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The Impact of the Power Transformer Connections on the Flow of Zero Sequence Current

Mohammed A. A. Aljuboori **Mohammed A. A. Alrawe** **Yousif M. Al-Younus**
mohammadalijuboori66@uomosul.edu.iq mauom@uomosul.edu.iq yousif1969@uomosul.edu.iq

Electrical Engineering Department, Collage of Engineering, University of Mosul, Mosul, Iraq

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ABSTRACT

The effect of the various winding connections of three phase two windings transformer on the fault current at the line to ground (SLG-fault) and the double line to ground (DLG-fault) is studied. The ground faults are unbalanced ; so, the analysis of these types of short circuit faults is divided into three balanced circuits which are known as symmetrical networks. The zero sequence impedance appears in some types of transformer connections and its effect is reflected in the fault current value. This paper examines with help of MATLAB software by simulating a generating station and different transformer connections, the impact of three-phase two windings transformer connections which occurs on a transformer secondary side to determine which the connections type of the transformer gives the maximum and minimum zero sequence component of ground fault current.

Keywords:

transformer connections, unsymmetrical faults, single line to ground fault, double line to ground fault current..

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1.INTRODUCTION

An Electrical fault causes failure of the electrical equipments in the power system such as: generators, transformers, bus bars, cables, and all other equipments in the power system [1]. Due to sudden ground faults in the system, the normal operating conditions are disrupted. Unfortunately, ground faults could happen where the phase will establish a connection with the ground, as a result of this fault a zero sequence current is established [2,3].

For the circuit shown in Figure (1), the connections of the transformers affecting the ground fault at the transformer generator unit are simulated, where it was found that the single line of the ground fault depends on the type of transformer configuration used. It is observed that the Yg-Yg transformer has a larger ground fault on the generator bus during SLGF on the secondary side of the transformer [**4**].

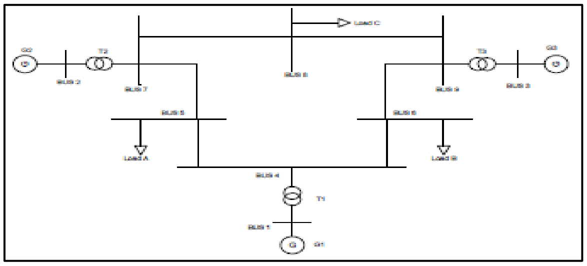

Figure 1. Single-line diagram

This paper analyses the influence of transformer connections at the zero current magnitude of SLG and DLG faults which might have occurred at the secondary side of a transformer for the transformer generator unit. As expected, the zero-sequence component will be larger in the case of connecting (dlta-Yg) because the visible impedance will be less than in the case of connecting (Yg-Yg)..

Power transformers can be forced to any possibility of abnormal conditions and faults [5]. The two general methods of connecting three-phase windings of transformers are: delta (Δ) and star (Y) connection, as shown in figure 2[6].

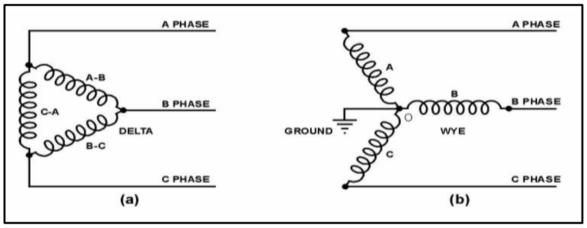

Figure 2: Three-phase transformer windings delta or star connections.

Almost 60-75% of faults in a system are SLG faults because SLG fault is the most repeated faults likely to take place in the power system. The consequence of the ground fault is determined by transformer connections and generating station arrangements. SLG is considered as unsymmetrical or unbalanced faults which create severe unbalanced operating conditions [7].

Besides that, 15% to 20% of faults in a power system are DLG faults. The DLG through metallic or a fault impedance are unsymmetrical or unbalanced faults that create severe unbalanced operating conditions. The SLG and DLG faults can be analyzed into three symmetrical components which are three balanced sets (positive, negative, and zero circuits) [8,9].

2. UNSYMMETRICAL FAULTS

Faults are the stream of a huge current over a wrong path which could cause huge damage to equipment and could lead to the shutdown of the electrical power. When SLG or DLG fault are occuring, the currents in the transformer connections and generating station arrangements become unequal and give rise to unsymmetrical fault currents [10]. The SLG and DLG fault can be converted into three free symmetrical components which vary in the phase sequence [11]. The key to analysis of Ground fault problems can be found by either:

(a) Kirchhoff's laws or
(b) Symmetrical components theory.

With the occurrence of the SLG or DLG fault, the currents in the three lines become unequal and unsymmetrical. The analysis of these types of fault problem can be obtained by the symmetrical components method [12].

In the symmetrical components method, any set of unbalanced 3-phase voltages or currents can be transformed into 3 balanced sets. These are:

a.The positive sequence follows the same sequence of the original circuit, all having the same phase sequence abc as the original set and denoted by Va1, Vb1,Vc1.. This sequence is signified by the symbol “1” or “+”.

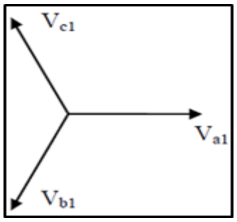

Figure 3: +ve sequence components

b.The negative sequence has an opposite sequence from the +ve sequence and denoted by Va2, Vb2, and Vc2.

The –ve sequence is signified by the symbol “-” or “2”.

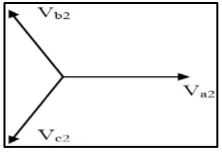

Figure 4: -ve sequence components

c.The A zero sequence set, all equal in magnitude and in the same phase and denoted by Va0, Vb0, Vc0 and known by the symbol “0” [13,14,15].

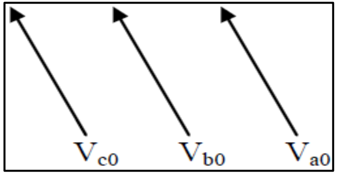

Figure 5: 0-sequence vectors (components).

According to above, any set of unbalanced 3-phase voltages or currents can be converted into 3 balanced sets.

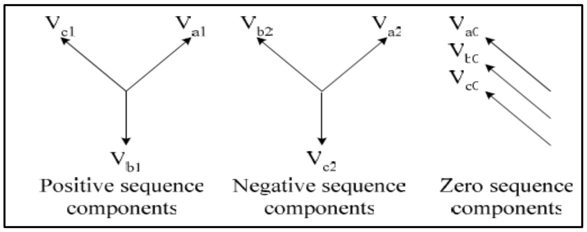

Figure 6: Three balanced sets of three unbalanced voltage phasors

3. THEVENIN EQUIVALENT CIRCUITS OF SEQUENCE NETWORKS

As shown in Fig. 5, the Thevenin networks for the sequence networks have only internal equivalent impedances, Z1, Z2 and Z0, respectively. The second method is preferred for unsymmetrical fault analysis [10].

Sequence Networks for unsymmetrical fault can be concluded by superposition and Thevenin's theorems. The Superposition theorem decomposes the faulted network into three sequence networks. While Thevenin's theorems replaced any linear network containing any number of voltage sources and impedances into a single e.m.f and an impedance of like sequence. Therefore, for the power system we can form three- sequence networks. These sequence networks, carrying current Ia1, Ia2, and Ia0 are then inter-connected to represent the different fault conditions. The positive sequence of thevenin network has an equivalent positive impedance, , Ea, and Z1equivalent voltage source

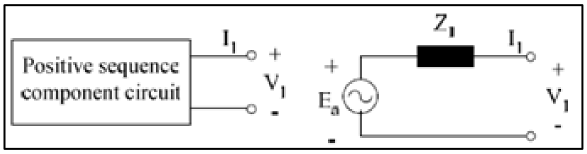

Figure 7. The positive sequence of Thevenin network

The negative sequence Thevenin network has an equivalent impedance, Z2

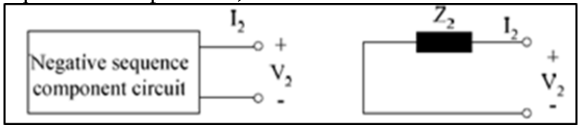

Figure 8. The negative sequence of Thevenin network.

The zero sequence Thevenin network has equivalent zero impedance, Zo.

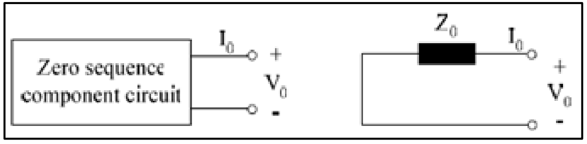

Figure 9. The zero sequence of Thevenin network

The sequence voltages Vo, V1, and V2 are zero, positive and negative, respectively and the sequence currents Io, I1, and I2 are zero, positive and negative, respectively. For the positive sequence Thevenin network, Ea. defines the Thevenin voltage seen from the fault point.

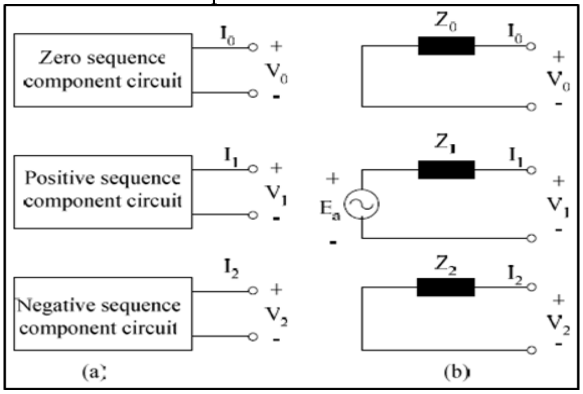

Figure 10: Thevenin equivalent sequence circuits

These sequence networks are inter-connected to represent the different fault conditions [16,17].

From above, it is noticed that the Thevenin networks for the zero and negative sequence networks have only equivalent impedances, Zo and Z2, respectively. Generators are connected or removed from the network for many reasons such as load variations, emergency outages, and maintenance. The generator is necessary to be synchronized with a power system before being connected to it [6].

4.SEQUENCE IMPEDANCES OF TRANSFORMERS

Because of the complexity of its zero sequence network as compared to its positive and negative components, the characteristic of the transformer is unique, which is dependent on how it is connected [11].

The possible connections of primary and secondary windings of two windings three phase transformer that are studied : Y-Y, Yg – Y, Yg – Yg, Δ – Y, Δ – Yg, (vi) Δ – Δ and Δ – Δ, (where Δ is delta connection, Yg is earthed star connection) [18].

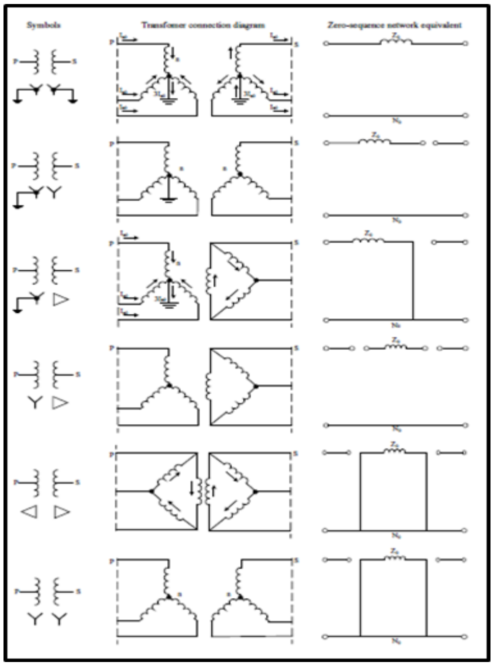

Figure 11: Zero-sequence network of three-phase Transformer according to its connection

Y–Y Connections of Transformer: When a transformer has at minimum two grounded-wye windings, zero-sequence current can be converted between the grounded-wye windings. Any impedance between the transformer neutral points and earth must be symbolized in the zero-sequence network as three times its value to properly account for the zero-sequence voltage drop through it.

Y-Δ and Δ-Y Connections: This zero sequence current can only exist in the closed delta winding and not on the line side of the winding. Because of this, an open circuit exists between the star and the delta sides. Zero sequence currents will be able to stream over the grounded-wye winding of the transformer.

Δ-Δ Connection: In the delta–delta connection the winding current is reduced by a factor of 1.73 to 58% of that in the Y-Y connection [6,11].

As shown in figure 5, for the delta connection and Wye (ungrounded), the zero sequence current that will flow to the reference bus of the faulted system is zero.

For Star-delta connections with neutral grounded, a zero sequence current will circulate in the delta winding without leaving the terminals of the transformer as a result of the grounded star winding. An open circuit exists between the star and the delta sides.

Because the zero sequence current can only exist in the closed delta winding and not on the line side of the winding. The equivalent circuit for this connection and all other models can be represented according to the above principles.

From figure. 1, it can be gotten that the figure indicates the right flow of the zero-sequence current from the primary to the secondary of the transformer according to its connection [15,18].

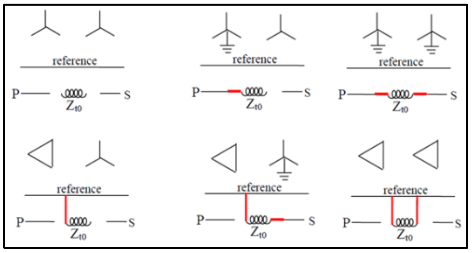

Figure 12: Single-line diagram for the zero sequence current flow of different transformer connections.

5. SINGLE LINE TO GROUND (SLG) FAULT ANALYSIS

SLG fault is usually referred to as unbalanced and unsymmetrical short-circuit fault. It occurs when one conductor makes contact with the neutral wire or falls to the ground.

Case 1: Metallic Line-to-Ground Short Circuit

The metallic SLG fault in a power system is given as diagram in Fig. 13.

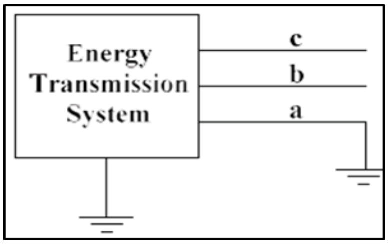

Figure 13. Representation of metallic SLG fault

The boundary conditions at the fault point:

$Va = 0,$

$Ib = 0,$

And $Ic = 0$ -----(1)

These can be converted to equivalent conditions in symmetrical components as follows:

$Va0 + Va1 + Va2 = 0 = Va$ -----(2)

Where Va1, Va2, and Vao represent, respectively, the positive, negative, and zero sequence voltage.

Also, $Ia0=Ia1=Ia2=Ia/3$ ----(3)

Where Iao, Ia1, and Ia2 represent, respectively, the zero, positive, and negative current.

$Ia1=Ia2=Iao=E/(Z1+Z2+Zo)$-----(4)

Z0, Z1 and Z2 are, respectively, zero, positive and negative impedance, is the fault impedance.

By using the conditions of Eq. (2) and (3), the sequence networks connections for the metallic SLG fault can be given in Fig. 14.

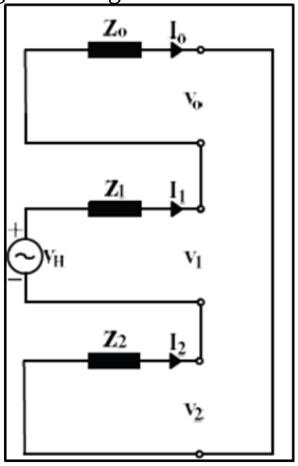

Figure 14. Sequence networks connection for metallic SLG fault

Case 2: SLG with Fault Impedance (ZF)

The SLG with fault impedance in a power system is given as a diagram in Fig. 15.

At SLG with ZF:

$I1=I2=Io=E/(Z1+Z2+Zo+3Zf)$--(5)

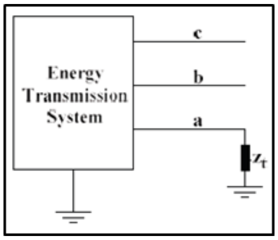

Figure 15. Representation of SLG with a fault impedance

Then, the fault current for each case is:

$$IF=I1+I2+I0=3I1=3I2=3 \text{ -----(6) [19].}$$

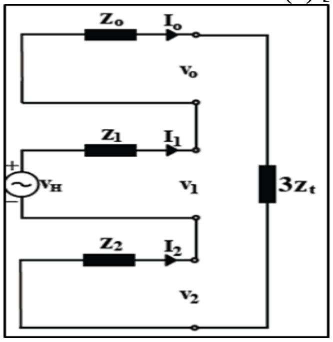

Figure 16. Sequence circuits connections for SLG with a fault impedance

6. DLG FAULT ANALYSIS

The DLG fault happens as a result of insulation collapse between phases and ground. Thus, the current of the network flows to earth through fault lines and the current of the healthy phase decreases to zero[9].

For unloaded generator–transformer set when DLG fault happens, the following boundary conditions are satisfied:

Assume the fault between phases ‘b’ and ‘c’ with the earth, as shown in figure.17.

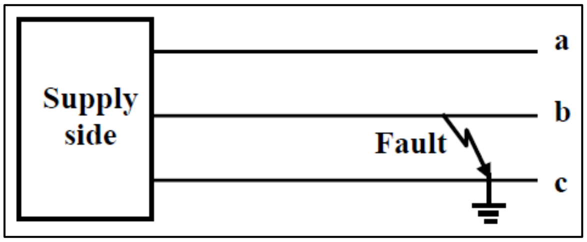

Figure 17: Metallic DLG on phases b-c.

Then,

$$Ia = 0 \text{----------(7)}$$

Since earth is the zero potential, the voltage between faulted phases and earth is zero,

$$Vb = Vc = 0 \text{----------(8)}$$

Hence, the derived conditions under DLG fault would be:

$$Va0=Va1=Va2=1/3Va \text{----------(9)}$$

$$If=Ib+Ic \text{ ----------- (10)}$$

$$Ia0+Ia1+Ia2=Ia= 0 \text{----------(11)}$$

Case.1: Solidly DLG fault without ZF

When DLG is a metallic, then:

$$ZF =0 \text{---------(12)}$$

$$Ia1=Ea/(Z1+Z2Z0/(Z2+Z0)) \text{ ----------(13)}$$

When the zero sequence is nonfinite,

$$Iao=-Z2/(Z2+Z0)\ .Ia1 \text{----------(14)}$$

$$Ia2=-Zo/(Z2+Z0)\ .Ia1 \text{----------(15)}$$

When the zero sequence is infinite,

$$Ia1=Ea/(Z1+Z2) \text{ ----------(16)}$$

From Equations (9) and (16), it is concluded that all three sequence networks connected in parallel at the fault position in order to simulate a double line to a ground fault [17,20].

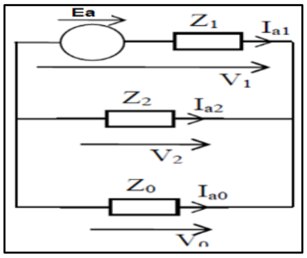

Figure 18: Connection for DLG fault

Case.2: Solidly DLG fault with ZF

With ZF, the zero sequence impedance is (Zo + 3ZF) in the zero sequence path [6].

The positive, negative, and zero currents with respect to the phase-a for each fault are[3,10],:

$$Ia1 = \{VF / [Z1+Z2(Zo+3ZF)/(Z2+Zo+3ZF)]\} \text{---(17)}$$

$$Ia2= -Ia1(Zo+3ZF)/(Z2+Zo+3ZF) \text{---------(18)}$$

$$Iao = -Ia1Z2/(Z2+(Zo+3ZF) \text{-----------(19)}$$

A typical representation of a double line to ground fault with fault impedance of Zf at fault point F is shown in Figure. 19, [12,21]:

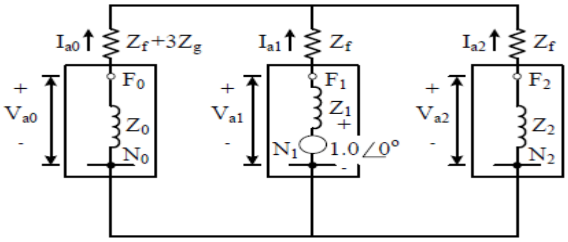

Figure. 19: The connection of the equivalent sequence networks of DLG fault with ZF

7. RESEARCH METHOD

7.1. SLG fault

To analyse the effect of various transformer connections during SLG fault, a model of unloaded transformer connections and generating station arrangements is simulated as illustrated in Figure (19).

Table (1), gives the tested network parameters, at Sbase=2MVA, Vbase=6.6Kv:

Table.1: Data of tested network(Gupta).

Parameter	Generator	Transformer
S(MVA)	2	2
VOLTAGE(kV)	6.6	6.6/11
+ve sequence impedance (X_1)	2.18	1.09
-ve sequence impedance (X_2)	1.526	1.09
zero sequence impedance (X_0)	1.526	1.09

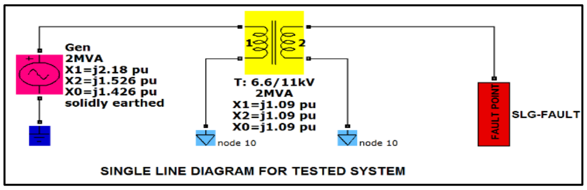

Figure 20: Single line diagram for the tested network.

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7.1.1. SLG with metallic

1- Case 1: Transformer is Y-Y connected

Transformer is Y-Y connected: In general, the sequence networks for this case are given in figure (20,21,22).

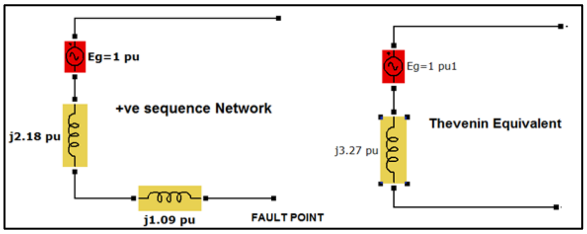

Figure 21: +ve sequence Network when the transformer connection is Y-Y.

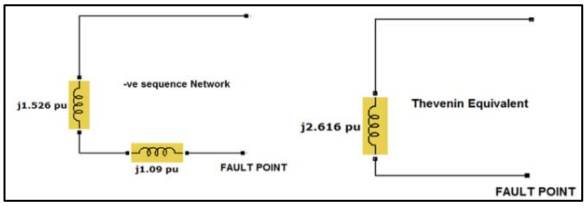

Figure 22:-ve sequence Network when the transformer connection is Y-Y.

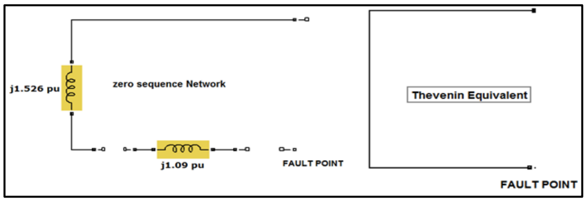

Figure 23: Zero sequence Network when the transformer connection is Y-Y.

The equivalent sequence network diagram for a single line-to-ground fault is:

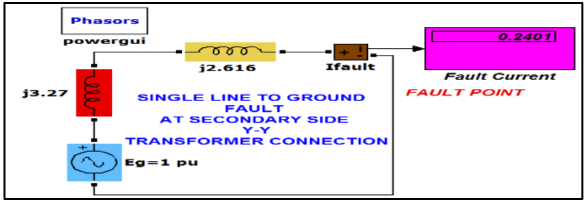

Figure 24: The equivalent circuit for metallic single line to ground fault at secondary side of Y-Y transformer connection.

The fault current for this case is (0.2401 pu), as shown in figure (24). For the rest of cases(case2-9), the fault current, the positive and negative sequence networks, and Thevenin's equivalent are the same as the case (1), but the different is in the zero sequence networks, as seen below.

For Transformer connections (Y- Δ,Y- Yg ,Yg- Y,Δ – Y, Δ - Δ and Yg – Δ), it is noticed, the symmetrical components for these cases are similar to the symmetrical components for case 1. Therefore, the same fault current at SLG fault in case1.

2- Case 2: Transformer is Δ - Yg connected

Transformer is Δ - Yg connected: This case is different from the above cases, this is done because the secondary side of the transformer is grounded star. So, the equivalent circuit becomes as follows.

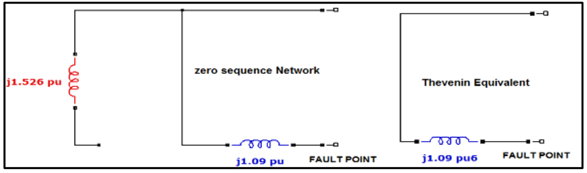

Figure 25:Zero sequence Network when the transformer connection is Δ-Yg.

The equivalent circuit for this case is:

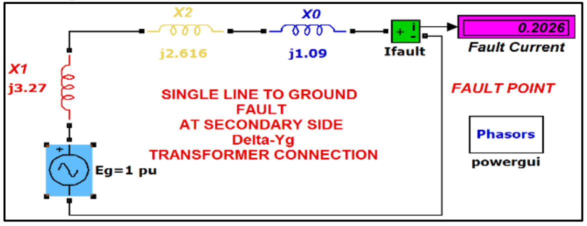

Figure 26: The equivalent circuit for metallic SLG

fault at the secondary side of the transformer (case2). It is noticed in this case the total impedance is increased because of the effect of zero impedance of the transformer when the transformer winding is Δ – Yg. The fault current becomes less than in the previous cases, as is shown in figure (25), and equal to (0.2026 pu).

3- Case 3: Transformer is Yg - Yg connected

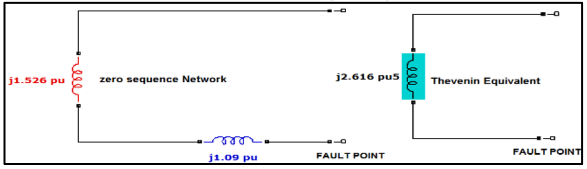

Figure 27:Zero sequence Network when the transformer connection is Yg-Yg.

The equivalent circuit for this is:

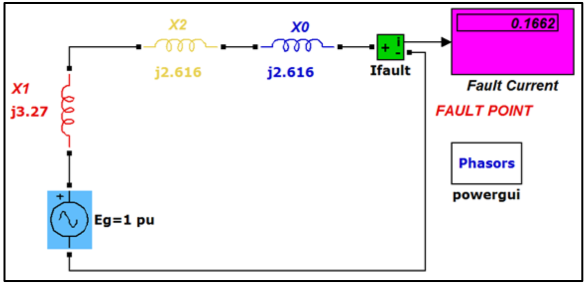

Figure 28: The equivalent circuit for metallic SLG

fault at secondary side of the transformer (case 3).

It is noticed in this case the total impedance is increased because of the effect of zero impedance of the generator and transformer when the transformer windings are Yg – Yg. The fault current becomes less than in the previous cases, as is shown, in figure (28) and equal to (0.1662 pu).

7.1.2. SLG with ZF:

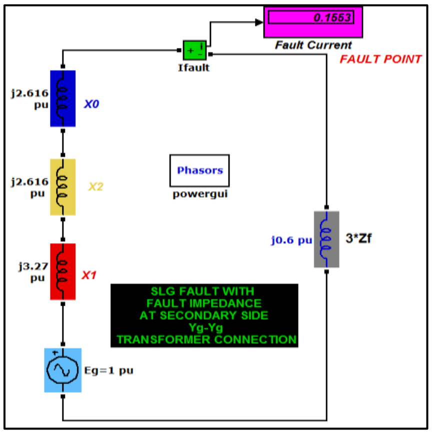

Figure 29: The equivalent circuit for SLG fault with

ZF at secondary side of the transformer

When the transformer windings are Yg – Yg. It is noticed in this case the total impedance is increased because of the magnitude of ZF is added to zero impedance of the generator and transformer. The fault current becomes less than in the previous cases, as is evident in figure (28) and equal to (0.1553 pu). At the rest of transformer connections, the fault impedance does not affect the fault current.

Figure 30, shows the results of all types of transformer connections:

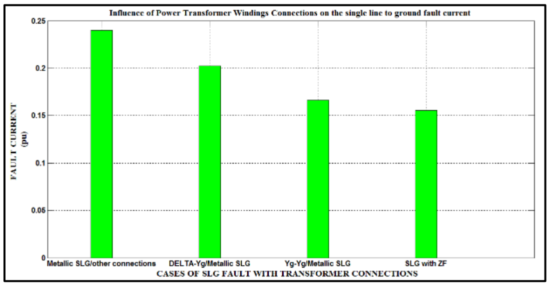

Figure 30 : Impact of Two Windings three -phase Power Transformer Connections on the Metallic/ZF SLG short circuit current

The minimum short circuit current at Yg-Yg connections of the power transformer with the fault impedance (ZF).

7.2. DLG fault:

To analyze the effect of various transformer connections during DLG fault, a model of unloaded transformer connections and generating station arrangements is simulated as illustrated in Figure (30). Table (1), gives the tested network parameters, at Sbase=2MVA, Vbase=6.6Kv:

Table.2: Data of tested network.

Parameter	Generator	Transformer
S(MVA)	2	2
VOLTAGE(kV)	6.6	6.6/11
+ve sequence impedance (X_1)	2.18	1.09
-ve sequence impedance (X_2)	1.526	1.09
zero sequence impedance (X_0)	1.526	1.09

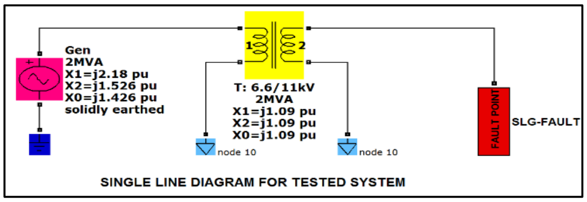

Figure 31: Single line diagram for the tested network.

7.2.1. Metallic DLG:

1- Case 1: Transformer is Y-Y connected

For this case the equivalent sequence network diagram for the DLG fault is:

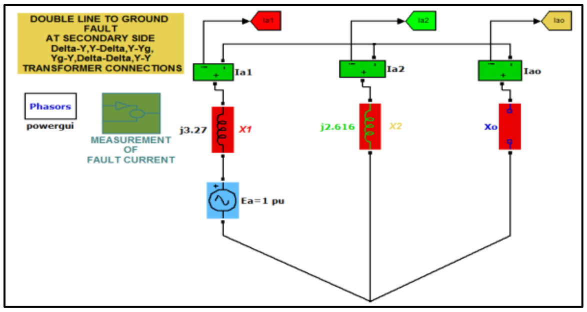

Figure 32: The equivalent circuit for metallic DLG fault at secondary side of Y-Y transformer connection.

The fault current for this case is (0.7203 pu). For Transformer connections (Y- Δ,Y- Yg ,Yg- Y,Δ – Y, Δ - Δ and Yg – Δ), it is noticed, the symmetrical components for these cases are similar to the symmetrical components for case 1. Therefore, the same fault current at DLG fault in case1.

2- Case 2: Transformer is Δ - Yg connected

This case is different from the above cases, this is done because the secondary side of the transformer is a grounded star. So, the equivalent circuit becomes as below:

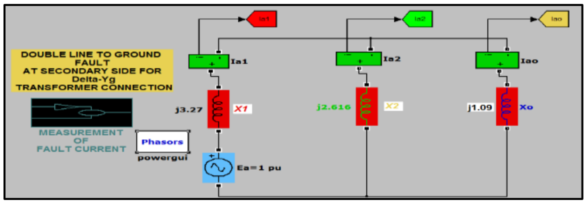

Figure 33: The equivalent circuit for metallic DLG

fault at the secondary side of the transformer (case2). It is noticed in this case, the zero impedance is (1.09 pu) because of the transformer winding is Δ – Yg. The fault current becomes greater than the previous cases and equal to (1.05 pu).

3- Case 3: Transformer is Yg - Yg connected

The equivalent circuit for this is:

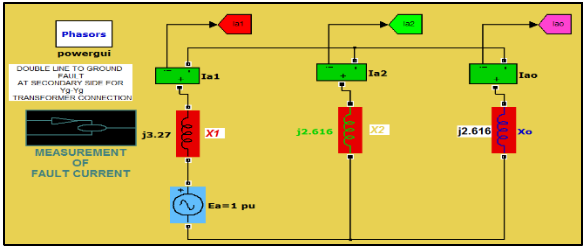

Figure 34: The equivalent circuit for metallic DLG fault at secondary side of transformer (case 3).

It is noticed at this case the zero impedance of the generator and transformer is increased because of the transformer windings are Yg – Yg. The fault current becomes less than the previous case and equal to (0.9261 pu).

The results of the above three cases are shown in figure.35 :

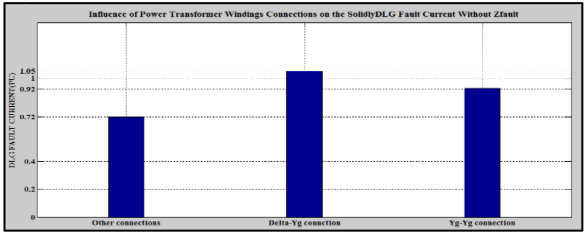

Figure 35: The DLG fault currents values for different connections of transformer windings at solidly DLG fault without ZF.

7.2.2. DLG with ZF:

4- Case 4: Transformer is Y-Y connected

The equivalent sequence network diagram for this case is: 0.5983

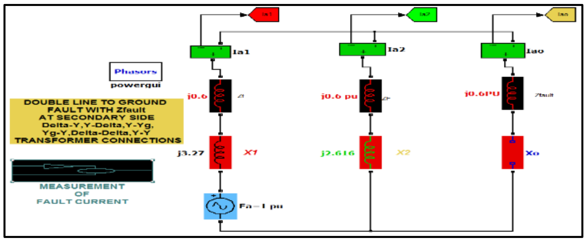

Figure 36: The equivalent circuit for metallic DLG fault at secondary side of Y-Y transformer connection.

The fault current for this case is (0.5983pu). For Transformer connections (Y- Δ,Y- Yg ,Yg- Y,Δ – Y, Δ - Δ and Yg – Δ), it is noticed, the symmetrical components for these cases are similar to the symmetrical components for case 1. Therefore, the same fault current at DLG fault in case1.

5- Case 5: Transformer is Δ - Yg connected

This case is different from the above case, this done because the secondary side of the transformer is grounded star. So, the equivalent circuit becomes as below:

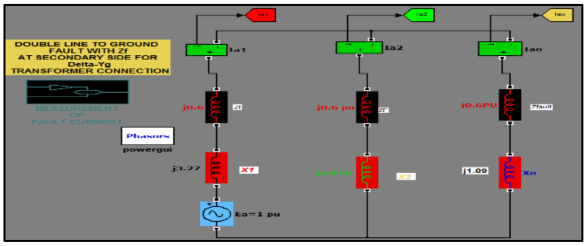

Figure 37: The equivalent circuit for metallic DLG

fault at the secondary side of the transformer (case5). It is noticed at this case the zero impedance is (1.09 pu) because of the transformer winding are Δ – Yg.

The fault current becomes greater than the previous cases and equal to (0.8517 pu).

6- Case 6: Transformer is Yg - Yg connected

The equivalent circuit for this is:

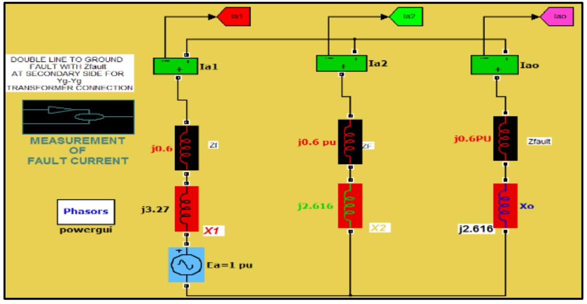

Figure 38: The equivalent circuit for metallic DLG fault at secondary side of transformer (case 6).

It is noticed in this case the zero impedance of the generator and transformer is increased because of the transformer windings are Yg – Yg. The fault current becomes less than the previous case and equal to (0.7740 pu).

The results of the above three cases are shown in figure.39:

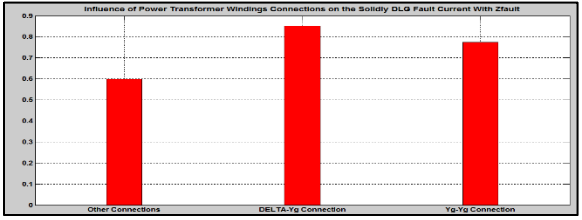

Figure 39: The DLG fault currents values for different connections of transformer windings at solidly DLG fault with ZF.

The minimum short circuit current at Yg-Yg connections of the power transformer with the fault impedance (ZF).

8. CONCLUSIONS

For SLG Fault: In this paper, by using representation with MATLAB software, the different types of windings connection of three-phase transformers have been tested. The case (1), despite the different connections of the two windings three-phase transformer, the fault current is the same due to the fact that the zero sequence impedance for all of these connections in the first case is not active. In this case, the fault current is the largest.

For SLG with ZF with (Yg–Yg connection), the fault current, as shown before, is the least because the zero sequence impedance is the largest value for all cases.

Finally, according to the simulation results, the best types of windings connection for the three-phase transformers are Yg-Yg connection with ZF which give the least fault currents and this fault current can be reduced with high grounding impedance, as shown in the equation (6).

The ground fault current can be reduced and limited by increasing the fault (grounding) impedance.

For DLG Fault: In this paper, by using representation with MATLAB software, the different types of windings connection of three-phase transformers have been tested. For DLG without ZF, case (1), despite the different connections of the two windings three-phase transformer, the fault current is the same due to the fact that the zero sequence impedance for all of these connections in the first case isn’t active. In this case, the fault current is minimum.

At Δ –Yg connection (case 2), the fault current, as shown in fig.13, is the largest because the zero sequence impedance is less than the value for the case3.

For DLG with ZF, case (4), despite the different connections of the two windings three-phase transformer, the fault current is the same due to the fact that the zero sequence impedance for all of these connections in the first case are not active. In this case, the fault current is minimum with respect to case 5 and case 6.

At Δ –Yg connection (case 5), the fault current, as shown in fig.17, is the largest because the zero sequence impedance is the less than value for cases 6.

Finally, according to the simulation results, the worst types of windings connection for the three-phase transformers are Δ-Yg connection without ZF (case 2).

Also, ZF minimizes the fault currents and this fault current can be reduced with high grounding impedance.

REFERENCES

[1] M. M. Rahman, M. F. Rabbi, M. K. Islam, and F. M. M. Rahman, "HVDC Over HVAC Power Transmission System: Fault Current Analysis and Effect Comparison," in *2014 International Conference on Electrical Engineering and Information & Communication Technology*, 2014, pp. 1–6.

[2] J. Santamaria, ”Analysis of Power Systems Under Fault Conditions," Thesis, California State University, Sacramento Summer 2011.

[3] W. P. Davis, "Analysis Of Faults In Overhead transmission Lines Fall," Thesis, California State University, Sacramento, 2012.

[4] A. R. Sultan and M. W. Mustafa, “Ground Fault Currents in Unit Generator Transformer at Various Voltage and Transformer Configurations,” *Indian Journal Of Applied Research*, vol. 3, no. 5, May 2013, ISSN - 2249-555X.

[5] D. F. Dakhlan, "Modeling Of Internal Faults In Three-Phase Three-Winding Transformers For Differential Protection Studies," MSc Graduation Thesis, Faculty of

Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, June 2009.

[6] A. Ibatullayeva, "Power Transformers in Electrical Transmission and Distribution Grids," Bachelor's Thesis, Power Engineering Department, Faculty of Electrical Engineering, Prague 2017.

[7] A. R. Sultan, M. W. Mustafa and M. Saini, "Ground Fault Currents in Unit Generator-Transformer at Various NGR and Transformer Configurations," in *2012 IEEE Symposium on Industrial Electronics and Applications*, 2012, pp. 136–140.

[8] F. Yalçın and Y. Yıldırım, "A Study of Symmetrical and Unsymmetrical Short Circuit Fault Analyses in Power Systems", *Sakarya University Journal of Science*, vol. 23, no. 5, pp. 879–895, 2019.

[9] W. D. Stevenson, *Elements of Power System Analysis*, 3rd edition, McGraw-Hill, 2015.

[10] V. K. Mehta, *Principles of power system*. New Delhi: S. Chand & Company, 2006.

[11] T. Senevirathne, "MATLAB GUI Based Educational Simulation Tool Box for Power Analysis," Master's thesis, Minnesota State University, Mankato, 2019.

[12] T. Thakur, ''Three Phase Faults Analysis of Power System," *Global Journals Inc. (USA)*, vol. 16, no. 5, 2016.

[13] J. Santamaria, ''Analysis Of Power Systems Under Fault Conditions,'' California State University, Sacramento, 2011.

[14] M. Arnaout, R. Rammal and S. Abdulnabi, "Electric Power System Simulator Tool in MATLAB," in *2016 3rd International Conference on Advances in Computational Tools for Engineering Applications (ACTEA)*, 2016, pp. 226–230.DOI: 10.5772/intechopen.68955.

[15] P. V. Gupta, M. L. Soni and U. S. Bhatnagar, "A Course In Electrical Power", *DHANPAT RAI & SONS,162, NAI SARAK, DELHI-110006(H.O JULLUNDUR)*, 1979.

[16] S. Koç and Z. Aydoğmus, "A Matlab/Gui Based Fault Simulation Tool For Power System Education," *Mathematical and Computational Applications*, vol. 14, no. 3, pp. 207-217, 2009.

[17] D. Flores, "Handling of Ground Fault in Distribution Networks", *Norwegian University of Science and Technology Department of Electric Power Engineering Regarding the Field Test Taken by SINTEF*, 2005.

[18] W. P. Davis, "Analysis Of Faults In Overhead Transmission Lines," Phd Thesis, California State University, Sacramento, 2012.

[19] J. R. Lucas, "Power System Analysis: Faults," Oct 2005.

[20] A. Meddeb and S. Chebbi, ''Fault Analysis and Control of Grounding Power Transformer," *Int. J. Signal and Imaging Systems Engineering*, vol. 9, no. 4/5, 2016.

[21] J. D. Sakala and J. S. J. Daka, "General Fault Admittance Method Line-To-Line-To-Ground Faults In Reference And Odd Phases," *Journal of Engineering Research and Applications* ,vol. 4, no. 2(Version 1), Feb 2014. ISSN : 2248-9622.

تأثير ترابطات محولة القدرة على سريان تيار التتابع الصفري

محمد احمد علي الجبوري **محمد علي عبدالله الراوي** **يوسف محمد اليونس**
mohammadalijuboori66@uomosul.edu.iq mauom@uomosul.edu.iq yousif1969@uomosul.edu.iq

جامعة الموصل - كلية الهندسة - قسم الهندسة الكهربائية - موصل - العراق

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الملخص

تمت دراسة تأثير الترابطات المختلفة لمحولة قدرة ثلاثية الطور ذات ملفين. ان الاعطال الأرضية هي أعطال غير متزنة و بالتالي يتم تحليلها الى ثلاث دوائر متزنة و التي تعرف بالدوائر المتماثلة. نتيجة لهذا التحليل و لكون هذه الأعطال هي أعطال أرضية ,تظهر لدينا ممانعة التتابع الصفري في بعض ترابطات المحولة و التي لها تأثير على قيمة تيار العطل الأرضي. باستخدام المحاكاة في برنامج ماتلاب تم محاكاة نموذج مبسط باستخدام ترابطات مختلفة لمحولة ثلاثية الطور مع محطة توليد لبيان تأثير هذه الترابطات على قيمة مركبة تيار التتابع الصفري لتيار العطل الأرضي من حيث قيمته القصوى و قيمته الدنيا.

الكلمات المفتاحية:
ترابطات المحولة, الأعطال الغير متماثلة, عطل ارضي لخط واحد, عطل أرضي مع خطين.