Improved Over Current Relay (OCR) Coordination Using Time Multiple Setting (TMS)

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Abstract. Proper coordination between overcurrent relay (OCR) is needed to improve the reliability of the power distribution system. By choosing the proper time multiple setting (TMS), an optimum setting of OCR coordination can be achieved. This study improve working time coordination of OCR bay transformer using time multiple setting. Simulations were carried out to see the performance of the OCR bay transformer against a 3 phase short circuit on the 20 kV outgoing bus. The 3 phase short circuit was chosen because it produces the largest fault current among other types of short circuits. The discussion focuses on the OCR bay transformer, consist of OCR incoming 20 kV and OCR outgoing 150 kV. Existing data and calculation results were used as a parameter in the simulation. Simulation results with existing tms 0.21 and 0.23 for OCR incoming 20 kV and OCR outgoing 150 kV, respectively, have the potential to cause miscoordination of the OCR working time. Smaller short circuit current, bigger potential miscoordination. Resetting tms improves coordination of OCR bay transformer working time according to the standard used. Bigger value of tms, as long as it meets the standar, better OCR working time coordination to protect phase-phase fault current.

1 Introduction

About 80% of faults in the electric power system are in the electric distribution system. About 70–80% of this fault is a ground fault, whereas 10–17% is a phase–phase to ground fault, 8%–10% is a phase–phase fault, and 2%–3% is a three–phase fault [1,2,3,4]. Although less common than phase-ground faults, the phase--phase fault currents are larger. Three phase fault current is a phase to phase fault with the largest fault current [5,6].

Overcurrent protection is the easiest technique to safeguard a power distribution system. In the event of a fault, the current would grow to several times the maximum load current. The overcurrent relay is a type of overcurrent protection, particularly for phase-phase faults [7,8]. The overcurrent relays measure the fault current and compare it to the preset for the relay current. When the current level exceeds the relay's current setting, the relay sends a trip signal to the Circuit Breaker (CB) after a delay, isolating the faulty region [9].

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Improving the reliability of the power distribution system necessitates coordinated efforts amongst OCR. A power distribution system's reliability is defined as its capacity to provide uninterrupted service to customers. If the circuit breaker closest to the source was operational, it would indicate a decrease in system reliability due to an increase in customer power outages [10].

The relay settings should therefore be properly updated in every region of the power system. By choosing the time multiple setting (TMS), an optimum setting of overcurrent relay coordination (OCR) coordination can be achieved [11]. The range of the time multiple setting is 0 to 1. Therefore, when the time setting is 0.1, the moving portions of the relay only need to move 0.1 times their entire distance in order to close the contact. An electrical relay's operating speed is dependent on the fault current's intensity. Relays will respond more quickly (higher shortcircuit currents) or more slowly (lower shortcircuit currents) depending on the current value detected by CTs in inverse-time OCRs because of their inverse time-current characteristic (higher short-circuit currents). In general, definite-time characteristics (with an instantaneous trip function) are designated for larger currents whereas inverse-time characteristics are often reserved for lower currents [12].

This study improve working time coordination of OCR bay transformer using time multiple setting. OCR in electric distribution system consist of feeder OCR and bay transformer OCR. Bay transformer consist of medium and high side OCR, for example side of 20 kV and 150 kV OCR. When fault current is relatively small, working time delay between OCR of 20 kV and 150 kV side is small. This condition can cause miscoordination.

2 Methodology

The method in this study is calculation and simulation based on figure 1:

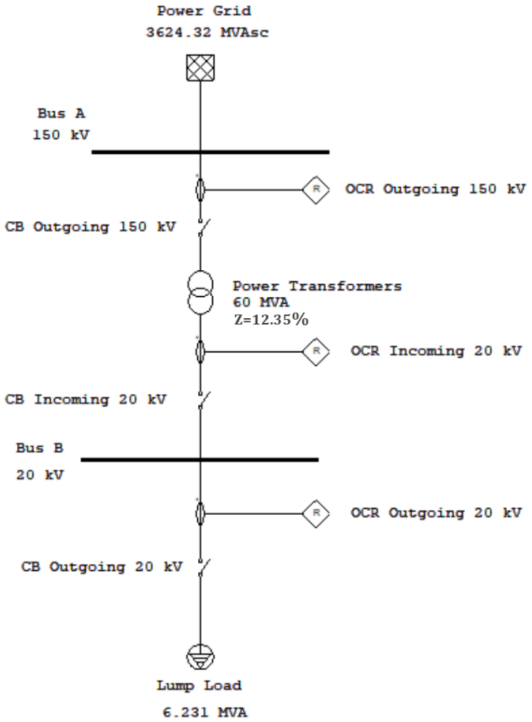

Figure 1. Single line study

There were calculations done to get: a) Three phase fault current value (If_{3p}) at outgoing of 20 kV bus; b) Setting time and tms outgoing 20 kV, incoming 20 kV, incoming 150 kV. Simulations were done to analyze and improve bay OCR coordination, consist of OCR incoming 20 kV and incoming 150 kV.

3 Result

3.1 Three phase fault current at outgoing of 20 kV bus

Fault current value influence by a positive sequence fault impedance at outgoing of 20 kV bus :

$$Z_1 = Z_s + Z_t$$

with :

Z_1 = positive sequence fault impedance at outgoing of 20 kV bus

Z_s = network positif sequence impedance at 20 kV side,

Z_t = transformer positif sequence impedance at 20 kV side.

The impedance of a network's positive sequence on the 150 kV side is:

$$X_s = \frac{(V_p)^2}{MVA_{(sc)}}$$

$$= \frac{(150\ kV)^2}{3624{,}32\ MVA}$$

$$= 6.21\ \Omega.$$

Transformer positif sequence impedance at 150 kV side is :

$$X_t = 12{,}35\%\ \text{x}\ \frac{(V_p)^2}{S_t}$$

$$= 12{,}35\%\ \text{x} \frac{(150\ kV)^2}{60\ MVA}$$

$$= 46.31\ \Omega$$

Positive sequence fault impedance at outgoing of 150 kV bus is :

$$Z_1 = 6.21\ \Omega + 46.31\ \Omega = 52.52\ \Omega$$

Three phase fault current value at primary side of transformer is:

$$If_{3p} = \frac{V_{ph}}{Z_1} = \frac{\frac{150.000\ V}{\sqrt{3}}}{46.31} = \frac{11{,}547}{\sqrt{52.52}^2} = 1648\ \text{A} = 12.284$$

kA

The impedance of a network's positive sequence on the 20 kV side is:

$$X_s = \frac{(V_p)^2}{MVA_{(sc)}}\ \text{x}\ \frac{(V_s)^2}{(V_p)^2}$$

$$= \frac{(150\ kV)^2}{3624{,}32\ MVA}\ \text{x}\ \frac{(20\ kV)^2}{(150\ kV)^2}$$

$$= 0.11\ \Omega.$$

Positive sequence impedance at 20 kV side of a transformer is :

$$X_t = 12{,}35\% \times \frac{(V_S)^2}{S_t}$$

$$=12{,}35\% \times \frac{(20\ kV)^2}{60\ MVA}$$

$$= 0.83\ \Omega$$

The positive sequence fault impedance at outgoing of 20 kV bus is :

$$Z_1 = 0.11\ \Omega + 0.83\ \Omega = 0.94\ \Omega$$

The three phase fault current value at secondary side of transformer is:

$$If_{3p} = \frac{V_{ph}}{Z_1} = \frac{\frac{20.000\ V}{\sqrt{3}}}{0{,}94} = \frac{11{,}547}{\sqrt{0.94}^2} = 12{,}284\ A = 12.284$$

kA

3.2 OCR Current setting (Iset) calculation

Primary current setting ($I_{set(p)}$) of OCR outgoing 150 kV :
The OCR setting is 1.2 is equivalent to the lowest nominal current (In) of the equipment. In this case is

$$tms = \frac{0{,}92}{3{,}89} = 0{,}23$$

Tms OCR incoming 20 kV :
In this study the existing OCR incoming 20 kV working time, t = 0,76 s. The tms OCR incoming 20 kV using the very inverse (VI) characteristic is:

$$t = tms \times \frac{0{,}14}{(\frac{If_{3p}}{I_{set}})^{0{,}02} - 1}$$

$$0{,}76 = tms \times \frac{0{,}14}{(\frac{12.284{,}05}{2080{,}86})^{0{,}02} - 1}$$

$$tms = \frac{0{,}76}{3{,}89} = 0{,}20$$

3.4 Simulation

Simulations were carried out to see the performance of the OCR bay transformer against a 3 phase short circuit on the 20 kV outgoing bus. The 3 phase short circuit was chosen because it produces the largest fault current among other types of short circuits, such as 2 phase and phase to ground. Existing data and calculation results from point 3.3. used as a parameter in the simulation circuit in Figure 2. The simulation results in the form of a coordination graph are shown in Figure 3. The

the transformer. The primary side current of the transformer is 230.95 A.

$$I_{set\ (p)} = 1.2 \times I$$

$$= 1.2 \times 230{,}95\ A$$

$$= 277.14\ A$$

Primary current setting ($I_{set(p)}$) of OCR incoming 20 kV :
The secondary side current of the transformer is 1734.05 A.

$$I_{set\ (p)} = 1.2 \times I$$

$$= 1.2 \times 1734.05\ A$$

$$= 2080.86\ A$$

3.3 Time multiple setting (Tms)

Tms OCR outgoing 150 kV :
Tms can be determined using OCR working time (t). In this study the existing t = 0,92 s. The tms OCR outgoing 150 kV using the very inverse (VI) characteristic is:

$$t = tms \times \frac{0{,}14}{(\frac{If_{3p}}{I_{set}})^{0{,}02} - 1}$$

$$0{,}92 = tms \times \frac{0{,}14}{(\frac{1.648{,}94}{277{,}14})^{0{,}02} - 1}$$

discussion focuses on the OCR bay transformer, namely OCR incoming 20 kV and OCR outgoing 150 kV.

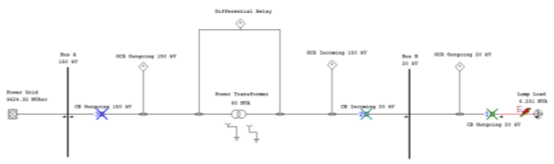

Figure 2. Three phase fault simulation at outgoing 20 kV

From the working time coordination curve in Figure 3, the x-axis shows the magnitude of the short-circuit current and the y-axis is the working time of the relay. If there is a phase-phase short circuit on the 20 kV outcoming bus, the 20 kV incoming OCR serves as the main protection of the bay transformer while the 150 kV outgoing OCR acts as a back up. The difference in working time for OCR incoming 20 kV with tms 0.21 and OCR outgoing 150 kV with tms 0.23 is very small and tends to get smaller when the current is getting smaller. This condition can cause incorrect operation, either the two OCR bays work at the same time or the outgoing 150 kV OCR works.

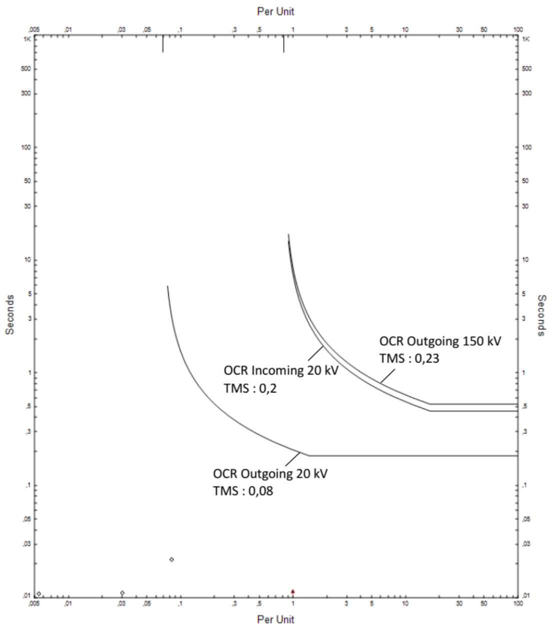

Figure 3. Result existing coordination OCR curve of three phase fault simulation at outgoing 20 kV

Resetting the OCR outgoing 150 kV dengan menaikkan the tms akan improve the working time coordination. Figure 4 shows the simulation results after resetting the tms on the OCR outgoing 150 kV from 0.23 to 0.53. The working time curve between the 20 kV incoming OCR as the main protection for the bay transformer and the 150 kV outcoming OCR has a better performance as a backup.

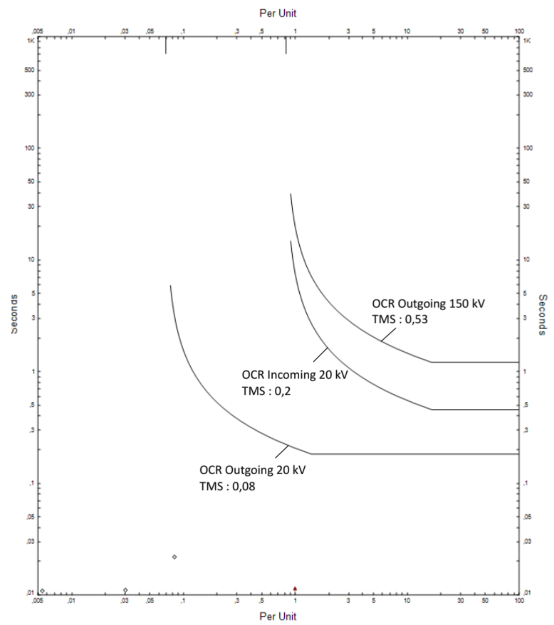

Fig. 4. Result improvement coordination OCR curve of three phase fault simulation at outgoing 20 kV using tms

In implementation, resetting tms to improve the working time coordination OCR, must refer to international standards, such as IEC 60255 standards or other international standards. Working time coordination between relay according to IEC 60255 standard is 0.4-0.5 s. Figure 5 shows the results of resetting OCR outgoing 150 kV based on IEC 60255 standard, with a delay time between 20 kV incoming OCR and 150 kV outgoing OCR of 0.45 s, so the working time of 150 kV outgoing OCR is 0.76 s + 0.45 s = 1.21 sec.

$$1{,}21 = \text{tms x } \frac{0{,}14}{\left(\frac{12.284{,}05}{2080{,}86}\right)^{0{,}02} - 1}$$

$$\text{tms} = \frac{1{,}21}{3{,}89} = 0{,}31$$

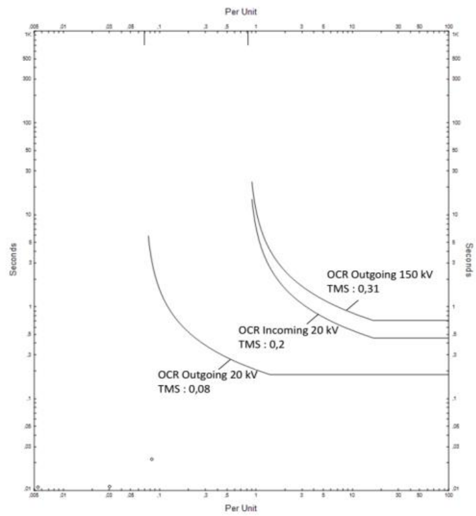

Fig. 5. Improvement coordination OCR curve of three phase fault simulation at outgoing 20 kV using tms based on IEC 60255 standard

4 Conclusion

1. Coordination of working time of the existing OCR bay transformer with tms OCR incoming 20 kV = 0.21 and tms OCR outcoming 150 kV = 0.23, potential for miscoordination, especially at relatively low short circuit currents.
2. Resetting tms improves coordination of OCR bay transformer working time according to the standard used.
3. For the same short-circuit current, the larger the tms the longer the OCR working time. This can be seen from the graph of working time that shifts up.

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