For example, a step up transformer with a delta connected secondary and a wye connected primary, is written as 'Dy1'. This indicates that the LV winding lags behind the HV by 30°. Transformer connection notation is very important to know the connection of the high voltage coil and low voltage coil in the main transformer tank (main tank) so that it can make it easier to identify the type of connection used.

Table 1. Transformer Relationship Notation

Transformer Connection	High Voltage (HV)	Low Voltage (LV)
1 Phase	I	i
Delta	D	d
Wye	Y	y
Zigzag	Z	z

In the vector groups of transformers there is the term clock number, which is the difference in the phase angle between the low-voltage coil side and the high-voltage coil. Each hour digit is multiplied by 30°. For example: 0 = 0°, 1 = 30°, 5 = 150°, 6 = 180°, 7 = 210° (-150°), 11 = 330° (-30°). Based on the value of the phase angle, the vector groups can be grouped as in table (2)

Table 2 Vector Groups Based on Lagging/Leading HV Coils against LV

o'clock	*Phase shift (deg)*	Vector Groups		
0	0	Yy0	Dd0	Dz0
1	30 lag	Yd1	Dy1	Yz1
2	60 lag		Dd2	Dz2
4	120 lag		Dd4	Dz4
5	150 lag	Yd5	Dy5	Yz5
6	180 lag	Yy6	Dd6	Dz6
7	150 lead	Yd7	Dy7	Yz7
8	120 lead		Dd8	Dz8
10	60 lead		Dd10	Dz10
11	30 lead	Yd11	Dy11	Yz11

The requirements for the transformer to be parallelized must meet the following criteria:

1. Parallel voltage ratio must be the same.
2. The polarity of the voltage must be the same.
3. The voltage impedance at full load must be the same.
4. The ratio of reactance to resistance must be the same.
5. The number of phases must be the same.
6. The transformer vector groups must be the same

Analysis Procedure

The research methodology used is a simulation using the MATLAB Simulink R2018a software and TTL as the measuring tool. Transformer synchronization is carried out to maximize the availability of transformers that have different vector groups. This research uses Dyn5 and Dyn11 type transformers which have different vector groups. This study also proves synchronization in practice based on the results of simulations with MATLAB. For the research flow chart according to Figure 1.

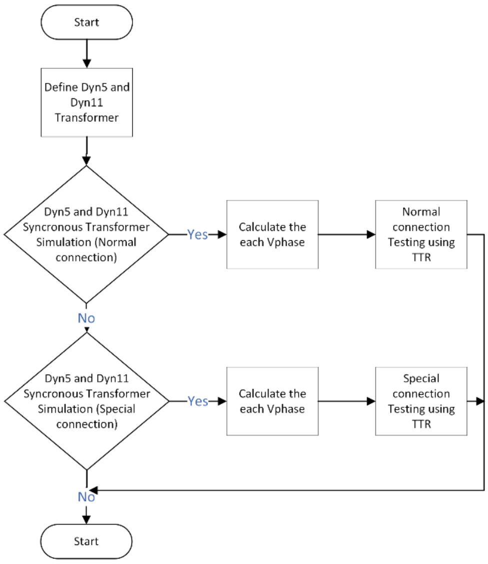


Figure 1. Research Flowchart

In this Research, modeling and simulation on Simulink work screens include:

1. Modeling of 3-phase transformer with Dyn5 and Dyn11 vector groups based on MATLAB GUI vector groups. This model is used to determine the terminal connections of the Dyn5 and Dyn11 transformers. This modeling will produce two transformers that have different vectors which will be shown from the clock vector.
2. Perform synchronous simulations with the same vector groups. This simulation aims to determine the effect of two transformers with the same vector (Dyn5 and Dyn5).
3. Perform synchronous and asynchronous simulations with different vector groups with normal connections. This simulation aims to determine the synchronous effect (can be paralleled because the vector groups are the same) and asynchronous (cannot be paralleled because the vector groups are different) of two transformers that have different vector groups (Dy5 and Dyn11) with normal connections (R-R, S-S, and T-T).
4. Perform asynchronous simulations with different vector groups with custom connections. This simulation aims to determine the effect of two parallels that have different vector groups by connecting with abnormal connections (R-T, S-S, T-R).

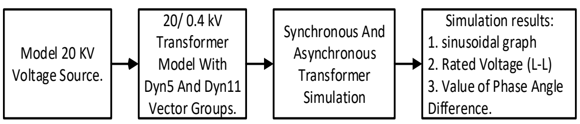


Figure 2. MATLAB Simulink Synchronized Transformer Simulation Modeling Steps

The steps in the simulation modeling are in accordance with Figure (2), in this step create two models of 20 / 0.4 kV distribution transformers on the MATLAB Simulink work screen with vector groups according to the data that appears on the MATLAB Vector group GUI (Figure 3).

Data Collection

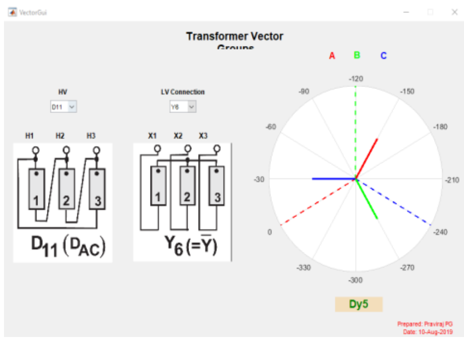
In this study, simulation modeling was carried out to replace the 20 / 0.4 kV distribution transformer with the Dyn5 and Dyn11 vector groups, in the whole experiment 4 (four) simulations were carried out to obtain the desired data, with the following details:

1. Simulation of Synchronous Transformer with the same vector (Dyn5 with Dyn5).
2. Simulation of asynchronous transformers with different vectors (Dyn5 with Dyn11).
3. Simulation of transformer synchronization with different vectors (Dyn5 with Dyn11) with normal cable connection.
4. Simulation of transformer synchronization with different vectors (Dyn5 with Dyn11) with abnormal cable connection (special).

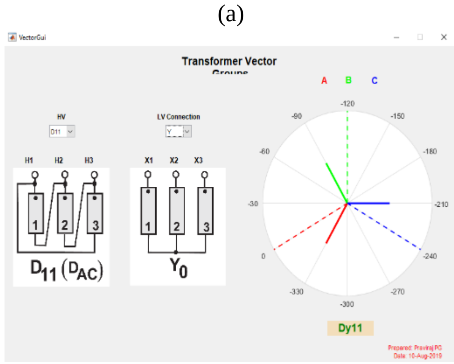
The simulation is expected to be able to describe the condition of the transformer in accordance with the original, the simulation results are in the form of a sinusoidal graphic image of the scope and values that appear on the display.

RESULTS AND DISCUSSION

In this study, the vector groups used are Dyn5 and Dyn11, for the connection vector groups can be seen in Figures (3a) and (3b).



(a)



(b)

Figure 3. Transformer Vector Groups In MATLAB Gui (a) Vector Group Dyn5, and (b) Vector Group Dyn11 [22].

From the picture above it can be seen that the phase angle difference between low voltage and high voltage for Dyn5 (Figure 3a) is 150° (lagging), while for Dyn11 (Figure 3b) it is -30° (Leading). One way to make this transformer parallel is to fulfill one of the requirements for synchronizing the transformer, namely the same polarity.

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A. Simulation of 20 / 0.4 kV Synchronous Transformer with Same Vector Group (Dyn5 and Dyn5).

This simulation is used to prove the effect of two transformers with the same vector group connected in parallel with the normal connection shown in Figure 4.

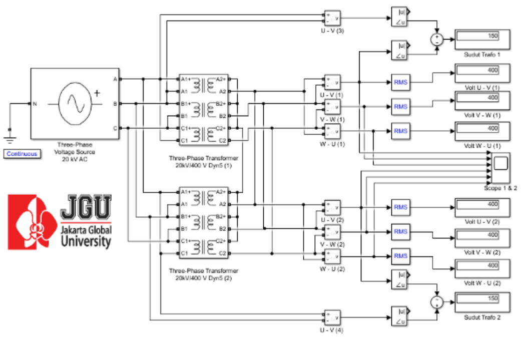

Figure 4. Synchronous Transformer Simulation Model Vector Groups Dyn5 and Dyn5.

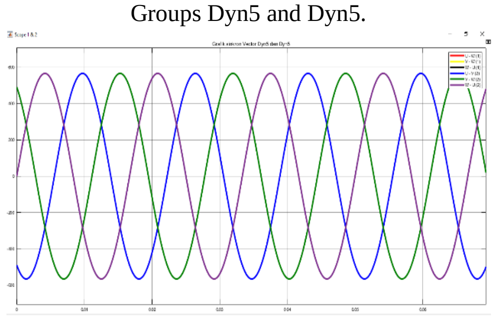

Figure 5. Voltage graph on Dyn5 and Dyn5 transformer synchronization simulation.

Table 3. Dyn5 & Dyn5 Transformer Synchronization Simulation Results on the low voltage side (Vrms)

Transformer 1 (Dyn5)			Transformer 2 (Dyn5)		
2u-2v (V) Red	2v-2w (V) Yellow	2w-2u (V) Black	2u-2v (V) Blue	2v-2w (V) Green	2w-2u (V) Purple
400	400	400	400	400	400

Table 4. Phase angle - phase at low voltage terminal to 1U (HV) phase reference terminal in transformer sync simulation (Dyn5 & Dyn5)

Transformer 1 (Dyn5)			Transformer 2 (Dyn5)		
2u Red	2v Yellow	2w Black	2u Blue	2v Green	2w Purple
150˚	-90˚	30˚	150˚	-90˚	30˚

Based on the simulation results in tables (3) and (4) data obtained that the transformer which has the same vector groups, there is no interference when paralleled. Where the phase angle difference between Transformer 1 and 2 is the same and it can be shown in Figure (5) that the 2u (red) and 2u (blue) phases are in one phase, and the other phases show the same results. Then transformers with the same vector (Dyn5 and Dyn5) can be connected in parallel by producing the normal voltage and same phase.

B. Simulation of 20 / 0.4 kV Asynchronous Transformer with different Vector Groups (Dyn5 and Dyn11).

This simulation is used to prove the effect of two transformers with the different vector group with the normal connection shown in Figure 6. Figure 7 shows the phase difference between Dyn5 and Dyn11 distribution transformers because these two transformers have different vector groups.

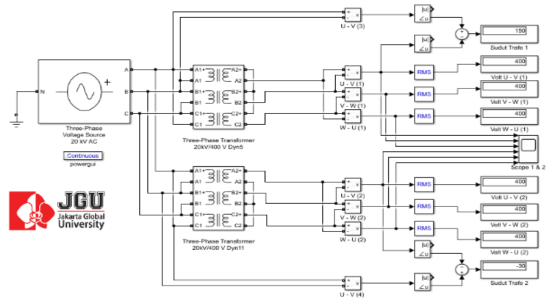

Figure 6. Asynchronous Transformer Simulation Model Vector Groups Dyn5 and Dyn11.

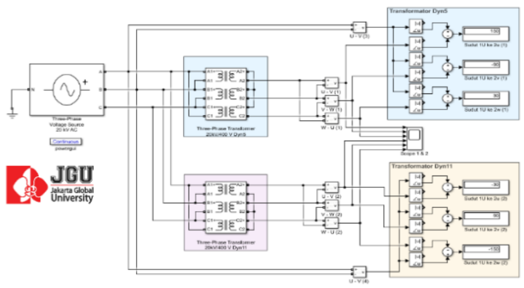

Figure 7. Simulation of phase angle measurement on Asynchronous Transformer (Dyn5 and Dyn11)

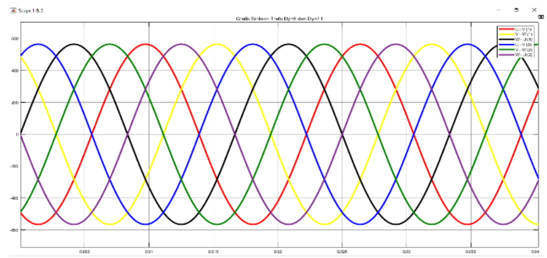

Figure 8. Voltage graph on asynchronous simulation of Dyn5 and Dyn11 transformers.

Table 5 Dyn5 & Dyn11 Transformer Asynchronous Simulation Results on the low voltage side (Vrms)

Transformer 1 (Dyn5)			Transformer 2 (Dyn11)		
2u-2v (V) Red	2v-2w (V) Yellow	2w-2u (V) Black	2u-2v (V) Blue	2v-2w (V) Green	2w-2u (V) Purple
400	400	400	400	400	400

Table 6 Phase angle - phase at low voltage terminal to 1U (HV) phase reference terminal in transformer Asynchronous simulation (Dyn5 & Dyn11)

Transformer 1 (Dyn5)			Transformer 2 (Dyn11)		
2u Red	2v Yellow	2w Black	2u Blue	2v Green	2w Purple
150˚	-90˚	30˚	-30˚	90˚	-150˚

Based on the simulation results in Tables (5) and (6), the data shows that transformers that have different vector groups but are not parallelized do not cause interference. Where the difference in phase angle between Transformer 1 and 2 has different results and it can be seen in Figure (8) that phase 2u (red) and phase 2u (blue) are not in phase and have a phase angle difference of 180°, and for other phases the results are the same.

C. Simulation of Synchronous Transformer 20 / 0,4 kV with Different Vector Groups (Dyn5 and Dyn11) Normal Connection.

This simulation is used to prove the effect of two transformers with the different vector group connected parallel with the normal connection shown in Figure 9. Figure 10 shows the same phase between Dyn5 and Dyn11 distribution transformers, but the output voltage become drop.

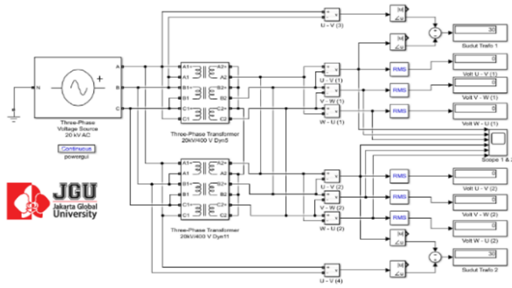

Figure 9. Synchronous Transformer Simulation Model Vector Groups Dyn5 and Dyn11 normal connection

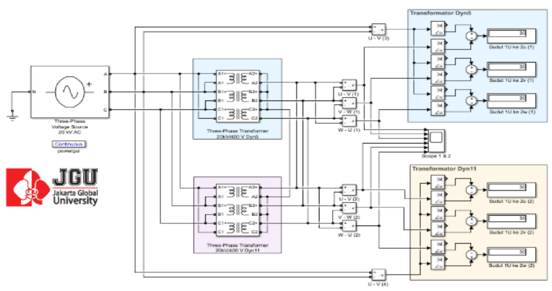

Figure 10. Simulation of phase angle measurement on synchronous transformers normal connection (Dyn5 and Dyn11)

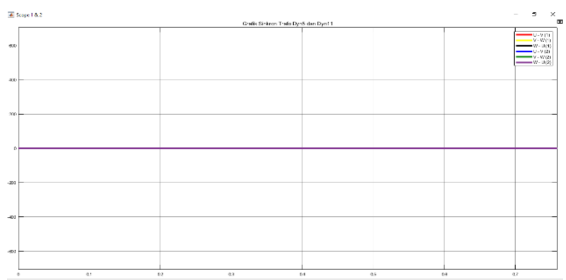

Figure 11. Voltage graph on synchronous simulation of normal connection transformers (Dyn5 and Dyn11).

Table 7 Dyn5 & Dyn11 Transformer synchronization Simulation Results on the low voltage side (Vrms) normal connection.

Transformer 1 (Dyn5)			Transformer 2 (Dyn11)		
2u-2v (V) Red	2v-2w (V) Yellow	2w-2u (V) Black	2u-2v (V) Blue	2v-2w (V) Green	2w-2u (V) Purple
0	0	0	0	0	0

Table 8 Phase angle - phase at low voltage terminal to 1U (HV) phase reference terminal in transformer sync simulation normal connection (Dyn5 & Dyn11)

Transformer 1 (Dyn5)			Transformer2 (Dyn11)		
2u Red	2v Yellow	2w Black	2u Blue	2v Green	2w Purple
30°	30°	30°	30°	30°	30°

Based on the simulation results in tables (7) and (8), it is obtained data that transformers that have different vector groups when paralleled with a normal relationship will cause interference. Where it can be seen in figure (11) all phases become 0, this indicates the transformer is experiencing a total disturbance (short circuit).

D. 20 / 0.4 kV Synchronized Transformer Simulation with Different Vector Groups (Dyn5 and Dyn11) Abnormal Connections.

This simulation is used to prove the effect of two transformers with the different vector group connected parallel with the abnormal connection shown in Figure 12. Figure 13 shows the same phase and the same output voltage between Dyn5 and Dyn11 distribution transformers.

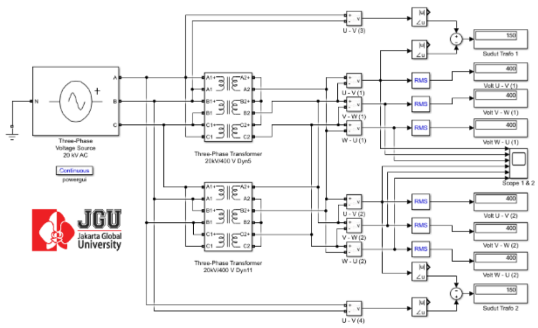

Figure 12. Synchronous Transformer Simulation Model Vector Groups Dyn5 and Dyn11 abnormal connection

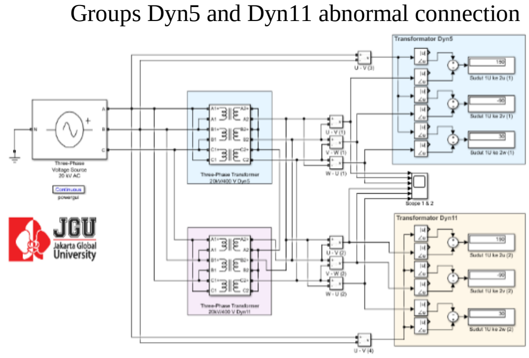

Figure 13. Simulation of phase angle measurement on synchronous transformers abnormal connection (Dyn5 and Dyn11)

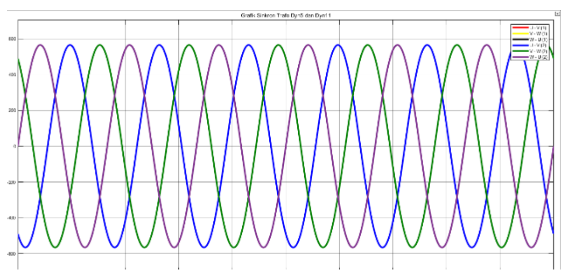

Figure 14. Voltage graph on synchronous simulation of abnormal connection transformers (Dyn5 and Dyn11).

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Table 9. Dyn5 & Dyn11 Transformer synchronization Simulation Results on the low voltage side (Vrms) abnormal connection.

Transformer 1 (Dyn5)			Transformer 2 (Dyn11)		
2u-2v (V) Red	2v-2w (V) Yellow	2w-2u (V) Black	2v-2u (V) Blue	2u-2w (V) Green	2w-2v (V) Purple
400	400	400	400	400	400

Table 10. Phase angle - phase at low voltage terminal to 1U (HV) phase reference terminal in transformer sync simulation abnormal connection (Dyn5 & Dyn11

Transformer 1 (Dyn5)			Transformer 2 (Dyn11)		
2u Red	2v Yellow	2w Black	2v Blue	2u Green	2w Purple
150˚	-90˚	30˚	150˚	-90˚	30˚

Based on the simulation results in tables (9) and (10) data obtained that transformers that have different vector groups (Dyn5 and Dyn11) when paralleled with an abnormal connection (Figure 12) will not cause interference. Due to the difference in the phase angle between Transformers 1 and 2, the results are the same and it can be shown in figure (14) that the 2u (red) and 2u (blue) phases have a phase difference of 0°, and for the other phases the results are the same. The results of this simulation (Figure 12) are in accordance with the results of the simulation (Figure 4). From the simulation data above Figures (12) and (13), for the connection the cable position can be described as follows:

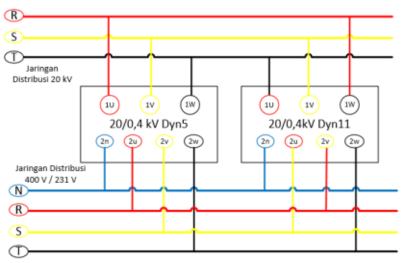


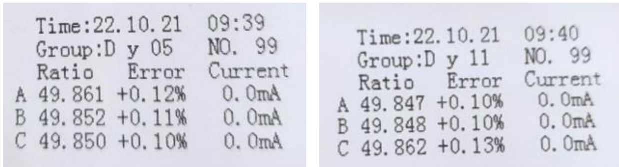
Figure 15. Synchronous transformer wiring diagram (Dyn5 & Dyn11)

E. 20 / 0.4 kV Synchronized Transformer Implementation with Different Vector Groups (Dyn5 and Dyn11) Abnormal Connections using TTR SAMGOR SG 7001.

Based on the simulation results that the parallel synchronization of Dyn5 and Dyn11 transformers (with different vector groups) with abnormal connections can be carried out and produce the same output voltage for each phase, then the implementation testing phase is carried out using a test tool, namely TTR SAMFOR SG 7001 which can be seen in Fig. Figure 16. Testing using this measuring instrument aims to prove the simulation results directly.

Figure 16. Turn Ratio Test of Dyn5 and Dyn11 using SAMGOR SG 7001

The results obtained are shown in Figure 16 (a) and (b). This test is carried out to synchronize Dyn5 and Dyn11 distribution transformers in parallel with abnormal connections that produce relatively the same voltage for Phase R (A-49,861 and A-49,847), Phase S (B-49,852 and B-49,848) and Phase T (C). -49.85 and C-49.862). The result of the voltage difference between the two voltage transformers is a maximum of 0.13% which indicates that the voltage difference standard from PLN is ±5%.



(a) (b)

Figure 16. Output of Turn Ratio Test of Dyn5 and Dyn11 using SAMGOR SG 7001

CONCLUSIONS

Based on the simulation results, several conclusions were obtained, including:

a. Transformer having the same group vector, voltage, number of phases and polarity, when synchronized there is no interference because there is no angular difference between the same phases.
b. Transformers that have different vector groups, if synchronized with normal connections, there will be interference caused by the difference in the angle of each phase being the same, where for Dyn5 and Dyn11 they have the same phase angle difference of 180°, so if they are forced to synchronize, damage will occur. Which is indicated by the loss of voltage and the loss of the angle difference of each phase, if under normal circumstances the difference between each phase in a 3-phase transformer is 120°.
c. Transformers that have different vector groups (Dyn5 and Dyn11) can be synchronized, without changing the connection in the transformer windings (vector group) by changing the position of the cable connection on one of the transformers, namely the position of the high-voltage cable (20 kV) and the position of the low-voltage cable connection (0,4 kV), with the arrangement according to figure (15) where for the high voltage side (Dyn11) phase R and phase T are exchanged, while on the low voltage side the voltage side (Dyn11) phase r and phase s are exchanged. Changes in the position of the HV and LV cable connections, resulting in a phase shift between the Dyn5 transformer and the Dyn11 transformer, so that during synchronization there will be no interference because there is no difference in the angle of the transformer.
d. For synchronizing transformers with other vector groups, further research is needed to determine the position of other cable connections so that good synchronization results are obtained.

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REFERENCES

[1] A. Wantoro, S. Samsugi, and M. J. Suharyanto, “Sistem Monitoring Perawatan dan Perbaikan Fasilitas PT PLN (Studi Kasus : Kota Metro Lampung),” *J. TEKNO*

KOMPAK, vol. 15, no. 1, pp. 116–130, 2021.
[2] R. Ondrialdi, U. Situmeang, and Zulfahri, "Analisis Pengujian Kualitas Isolasi Transformator Daya di PT. Indah Kiat Pulp and Paper Perawang," *SainETIn*, vol. 4, no. 2, pp. 72–81, 2020, doi: 10.31849/sainetin.v4i2.6288.
[3] R. Idris, "Analisis Hasil Pengujian Tahanan Isolasi Berdasarkan Hasil Uji Indeks Polarisasi, Breakdown Voltage, dan Tangen Delta," p. 57, 2020.
[4] D. A. Saputra, "Analisis Pengujian Transformator Daya Mt24 150KV/33KV 90MVA Di PT. Vale Indonesia, Sorowako - Sulawesi Selatan.," Universitas Muhammadiyah Malang, 2018.
[5] M. Manurung, "Studi Pengujian Vektor Group Transformator Distribusi Tiga Phasa," Universitas Sumatera Utara, Medan, 2010.
[6] R. Andriansyah, "Analisis Operasi Paralel Transformator Unit Gardu Bergerak Beda Jam Trafo Di Unit Pelaksana Pelayanan Pelanggan Semarang," *Pustakawan Reviewer UNISSULA*, Nov. 2020.
[7] SPLN D3 002-1:2007, *Spesifikasi Transformator Distribusi*. Jakarta, 2007.
[8] B. Y. Husodo and F. Firmansyah, "Analisis Vector Group Pada Hubungan Paralel Transformator Unit Gardu Bergerak.," *J. Teknol. Elektro*, vol. 7, no. 3, 2016, doi: 10.22441/jte.v7i3.890.
[9] N. ; F. ; F. Sudarmantoro, "Evaluasi Hubungan Paralel Transformator Fakultas Teknik Universitas Riau Pada Kondisi Beban Normal dan Beban Puncak," *Jom FTEKNIK*, vol. 2, no. 1, pp. 1–17, 2015.
[10] H. Liu, C. Mao, J. Lu, and D. Wang, "Parallel technology of electronic power transformer and conventional power transformer," *Dianli Xitong Zidonghua/Automation Electr. Power Syst.*, vol. 32, no. 18, pp. 49–54, 2008.
[11] D. R. Zemskyi and D. O. Bosyi, "Energy Efficient Modes of Distribution Power Supply Systems with Different Vector Group Of Transformer," pp. 2–7, 2019.
[12] R. T. Ugale, K. D. Mejari, and B. N. Chaudhari, "Design of Transformer with Flexible Vector Group Combinations and Adjustable Voltage Levels," *Proc. - 2018 23rd Int. Conf. Electr. Mach. ICEM 2018*, pp. 683–689, 2018, doi: 10.1109/ICELMACH.2018.8507157.
[13] B. W. Dionova, T. Hidayat, S. Wilyanti, D. J. Vresdian, A. A. Hapsari, and M. N. Mohammed(, "Comparative Analysis of Windings and Vector Groups in 20 / 0 . 4 kV Distribution Transformers at," vol. 18, no. 3, pp. 2–6, 2022.
[14] N. Fernando, L. Meegahapola, and C. Thilakarathne, "Solid state transformer parallel operation with a tap changing line frequency transformer," *2017 IEEE Innov. Smart Grid Technol. - Asia Smart Grid Smart Community, ISGT-Asia 2017*, pp. 1–6, 2018, doi: 10.1109/ISGT-Asia.2017.8378448.
[15] B. Yang, "Reliability of parallel connected power transformers with failure correlation and its preventive maintenance," *2014 17th Int. Conf. Electr. Mach. Syst. ICEMS 2014*, pp. 1044–1047, 2014, doi: 10.1109/ICEMS.2014.7013623.
[16] Z. Zhu, X. Mou, S. Sun, and C. Zhang, "Qualitative calculation and simulation analysis of transformer parallel operation," *Proc. - 2013 2nd Int. Symp. Instrum. Meas. Sens. Netw. Autom. IMSNA 2013*, pp. 1027–1030, 2013, doi: 10.1109/IMSNA.2013.6743456.
[17] W. Johan and Y. Ridal, "STUDI ANALISA KINERJA HUBUNG PARALEL TRANSFORMATOR DISTRIBUSI DENGAN TRANSFORMATOR UNIT GARDU BERGERAK (UGB) PADA BEBAN TIDAK SEIMBANG DI PT. PLN (PERSERO) ULP BELANTI PADANG - Univ. Bung Hatta Repository," Universitas Bung Hatta, 2022.
[18] N. K. Hardi, "STUDI IMPLEMENTASI PEMASANGAN UNIT GARDU BERGERAK UNTUK PENINGKATAN KEANDALAN JARINGAN DI PT PLN DISTRIBUSI JAKARTA RAYA AREA TANJUNG PRIOK," UNIVERSITAS MERCU BUANA, 2018.
[19] G. D. Antoro and A. Syakur, "Sinkronisasi Trafo Unit Gardu Bergerak (UGB) dengan Trafo Distribusi di Lingkungan PLN," *JTET(Jurnal Tek. Elektro Ter.*, vol. 9, no. 3, pp. 11–16, 2020.
[20] M. Sumardi, Sadi & Arief, "Pengukuran Perbandingan Belitan Pada Transformator 3 Phasa 50 Hz 250 kVA," *J. Tek.*, vol. 3, no. 2, pp. 67–74, 2014, doi: 10.31000/jt.v3i2.1381.
[21] R. Fadly, "Analisa Pengujian Tahanan Isolasi Trafo Daya 10 MVA 70/20 KV Pada Gardu Induk Talang Ratu PT.PLN (PERSERO) Palembang," vol. 53, no. 9, pp. 1689–1699, 2014.
[22] MATLAB Central, "Transformer Vector Groups - File Exchange -."

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