Increased reliability over current relay (ocr) as a transformerprotection with non-cascade coordination patterns

by Hari Prasetijo

Increased reliability over current relay (ocr) as a transformer protection with non-cascade coordination patterns

To cite this article: Hari Prasetijo *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci*. **746** 012043

IOP Conf. Series: Earth and Environmental Science **746** (2021) 012043 doi:10.1088/1755-1315/746/1/012043

Increased reliability over current relay (ocr) as a transformer protection with non-cascade coordination patterns

Hari Prasetijo[*], Ari Fadli, Priswanto, Widhiatmoko Herry Purnomo
Electrical Engineering, University of Jenderal Soedirman

[*]Email: hariprasetijo73@gmail.com

Abstract. Protection using Over Current Relays (OCR) with cascade coordination patterns is commonly used in 20 kV primary distribution networks to protect transformers from phase to phase fault currents. To anticipate a large fault current, the OCR feeder is equipped with an instant time setting. The problem occurs when the OCR feeder or PMT feeder fails to work then the transformer will be at risk because it is burdened with the fault current for a relatively long time. This study will discuss the use of a non-cascade pattern for the coordination of OCR feeders and incoming OCR in a primary distribution system supplied by a 60 MVA transformer, 150/20 kV from the substation by the calculation method. OCR feeders use very inverse (VI) characteristics and OCR inverses use standard inverse (SI) characteristics. A large feeder fault current is obtained by determining the 3 phase fault current upstream of the feeder as 7 x the nominal current (In) of the transformer. The result is that when the PMT feeder fails to work, the incoming OCR cascade coordination pattern will work with a time of 1.05 seconds. Meanwhile, if we use a non-cascade pattern the incoming OCR will work in the time setting of 0.3 seconds. Work time difference of (1.05 - 0.3 = 0.75 s) shows an increase in protection reliability and reduces the risk of damage to the transformer.

1. Introduction

Outages in the distribution power system are expected to have a localized effect. Fault Statistics show that distribution power systems contribute the most to customer interruptions and failure events [1],[2]. Among all faults, a balanced 3-phase fault current is the largest fault current. However, it is one of the least to occur [3],[4]. Over-current relay (OCR) is a relay in the distribution power to protect the transformer from phase to phase fault current, include 3-phase fault current.

This relay works by comparing the input current and the relay current setting. If it exceeds the relay current setting, the relay will send a trip signal to the Circuit Breaker (CB) after a time delay applied to the settings [5],[6]. Three-phase faults can occur at the feeder or 20 kV bus. If the fault occurs at the feeder, the OCR feeder must work first and OCR incoming will work as a backup. If the fault occurs at a 20 kV bus, the OCR incoming must work. So OCR feeder and OCR incoming must be coordinated to obtain selective, sensitive, and reliable working [7],[8]. Proper coordination between OCR feeder and OCR incoming is needed to improve the reliability of the power distribution system. Reliability of a power distribution system is defined as the ability to deliver uninterrupted service to the customer. The closer the circuit breaker to the source works, the less reliable because of more customer outage from the distribution power system [9]. Generally, the coordination pattern used in the radial distribution system is cascade coordination. This coordination pattern is to be less reliable in protecting power transformers when a large fault current occurs, for example, 3 phase fault very close to the bus 20 kV. OCR feeder will detect fault current and send a signal trip to the Circuit Breaker (CB) feeder, but if the OCR feeder or CB fails to work, the incoming OCR will take over to protect the transformer by sending the signal trip to the incoming CB. With a cascade pattern, the OCR incoming will work using a delay time. It will be a risk for the transformer because the transformer receives a very large current in an amount of time [10],[11].

This study compares the work reliability of feeder OCR and incoming OCR using the cascade coordination pattern and the non-cascade coordination pattern. The study was conducted on a 60 MVA, 150/20 kV power transformer that supplies a 20 kV primary distribution system.

2. Methodology

The method in this study is a calculation based on Figure 1. Calculations were performed on feeder (F1), 23.1 km length, to get :

a. Fault current value occurred at the bus 20 kV.
b. Setting time, Tms and Working time OCR feeder and OCR incoming

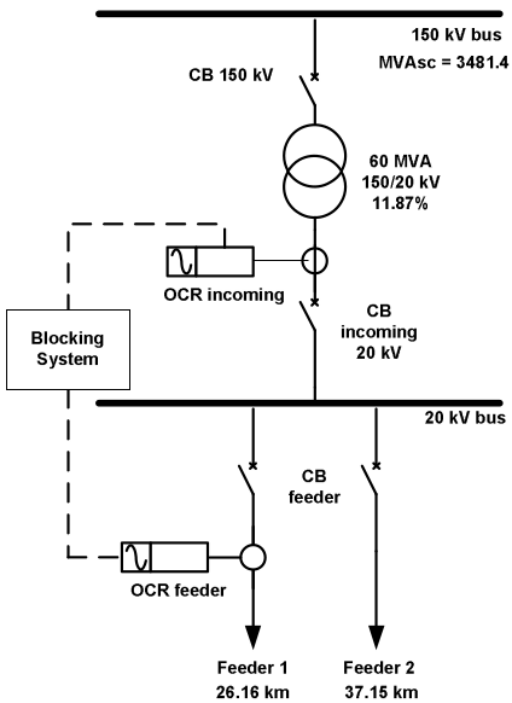

Figure 1. Single line study.

3. Result

3.1. Fault current at 20kV bus

Fault current calculation requires a positive sequence fault impedance on the 20 kV bus (Z1) that consists of network impedance (Z_N), transformer impedance Z_T), cable impedance (Z_L).

IOP Conf. Series: Earth and Environmental Science **746** (2021) 012043 doi:10.1088/1755-1315/746/1/012043

3.2. Network impedance calculation (ZN)
Network impedance 20 kV is calculated from the 150 kV side :

$$Z_{s150kV} = \frac{(KV)^2}{MVAhs} = \frac{150^2}{3481.4} = j\,6{,}463\Omega$$

$$Z_{s20\,kV} = \frac{(20kV)^2}{(150\,kV)^2} x\, Z_{s150\,kV} \;= \frac{20^2}{150^2} x\; j6{,}463 = j\;0{,}114\Omega = \frac{0{,}114\Omega}{6{,}667\,\Omega} = 0{,}01722\;\; pu$$

3.3. Transformer impedance calculation (ZT)
From figure 1, transformer impedance is : Z_T = 11,87 % = 0,1187 pu

3.4. Cable impedance calculation (ZL)
The type of cable used is IEC 6502-2, 630 mm^2 with impedance 0,1259 Ω/km. The cable length from the transformation to the 20 kV bus is 90 m. So the cable impedance (Z_L):

$$Z_{cable} = 0.09\;km\;x\;0.1259\;\Omega / km = 8.49\;x\,10^{-3}\Omega = \frac{60}{20^2} x\,8.49\,x10^{-3}\;pu = 1.275\text{ x }10^{-3}\text{ pu}$$

Positive sequence fault impedance at 20 kV bus incoming (Z1) is:

$$Z_1 = Z_N + Z_T + Z_L = 0{,}01723 + 0{,}1187 + (1{,}275 \text{ x } 10^{-3}) = 0{,}1372 \text{ pu}$$

3.5. Fault current calculation at 20kV bus
The largest fault current is the 3 phase fault which is calculated using the following equation:

$$I_{f\,3\phi} = \frac{V}{Z_1} = \frac{1}{(0 + j0{,}1372)} = 7.289 \angle -90^0\;\;pu = 12624\;\angle -90^0\;A$$

3.6. OCR Current setting (Iset) calculation

3.6.1. Incoming OCR current setting OCR incoming uses a current transformer (CT) with a ratio of 2000/5 A. The OCR setting is 1.2 of the lowest nominal current (In) of the equipment, that is the transformer. In the secondary side of the transformer is 1732.05 A.

Iset = 1.2 x In 20 kV = 1.2 x 1732,05 A = 2078.46 A ~ 2100 (primary)

3.6.2. Feeder OCR current setting
Feeder OCR uses CT with a ratio of 600/5. OCR feeder current settings:

Iset = 1.2 x In CT = 1.2 x 600 A = 720 A (primary)

3.7. Time multiple setting (Tms)

3.7.1. Tms incoming OCR Tms is a setting for the relay's working time. Tms can be calculated with determined incoming OCR working time for fault at 20 kV bus first, in this study be chosen to20 = 1 second. This value is chosen to provide an opportunity for feeder OCR as the main protection to work first. Then the incoming OCR Tms value using the very inverse (VI) characteristic:

$$Tms = \frac{\left[\frac{I_2 f\,20}{I_{set}}\right] - 1}{13.5} x\,t_0 20 = \frac{\left[\frac{12624}{2100}\right] - 1}{13.5} x1 = 0.371$$

IOP Conf. Series: Earth and Environmental Science **746** (2021) 012043 doi:10.1088/1755-1315/746/1/012043

3.7.2. Tms OCR feeder The relay work time in the feeder must be faster than the relay work time installed on incoming. The value taken for the time setting is not less than 0.3 seconds with the aim that the relay does not trip due to the inrush current of the distribution transformer connected to the distribution network. In this calculation, the selected value is 0.4 seconds.
Relay characteristics use Inverse Standards (SI). So the Tms value that will be set up in the feeder is as follows.

$$Tms = \frac{\left[\frac{I_{SC}}{I_{Set}}\right]^{0,02} - 1}{0,14} x\, t = \frac{\left[\frac{12624}{720}\right]^{0,02} - 1}{0.14} x 0.4 = 0.17$$

3.7.3. OCR Working time (tOCR). The three-phase fault current on a 20 kV bus is 12624 A, about 7.286 times the nominal current of the transformer (In = 1732.05A). The following will be calculated incoming tOCR and feeder tOCR for example feeder fault current of 4, 5, 6, and 7 times the nominal current of the transformer.

3.7.4. Working time Incoming OCR (tOCR) using very inverse characteristic

I primary = 6 In = 6 x 1732.05 ~ 10392 . Working time :

$$t = \frac{13.5}{\left[\frac{I_{primer}}{I_{set}}\right] - 1} xTms = \frac{13.5}{\left[\frac{10392}{2100}\right] - 1} x 0.371 = 1.27\ s$$

I primary = 7 In = 7 x 1732.05 ~ 12124 A. Working time :

$$t = \frac{13.5}{\left[\frac{I_{primer}}{I_{set}}\right] - 1} xTms = \frac{13.5}{\left[\frac{12124}{2100}\right] - 1} x 0.371 = 1.05\ s$$

Table 1 shows the characteristics of OCR incoming working time to fault currents 3 x In until 7 x In.

Table 1. Working time OCR *incoming*

Fault Current		Working Time (Very Inverse)
xIn	Ampere	Incoming OCR (s)
7In	12124	1.05
6.5In	11258	1.15
6In	10392	1.27
5.5In	9526	1.42
5In	8660	1.60
4.5In	7794	1.85
4In	6928	2.18
3.5In	6062	2.65
3In	5196	3.40

Working time feeder OCR (tOCR) feeder using standar invers characteristic

I primary = 6 In = 6 x 1732.05 ~ 10392 A. Working time :

$$t = \frac{0.14}{\left[\frac{Isc}{Iset}\right]^{0.02} - 1} x Tms = \frac{0.14}{\left[\frac{10392}{720}\right]^{0.02} - 1} x 0.17 = 0.43s$$

I primary *= 7 In = 7 x 1732.05 ~ 12124 A. Working time :*

$$t = \frac{0.14}{\left[\frac{Isc}{Iset}\right]^{0.02} - 1} x Tms = \frac{0.14}{\left[\frac{12124}{720}\right]^{0.02} - 1} x 0.17 = 0.41s$$

Tabel 2. Working time OCR *feeder*

Fault Current		Working Time (SI)
In	Ampere	Feeder OCR (s)
7In	12124	0.41
6.5In	11258	0.42
6In	10392	0.43
5.5In	9526	0.45
5In	8660	0.47
4.5In	7794	0.49
4In	6928	0.51
3.5In	6062	0.55
3In	5196	0.59

Table 3. Comparision working time OCR feeder and incoming

Fault Current		Working Time (VI)	Working Time (SI)	Δt
xIn	Ampere	Incoming OCR (s)	Feeder OCR (s)	(s)
7In	12124	1.05	0.41	0.64
6.5In	11258	1.15	0.42	0.73
6In	10392	1.27	0.43	0.83
5.5In	9526	1.42	0.45	0.97
5In	8660	1.60	0.47	1.14
4.5In	7794	1.85	0.49	1.36
4In	6928	2.18	0.51	1.66
3.5In	6062	2.65	0.55	2.11
3In	5196	3.40	0.59	2.81

Table 2 shows the characteristics of OCR incoming working time to fault currents as large as 3 x In until 7 x In. Comparison working time OCR feeder and OCR incoming were tabulated in table 3. From the table can be informed :

a. the larger the fault current, the shorter working time both of OCR.
b. OCR feeder working time smaller than OCR incoming because as main protection. For example, when 12124 A fault current (7 x In) occurs in the feeder, the OCR feeder will work in 0.41 s. If the OCR feeder fails to work, OCR incoming will work 1.05 s after a fault or 0.64 s (Δt) after the OCR feeder fails to work.

Figure 2 showed a comparison of the graphic working time OCR feeder and OCR incoming as backed up for several quantity fault currents along the feeder. The blue solid line for OCR incoming and orange solid line for OCR feeder.

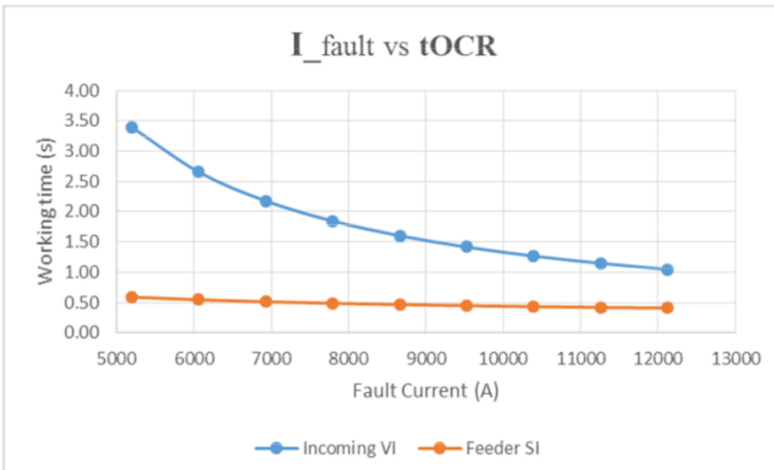

Figure 2. Comparison working time OCR feeder and incoming

3.8. Cascade pattern OCR coordination

The OCR setting calculated in 3.1 - 3.5 is a cascade protection pattern. To speed up the handling of very large fault currents the cascade pattern protection is equipped with instantaneous settings. In the cascade pattern, instantaneous settings are only applied to the feeder. While the working time for incoming is the same as the initial settings. Instantaneous settings in the feeder that are applied to a cascade pattern at least 0.8 x 4 x In transformer :

$$Setting\ I>>=3.2\,x\,In\,transformer\ 20\,KV\ =3.2\,x1732.05\,A=5542.56\text{ A (primary)}$$

$$I>>=\frac{Setting\ I>>}{CT\,20}=\frac{5542.56\,A}{600/5}=48.2\text{ (secondary)}$$

For example, setting I >> is 7 with instant time (t >> = 0 seconds). The 7 x In fault current occurs in the upstream feeder because the 3 phase fault current on the 20 kV bus is 7.286 x In. The application of this cascade setting is only effective if the feeder OCR and CB conditions are in normal working conditions. But when OCR and CB in the feeder fail to work, incoming OCR and CB will trip following the initial set of incoming OCR work time. Therefore, the relay to be less reliable when

IOP Conf. Series: Earth and Environmental Science **746** (2021) 012043 doi:10.1088/1755-1315/746/1/012043

very large fault-currents occurred. If a fault current occurs seven (7) times the nominal current of a 20 kV transformer, then:

Isc = 7 x 1732,05 A = 12124 A (primary)

I secondary = 12124 ÷ 600/5 = 101.0 A (secondary)

When the feeder OCR and CB are in a normal condition, the feeder OCR will work instantly to give trip signal to the feeder CB. However, if the condition of the feeder OCR and CB fails to work, incoming OCR must work to secure the system. The problem is that setting the incoming OCR work time very slow to secure the system. In the calculation as follows:

Isc = 7 x 1732,05 A = 12124 A (primary)

$$t = \frac{13.5}{\left[\frac{I_{primer}}{I_{set}}\right] - 1} x Tms = \frac{13.5}{\left[\frac{12124}{2100}\right] - 1} x 0.371 = 1.05$$

So incoming OCR will work in 1.05 seconds when fault current 12124 A occurred. This is very risky for the safety of the transformer from a large fault current

3.9. Noncascade patern OCR coordinatione

The difference between the cascade pattern and the non-cascade pattern lies in the application of its instantaneous settings. For the cascade pattern, instantaneous settings are applied only to the feeder OCR. while for the non-cascade pattern, instantaneous settings are applied to the feeder and incoming OCR.

3.9.1. Instantaneous setting incoming OCR. The instantaneous incoming OCR setting is 7 x In the 20 kV side transformer with a time setting of 0.3 seconds. So with non-cascade pattern when there is a fault current as 12124 A incoming OCR will work within 0.3 seconds while the cascade pattern works within 1.05 seconds.

3.9.2. Blocking system OCR. This blocking system is implemented to prevent incoming OCR and feeder OCR from working at the same time. The blocking system works when a very large disturbance, according to instantaneous settings, occurs in the feeder which is also felt by incoming OCR.

3.9.3. A large fault current when feeder OCR and CB normally work condition. When a large fault current occurs in the feeder and meets the instantaneous setting, the feeder OCR and the incoming OCR will sense the current. If the condition of feeder OCR and CB are normal, the instantaneous setting on the feeder OCR feeder will work and give an order signal for CB to instantaneously work. Even though the incoming OCR felt a disturbance, it did not directly trip the incoming CB. This is because when the feeder OCR senses the fault current, the feeder OCR will send a signal to the feeder CB to work instantaneously and send a signal to the incoming OCR to block the instantaneous trip of incoming CB.

3.9.4. A large fault current when feeder OCR and CB abnormally work condition If the feeder OCR and CB fail to work when a large fault current occurs in the feeder that appropriates with the feeder OCR instantaneous setting, the incoming OCR will continue to feel the fault current and the incoming OCR instantaneous setting will work to tripping incoming CB with the instantaneous working time 0.3 seconds.

IOP Conf. Series: Earth and Environmental Science **746** (2021) 012043 doi:10.1088/1755-1315/746/1/012043

4. Conclusion

1. From the calculation, the non-cascade coordination pattern will be more reliable compared to the cascade coordination pattern in overcoming a very large fault current. Because with the instantaneous setting on the incoming OCR, the OCR working time using a non-cascade pattern is faster compared to the cascade pattern when the OCR and CB feeder fails to work. The time difference obtained is about 0.75 seconds.
2. Cascade and non-cascade OCR settings patterns have the same reliability as a large fault current when the OCR and CB feeders work normally.
3. The application of non-cascade OCR settings is more reliable in overcoming fault currents in order to protect the transformer from any conditions.

References

[1] S.-A. Yin and C.-N. Lu 2009 Distribution feeder scheduling considering variable load profile and outage costs. *IEEE Transactions on Power Systems* **24** no. 2 652–660

[2] Guoyan Chen, et.al. 2017. Reliability Evaluation of Distribution System with Distributed Generation. *IOP Conf. Series: Materials Science and Engineering* **224** (2017) 012035.

[3] Horia Balan, et. Al.2018. Modeling Three-Phase Short-Circuits for Radial Distribution Systems. Annals of the University of Craiova, *Electrical Engineering series*, No. 42, Issue 2, 2018; ISSN 1842-4805

[4] A. Golzarfar, A. R. Sedighi, A.Asadi 2015 Optimal Placement and Sizing of Fault Current Limiter in a Real Network: a Case Study. *IJE TRANSACTIONS C: Aspects* **28**, No.3, (March 2015) 402-409.

[5] Uma U.Uma, I.K.Onwuka 2014 Overcurrent Relay Setting Model for Effective Substation Relay Coordination. *IOSR Journal of Engineering (IOSRJEN)* **04**, Issue 05 (May. 2014), ||V2|| pp 26-31

[6] Atul Jaysing Patil et.al. 2019 A Literature Review: Traditional and Advanced Protection Schemes of Power Transformer *International Journal of Engineering Research and General Science* **7** Issue 2

[7] Acharya Sandesh et.al 2016 Coordination of Overcurrent Relay for Radial and Parallel feeder Networks Research *Journal of Engineering Sciences* **5**(5), 1-8

[8] Abdulfetah SHOBOLE 2017 Protection Coordination Practice in Electrical Substation Part-1 Overcurrent and Earth Fault Protection - Case Study of Siddik Kardesler Substation (SKS), Istanbul *Turkey Journal of Science GU J Sci* **30**(4) 180-198

[9] Ulas Eminoglu, Ridvan Uyan.2016. Reliability Analyses of Electrical Distribution System: A Case Study. *International Refereed Journal of Engineering and Science (IRJES)* **5**, Issue 12 94-102

[10] Jorge Betanzos Manuel 2010 Protecting Distribution Feeders for Simultaneous Faults *37th Annual Western Protective Relay Conference Spokane, Washington October 19–21, 2010*

[11] Reza Jalilzadeh Hamidi et.al. 2019 Optimal time-current graded coordination of multistage inverse-time overcurrent relays in distribution networks *International Transaction on Electrical Energy System* **29** issue 5

Increased reliability over current relay (ocr) as a transformerprotection with non-cascade coordination patterns

ORIGINALITY REPORT

2%	2%	2%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	yang.gatech.edu Internet Source	1%
2	B.P. Lang, A. Pahwa. "Power distribution system reliability planning using a fuzzy knowledge-based approach", IEEE Transactions on Power Delivery, 2000 Publication	<1%
3	www.pashudhanpraharee.com Internet Source	<1%
4	pnrsolution.org Internet Source	<1%
5	www.mdpi.com Internet Source	<1%
6	www.researchgate.net Internet Source	<1%
7	Ali Ridha Al‐Roomi. "Optimal Coordination of Power Protective Devices with Illustrative Examples", Wiley, 2021	<1%