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# Transformer Differential Protection of IEEE 14 Bus Using DigSilent

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**ABSTRACT:**This paper analyses a study on IEEE 14 bus power system using DigSilent software. The simulation of load flow study is performed using IEEE 14 bus system. The simulation of short circuit study is performed for the IEEE 14 bus system. The different protection schemes are studied for the given power system network. Further the simulation is carried out for transformer differential protection scheme using DigSilent software for the IEEE 14 bus system.

**KEYWORDS:**Load flow analysis, transformer differential protection, DigSilent, SEL487E

## I. INTRODUCTION

A load-flow study is a steady-state analysis whose target is to determine the voltages, currents, and real and reactive power flows in a system under a given load conditions. Power flow analysis is very important in planning stages of new networks or addition to existing ones like adding new generator sites, meeting increase load demand and locating new transmission sites. The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels. It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and new lines. It determines the voltage of the buses. The voltage level at the certain buses must be kept within the closed tolerances. System transmission loss minimizes. Economic system operation with respect to fuel cost to generate all the power needed The line flows can be known. The line should not be overloaded, it means, we should not operate the close to their stability or thermal limits. A short circuit is an abnormal condition of relatively low resistance between two points of differing potential in a circuit, usually resulting in a flow of excess current. The purpose of the short circuit study is to determine the fault current available at the various buses on your system. These are worst-case single and three phase bolted faults. With this information you can determine if your equipment is sized appropriately and will not fail during a fault event. The waveform-based approach that enhances the differential protection dependability by detecting the geomagnetically induced current and overriding the Harmonic blocking signals for the internal faults by recognizing the waveforms are all asymmetric in one direction [1]. The novel method to discriminate between the magnetizing inrush and external and internal fault currents in power transformers. It is executed by using fuzzy expert system [2]. In case of a three-phase short circuit, stability of a power transformer differential protection's operation is higher than in case of one-phase short circuits. Hence real time simulation is required for effective utilization[3-4]. The trip time taken is (50 micro sec) is also acceptable in order to ensure that the algorithm will give a proper decision to discriminate between a fault current and an inrush current. The relay is restrained in all the cases for the inrush current, normal load current or the external fault current. The simulation is done using MATLAB Simulink environment. The work can be improved when it is simulated using real time software [6]. The protection based on combined S transform (DST) and SVM algorithm provides a differential protection for Power Transformer which provides much more security than the other existing DWT, ANN. The experimental results can be executed for better enhancement of results [7-11]. Paper is organized as follows. Section II describes about DigSilent software. The implementation of transformer differential technique using the DigSilent software is given in Section III. Section IV presents simulation results. Finally, Section V presents conclusion.

## II. DIGSILENT SOFTWARE

A short circuit study is used to determine the worst-case current scenario during a three phase and single phase bolted fault. This is critical design information when selecting equipment for a new design, and replacing existing equipment during upgrades. Two factors contributing to the fault current is the size and impedance of the transformer supplying the circuit, and the available fault current that can be supplied by the utility, and on-site generation. These may be due to

internal or external effects. Internal effects include breakdown of transmission lines or equipment, aging of insulation, deterioration of insulation in electrical equipment. External effects include overloading of equipment, insulation failure due to lightning surges and mechanical damage by public. Arcing faults can lead to fire and explosion in equipment such as transformers and circuit breakers. Abnormal currents cause the equipment to get overheated, which further leads to reduction of life span of their insulation. The operating voltages of the system can go below or above their acceptance values that creates harmful effect to the service rendered by the power system. The DigSilent is the preferred high-end tool for solving problems related to transmission distribution and industrial power systems. It is easy to use, fully Windows compatible and combines reliable and flexible modelling capabilities with state-of-the-art algorithms and unique database concepts. DigSilent is a leading power system analysis software application for use in analysing generation, transmission, distribution and industrial systems. It covers the full range of functionality from standard features to highly sophisticated and advanced applications including wind power, distributed generation, real-time simulation and performance monitoring for system testing and supervision. DigSilent fully covers your daily needs including high-end applications in new technologies such as wind power and distributed generation. Besides the stand-alone functionality, the DigSilent software engine integrates smoothly into GIS, DSM or EMS supporting open system standards. DigSilent is the most economical solution as data handling, modelling capabilities and overall functionality replaces a set of other software systems minimizing project execution costs and training requirements. The all-in-one DigSilent solution is optimizing your workflow aspects in the best possible way. The transformer is one of the major equipment in power system. It is a static device, totally enclosed and usually oil immersed, and therefore the fault occurs on them are usually rare. But the effect of even a rare fault may be very serious for a power transformer. Hence the protection of power transformer against possible fault is very important. The fault occurs on the transformer is mainly divided into two type external faults and internal fault. External fault is cleared by the relay system outside the transformer within the shortest possible time in order to avoid any danger to the transformer due to these faults. The protection for internal fault in such type of transformer is to be provided by using differential protection system.

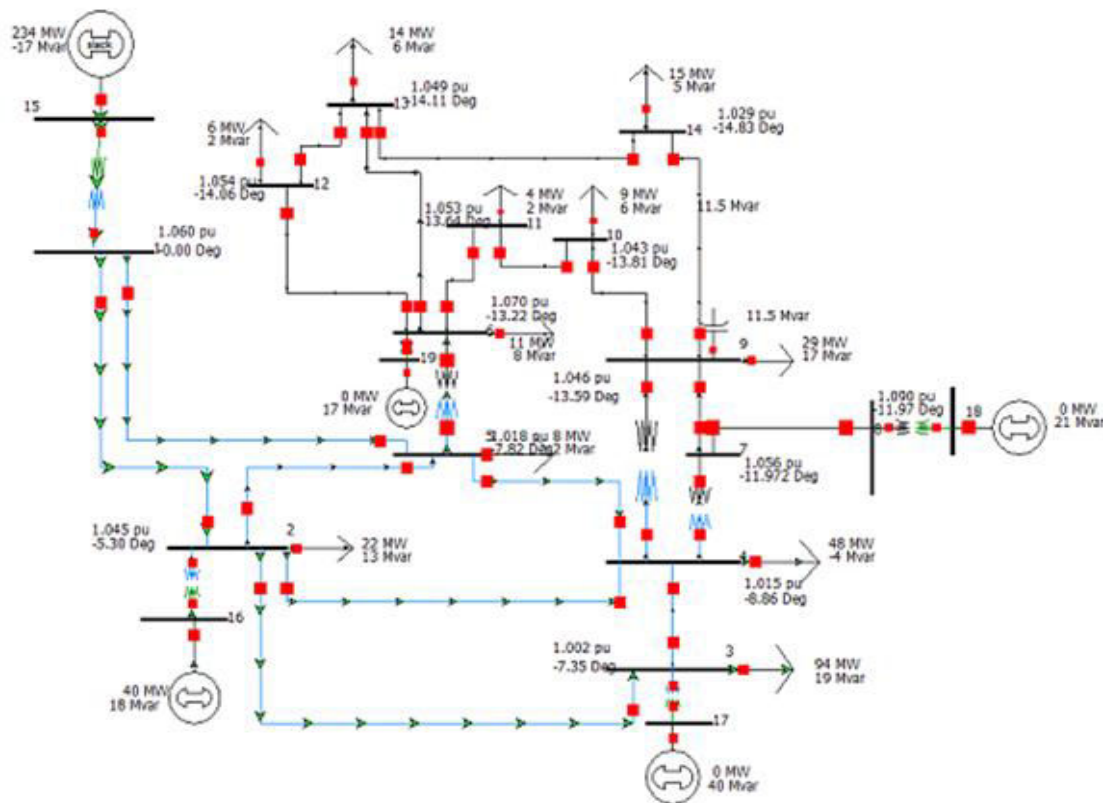


Fig 1. IEEE 14 bus power system

### III. TRANSFORMER DIFFERENTIAL PROTECTION

The working principle of Differential Protection System explained as follows. Normally, the operating coil carries no current as the current are balanced on both the side of the power transformers. When the internal fault occurs in the power transformer windings the balanced is disturbed and the operating coils of the differential relay carry current corresponding to the difference of the current among the two sides of the transformers. Thus, the relay trips the main circuit breakers on both sides of the power transformers is shown in figure 1. The protection for internal fault for the transformer is to be provided by using differential protection system. The steps are followed in the power factory software. Draw the diagram, enter the data and perform the load flow for the test system. Include the circuit breaker, configure the current transformer settings and relay settings. Perform load flow and short circuit in internal zone and external zone. This seminar gives eye opener for the protection in the electrical power system. The three bus test system and the outputs is shown in figure below. The procedure for implementing transformer differential protection relay is as follows. Right click in transformer to be protected and choose disconnect element. Choose junction and put it near to both side of the transformer. Right click in the transformer and choose connect element. Select circuit breaker and connect it into bus bar. Close circuit breaker by double click it. For setting CT (current transformer): Right click new device, current transformer, name it as CT. Go to type, new project, name it as CT, put primary equal to 100A and secondary equal to 5 A. To change the location: Go to cubicle, choose the bus bar, go to each switch, choose the switch which contains circuit breaker, and Go to arrow double click then ok. File- import-SEL487E- activate the project-check the relay library. For setting a relay: Right click the small box (cubicle), new device, relay model, relay time, select project, go to + sign of relay library, + sign of Schweitzer, + sign of SEL 487E, choose SEI 487E 5A then ok. Next double clicks the buses that near to the transformers to see the voltage how much. Right click the small box (cubicle), edit devices, double click relay model, and make all the components in net element out of service except (S measurement, T measurement, differential and logic). Right click the small box (cubicle), edit device, double click relay model, go to create CT for second winding of transformers, name it as CT, put primary equal to 100A and secondary equal to 5A. To change the location: Go to cubicle, choose the bus bar, Go to each switch, choose the switch which contains circuit breaker, and Go to arrow double click then ok. Go to S measurement double click, go to edit Adapter double click enter the value of voltage. Go to T measurement double click, go to Edit Adapter double click enter the value of voltage, ok, close. Double click junction enters the bus voltage, then ok. Perform the load flow calculation. Right click the junction, calculate, short circuit, execute. Right click the cubicle, show, differential protection plot. See the tripping time when create fault (short circuit) in bus bar and near to the transformer.

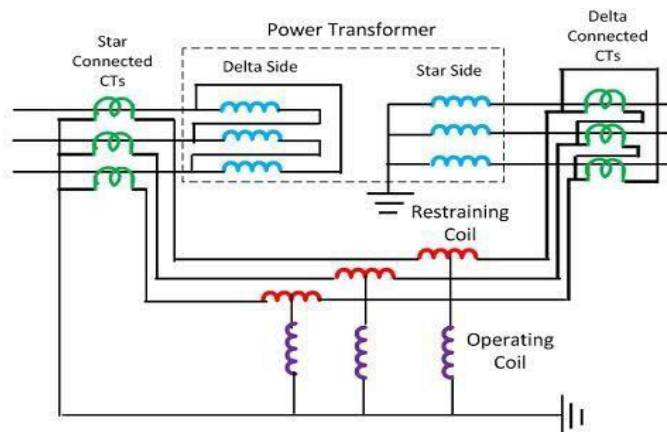


Fig 2. Differential protection for power transformer

### IV. EXPERIMENTAL RESULTS

The simulation of differential protection is exhibited using matlab Simulink environment using phase difference algorithm, relay logic and wavelet algorithm is discussed in the literature [12-14]. The IEEE 14 bus system is drawn in the graphic window and the data are entered in the DigSilent software and is shown in figure 3.

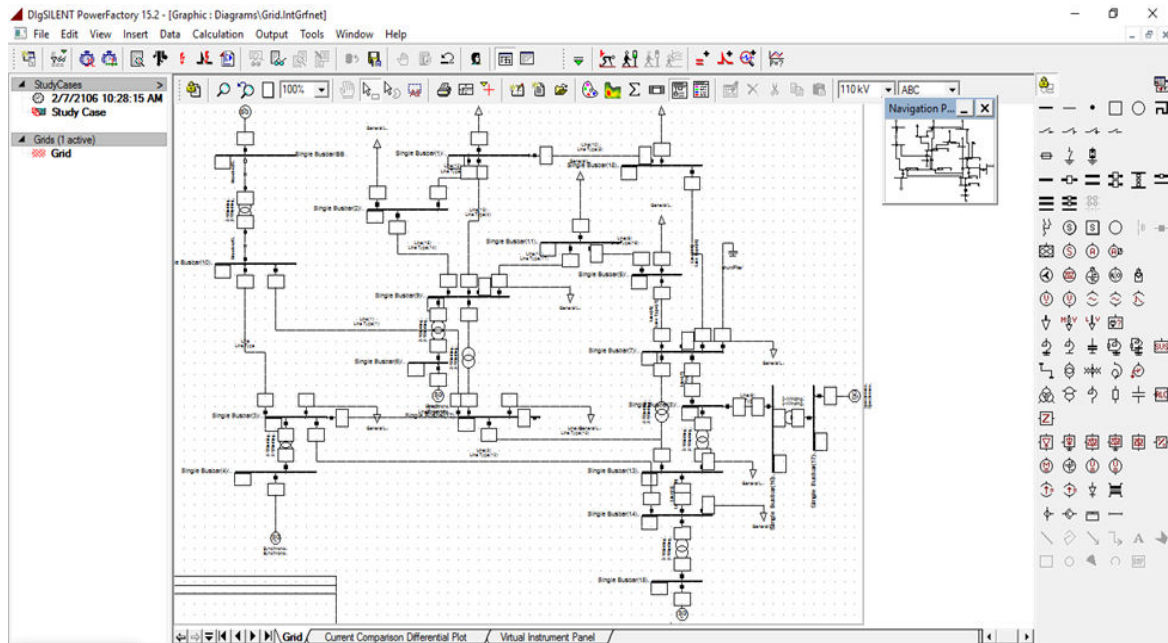


Fig 3.IEEE 14 bus in DigSILENT Software

The load flow is executed by using the DigSILENT software and the convergence is achieved in five iterations as shown in figure 4.

```

DigSI/info - Element 'Synchronous Machine(2)' is local reference in separated area of '1'
DigSI/info - Element 'Synchronous Machine' is local reference in separated area of '1'
DigSI/info - Grid split into 2 isolated areas
DigSI/info - Calculating load flow...
-----
DigSI/info - Start Newton-Raphson Algorithm...
DigSI/info - load flow iteration: 1
DigSI/info - load flow iteration: 2
DigSI/info - load flow iteration: 3
DigSI/info - load flow iteration: 4
DigSI/info - load flow iteration: 5
DigSI/info - Newton-Raphson converged with 5 iterations.
DigSI/info - Load flow calculation successful.
-----
DigSI/info - Report of Control Condition for Relevant Controllers
DigSI/info -
DigSI/info - 'Grid\Synchronous Machine.EleSym':
DigSI/wrnng - 'Synchronous Machine': Maximum Reactive Power Limit exceeded ( Q = 91.89 Mvar > Qmax = 25.00 Mvar )
DigSI/wrnng - 'Synchronous Machine': Maximum Active Power Limit exceeded ( P = 224.40 MW > Pmax = 0.00 MW )
DigSI/info -
-----
| DigSILENT | Project:
| PowerFactory |
| 15.2.6 | Date: 3/19/2018
-----
| Load Flow Calculation | Complete System Report: Substations, Voltage Profiles, Grid Interchange | | |
| AC Load Flow, balanced, positive sequence | Automatic Model Adaptation for Convergence | No |
| Automatic Tap Adjust of Transformers | No | Max. Acceptable Load Flow Error for |
| Consider Reactive Power Limits | No | Nodes | 1.00 kVA |
| | | Model Equations | 0.10 % |
-----
| Grid: Grid | System Stage: Grid | Study Case: Study Case | Annex: / 1 |
-----
| rated | Active Reactive Power | | | | | | | | | | | | | | |
| Voltage | Bus-voltage | Power Power Factor Current Loading | | | | | | | | | | | | | |
| [kV] [p.u.] [kV] [deg] [MW] [MVar] [-] [kA] [%] | | | | | | | | | | | | | |
-----
| (Single Busbar(1) | | | | | | | | | | | | | |
| BB 132.00 0.98 129.97 -26.90 | | | | | | | | | | | | | |
| Cub_1 /Lod General Load 14.00 6.00 0.92 0.07 | | | | | | | | | | | | | |
| Cub_1 /Line Line(10) -0.13 1.79 -0.07 0.01 0.80 | | | | | | | | | | | | | |
| Cub_1 /Line Line(12) -1.23 -0.94 -0.79 0.01 0.69 | | | | | | | | | | | | | |
| Cub_1 /Line Line(13) -17.64 -6.85 -0.88 0.06 6.39 | | | | | | | | | | | | | |

```

Fig 4.Convergence of IEEE 14 bus using DigSILENT Software





It is observed that when the three phase symmetrical fault occurs at outside the zone of transformer, the differential relay does not activate and it shows the tripping time 99999 seconds is shown in figure 7.

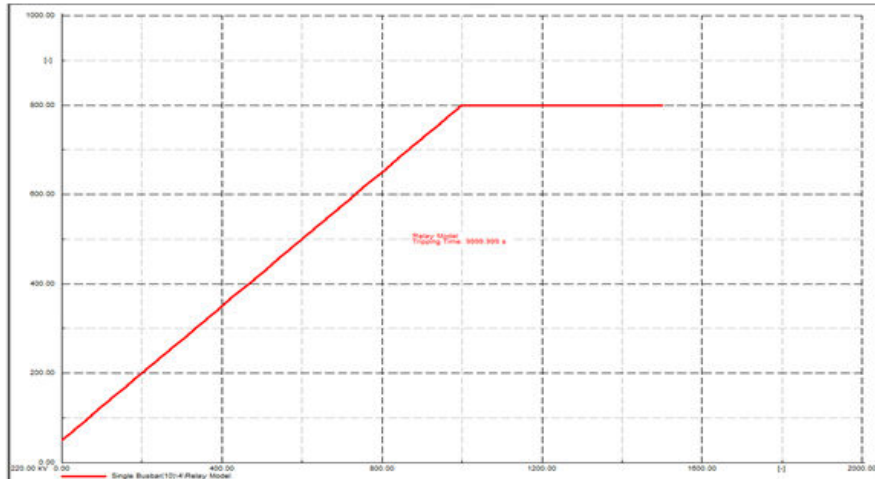


Figure 7 outside zone of transformer differential protection

When the three phase symmetrical fault occurs at inside the zone of transformer, the differential is activated and the tripping time is 0.015 seconds as shown in figure 8.

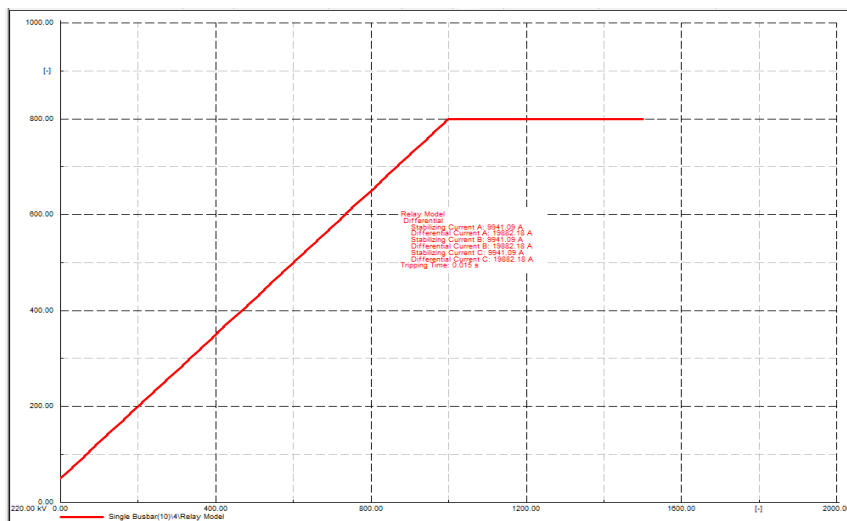


Figure 8 inside zone of transformer differential protection

## V. CONCLUSION

This paper successfully completed the load flow and short circuit study for IEEE 14 bus power system network. The load flow study is simulated using DigSilent software by using Newton Raphson method. The result is converged in 5 iterations. The transformer differential protection is implemented using SEL487E relay model in the DigSilent software. It is observed that when three phase short circuit fault occurs near the junction of transformer terminals the differential relay activates in the transformer zone only. When three phase fault occurs at other than transformer zone the relay does not activate. In future this study can be implemented by using overcurrent protection for IEEE 14 bus system.

## REFERENCES

- [1] B. Ahmadzadeh-Shoostari and A. Rezaei-Zare, "A Waveform-Based Approach for Transformer Differential Protection Under GIC Conditions," in IEEE Transactions on Power Delivery, vol. 37, No. 6, 2022
- [2] SeyedMasoodLaMoosavi, YaserDamchi, Mohsen Assili, "A new fast method for improvement of power transformer differential protection based on discrete energy separation algorithm, International Journal of Electrical Power & Energy Systems, vol. 136, 2022
- [3] B. Ahmadzadeh-Shoostari and A. Rezaei-Zare, "Advanced Transformer Differential Protection Under GIC Conditions," in IEEE Transactions on Power Delivery, vol. 37, No. 3, 2022
- [4] Hasheminejad, S "A New Approach for the Transformer Differential Protection Based on S-Transform and Fuzzy Expert System," Journal of Applied Research in Electrical Engineering, vol. 1, No. 2, 2021
- [5] IlyaLitvinov, Aleksandra Naumova, VasilyTitov, AndreyTrofimov, Elena Gracheva, "The study of power transformer differential protection's operation in the internal fault conditions," E3S Web Conf. 288 01096, 2021.
- [6] Nikhil Kumar Sharma and Naveen kumarSahu, "Protection of Power Transformer by Advanced Differential Protection Scheme," International Journal of Recent Scientific Research, vol. 6, No. 11, 2015
- [7] SRISTI SHUKLA, VIVEK BARGATE, "Review on Power Transformer Protection Scheme with Non-Linear Load," Iconic Research and Engineering Journals, vol.2, No .10, 2019
- [8] PrasenjitDey, Prof. Priyanath Das, Dr. Ajoy Kumar Chakraborty, "Implementation of Power Transformer Differential Protection Based on Clarke's Transform and Fuzzy Systems," International Journal of Engineering Research & Technology (IJERT), vol. 1, No. 7, 2012
- [9] Mario Orlando Oliveira, Arturo SumanBretas, Gustavo DornellesFerreira, "Adaptive differential protection of three-phase power transformers based on transient signal analysis," Electrical Power and Energy Systems," vol .57, 2014
- [10] Danielly C. G. Rocha, Wesley H. Batista, Aurélio L. M. Coelho, Marcos R. Araujo, "Practical approach to testing the transformer differential protection for internal and external faults, CT saturation and inrush transients," The 14th International Conference on Developments in Power System Protection, 2018
- [11] H. Khorashadi-zadeh and Z. Li , "A Sensitive ANN Based Differential Relay for Transformer Protection with Security against CT Saturation and Tap Changer Operation", Turkish Journal of Electrical Engineering and Computer Science, vol. 15, no. 3, 2007
- [12] Nassim A. Iqteit, Khalid Yahya, "Simulink model of transformer differential protection using phase angle difference based algorithm," International Journal of Power Electronics and Drive System (IJPEDS), vol. 11, No. 2, 2020
- [13] N S Azizan, C L Wooi, Bismail, S N M Arshad, M Isa, W A Mustafa and MNK Rohani, "Simulation of differential relay for transformer protection," International Symposium on Engineering and Technology (ISETech), 2019
- [14] Mudita Banerjee, Anita Khosla, "Differential Protection of Power Transformer using Wavelet Transform," International Journal of Recent Technology and Engineering (IJRTE), vol .8, No .3, 2019
- [15] Badri Ram & D N Vishwakarma, "Power System Protection And Switchgear," Tata McGraw-Hill, Second Edition ,New Delhi, 2008, pp.346-379

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