Development of 3 Phase Transformer Module Using Isolation Transformer for Simulation of Electrical Power System

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Abstract. A Transformer in the electric power system means transforming electrical power from high/medium voltage to low voltage. Three-phase transformers in electric power systems can be connected in a variety of relationships according to the needs of the network and consumers. Implementation in practice in the workshop is difficult to do with the condition of the availability of electricity grid voltage and the available load voltage for various types of loads. The isolation transformer module provides an alternative to the various possibilities of transformer experiments with various variations of transformer relationships and variations in load relationships under voltage conditions according to the network and consumer loads. Experiments of various transformer relationships with balanced and unbalanced loads can be carried out safely for measurement. The results of the empty load measurement show that the input voltage and output voltage show a value that is close to the same.

Keywords: transformer, power grid, electrical load

1. Introduction

Transformers are one of the most important components of the electric power system. The transformer functions to move power from the primary and secondary sides. Based on the number of factors, the transformer is divided into two (2) namely the 1-stroke transformer and the 3-stroke transformer. Based on the comparison between the input voltage and the output voltage, the transformer consists of a step-up transformer and a step-down transformer. By function, it consists of a power transformer, a measuring transformer, and an isolation transformer.

The electric power grid system uses a three-phase system consisting of R, S, and T phases with a phase angle difference of 120ºL [2]. There are electricity consumers who use the 3-phase system, especially for industry, government, and private agencies, and homes with power above 11 kVA. This 3-phase electricity requirement requires a 3-phase transformer to arrive at the electricity customer because the distribution system uses a voltage of 20-30 kV, while the equipment / electrical load uses a voltage of 220-230 V [3]. The 3-phase transformer based on its construction consists of a 3-stroke single transformer and 3 1-phase transformers arranged into a 3-stroke transformer. The primary and secondary winding relationships for the two types of transformers can be carried out with the Dyn, YnD, or Yyn relationship systems that adjust to the primary voltage system and load requirements [6].

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Understanding transformer analysis for electrical engineering graduates is needed because transformers are a very important part of electric power systems. Understanding transformer analysis can be done with an in-depth study of the characteristics of various types of transformers, both 1-phase and 3-phase. Therefore, the availability of various types of transformers in the laboratory is needed which are equipped with appropriate measuring instrument equipment. However, the problem that arises is the provision, operation, maintenance, and placement of transformer 3 phases and requires special laboratories such as distribution laboratories or high voltages. Meanwhile, the laboratory of the Department of Electrical Engineering Education (JPTE) Faculty of Engenering Universitas Negeri Medan does not yet exist and the availability of transformers and measuring instruments needed is still limited.

The need for the provision of 3-phase transformers along with supporting equipment can be pursued by modifying 3 (pieces) of 1-phase transformers converted into 3-phase transformers. Based on the availability of available electrical voltage (220 V / 380 V and the simulation of existing electrical loads, the 1-stroke transformer needed is a transformer of 3 pieces of insulation. The consideration is that the input and output of the isolation transformer have the same voltage, so it does not cause problems with the primary voltage source and electrical load with a voltage of 220/ 380 V.

A transformer is an electrical device that can move and convert electrical energy from one or more electrical circuits to another, through magnetic coupling, and based on the principle of electromagnetic induction [3]. The basic principle of a transformer is based on mutual induction between two coils connected by a magnetic flux through a core. When the primary coil is connected with alternating current, it will cause a magnetic flux that changes. Based on Faraday law the changing flux will induce an electromotive force (GGL) to the secondary coil through the transformer core [6]. Emf induction from the primary coil to the secondary coil is called reciprocal induction.

The equation in transformer analysis, namely the RMS value induced on the primary coil [6] is:

E= induction e.m.f/entanglement x number of windings of the primary coil (1)

or

$$E1 = 4.44 \times f \times N1 \times \Phi m \quad (2)$$

or

$$\text{Volts} = 4.44 \times f \times N2 \times B \times A \text{ Volt} \quad (3)$$

Similarly, the secondary coil applies the same so that the equation on the secondary side [6] is:

$$E2 = 4.44 \times f \times N2 \times \Phi m \quad (4)$$

or

$$\text{Volts} = 4.44 \times f \times N2 \times B \times A \text{ Volts} \quad (5)$$

Based on its function, the transformer consists of:

(1) Power Transformer

(2) Insulation transformer

(3) Auto Transformer

(4) Measuring transformer

The power transformer serves to move power from the primary side to the secondary side [3]. An isolation transformer is a transformer in which the voltage on the secondary side is equal to the voltage on the primary side. An autotransformer is a transformer that has one winding that functions as a primary winding and a secondary winding. A current transformer is a transformer that is used to lower the electric current from the network so that an electric current measurement can be carried out with a very large value of 6000 A. Voltage transformer is a transformer that functions to measure high charges on the line by lowering the voltage so that it can be read on the measuring instrument.

2. Research Methods

This research was carried out at the Department of Electrical Engineering Education, Faculty of Engineering UNIMED in 2022. The development steps of the 3-phase transformer are carried out based on the literature review and development model of Borg and Gall [1], which includes: Preliminary Study, Feasibility Study, Planning for the Manufacture of the 3 phase Transformer module, 3-phase Transformer Development, and 3-phase transformer testing.

Data collection was carried out by conducting experiments on a 3-phase transformer module composed of 3 isolation transformers. Transformer 3-phase testing is carried out by the following procedure:

1. Transformer polarity testing is to determine the order of transformer polarity, especially the secondary winding terminals.
2. Transformer 3-phase testing was carried out with the first experiment using the Y-Yn relationship system with load variations from 0.25 to full load loads (according to transformer capacity).
3. Experimenting with the two systems of the Delta-delta transformer relationship, the load variation was made the same as the Y-Yn relationship. Because the maximum voltage limit in the transformer is 225 V, it is necessary to adjust the input voltage allowed in the primary coil, which is a maximum of 225 V. Line voltage in the delta connection is $\sqrt{(3)}$ x phase voltage [2], then the maximum input voltage of each phase is $225/\sqrt{(3)} = 130$ V
4. Experiments into three delta-star relationship systems, with load variations the same as previous relationships. Because the maximum voltage limit in the transformer is 225 V, it is necessary to adjust the input voltage allowed in the primary coil, which is a maximum of 225 V. Line voltage in the delta connection is $\sqrt{(3)}$ x phase voltage [2], then the maximum input voltage of each phase is $225/\sqrt{(3)} = 130$ V

3 Results of Research and Discussion

Table 1. R-S Phase Measurement Results Symmetrical Load Yyn Relationship System

No	load	Input				Output			
		V	A	Cos φ	Watt	V	A	Cos φ	Watt
1	0,25 load	223	0,24	0,85	45,4	225	0,24	0,86	46,4
2	0, 5 load	223	0,45	0,88	88,3	225	0,42	0,89	84,1
3	0,75 load	223	0,74	0,86	141,9	224	0,70	0,88	137,9
4	Full load	223	0,98	0,87	190,1	224	0,95	0,88	187,2

Table 2. S-R Phase Measurement Results Symmetrical Load Yyn Relationship System

No	load	Input				Output			
		V	A	Cos φ	Watt	V	A	Cos φ	Watt
1	0,25 load	223	0,24	0,85	45,5	225	0,24	0,86	46,4
2	0, 5 load	223	0,45	0,88	88,3	225	0,42	0,89	84,1
3	0,75 load	224	0,74	0,86	142,6	225	0,70	0,88	138,6
4	Full load	224	0,98	0,87	191,0	225	0,95	0,88	188,1

Table 3. T-R Phase Measurement Results Symmetrical Load Yyn Relationship System

No	load	Input				Output			
		V	A	Cos φ	Watt	V	A	Cos φ	Watt
1	0,25 load	223	0,24	0,85	45,5	222	0,24	0,86	45,8
2	0, 5 load	223	0,45	0,88	88,3	224	0,42	0,89	83,7
3	0,75 load	223	0,74	0,86	141,9	223	0,70	0,88	137,4
4	Full load	223	0,98	0,87	190,1	223	0,95	0,88	186,4

Table 4. R-S Phase Measurement Results Symmetrical Load DD Relationship System

No	load	Input				Output			
		V	A	Cos φ	Watt	V	A	Cos φ	Watt
1	0,25 load	215	0,24	0,85	43,9	218	0,24	0,86	45
2	0, 5 load	215	0,45	0,88	85,1	218	0,42	0,89	81,5
3	0,75 load	215	0,74	0,86	136,8	218	0,70	0,88	134,3
4	Full load	215	0,98	0,87	183,30	218	0,95	0,88	182,2

Table 5. S-T Phase Measurement Results Symmetrical Load DD Relationship System

No	load	Input				Output			
		V	A	Cos φ	Watt	V	A	Cos φ	Watt
1	0,25 load	215	0,24	0,85	43,9	217	0,24	0,86	44,8
2	0, 5 load	215	0,45	0,88	85,1	217	0,42	0,89	81,1
3	0,75 load	215	0,74	0,86	136,8	216	0,70	0,88	133,
4	Full load	215	0,98	0,87	183,3	216	0,95	0,88	180,6

Table 6. T-R Phase Measurement Results Symmetrical Load DD Relationship System

No	load	Input				Output			
		V	A	Cos φ	Watt	V	A	Cos φ	Watt
1	0,25 load	215	0,24	0,85	43,9	217	0,24	0,86	44,8
2	0, 5 load	215	0,45	0,88	85,1	217	0,42	0,89	81,1
3	0,75 load	215	0,74	0,86	136,8	217	0,70	0,88	133,7
4	Full load	215	0,98	0,87	183,3	217	0,95	0,88	181,4

Table 7. R-S Phase Measurement Results Symmetrical Load DYn Relationship System

No	load	Input				Output			
		V	A	Cos φ	Watt	V	A	Cos φ	Watt
1	0,25 load	215	0,24	0,85	43,8	217	0,24	0,86	44,8
2	0, 5 load	215	0,45	0,88	85,1	217	0,42	0,89	81,1
3	0,75 load	215	0,74	0,86	136,8	217	0,70	0,88	133,6
4	Full load	215	0,98	0,87	183,3	217	0,95	0,88	181,4

Table 8. S-T Phase Measurement Results Symmetrical Load DYn Relationship System

No	load	Input				Output			
		V	A	Cos φ	Watt	V	A	Cos φ	Watt
1	0,25 load	215	0,24	0,85	43,8	218	0,24	0,86	44,2
2	0, 5 load	215	0,45	0,88	85,1	217	0,42	0,89	81,6
3	0,75 load	215	0,74	0,86	136,8	216	0,70	0,88	133,0
4	Full load	215	0,98	0,87	183,3	216	0,95	0,88	180,6

Table 9. T-R Phase Measurement Results Symmetrical Load DYn Relationship System

No	load	Input				Output			
		V	A	Cos φ	Watt	V	A	Cos φ	Watt
1	0,25 load	215	0,24	0,85	43,8	217	0,24	0,86	44,8
2	0, 5 load	215	0,45	0,88	85,1	217	0,42	0,89	81,4
3	0,75 load	215	0,74	0,86	136,8	217	0,70	0,88	133,6
4	Full load	215	0,98	0,87	183,30	217	0,95	0,88	181,4

2.1 Results of Research and discussion

2.1.1 Research Results

1) needs analysis

The development of a 3-stroke transformer module requires the following materials: 3 pcs isolation transformers, 3 pcs amper meters, 3 pcs volt meters, 3 pcs cos Q meters, resistive, inductive, and capacitive loads

2) 3-stroke transformer module planning

Based on the needs analysis, a box-shaped module design was made that was easy to use to conduct various types of experiments on transformer 3-phase

3) Development of a 3-transformer module

Modules are arranged based on planning and equipped with job sheets that contain various types of experiments on transformers 3-phase with various types of loads

4) Test results against modules

Testing is carried out to obtain data on whether the 3-phase transformer module consisting of 3 pcs isolation transformers can be used to carry out various transformer testing experiments with resistive, inductive, and capacitive loads. The test results with various types of transformer 3-phase relationships with loads are inductive as in table 1 until table 9

2.2. Discussion

The transformer in the electric power system functions as a shifter of electrical power from the primary side to the secondary side without changing the magnitude of the power and frequency. The change in the magnitude of the parameter lies in its voltage and current according to the equation:

Pprimer = Psekunder or Vprimer x I primary = Vsekunder x Isekunder [5]. The comparison of the primary voltage with the secondary or the primary current with the secondary current is called the comparison of the transformation with the notation "a" formulated into:

$V_p/V_s = I_s/I_p = a$, [6] based on the comparison of these transformations then: if $a>1$ is called a step-down transformer, and if $a<1$ then the transformer is a step-up transformer.

Based on the number of factors, the transformer is divided into a 1-phase transformer and a 3-phase transformer. Three-phase transformers can be made in one three-phase transformer construction and can also be composed of three 1-phase transformers [5]. The three-phase transformer practice module arranged consists of 3 pcs 1-phase transformers. The preparation of three transformers of one phase can be carried out after the transformer has been tested for determining the polarity of the transformer. The goal is to equalize the polarity of each transformer so that there is no phase shift in the relationship between the three-phase.

The transformer test using the Yyn relationship means that on the primary side, star (Y) is connected and on the secondary side is connected star (y) and n means that there is a neutral wire at the star point on the secondary side. The measurement results in the loaded test start from a load of 0.25 to a full load on each phase (R-S; S-R and T-R) show that the voltage on the primary side and the secondary side is stable (222 V – 224 V). The difference in voltage values can occur due to differences in the number of primary/secondary windings of one transformer with another, for example, a difference of 0.5 windings or more. In addition, there can also be differences in the input voltage coming from the output autotransformer. However, the relatively small difference has little effect on the load of the 3-phase.

The transformer test with the delta-delta relationship system (DD) means that the primary and secondary sides are connected delta. Since the design of the transformer voltage on the primary side is 220 V – 225 V, the input at the delta connection must be arranged in such a way that the voltage at the primary winding is a maximum of 225 V. Based on this, the maximum voltage of the primary side input (Phase-Neutral) is: $(225\ V)/\sqrt{3} = 130\ V$. Thus the voltage between phase (R-S; S-T and T-R) or the voltage in the primary winding becomes a maximum of 225 V. if directly connected to the source of three phases with a phase voltage of 220 V, the primary winding will get a voltage of 381 V so that it can damage the insulation of the primary coil winding, as well as the secondary winding, will experience similar things.

A Transformer test with a delta-star relationship system (Dyn) means that on the primary side, delta (D) is connected and the secondary side is connected to star (Yn). Just like in the DD relationship, the input voltage at the Dyn relationship is a maximum of 130 V, so the voltage at the secondary winding is also a maximum of 130 V. Thus the output voltage R-S = S-T= T-R= 225 V, and the voltage R-N=S-N=T-N=130 V. Thus the output voltage R-S = S-T= 225 V and the voltage R-N=S-N=T-N=130 V.

Based on the test results of the three-phase transformer module which is composed of three one-phase transformers as in table 1 to table 9, show that the module can be used for three-phase transformer practice activities by students. The practice of transformers, either one-phase or three-phase transformers for electrical engineering students, is very important because it is part of the competence in the field of electrical machinery. Based on this module, students can conduct various experiments on one-phase and three-phase transformers, starting from determining the polarity of the transformer, transform comparison, testing transformer characteristics, parallel transformer one phase, and various variations of the three-phase transformer relationship system both on the primary and secondary sides. In addition, it can also be developed with various variations of loads (resistive or inductive, or capacitive loads) on the secondary side.

4 Conclusions

Based on the results of the study, it can be concluded as follows Three-phase transformers can be arranged from three one-phase isolation transformers with input voltage according to the voltage source in the Electrical Engineering Laboratory

The composed three-phase transformer module can be used by students to experiment with various types of transformer relationship systems

The three-flavored transformer module can be used for transformer testing experiments, namely polarity test, transformation comparison, short circuit, and transformer characteristics

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