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VOL. 8, NO. 8, AUGUST 2013 ISSN 1819-6608 ARPN Journal of Engineering and Applied Sciences 2006-2013 Asian Research Publishing Network (ARPN). All rights reserved. www.arpnjournals.com 586 INVESTIGATING THE EFFECT OF DIFFERENT THREE-PHASE TRANSFORMER CONFIGURATIONS IN SINGLE POWER SOURCE A.R.Sultan, M.W. Mustafa and M.Saini Faculty of Electrical Engineering, Universiti Teknologi Malaysia E-Mail: rizal.sultan@fkegraduate.utm.my ABSTRACT This paper investigates the effect of different three-phase transformer configurations in single power source.

New investigating simulation models for single power source are presented. The models of transformer configuration for each side (primary and secondary) used were Y (wye), Yn (wye-grounded) and ? (delta). The effect of ground fault is determined by generating station arrangements and transformer configurations. The simulation of single power source showed the performance generator within the SLG fault at various three-phase transformer configurations.

Simulation was conducted in PSCAD/EMTDC 4.2.0 and the results were analyzed, presenting comparison of the fault impact at different three-phase transformer configurations. It was clearly shown that the SLG fault current at the single power source was highly dependent upon the type of the three-phase transformer configurations used during the ground fault at the secondary side of the transformer. Keywords: single power source, ground fault currents, three phase transformer configurations. INTRODUCTION In general, a step up transformer in electric power station can be categorized as unit generator-transformer configuration, unit generator-transformer configuration with generator breaker, cross-compound generator and generator involving a unit transformer (IEEE, 2006).

Ground fault at the transmission line or busbar can affect the system configuration of the generator. Knowledge of ground fault at transformer winding configurations is essential to choose an appropriate transformer for service requirement. Research and applications on transformers have been carried out for d ecades. IEEE std. C57.12.70- 2000 provides guides and recommended practices for terminal marking and configurations for distribution and power transformers. IEEE st d. C57.116-1989 provides guides for direct configuration of transformers to generators, while IEEE std. 519-1992 and IEEE std.

142- 2007 address the harmonics and system grounding related to transformers, respectively. The transformer configurations with the propagation of voltage sags (M.T. Aung. et al., 2006) can influence the performance of voltage sags inside the industry facility, depending on the function of transformer configurations used in the service transformer. The different transformer configurations have significant impacts on the voltage unbalance factor in the system.

It is found that the Yn-Yn transformer connected to the generator and the ? -Yn transformer connected to the load will reduce the unbalance (H. Ying-Yi., et al ., 1987). Reference (Zielichowski M., et al ., 1998) describes the effect of the voltage transformers on the operating conditions of a ground-fault protection system for unit-connected generators. The magnitude of ground fault current, especially at the generator and transformer are determined by the generator and transformer winding impedance (IEEE, 2006; Fulczyh M, et al., 2002).

The protection for generators are influenced by the arrangement and selection of how the generators are united into the system and by the overall generating station arrangement. This paper presents the effect of three phase transformer configurations, which were denoted as wye (Y), wye-grounded (Yn) and delta (?) in each side primary and secondary for single power source in unit generator- transformer configuration. Ground fault current The majority of electric a faults involved ground.

Even faults that are initiated a phase to phase spread quickly to any adjacent metallic housing, conduit, or tray that provides a return path to the system grounding point. Ungrounded systems are also subject to ground faults and require careful attention to ground detection and ground- fault protection. The ground-fault protective sensitivity can be relatively independent of continuous load current values and, therefore, have lower pickup settings than phase protective devices, The ground-fault currents are not transferred through system power transformers that are connected ? -Y or ? -? , the ground-fault protection for each system voltage level is independent of the protection at other voltage levels (Saadat H., 1999).

As illustrate, any current flowing as a result of a SLG fault on the secondary side of the transformer will appear, as shown in Figure-1, as a line-to-line fault at the generator output. This type of fault is the most damaging to the generator because of its negative sequence content. There will be no zero-sequence current flow in the generator even though the generator is grounded. Zero- sequence current will circulate in the delta winding of this transformer. VOL. 8, NO.

8, AUGUST 2013 ISSN 1819-6608 ARPN Journal of Engineering and Applied Sciences □2006-2013 Asian Research Publishing Network (ARPN). www.arpnjournals.com 587 Figure-1. Zero-sequence currents during SLG fault at a Yn side of transformer (IEEE, 2007). Three phase transformer configurations The primary and secondary winding of the transformer can be connected in either wye (Y), delta (?) or wye-grounded (Yn) configurations. These result in nine possible combination of configurations are Yn-Yn, Yn-Y, Yn-? , Y-Yn, Y-Y, Y- ? , ? -Yn, ? -Y and ? -? .

The zero- sequence impedance seen looking into a transformer depends upon the configuration of the winding. The zero- sequence impedance of a ? winding is infinite, whereas the zero-sequence impedance of a Y-connected winding is a series composite of the zero-sequence impedance of the transformer and the impedance of any neutral grounding devices that might be present. Thus, an ungrounded Y- winding would present infinite zero-sequence impedance because the absence of a neutral grounding configuration appears as an open circuit in series with the zero-sequence impedance of the transformer winding itself (Saadat. 1999).

RESEARCH METHOD This section presents the performance of various transformer configurations at the generator bus during SLG faults in generator bus and transformer bus, in the form of simulation model as illustrated in Figure-2. This Figure shows that the simple model unit generator transformer for single power source has been designed to represent the real system. The generator is represented by three phase voltage source model and transformer is represented by three phase two winding transformer.

The following are the initial system parameters to the testing model (PSCAD Manual). ? Generator = 100 MVA, 13.8 kV, 60 Hz, Yn (solidly grounding) ? Transformer = 100 MVA, 60 Hz, 13.8/230 kV ? Transmission Line configuration = 100 km, 60 Hz, relative ground permeability = 1.0 ? Load = 100 MW, 25 MVAR, 230 kV, 60 Hz ? Time to apply fault at 0.2 second with duration of fault is 0.05 second. Extensive simulation tests were carried out using PSCAD/EMTDC 4.2.0 software.

The adjusted parameters were as follow: ? The type of transformer configuration was changed. The type of transformer configuration were Y, Yn and ? as primary and secondary transformer configurations. ? Fault location at generator bus and transformer bu. Figure-2. One line diagram for simulation. ANALYSIS OF SIMULATION RESULTS In this simulation, magnitude of current from generator to fault location had simulated for SLG fault at generator bus and secondary side bus of the transformer. For this simulation, the generator grounding method are solidly, SLG fault at phase a with fault resistance 0.01 ohm.

The fault occurred at 0.2 second with fault duration 0.05 second. The effect of different three phase transformer configuration has simulate for three condition, namely simulation of normal operation, internal fault state (ground fault location at generator bus) and external fault state (ground fault location at secondary side of transformer). Simulation of normal operation state In normal operation state, output of current and voltage are same for distinct transformer configuration.

Waveform of normal current and voltage can be show at Figures 3-4. Within balanced load assume during normal condition, there are no current through generator neutral. 0.15 0.2 0.25 0.3 -6 -4 -2 0 2 4 6 Time (seconds) Current (kA) phase a phase b phase c Figure-3. Current waveform for normal condition. VOL. 8, NO. 8, AUGUST 2013 ISSN 1819-6608 ARPN Journal of Engineering and Applied Sciences □2006-2013 Asian Research Publishing Network (ARPN). All rights reserved. www.arpnjournals.com 588 0.15 0.2 0.25 0.3 -200 -150 -100 -50 0 50 100 150 200 Time (seconds) Voltage (kV) Phase a Phase b Phase c Figure-4. Voltage waveform for normal condition.

Simulation of internal fault state In internal fault st ate simulation, Yn-Yn transformer condition with solidly generator grounding as an initial state. Waveform of fault current and voltage can be show at Figures 5-6. For this condition, magnitude of generator current supply to fault location as same for other transformer configuration with value 35.363 kA. Ground fault current through in generator grounding neutral also same for other transformer configuration caused by SLG fault current with magnitude 35.206 kA. 0.15

0.2 0.25 0.3 -30 -20 -10 0 10 20 30 40 Time(seconds) C urrent (k A) phase a phase b phase c Figure-5. Current waveform for internal fault state at generator bus. 0.15 0.2 0.25 0.3 -15 -10 -5 0 5 10 15 Time (seconds) Voltage (kV) phase a phase b phase c Figure-6. Voltage waveform for internal fault condition at generator bus. Simulation of external fault state In this condition, it is clearly shown that the magnitude of fault current delivery from generator to fault location is dependent on the kinds of the transformer configuration used. In general, the waveform of fault current for various of transformer configuration are demonstrated in Figure-7.

The Figure shows transformer Yn-Yn configuration had higher magnitude of generator current for SLG fault at secondary side of the transformer than other transformer configurations. Detail comparison for every transformer configuration group as shown in Figures 8- 9. 0.15 0.2 0.25 0.3 -15 -10 -5 0 5 10 15 20 25 30 Time (seconds) Current (kA) Yn-Yn Yn-Y Yn-D Y-Yn Y-Y Y-D D-Yn D-Y D-D Figure-7. Current Waveform in generator bus for distinct transformer configurations.

For Yn at primary side of transformer, the higher current by Yn-Yn transformer configuration followed by Yn-Y and Yn- ? . (see Figure-8 (a)). The similar condition for Yn at secondary side of tr ansformer, (see Figure-8(b)) the higher Yn-Yn transformer configuration followed by ? -Yn than Y-Yn configuration. 0.15 0.2 0.25 0.3 -15 -10 -5 0 5 10 15 20 25 30 Time (seconds) C u rre n t (k A) Yn-Yn Yn-Y Yn-D a. Simulation result for Yn-configuration at the primary side of a transformer 0.15 0.2 0.25 0.3

-15 -10 -5 0 5 10 15 20 25 30 Time (seconds) Current (kA) Yn-Yn Y-Yn D-Yn b. Simulation result for Yn-configuration at the secondary side of a transformer Figure-8. Simulation output for Yn configuration at a primary and secondary side of the transformer. Figure-9(a), presents simulation output for Y configuration at primary side of transformer. In this VOL. 8, NO. 8, AUGUST 2013 ISSN 1819-6608 ARPN Journal of Engineering and Applied Sciences 2006-2013 Asian Research Publishing Network (ARPN). All rights reserved. www.arpnjournals.com 589 condition, the current waveforms are same for Y-Yn and Y-Y. In this condition magnitude of current are higher than Y- ? transformer configuration.

The similar condition for Y configuration at secondary side of transformer (see Figure-9(b)) the current wavefo rm is same for Yn-Y and Y-Y configuration. 0.15 0.2 0.25 0.3 -10 -5 0 5 10 15 Time (seconds) Current (kA) Y-Yn Y-Y Y-D a. The simulation result for Y-configuration at the primary side of a transformer 0.15 0.2 0.25 0.3 -10 -5 0 5 10 15 Time (seconds) Current (kA) Yn-Y Y-Y D-Y b. The Simulation result for Y-configuration at the secondary side of a transformer Figure-9. Simulation output for Y-configuration at a primary and secondary side of the transformer.

As shown in Figure-10(a), for ? -configuration at primary side of transformer, the higher current by ? -Yn transformer configuration followed by ? -? and ? -Y. The similar condition for ? -configuration at secondary side of transformer (see Figure-10(b)) the higher ? -? transformer configuration followed the same magnitude of Yn- ? and Y-? transformer configuration. 0.15 0.2 0.25 0.3 -15 -10 -5 0 5 10 15 20 25 Time (seconds) Current (kA) D-Yn D-Y D-D a. Simulation result for ? -configuration at the primary side of a transformer 0.15 0.2 0.25 0.3 -10 -5 0 5 10 15 Time (seconds) C u rre n t (k A) Yn-D Y-D D-D b.

Simulation result for ? -configuration at the secondary side of a transformer Figure-10. Simulation output for ? -configuration at a primary and secondary side of the transformer. CONCLUSIONS This paper presents a simulation of the effect transformer configurations on SLG fault at single power source in the unit generator transformer. It is clearly shown that the magnitude of the single line to ground fault is dependent on the kind of the three-phase transformer configuration used especially for SLG fault at the transformer bus. From the finding, magnitude of fault current from generator to fault location at the Yn-Yn transformer configuration had 26.893 kA. It is higher magnitude of generator current for SLG fault at secondary side of the transformer than other transformer configurations.

In this condition, there was a route for zero sequence current to flow in a primary and secondary of the transformer. The magnitude of SLG fault was similar for Yn-Y, Y-Yn, Y-Y, ? -Y and ? -? configuration, which was 11.283 kA. The lowest SLG fault from generator to fault location for Yn- ? and Y- ? configuration was 8.697 kA. REFERENCES Fulczyk. M and Bertsch. J. 2002. Ground-Fault Currents in Unit-Connected Generators with Different Elements Grounding Neutral. IEEE Transactions on Energy Conversion. Vol. 17, March. H.

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