EXPERIMENT P5: DIFFERENTIAL RELAY PROTECTION

Related course: KIE4004 (Power System)

OBJECTIVES:

1. To learn how to protect a single-phase power transformer
2. To learn how to protect a three-phase power transformer in YY and ∆Y-connections

EQUIPMENT:

MV 1100 Load resistor
MV 1100-235 3-phase load resistor 230 V
MV 1101 Reactor load bank
MV 1102 Capacitor load bank
MV 1103 3-phase power supply 0-230 V
MV 1233 Oscilloscope
MV 1400 Pushbutton box for the breaker
MV 1429 Terminal Board
MV 1435 Differential relay trainer
MV 1500 Switch
MV 1911 Single-phase power transformer
MV 1915 Three-phase power transformer
MV 1922 Ammeter 1A and 2A
MV 1923 Ammeter 6A and 12A
MV 1926 Voltmeter
MV 1957 Rheostat 0-5 Ohm, 6.3A
MV 1959 Rheostat 0-50 Ohm, 2.0A (Fault resistor)
Ohmmeter (Multimeter)
Clip-on ammeter or multimeter with a current probe

INSTRUCTIONS:

1. Record all your results and observations in a log book or on a piece of paper
2. Follow the demonstrator's instructions throughout the experiment

REFERENCE(S):
Refer to the main references of KIE4004

TEST:
TEST 1: Fault simulation on a single-phase power transformer
TEST 2: Fault simulation on a three-phase power transformer in YY-connection
TEST 3: Fault simulation on a three-phase power transformer in ΔY-connection

INTRODUCTION:

The main principal of a differential protection is the input current of a protected object shall be the same as the output current. For cables, busbars and generators, the protection is simple but for a transformer, the ratio and the phase shift must be considered.

Differential relay protection scheme has a simple construction as shown in Figure 1. The relay compares the currents between the primary and secondary sides. Differential comparison is one of the most accurate and effective methods in providing protection against internal faults. If $I_{primCT} = I_{secCT}$, then $I_{diffCT} = 0$ and the differential circuit takes no current. Both sides of the circuit have the same current.

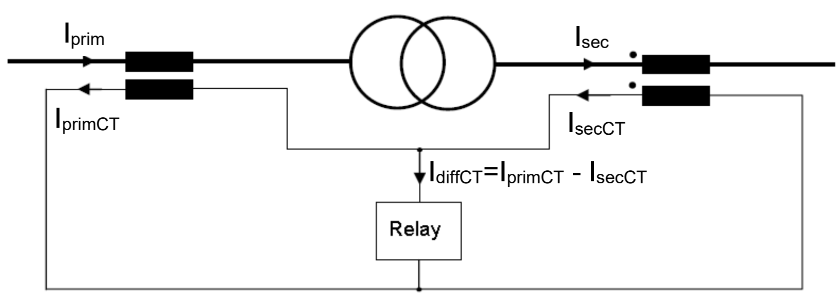

Figure 1: Differential relay protection scheme

If $I_{diffCT} = I_{primCT} - I_{secCT}$ is too high, it is likely that a fault has occurred inside the test object. However, if a fault occurs, the unbalanced current must follow into the differential circuit and the fault can be detected. The reason why the current must find a way depends on Kirchhoff's current law and the law of ampere-turn balance of a current transformer (CT). The currents on the primary and secondary side of CT are defined by the external circuits. Thus, the secondary current follows the CT ratio.

TEST 1: Fault simulation on a single-phase power transformer

1. For single-phase power transformer (MV 1911), connect the secondary windings in series as shown in Figure 2. This represents a single-phase transformer 230V/230V.
2. Connect the circuit as shown in Figure 3. Insert a voltmeter between L1 and L3 of the power supply. Use Load as resistive load *R* (MV 1100) and set it to maximum resistance.
3. Turn ON the power supply and increase the voltage up to 80 V between L1 and L3.
4. Connect a fault resistor (MV 1959 Rheostat 50 Ohm) in different parts of the circuit as indicated in Table 1 and observe whether tripping happens or not.

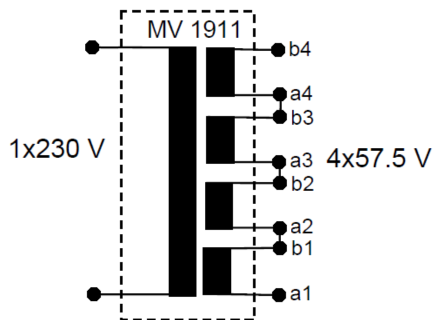

Figure 2: Connection of MV 1911 to make a single-phase power transformer with ratio 1:1

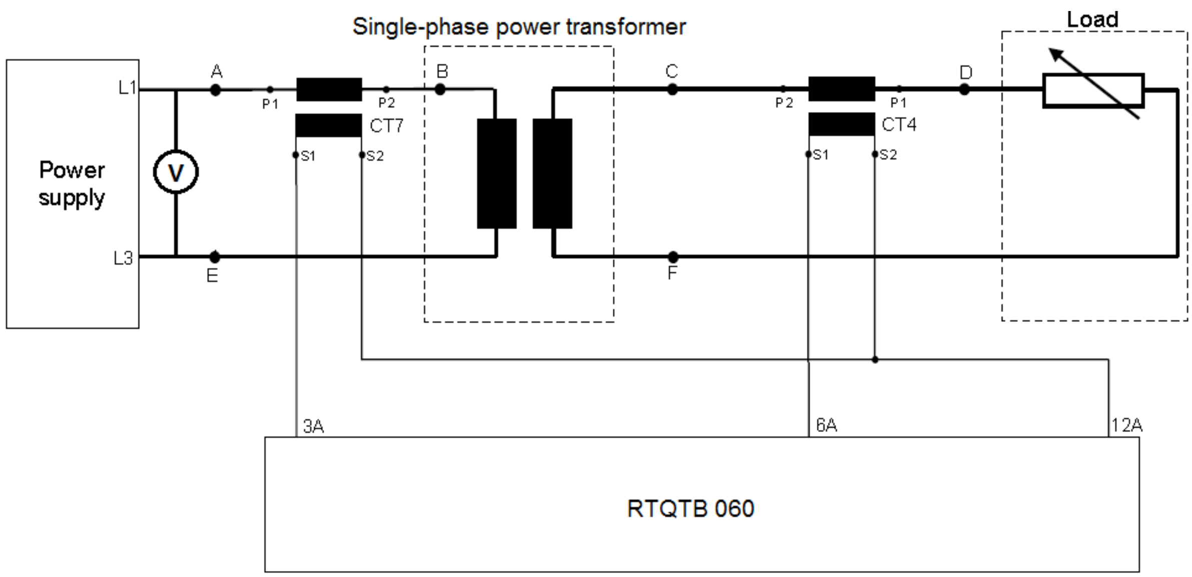

Figure 3: Differential relay protection on single-phase power transformer

Table 1

Load	Fault resistor between	Trip (Yes/No)
R	A – E	
R	B – E	
R	C – F	
R	D – F	
R	B – C	
R	A – D	
R	C – D	

TEST 2: Fault simulation on a three-phase power transformer in YY-connection

1. For three-phase power transformer (MV 1915), connect each of the primary and secondary windings as Y-connection as shown in Figure 4.
2. Connect the circuit according to Figure 5. Insert a voltmeter between L1 and L2 of the power supply. Use Load as 3-phase load resistor *R* (MV 1100-235) and set it to maximum resistance.
3. Turn ON the power supply and increase the voltage up to 80 V between L1 and L2.
4. Connect the fault resistor (MV 1959 Rheostat 50 Ohm) between the points as stated in Table 2 and observe whether tripping happens or not.

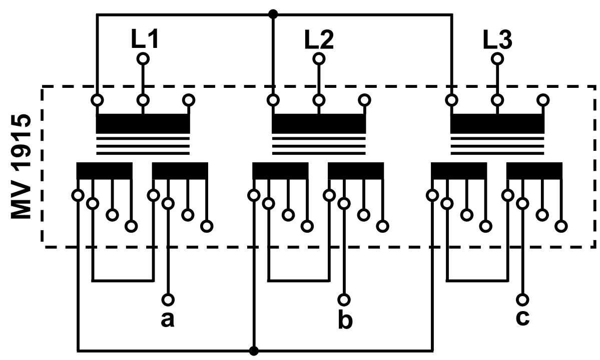

Figure 4: Connection of MV 1915 three-phase power transformer with YY-connection

Table 2

Load	Fault resistor between	Trip (Yes/No)
R	A – E	
R	B – E	
R	C – F	
R	D – F	
R	B – C	
R	A – D	
R	C – D	
R	E – F	
R	A – I	
R	B – G	
R	G – C	
R	D – E	
R	F – H	
R	J – D	

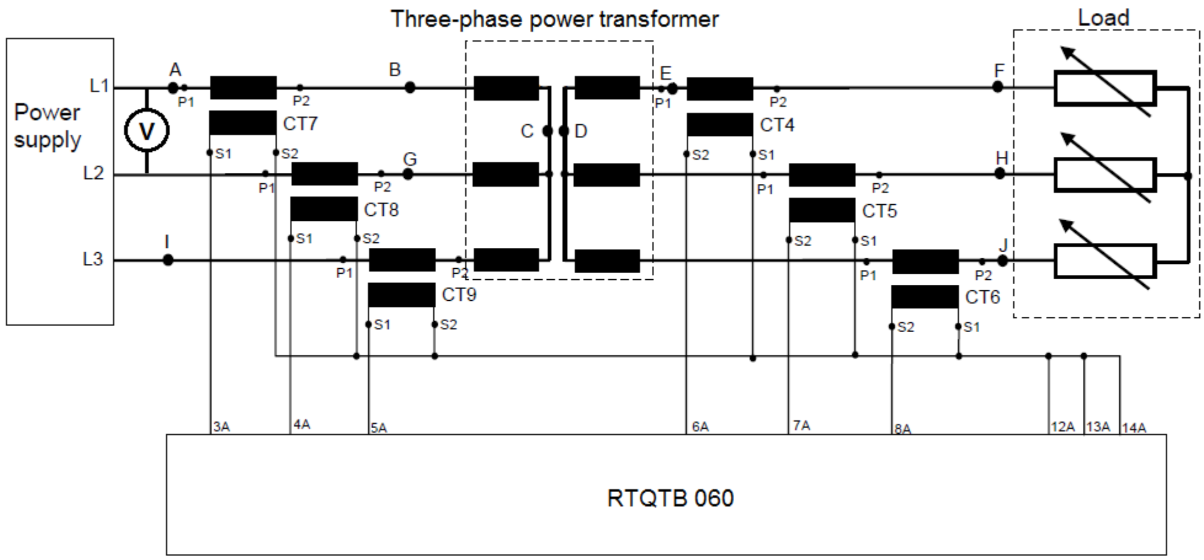

Figure 5: Differential relay protection on three-phase power transformer with YY-connection

QUESTIONS:

1. Why the protection relay does not trip when a fault resistor is connected between point F and H?
2. Why does the protection trip when a fault resistor is connected between point B and G?
3. Why the protection relay does not discover a fault between point C and D?
4. Will this protection system behave differently if the same experiment is repeated with non-symmetrical load?
5. What type of fault is created when a fault resistor is connected between point F and H?

TEST 3: Fault simulation on a three-phase transformer in ΔY-connection

1. Continued from TEST 2, for three-phase power transformer (MV 1915), connect the primary windings as Δ-connection as shown in Figure 6. The secondary sinding remains as Y-connection.
2. Continued from TEST 2, connect the circuit according to Figure 7. Set the connection around CT10-CT12 according to Figure 7.
3. Turn ON the power supply and increase the voltage up to 80V between L1 and L2.
4. Connect the fault resistor between the points as shown in Table 3 and fill in Table 3.

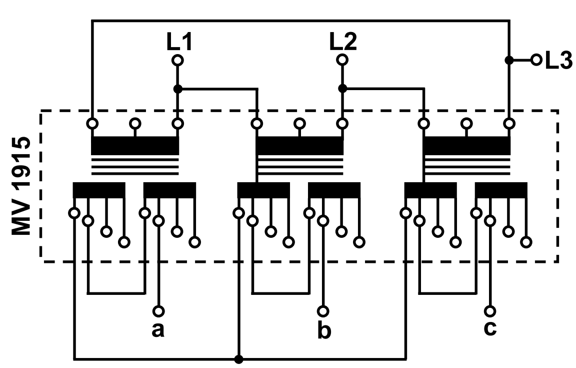

Figure 6: Connection of MV 1915 three-phase power transformer with ΔY-connection

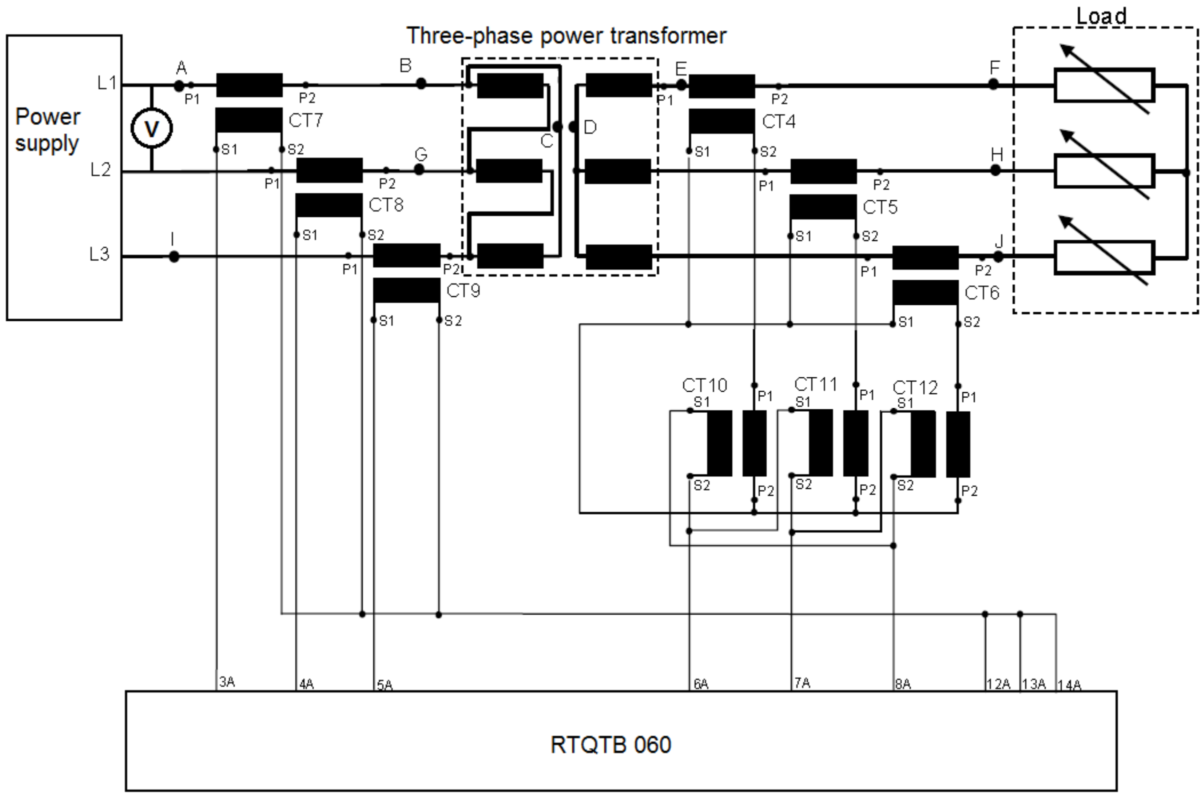

Figure 7: Differential relay protection on three-phase power transformer with ΔY-connection

Table 3

Load	Fault resistor between	Trip (Yes/No)
R	A – E	
R	B – E	
R	C – F	
R	D – F	
R	A – D	
R	C – D	
R	E – F	
R	A – I	
R	B – G	
R	G – C	
R	D – E	
R	F – H	
R	J – D	

QUESTIONS:

1. Why the protection relay does not trip when a fault resistor is connected between point F and H?
2. Why the protection relay trips when a fault resistor is connected between point B and G?
3. Why the protection relay does not discover a fault between point C and D?
4. What type of fault happens when a fault resistor is connected between point F and H?
5. What type of fault when the fault resistor is connected between point D and E, if the neutral point is connected to ground (as common)?

END OF EXPERIMENT