

# Improved Protection Scheme for RSU 15MVA Power Transformer

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**Abstract-** *The project focuses on the design and the application of differential protection scheme for 15MVA power transformer. load flow analysis on voltages, real and reactive power generated and absorbed across the entire system load is carried out., also, A well simulated coordination employs circuit breakers at various load points as required by the network in question, ensuring proper tripping of the appropriate breaker under fault conditions. The maximum and minimum fault current are all three-phase symmetrical (30 cycle network) values and the pre-fault voltage equaled 100 percent of the nominal voltage. Furthermore, A current time interval (CTI) of 3.5 seconds was used between the relays and was later increase to 4 seconds base on time of operation between the relays to ensure proper coordination between the relay elements, total reactive power of 6513kVar, fault current of 3,137.77 (A) and a mismatch of 0.1MVA was obtained. it was noticed that the transformers and buses were overloaded, but with an upgrade of transformer rating,  $2 \times 15MVA$  and implementation of  $90 \times 300KVar$  capacitor bank major improvement was attained. The model was created using ETAP software.*

**Indexed Terms-** *Transformer, Protection, Line, Relay, Coordination, Circuit Breaker, Overload, ETAP, Software, Capacitor, Banks.*

## I. INTRODUCTION

Transformers are critical and expensive power system components. They are employed for transformation or transfer of electric power from one circuit to another through electromagnetic induction and without a change of frequency. A major goal of protecting transformers is to minimize faults and consequent damage as any unscheduled maintenance or repairs

especially replacement of faulty part or a complete transformer is labor intensive, time-consuming, and expensive [1]. Transformers are mainly designed to operate between 40-60% of their full loads for continuity of operation and sustained reliability. Operating them over an extended period under abnormal conditions of faults and overloads will compromise their life and health. There are two types of faults occurring in a transformer; internal faults and through faults or external faults [2]. In some cases, and depending on the size, the transformer has to be transported for repairs, which can take a considerable amount of time. Its main purpose is to obtain an optimal compromise between protection and selectivity. The analysis includes determining fault clearing time and coordination of upstream electrical protective equipment. Proper coordination and disruption clearing time can help reduce damages to electrical equipment and protect workers from harm.[3]. In power system protection relays and circuit breakers is the major instrument for large interconnected power system. We need proper protection to isolate the faulted region from healthier network [4]. When a fault occurs in a transformer, the damage is proportional to the dissipated fault energy which relates to the fault time. The transformer should therefore be disconnected from the network as soon as possible. Fast reliability protective relays are therefore used for detection of faults. Monitors can also detect faults and sense abnormal conditions which may develop into a fault. The size of the transformer and the voltage level has an influence on the extent and choice of protective equipment. Monitors prevent faults and protective relays limit the damage in case of a fault this project will employ the use of differential protection which has the task to protect particular zone from the difference in current that is entering and leaving from one side to another in a particular zone. The differential protection function protects the zone between the main and additional current sensors inside

the protected zone between the sets of current transformers (CT). Transformers have to be protected from both internal and external faults with sensitive and selective devices that can quickly and effectively interrupt the flow of energy of the fault location in order to reduce the transformer damage. Relays and circuit breakers are standard equipment used for transformer protection. For different short-circuit overloads, relays should provide actuation times as a function of the load, so that its response curve fits the curve provided by the transformer manufacturer. There are a series of well-developed and established protection schemes that can detect overloaded circuit conditions. Such schemes are used to program protection devices to interrupt the faults or to perform an alarm indicating the zone where and when the fault occurred. The protection elements are installed on the main circuit or on the transformer itself depending on the type of scheme to perform and the type of maneuver to be executed. Among the many protection schemes 12 that can be performed, the most common are overload and short circuit protection which can be grouped as direct and indirect types.

Significance of this project is to stimulate a new interest for other students who also may be interested in the area of design of a 15MVA transformer protection scheme and perhaps could as well complete favorably with the imported types; it will also create Job opportunities.

The research works considered a load flow study using ETAP (Electrical Transient Analyzer Program) platform, load flow and simulation.[5].

## II. MATERIALS AND METHODS

In this project work, the materials used for the analysis are: Single line diagram of PHED injection substation RSU, ETAP software and a computer system. The method to be used in this study is differential protection, Transformers (CT and VT), ETAP for modelling and simulation.

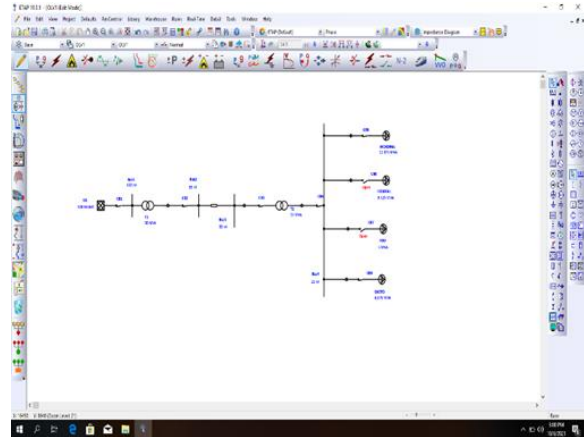


Figure 1: Representation of the Network on ETAP

### 2.1 Differential Protection Relays (87)

Differential protection of the main transformer requires comparison of LV and HV currents, entering and leaving the transformer. Microprocessor based relays are equipped with second a harmonic restraint feature to prevent unwanted operations during rapid voltage recovery following the clearance of a close in-system fault. The operating zone of this scheme is restricted to the primary equipment encompassed by the high and low side current transformers and thus the scheme requires no current or time coordination with other systems. Due to the high slope characteristic, the sensitivity is dependent upon the through-fault current component and a significant portion of the winding may not be fully protected. Two three-phase sets of current transformers are commonly used, one set on the high voltage side and one set on the low voltage connections. Ratios are selected to ensure that a secondary current match is achieved between the HV and LV current transformers within the tap setting range of the relay used, allowing for the phase correction required across the main transformer [6].

Table 1. 132/33kv Transformer Data

S/N	Name	S (MVA)	Z (%)
1	T1	30	12.27
2	T2	15	10.28
3	T3	15	10.28

### 2.2 T1 Primary, Secondary and Ground Rated Currents

T1 Primary Rated Current

$$I_{\text{rate-primary T1}} = \frac{\text{MVA}}{\sqrt{3} \times \text{KV}} \quad (1)$$

$$I_{\text{rate-primary T1}} = \frac{30 \times 10^6}{\sqrt{3} \times 132 \times 10^3} = 131.22 \text{ (A)} \quad (2)$$

This is the rated current on the primary side of the 30 MVA power transformers.

#### T1 Secondary Rated Current

$$I_{\text{rate-secondary T1}} = \frac{\text{MVA}}{\sqrt{3} \times \text{KV}} \quad (3)$$

$$I_{\text{rate-secondary T1}} = \frac{30 \times 10^6}{\sqrt{3} \times 33 \times 10^3} = 524.86 \text{ (A)} \quad (4)$$

This is the rated current on the secondary side of the 30 MVA power transformers. The effect of the transformer and system impedances are neglected in both in the primary and secondary rated currents calculations.

#### T1 Ground Rated Current

$$I_{\text{rated-Gnd T1}} = \frac{\text{MVA}_{\text{Load}/3}}{\sqrt{3} \times \text{KV}} \quad (5)$$

$$I_{\text{rated-Gnd T1}} = \frac{15 \times 10^6/3}{\sqrt{3} \times 33 \times 10^3} = 87.48 \text{ (A)} \quad (6)$$

This is the single-phase current from of the ground of the 30 MVA transformer through one of the two 15MVA loads and back to the ground of the transformer ground. Since the loads are similar, only one ground ( $I_{\text{groundT1}}$ ) is calculated.

**2.3 Determining the Current Transformer (Ct) Ratios**  
The computed primary and secondary rated currents are used to determine the CT ratios for the differential relay.

$n_{CT1}$  = CT ratio of the primary to secondary CT currents. This CT is connected on the primary side of the 30 MVA power transformer.

$$n_{CT1} = \frac{I_{1n}}{I_{2n}} \quad (7)$$

Where  $I_{1n}$  = primary rated current going through the CT and  $I_{2n}$  = secondary current seen by the CT winding leads

$n_{CT1} = \frac{250}{50} = 50$ , where 50 is the primary to secondary CT current ratio.

$n_{CT2}$  = CT ratio of the primary to secondary CT currents. This CT is connected on the secondary side of the 30MVA power transformer.

$$n_{CT2} = \frac{I_{1n}}{I_{2n}} \quad (8)$$

where  $I_{1n}$  = primary rated current going through the CT and  $I_{2n}$  = secondary current seen by the CT winding leads.

$n_{CT2} = \frac{1200}{5} = 240$ , where 240 is the primary to secondary CT current ratio.

$n_{CT3}$  = CT ratio of the primary to secondary CT currents. This CT is connected on the wye-ground of the 30MVA power transformer.

$$n_{CT3} = \frac{I_{1n}}{I_{2n}} \quad (9)$$

where  $I_{1n}$  = primary rated current going through the CT and  $I_{2n}$  = secondary current seen by the CT winding leads.

$n_{CT3} = \frac{250}{50} = 50$ , where 50 is the primary to secondary CT current ratio

#### 2.4 Circuit breaker Secondary Currents

These currents are computed by using the primary and secondary calculated currents on the primary and secondary side of the 30 MVA, and the current ratios of the current transformer.

##### Primary Side of T1

Computing the secondary current, the 87, and 50/51 relays will see from the primary rated current of the 30 MVA transformer and the selected CT turn ratio.

$$I_{\text{High-sec}} = I_{\text{Rated-primary T1}} \times \frac{1}{n_{CT1}} \quad (10)$$

$$I_{\text{High-Sec}} = 131.22 \times \frac{5}{250} = 2.62 \text{ (A)} \quad (11)$$

##### Secondary Side of T1

Computing the secondary current, the 87 relay will see from the secondary rated current of the 30 MVA transformer and the selected CT turn ratios.

$$I_{\text{Low-sec}} = I_{\text{Rated-sec T1}} \times \frac{1}{n_{CT2}} \quad (12)$$

$$I_{\text{Low-sec}} = 524.86 \times \frac{5}{1200} = 2.19 \text{ (A)} \quad (13)$$

##### Ground Side Wye-GND of T1

Computing the secondary current, the 50N relay will see through the solidly ground of the 30 MVA transformer and the selected CT turn ratios.

$$I_{\text{Ground1-sec}} = I_{\text{Rated-Gnd1}} \times \frac{1}{n_{CT3}} \quad (14)$$

$$I_{\text{Ground1-sec}} = 87.48 \times \frac{5}{250} = 4.18 \text{ (A)} \quad (15)$$

2.5 CT Performance Calculations

To determine the maximum fault current through each set of differential CTs, the 87 relay for a transformer through fault on each of the buses served by the CT1 and CT2 transformers, an infinite bus (conservative approach) on the high voltage side of the transformer was assumed. This assumption ignores the system impedance. The maximum current that the relays and CTs will see during a three-phase through fault is calculated as follows:

2.6 30 MVA Transformer Primary through Fault Current

$$I_{\text{Through-primaryT1}} = \frac{MVA}{\sqrt{3} \times kV_{\text{primary}} L-L \times \% Z} \quad (16)$$

$$I_{\text{Through-primary}} = \frac{30 \times 10^6}{\sqrt{3} \times 132 \times 10^3 \times 12.27} = 3,137.77 \text{ (A)} \quad (17)$$

2.7 Restraint Slope Settings (SLP)

$$\text{Slope 2} = \frac{I_{\text{primT1}} - I_{\text{secT1}}}{I_{\text{primT1}} + I_{\text{secT1}}} \times 100 \quad (18)$$

$$\text{Slope 2} = \frac{3,137.77 - 15,688.9}{3,137.77 + 15,688.9} \times 100 \quad (19)$$

$$\text{Slope 2} = 45.2\% \quad (20)$$

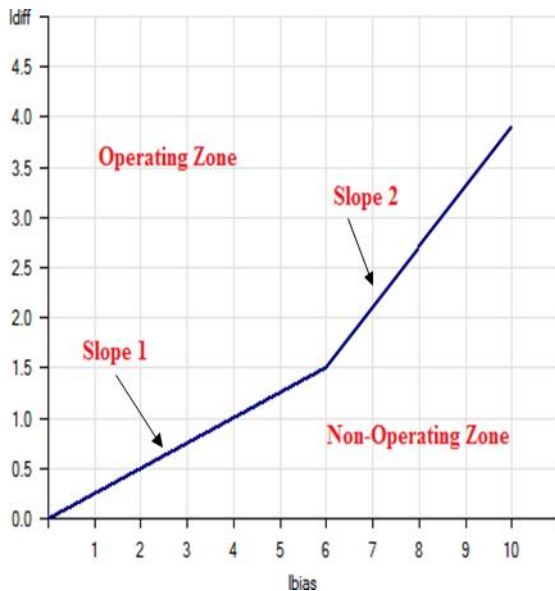


Figure 2 Differential Operating Slope Zones

Therefore, the slope for the 30 MVA power transformer would be set at 45% to compensate for the differential CT's mismatch.

2.8 System Losses

The power losses in the system is 6513kVar

III. RESULTS

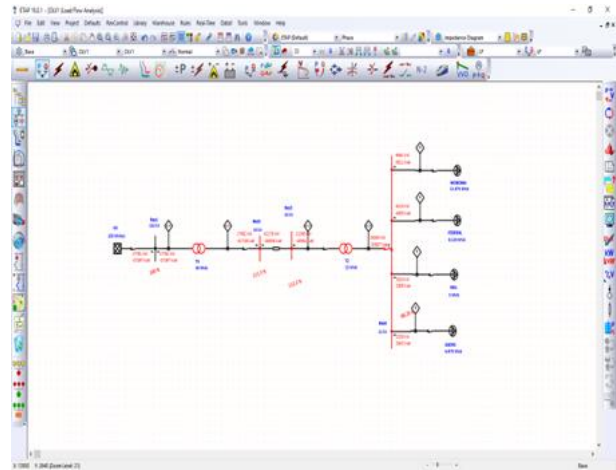


Figure-3: ETAP Simulation Result of RSU Feeders. (A composite network)

Load flow analysis carried out in figure 2, Shows that all buses except the swing are critically under and over loaded below and beyond the IEEE statutory voltage deviation level. Investigation report suggest an upgrade of the power transformer in the substation that is, from 1 × 15MVA to 2 × 15MVA thereby enhancing power flow and effective protection.

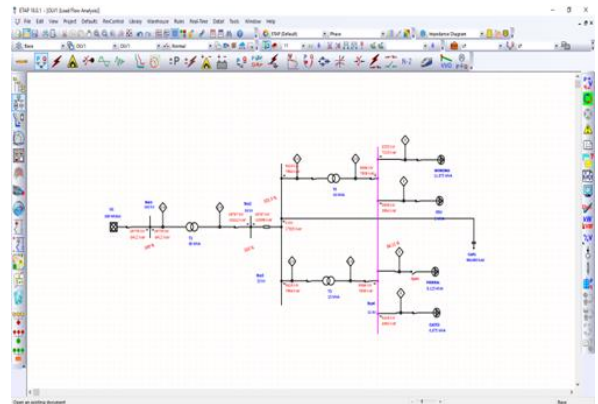


Figure-4: Load flow result after improvement of RSU Network.

By implementation of Capacitor banks of appropriate size in the tune of 90 × 300KVAR alongside, transformer upgrade by an increase of 30 MVA in the substation, in Figure 3, all buses were declared healthy with a minimum voltage profile level of 96.1% at bus 4.

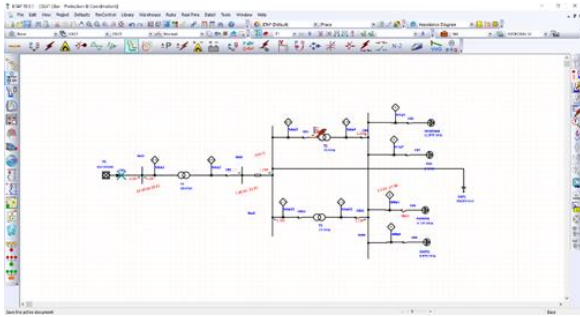


Figure-5: Relay Coordination Scheme in RSU

In figure 5, To effect quality protection scheme, an analysis of a sequential 3 phase fault is applied to T2 (15MVA) and circuit breaker 3 adjacent to bus 2 and 1 respectively, Due to poor relay coordination a tripping command meant to be sensed by relay5 is rather sensed by relay1, faulting and damaging the system equipment with total isolation of all network users.

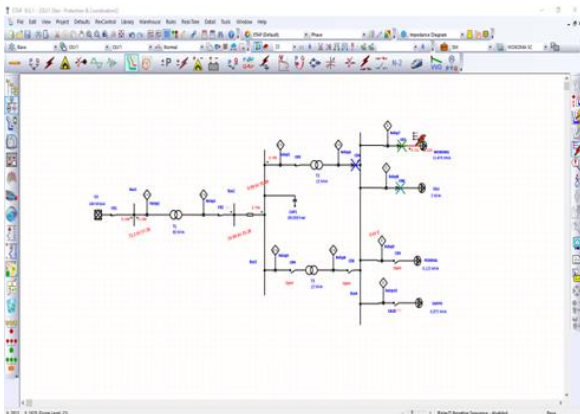


Figure-6: Improved Coordination Result

To avoid crucial damage of the system, proper feeder co-ordination in respect to discrimination by time is suggested and implemented in Figure 6. Evidently, with a closed breaker to Ojoto and Federal in open state, Wokoma feeder was faulted and breaker 7, 8 and 4 responded sequentially in line with their configuration. CB 7 acted as the primary while CB 8 and 4 acted as backup for the feeder under consideration.

#### CONCLUSION

Differential protection scheme which has the task to protect a particular zone from the difference in current entering the primary side and leaving from secondary

is implemented in the system. Proper coordination accompanied with an upgrade of the equipment can greatly improve the efficiency caused by overexcitation of transformer. Analysis carried out resulted an over-load and under-load on the transformers and buses, but with the upgrades on the transformer and introduction of capacitor bank major improvement was ascertained in the system as regards voltage profile and power loss. Also, proper tripping of relay and circuit breaker at various load points in the network under faulty condition was actualized.

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