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Design of Differential Protection System and its Settings for 20MVA Industrial Transformer

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Abstract
In this paper, describes about "design of differential protection system and its settings for industrial transformers "One of the most important and primary protection of transformer for internal faults is Transformer Differential Protection. Present trend is to use a Low Impedance Differential Protection Relay for Transformer Differential Protection. For the safety of transformer, it is imperative to set the Differential Protection Relay correctly. This paper describes the method to calculate settings of Low Impedance Differential Protection for a two-winding transformer. The aim of this work is to analyse the performance of a numerical differential protection of power transformer through different operating conditions of power transformer which causes unwanted response of the installed differential relay.
Keywords: Transformer, Differential Protection, Slope, Relay, Low Impedance, Restraining Coil, Operating Coil, Restraining Current, Operating Current, Pickup Setting.

Introduction
protection relay. For better understanding, typical calculations are provided.
Differential Relay Differential protection is one of the primary protections against phase to phase and phase to ground fault within transformer. Accurate setting of Transformer differential protection relay is of utmost importance to protect the transformer. Wrong setting of Transformer differential protection relay may lead to; a) Severe damage to transformer for internal fault. b) Inadvertent tripping of transformer for fault outside differential protection zone, resulting into loss of power to the healthy system. This paper describes the criteria / steps to set Low impedance transformer differential

Differential Relay
Differential protection is the best technique in protection. In this type, entering and leaving current at the protected zone or area are compared by current transformers (C.T.s). If the net difference is zero, it means no fault. This system is operating in two following principles:
- Current balance principle
- Voltage balance principle Differential protection is applicable to all parts of the power system:
- Generator
- Transformers
- Motors
- Buses
- Lines and feeders
- Reactors and capacitors

There are two basic types of differential protection
- Current Balance Differential protection
- Voltage Balanced Differential Protection

Current Balance Differential Protection:
Operation during internal and external fault conditions Fig.1 shows the basic current differential protection based on current balance principle. [1] At normal conditions and for external fault at F,

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CT1 and CT2 circulate currents at their secondary's Is1and Is2 (Is1=Is2) and no current flow through the relay (ΔI= Is1-Is2=0), hence the relay will not operate. If fault occurs at point F within the protected zone (internal fault) as shown in Fig.2, and the fault is fed from both sides, then current through C.T2 will be reversed.
Therefore, a current ΔI= Is1+Is2 will flow in the operating winding of the relay. This will cause the relay to trip the circuit breaker connected to the faulty system. Hence the relay trips when | Is1+Is2|>|I|, |I|≥ pick up current of relay.
TRANSFORMER RATIO CORRECTION OF CURRENT TRANSFORMER
A. Transforming Ratio Correction of Current Transformer Output currents of the CTs differ from the rated current at the rated load of the power transformer as shown in Fig.3. The CT transforming ratios can be corrected on both sides of the power transformer with the protected unit settings. First, the primary current of the power transformer must be calculated (on both sides) when the apparent power and phase-to-phase voltage are known. The rated load of the power transformer (or) primary current

$$I = MVA/\sqrt{3} \times KV$$

Components required

S. No	Required Components
1	Intelligent Electronic Device (IED)-7UT613
2	A laptop with Digsi-4 Software
3	Communication cable (PC to IED)
4	Secondary Injection kit

Differential Protection
High Impedance Differential Protection
High impedance protection system is a simple technique which requires that all CTs, used in the protection scheme, have relatively high knee point voltage, similar magnetizing characteristic and the same ratio. These CT shall be installed in all ends of the protected object. Figure-1 shows a typical scheme for High impedance differential protection of a two-winding transformer. Differential Current ID = I1 I2. If differential current ID exceeds the set value, relay operates and gives trip command to transformer circuit breakers.

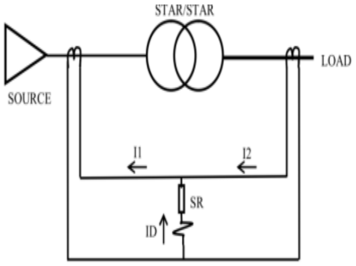

Figure-1: High Impedance Differential Protection Low Impedance Differential Protection
Low impedance differential protection systems have many positive attributes compared to high impedance differential protection like no need of selecting identical characteristics CT'S

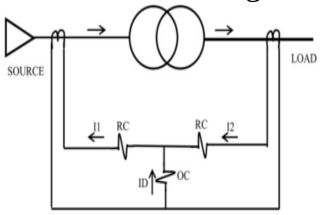

Figure-2: Low-Impedance Differential protection

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Figure-2 shows a typical scheme for Low impedance differential protection of a two-winding transformer. It is also known as Biased differential protection. This type of relay has a Restraining Coil and an Operating Coil. This protection operates and issues the trip if the differential current crosses the bias current

Operating characteristics of Low impedance Differential Protection

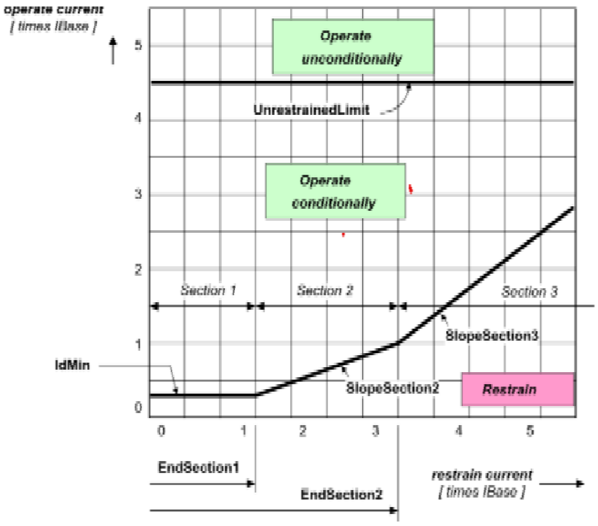
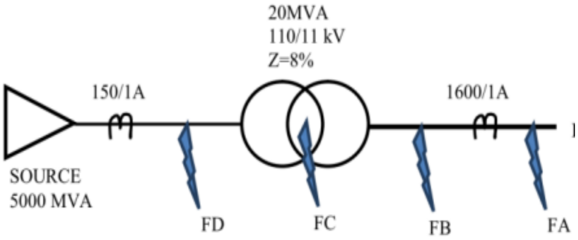


Figure-3: Slope characteristics

Setting Calculation and its slope characteristics



On 100MVA Base

XS = 100/5000 = 0.02 PU

XT = (100 x 0.08) / 20 = 0.4 PU

• Three phase faults on 11 kV side (at location FA and FB)

Fault level = 100 / (XS + XT)

Fault level = 238.1 MVA

Fault condition	Restraining current (IRES)	Operating current (ID)
External fault FA	8.33A	0.53 A
11KV Internal fault FB	8.33A	8.33 A

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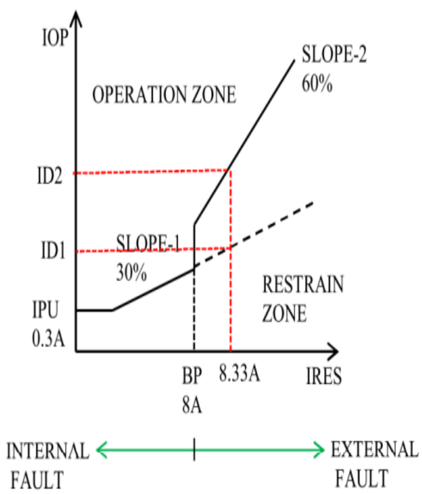
Transformer Internal Fault FC	15.9A	15.9 A

Through-flowing current under healthy condition or an external fault: I1 flows into the protected zone, I2 leaves the protected zone, i.e., thus has opposite sign, i.e. I2 = –I1, and consequently |I2| = |I1|
IDIFF = |I1 + I2| = |I1 – I1| = 0
I rest = |I1| + |I2| = |I1| + |I1| = 2·|I1|
• Three phase faults at 50% impedance of transformer (at location FC)
In this case Transformer impedance = 0.5 x 8 = 4%. Hence XT = 0.2 PU
Fault level = 100 / (XS + XT)
Fault level = 454.54 MVA
= 2.385 kA @ 110 kV
• Three phase faults on 110 kV side (at location FD)
Fault level = 5000 MVA
= 26.24 kA @ 110 kV
Required Slope characteristic
I rest = |I1| + |I2| = |I1| + |I1| = 2·|I1|
no tripping effect (IDiff = 0); restraint (I Rest) corresponds to twice the through-flowing current.
b) Internal fault, fed from each end e.g., with equal currents:
In this case, I2 = I1, and consequently |I2| = |I1|
IDiff = |I1 + I2| = |I1 + I1| = 2·|I1|
I Rest = |I1| + |I2| = |I1| + |I1| = 2·|I1
tripping effect (IDiff) and restraining (I Rest) quantities are equal and correspond to the total fault current.
c) Internal fault, fed from one side only:
In this case, I2 = 0
IDiff = |I1 + I2| = |I1 + 0| = |I1|
I Rest = |I1| + |I2| = |I1| + 0 = |I1|
tripping effect (IDiff) and restraining (I Rest) quantities are equal and correspond to the fault current fed from one side. This result shows that for internal fault IDiff = I Rest. Thus, the characteristic of internal faults is a straight line with the slope 1 (45°) in the operation diagram as illustrated in Figure 2-19 (dash-dotted line).



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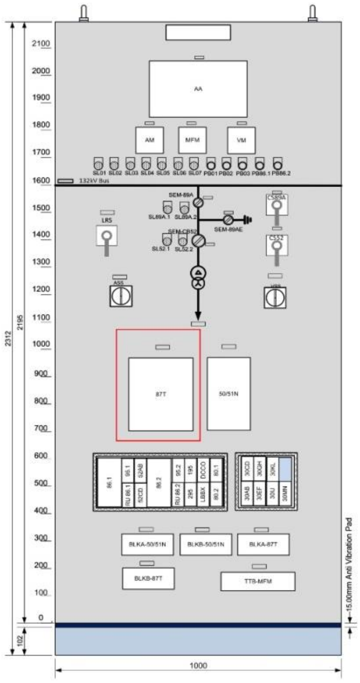

Fig 4 General Settings Of Block Diagram

DEVICE NO	DESCRIPTION	TYPE	132kV CB INITIATE LBB	GRP-1 3-PH TRIP RELAY	GRP-2 3-PH TRIP RELAY	MAIN CB TC-1 R,Y,B-PHASE	MAIN CB TC-2 R,Y,B-PHASE	LV TC-1	LV TC-2	96OPTD. OF ALL BAYS	DR TRIGGER
87T	TRAFO DIFF. PROTN-87T	7UT613		x	x						x
64R-HV	HV REF PROTECTION			x	x						x
51NS	STANDBY EARTH FAULT RELAY	7SJ66		X	X						X
50/51N	O/C &E/F PROTN.	7SJ66		X	X						X
86.1	GR-1 3-PH TRIP RELAY	RXMVB4	x			x	x	x	x		x
86.2	GR-2 3-PH TRIP RELAY	RXMVB4	x			x	x	x	x		x
30AB	WTI TRIP	RXSF1		x	x						x
30CD	OTI TRIP	RXSF1		x	x						x
30GH	PRV- TRIP	RXSF1		x	x						x
50LBB	LBB PROTN	7SJ66						x	x	x	x
LV	TRIP FROM LV SIDE(LV REF)			x	x						
	96 OPTD.(FROM HV)	RXMVB2				x	x	x	x		
	LV LBB OPTD.					x	x				
	96 OPTD.(FROM LV)		x								

x — INITIATION CONTACT (HARD WIRED)

Fig 5 Line diagram

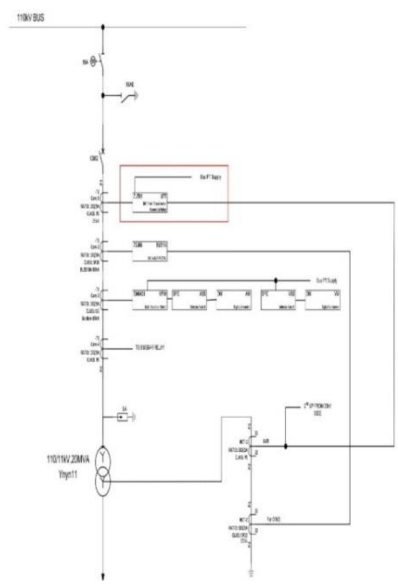

Fig 6 settings for different types of protection strategies

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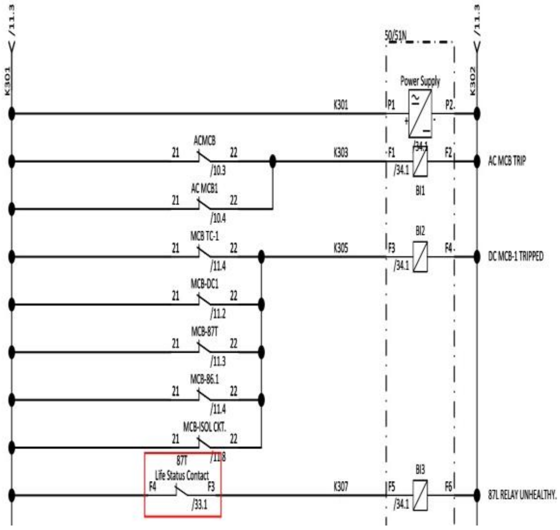

Fig 7 Binary Inputs (BI) Settings

CONCLUSION

The proposed relay setting can be used for differential protection to protect 20MVA industrial transformer. These settings can also be tested by creating both internal and external faults. Digsi simulation facilitates various relay testing conditions like, fault induction, relay responses, system stability and lot other features. This paper has demonstrated the capability and the ease of testing complex power system components.

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