iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: IV Month of publication: April 2018

DOI: http://doi.org/10.22214/ijraset.2018.4580

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

Ground Fault Detection using Zigzag Grounding Transformer in Ungrounded System

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Abstract: The prime purpose of grounding transformer is to provide a neutral point on a three-phase ungrounded power system. The configuration of grounding zigzag transformer is usually wye-delta or zig-zag. The basis of this paper is a system where ungrounded connection is detected. The bus rated 15KV between two transformers falls on delta connected winding of transformer. As a fact, Delta connected system has no grounding provision. In case the ground fault occurs on bus, there is no means the fault can be detected and fault current has no path to flow. As a solution a grounding zigzag transformer is suggested. Using PSCAD/EMTDC simulator, effects of balanced and unbalanced load, single line to ground and double line to ground fault is simulated.

Keywords: Ungrounded system, zig-zag transformer, single line to ground fault, double line to ground fault, PSCAD/EMTDC Software.

I. INTRODUCTION

Historically, a gradual trend in power system has been from ungrounded system, to resistance grounded and to finally solid or effective grounded. In ungrounded system, the free-neutral permitted loads to be fed with fewer interruptions than grounded neutral. Also relaying had not come into major use, so many prolonged outages were avoided by the ungrounded operation. The principal advantage of ungrounded system is its ability to clear ground faults without interruption. However, with the growth of systems, the limitations became prominent. The increased fault currents on Ground fault, the increased faults of transient grounds (from lightning, or momentary contacts) were no longer self-clearing. Ungrounded systems have higher over voltages during faults and switching operations Therefore, it evident that an ungrounded-neutral system will result in more equipment damages than some form of grounded system.

The grounding transformer provides source to zero sequence currents and stabilizes the system neutral. The preferred location for the zigzag transformer is at the source substation, connected either to the power transformer leads or the station bus.

The grounded systems employ some method of grounding namely solid grounding, resistance grounding, reactance grounding, Peterson coil grounding or zigzag transformer grounding. The best possible way to attain the system neutral for grounding purpose in three-phase systems is to use source transformers or generators with wye-connected windings. That's how the neutral is then available. Another option is to apply grounding transformers when system neutral is not available.

If existing delta-connected systems are to be grounded, the best option is grounding transformers may be used to obtain the neutral. The configuration of grounding transformers may be wye-delta, or zigzag type as shown in Figure 1.

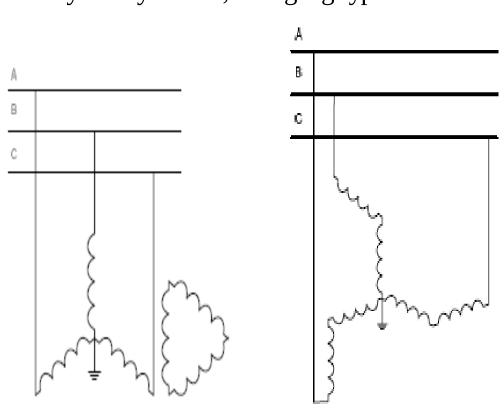

Figure 1.Types of grounding transformer winding

II. ZIGZAG GROUNDING TRANSFORMER THEORY

A. Construction and Working of Grounding Transformer

The impedance of the zigzag grounding transformer to three phases current is higher, hence when there is no fault or unbalanced current on the systems, only a small magnetizing current flows in the windings. The transformer impedance to ground currents is low so it allows high ground current to flow which could be then detected by protection circuit. The grounding transformer divides the ground current into three equal components; three currents are in phase with each other and they flow in three windings of the transformer. The winding configuration is seen from Figure 2. When these three equal currents are flowing, the current in one section of the winding of each leg is in an opposite direction to that in the other section of the winding on that leg as shown in Figure 3.

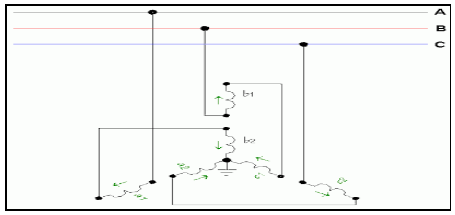

Figure 2. Winding arrangement in zigzag transformer

This causes force the ground-fault current to have equal distribution in the three lines and results in low impedance of the ground currents.

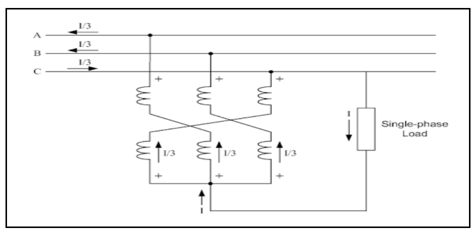

Figure 3. Fault current distribution

B. Functions of Grounding Transformer

Grounding transformers have following functions:

1) To provide a source to ground fault current during line to ground faults
2) To limit magnitude of transient over voltages in case of restriking ground fault
3) To stabilize the neutral.

The majority faults in power system are single line ground variety. Hence, continuity of power is maintained if no automatic tripping is done for this common type of fault. But ultimately, the fault must be located. The functions of grounding transformers is to enable fault detection and, if desired, isolation of phase-to –ground fault.

C. Rating of Grounding Transformer

Following is the single line diagram of the targeted system.

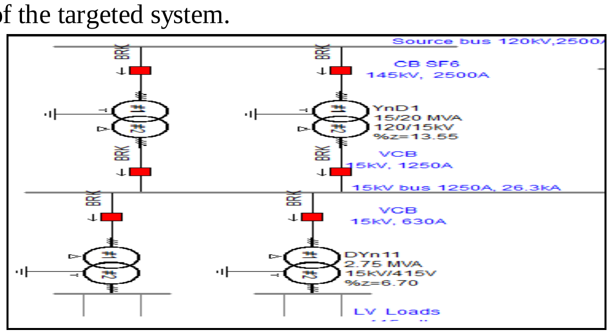

Figure 4. Single line diagram of system

The system has 15KV bus which is surrounded by delta winding of both transformers. The calculations to specify a zigzag grounding transformer is done.

Since it is normally only required to carry short-circuit ground current until the circuit breakers clear the fault and de-energize the faulted circuit, it is common practice to rate it on a short time such as 10 s.

The rating of a three-phase zigzag grounding transformer, in kVA is equal to the rated line-to-neutral voltage in kV times the rated neutral current that the transformer is designed to carry under fault conditions for a specified short time. Most grounding transformers are designed to carry currents for 10 s or 1 min. This is the reason they are much smaller in size than and continuously rated transformer with the same rating. Rated kVof a grounding transformer is the line-to-line voltage for which it is designed. A grounding transformer constructed in accordance with IEEE std 32-1972 will have a continuous rating of 3% for a 10 s rated unit. This value would correspond to a 45A continuous rating for the 1500A transformer specified. For higher values of continuous current are required, the size and cost of the grounding transformer increases. A 1 min rated transformer unit would have 7% of the continuous current rating.

Transformer data:

Transformer	Transformer 1	Transformer 2
connection	YnD1	DYn11
kV rating	120/15 kV	15/0.415 kV
MVA rating	15/20	2.75
% impedance	13.55%	6.70%

The calculation of rating of zigzag transformer is following:

D. For ONAN Cooling of Transformer 1

Fault MVA = sqrt(3)*V*If…………(If= fault current)

Positive and negative sequence impedance Z1=Z2=Base MVA/ Fault MVA…………………..(Z1 & Z2= positive & negative sequence impedance)

Zo = Z total – (Z1 + Z2)…………….(Zo=zero sequence impedance)

Short time kVA rating = 26 MVA (if constructed as wye-delta transformer)

Short time kVA rating = 15 MVA (if constructed as zig-zag transformer)

KVA rating required = sqrt(3)*Vph*Iph=750kVA.

Similarity for ONAF cooling,

KVA rating required = sqrt(3)*Vph*Iph=900kVA.

III.SIMULATION MODEL AND ANALYSIS

Simulation is done is PSCAD/EMTDC software. The zigzag transformer is modeled using PSCAD library. To understand the effects, different conditions are case studied and performance is analyzed.

A. Effects of Balanced Load

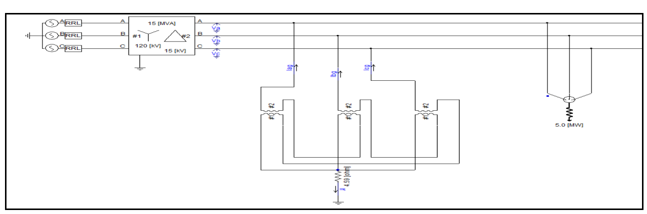

Figure 5. Balanced load connected on bus

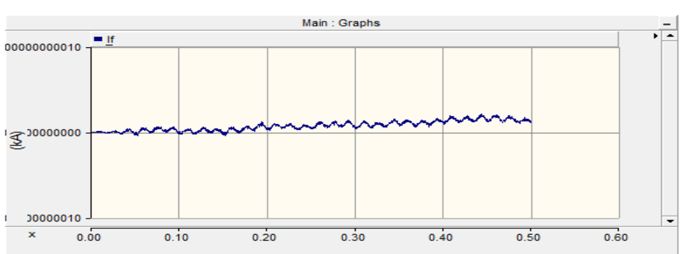

Figure 6. Ground current for balanced load

The ground current is of very much minor value in presence of balanced load.

B. Effects of Unbalanced load

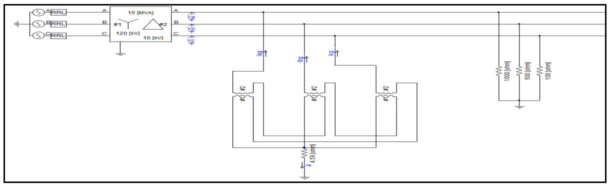

Figure 7 Unbalanced load connected to bus

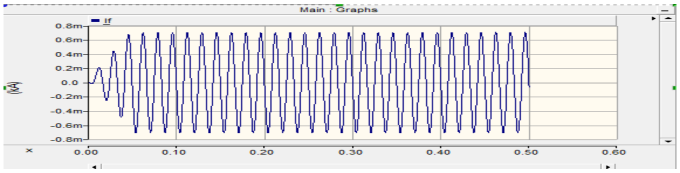

Figure 8 ground current for unbalanced load

The ground current is higher than balanced load condition and reaches up to 0.6mA.

C. Effects of Single Line to Ground Fault

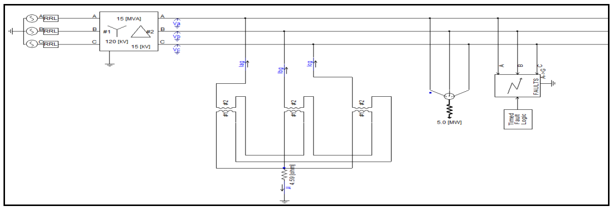

Figure 9. Single line to ground fault

Here, single line to ground fault on phase A is applied on bus at 0.08sec to 0.12sec. The three-phase voltage measured at secondary of each winding is observed as well as fault current.

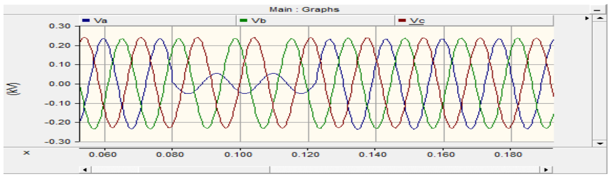

Figure 10. Phase voltages under Phase A to ground fault condition

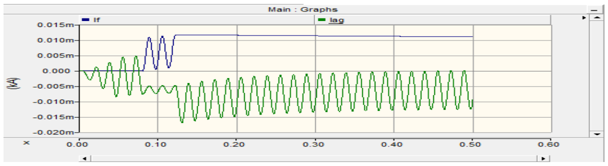

Figure 11. Ground current under Phase A to ground fault condition

D. Effects of Double Line to Ground Fault

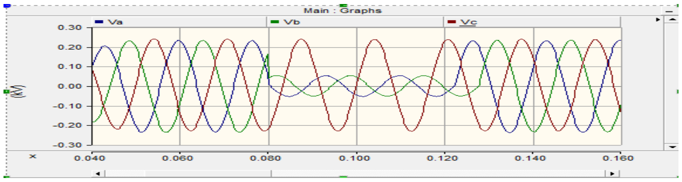

Figure 12. Phase voltages under double line to ground fault condition

Here, the double line to ground fault is applied between phase A and phase B to ground.

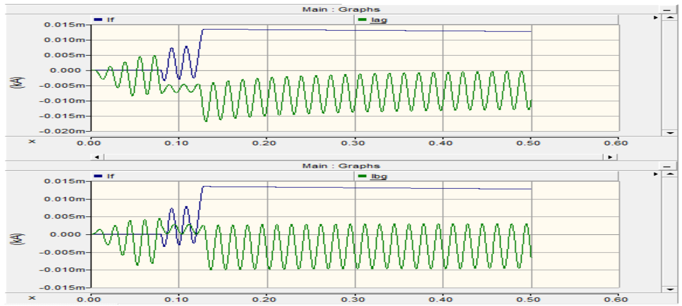

Figure 13. Ground current under double line to ground fault condition

IV. CONCLUSIONS

In this paper, the importance of zigzag grounding transformer to establish neutral point is discussed. Performance of grounding transformer is analysed for different fault conditions with the help of simulation in PSCAD/EMTDC.

V. ACKNOWLEDGMENT

The authors express immense pleasure to present this paper. The support, guidance and motivation provided by every single individual in making of this research is warmly appreciated.

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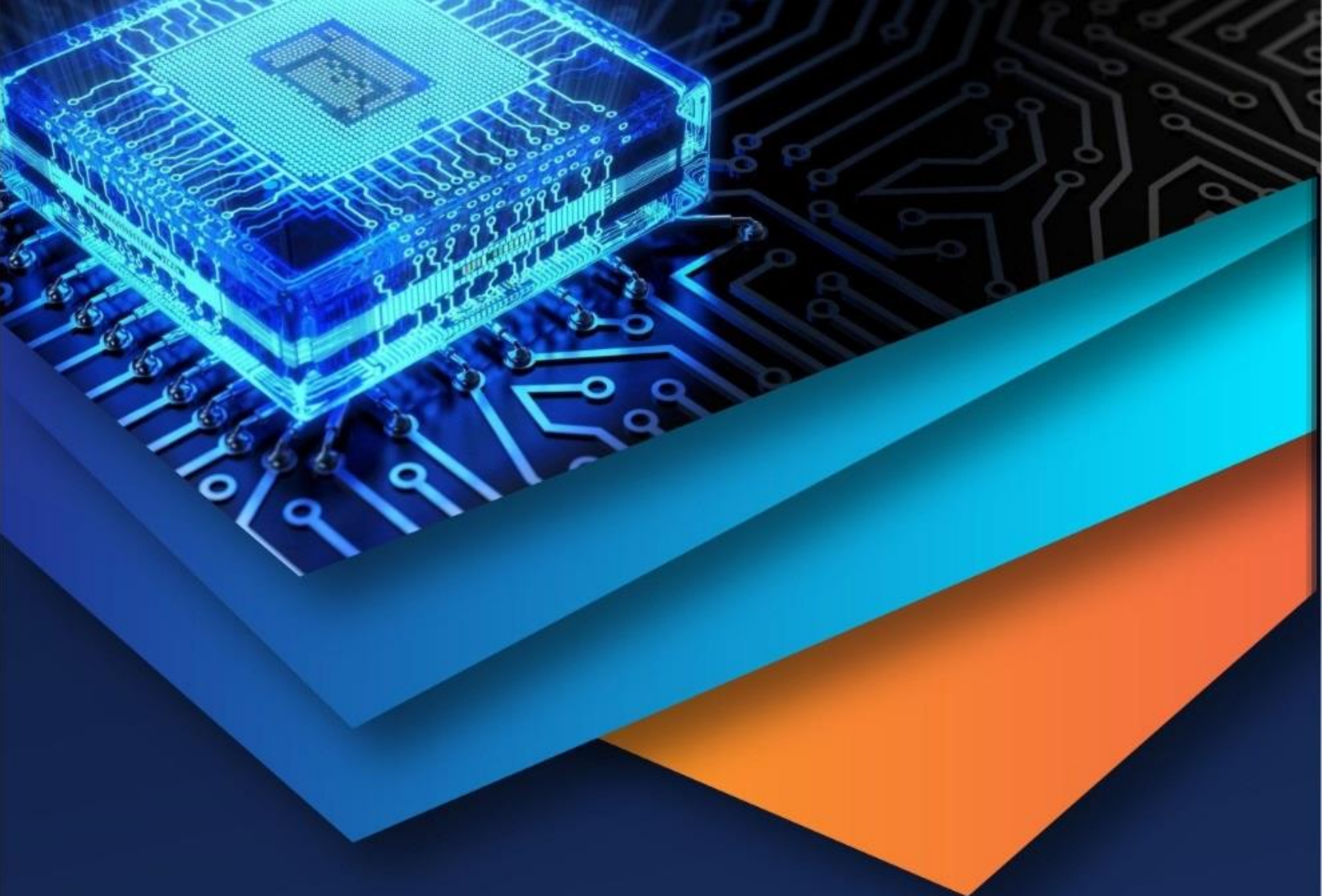

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