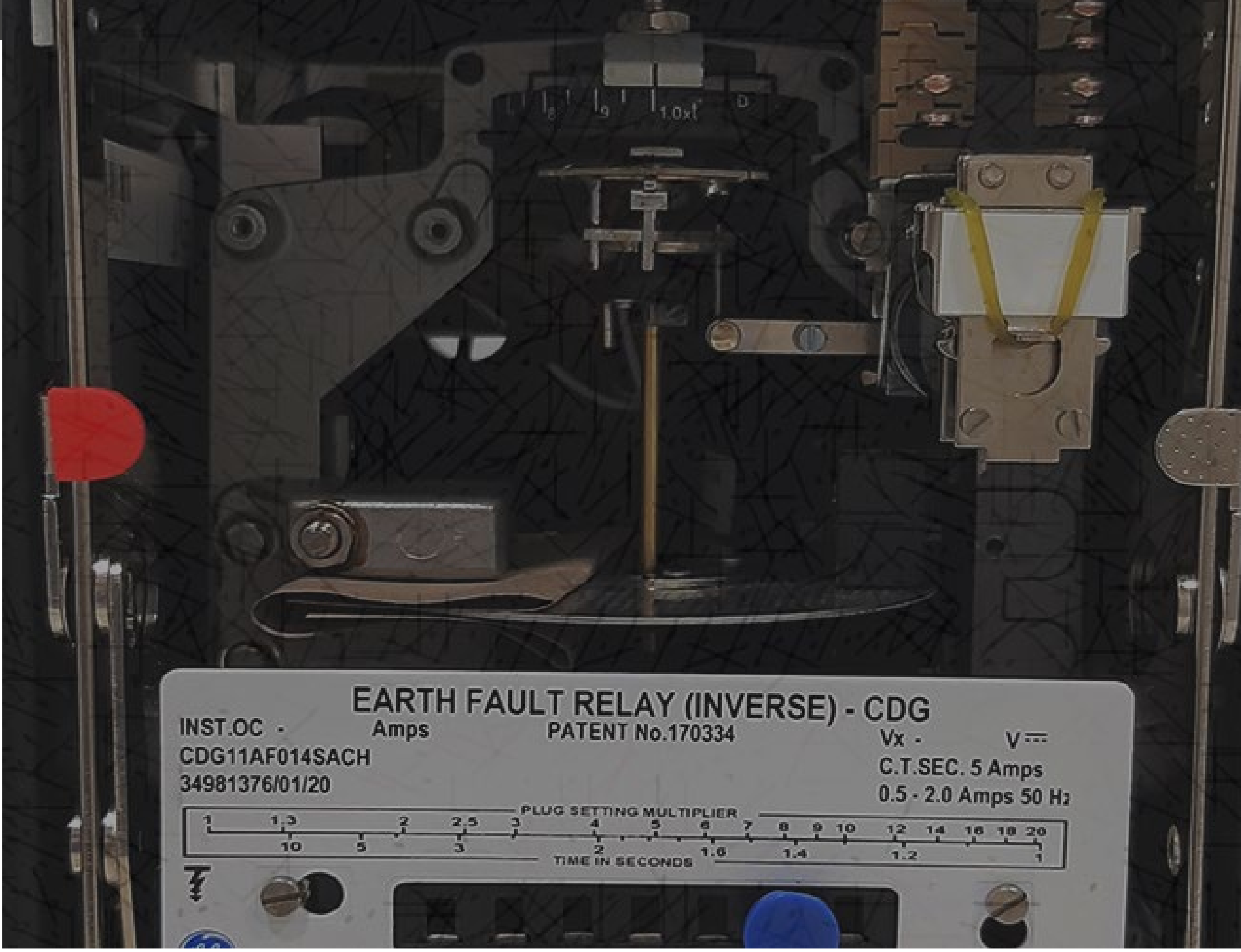


Time and Space in an OCEF Relationship

Written by **Karl M.H. Lai**

OCEF Protection is an introductory chapter on power system protection and is a widely used non-unit protection with grading for faults detection and clearance in power networks. This article discusses various aspects of OCEF Protection, including the types of relays, the coordination studies and their concerns, the effects of CT mismatch, and the applications and incidents of OCEF protection in the transmission network in Hong Kong.

Introduction to OCEF Protection

Overcurrent Earth Fault (OCEF) protection is the basic protection to any power systems. It is designed to detect overcurrent and ground fault in power systems, and it prevents equipment thermal and mechanical damage and ensures safety. These protections can be implemented with various types of relays, ranging from traditional electromechanical (EM) OCEF relay to modern digital OCEF relay, each offering unique advantages in terms of sensitivity, response time, reliability, and adaptability to different system configurations.

In Hong Kong, OCEF relays are often employed as main protection in distribution network such as for the busbars in customer substations, and backup protection in transmission network, such as 132kV RMU feeders. It could be a non-unit protection with grading in terms of inverse definite minimum time (IDMT) curves, or a unit protection with definite time lag (DTL) overcurrent setting.

This report explores the characteristics in OCEF relays and considerations in practical OCEF applications.

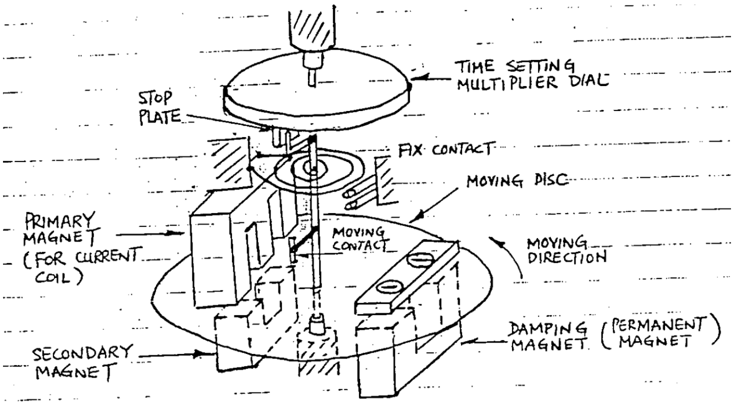
Comparison between EM OC Relay and Digital OC Relay

The principle of EM OCEF relay lies on torque balance and acceleration of disk rotation mechanism as illustrated in Figure 1 and 2 due to large electromagnetic force driven by large current in secondary circuit. The torque exhibits in EM OCEF relays are:

Induction torque due to fault current: $T_I = K_q \times I^2$
Spring torque: $T_S = K_q \times I_{PU}^2$
Damping torque from damping magnet: $T_D = K_d \times \omega$

Disk motion can be represented in the following equations:

$$\Sigma T = T_I - T_S - T_D = 0 \;\rightarrow\; T_S\left[\left(\frac{I}{I_{PU}}\right)^2 - 1\right] = K_d \frac{d\theta}{dt} = K_d \frac{\theta}{t}$$



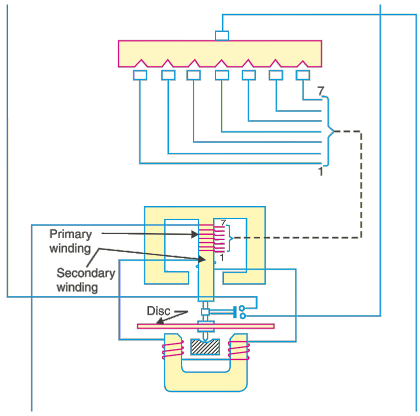


Figure 1: Structure of Electromechanical OCEF Relay (left)
Figure 2: Schematic of Electromechanical OCEF Relay with Plug Setting (right) [4]

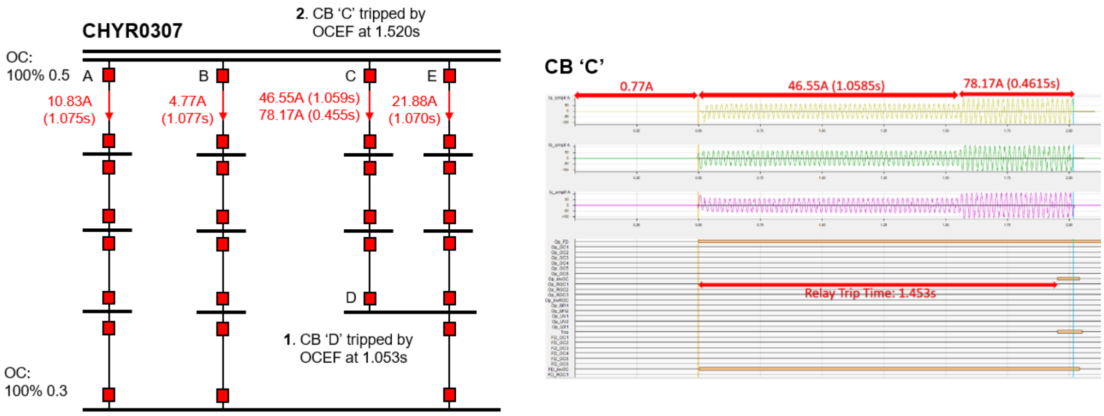


Figure 3: Example for Digital OCEF Operation Time Calculation

The operation time for disk rotation can be calculated with

$$t = \frac{K_d \theta}{T_S}\left(\frac{1}{\left(\frac{I}{I_{PU}}\right)^2 - 1}\right).$$

Hence, a general IDMT characteristics is represented by

$$t = TM\left(\frac{\alpha}{\left(\frac{I}{I_{PU}}\right)^\beta - 1}\right).$$

The following table concludes the parameters for different relay characteristics [1].

Relay Characteristics	α	β
Inverse Time O/C or IDMT	0.02	0.14
Very Inverse	1.00	13.5
Extreme Inverse	2.00	80.0

Digital OCEF relay mimics the rotating disk philosophy. As an example, as illustrated in Figure 3, CB 'D' was tripped on 1.058s so that the fault current flow changes and the current experienced at CB 'C' was increased from 46.55A to 78.17A in secondary. From the rotating disk philosophy, full rotation for the disk in CB 'C' requires 1.534s.

$$0.5 \times \frac{0.14}{\left(\frac{46.55}{5}\right)^{0.02} - 1} = 1.534 \text{ sec}$$

However, CB 'D' was tripped at 1.058s, the disk was rotated 69% (1.058 / 1.534) of full travel.

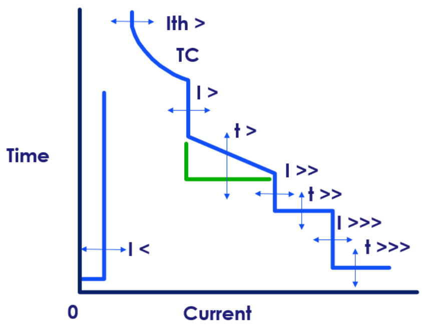
$$0.5 \times \frac{0.14}{\left(\frac{78.17}{5} \times 0.95\right)^{0.02} - 1} = 1.262 \text{ sec}, \quad \frac{0.395 \text{ sec}}{1.262 \text{ sec}} = 31\%$$

The latter 31% was completed at 0.395s, in which the CB 'C' requires 1.453s (1.058s + 0.395s) to trip.

Performance of EM OCEF relay and digital OCEF relay are compared as follows.

- **Reliability**: EM OCEF relay employs electromechanical torque to drive the disk to close the trip (and alarm contact). If the relay is placed in good condition with limited moisture and dust, the relay can reliably operate with current. Digital OCEF, however, often not performed as expected in hard condition, such as those placed in switchgear room, possibly leading to self-reboot or even relay failure. Although it has watchdog function to alarm any inoperative conditions, it can still possibly fail to trip before replacement.

- **Flexibility in Grading**: EM OCEF relay can only provide single characteristics. Digital OCEF, however, often provides more characteristics in one relay, in which it is possible to combine 6 curves (NI, EI, DTL, thermal) with different logics, as depicted in Figure 4. It could provide cold load protection [5] in Figure 4, which is an adaptive OCEF protection with a higher setting upon energization to avoid tripping due to inrush or stalling current dependent on discharge duration, operation and restoration mode, presence of distributed



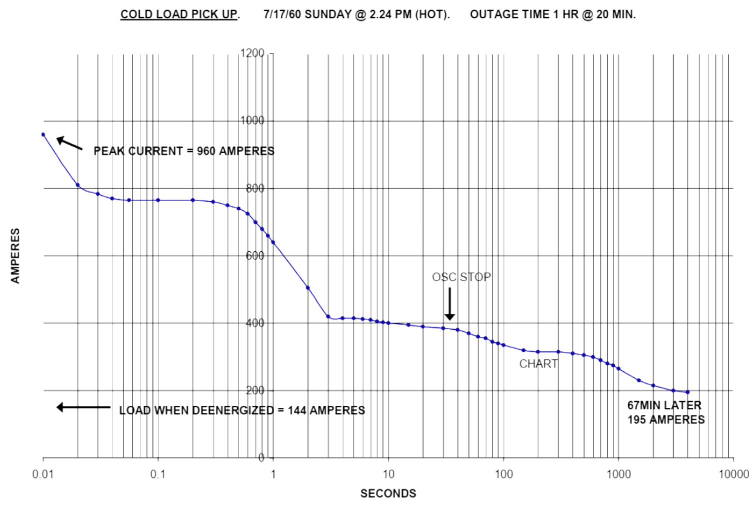


Figure 4: Possible OCEF Curve Constructed in Digital OCEF Relay (left)
Figure 5: Cold Load Pickup as a Composition of Inrush and Loss of Load Diversity [5] (right)

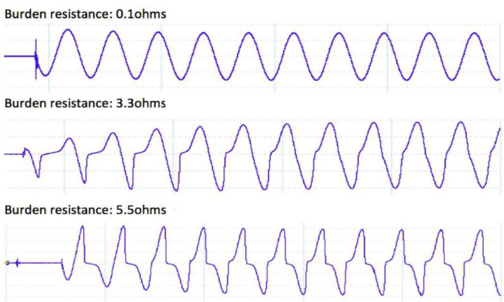


Figure 6: Current Distortion due to Increased Burden Resistance (right) [7]

generation and types of connected load. This could allow low set the plug setting without leading to tripping upon energization and allow faster operation.

- **Size and Space**: Traditional scheme often required large space to accommodate all three relays (2 x OC + 1 x EF) while modern scheme with digital relays often provides protection to all three phases and earth fault (measured and calculated) with one relay, possibly be incorporated in bay relay in which could also provide switchgear control function.

- **Burden**: EM OCEF, unlike digital OCEF, is often a large burden relay, which could not be placed in series with another relay for a single current transformer (CT). However, due to limited CT provided in switchgear, CTs for OCEF are often shared with breaker failure protection (BFP) or bay module for instrumentation. Limited burden on CT or high burden on EM OCEF relay could be a constraint to protection design. Also, a high voltage is often built up due to high burden (relay + lead) which leads to CT saturation, and hence distorted waveform with reduced current magnitude, as depicted in Figure 6. It could lead to delayed operation in OCEF protection.

- **Filtering:** EM OCEF is driven by induction torque generated by fault current. The fault current could be impulsive with DC offset or under resonance due to ringing effect. Yet, the fault current still creates a torque proportional to the square current. For digital OCEF relay, it has a DC offset filtering function in which the torque calculation often only includes symmetrical current in which transient overreach effect is limited. Conservative coordination time interval (CTI) could be resulted with improper selection of current magnitude (momentary, initial symmetrical or interrupting current) in coordination studies [6].

- **Other Functions**: Thermal Overload which employs thermal model to calculate equipment temperature with dissipated and released energy due to power loss and trip upon high temperature to avoid dielectric degradation and Breaker Wear Condition which allows recording on the number of close-open cycles to ensure good breaker condition and reduce the chance of breaker failure are also provided in normal OCEF relay. Also, it also allows sequence-of-event (SOE) and waveform recorder for fault analysis.

OCEF Grading and its Application in 11kV Legged Ring

OCEF intrinsically assumes fault current flow from a source to a load, and the breakers in between should be tripped in steps with time interval. Proper discrimination between various protective devices is also necessary (from main protection with around 60ms to local backup with 300ms, then to remote backup in order of seconds) such that a fault could be cleared from system selectively and supply to customers not directly affected by the faulty section of the systems should be maintained.

Prinicple of grading [8] includes

- **Discrimination by time**: Fault in upper section should be cleared with a delay t_1 after the designed operation time of downstream section. It can provide discrimination with long enough delay, regardless the fault current observed, yet it leads to unacceptable long duration for fault clearance at source end in a large network.

- **Discrimination by current**: Definite Time Lag Overcurrent (DTLOC) can be applied in layers with different current setting to clear faults with considerable large current difference between two layers. It is possible when there is a

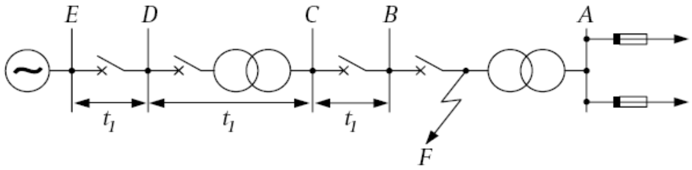


Figure 7: Discrimination by Time[8]

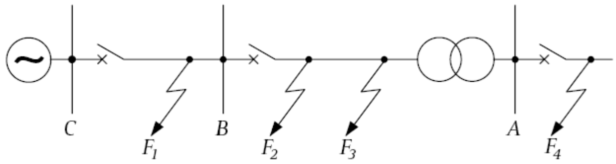


Figure 8: Discrimination by Time[8]

large impedance in between two layers. For example, high set overcurrent (HSOC), as a unit protection, is applied at the upstream of 132/11kV transformer to clear the fault only at the HV side, possibly occurred at the cable sealing end of the transformer. The disadvantage of such grading is that it cannot differentiate fault before and after a breaker, in which the impedance of two layers is small.

- **Discrimination by current and time**: IDMT characteristics often allows faster operation time for relay nearest to the source, where the fault level is the highest, and the increase of number of breakers in series without increasing the time setting of relays at power source. It could also increase the number of breakers in one busbar, in which inoperative OCEF due to current sharing at minimum fault level condition could be solved by lowering the current setting and slightly increase the time multiplier to allow more sensitive operation and enough grading margin at maximum fault level condition. However, it requires determination of both time multiplier setting (TM) and plug setting with selected inverse characteristics.

Grading margin is the time interval between the operation of two adjacent relays depends on fault interrupting duration of circuit breaker, relay overshoot (for EM OCEF), errors (from current measurement and time operation) and safety margin for a complete fault clearance. With faster modern circuit breakers and lower relay overshoot, EM relay and digital relay can have 0.4s and 0.25s grading margin respectively.

In a OCEF grading study from a 11kV legged ring applied in Hong Kong, it is often graded from customer substation (S/S), node substation and primary substation to the HV side of 132/11kV transformer with the following setting as illustrated in Figure 9.

Location with OCEF installed	OC	EF	CT Ratio
Transformer HV	50%, 0.7	30%, 0.5	400/1
Feeder at Primary S/S	100%, 0.5	30%, 0.5	400/5
Feeder at Node S/S	100%, 0.3	30%, 0.3	400/5
Feeder at Customer S/S	100%, 0.1	30%, 0.1	400/5

As illustrated in Figure 9(a), the general thumb rule in OCEF grading (or coordination study) is to provide an OCEF setting with acceptable grading margin between minimum and maximum fault level. To avoid delaying too much on the OCEF operation at the upstream, discrimination of current and time is often used such that the grading margin is often marginal at its critical value, often located at maximum fault level, in between two curves. Hence, to ensure the OCEF relay operates with selectivity and stability, it should be checked that

- OC elements should keep its stability at least under 120% of full load to allow temporary overload, in which there could be impulsive load or motor load, given that they are protected by customers' OCEF with designed setting such that their OCEF will trip before upstream.
- OCEF should be still operative at minimum fault level.
(It is not wise to grade at current under minimum fault level, as it is always possible to find a high impedance fault which has fault current much lower than its full load. The fault either evolves itself to larger one or extinguishes and clears itself.)
- OCEF should provide enough grading margin at maximum fault level and not to further delay the operation time by requesting a higher setting.
(As illustrated in Figure 9(b), the increase in transformer rating only increases the full load current and maximum fault level, given that the transformer impedance for 132/11kV transformer is assumed to be around 26% - 28%.)
- Grading should also ensure discrimination with possible measurement error and operational time delay.

From coordination studies, number of legs in a 11kV ring should be limited to 4 only, given that a minimum grading margin of 0.4s is provided. It is a result of grading with a 35MVA transformer. Transformer with a larger rating will lead to a more demanding grading margin as illustrated in Figure 9(b). To avoid further increase the time multiplier setting to provide better grading margin, numbers of legs supplied with any transformers should be limited to 4. Another consideration is current sharing problem at minimum fault level. If the number of legs is increased beyond 4, fault current distributed in each leg may lead to prolonged tripping or even without operation. If in case the plug setting is reduced to allow sensitive tripping at low load condition, the time multiplier must be increased to fulfil the grading margin requirement, and hence, further delayed tripping at upstream. It is required to keep the OCEF time multiplier setting at 11kV legs between 0.3 and 0.5.

4-legged ring applied in 11kV distribution network with graded OCEF is an efficient network design for better operational flexibility and system security with the following advantages.

- Standard legged ring offers parallel supply at any customer substation, in which a single cable fault could not create a load loss.

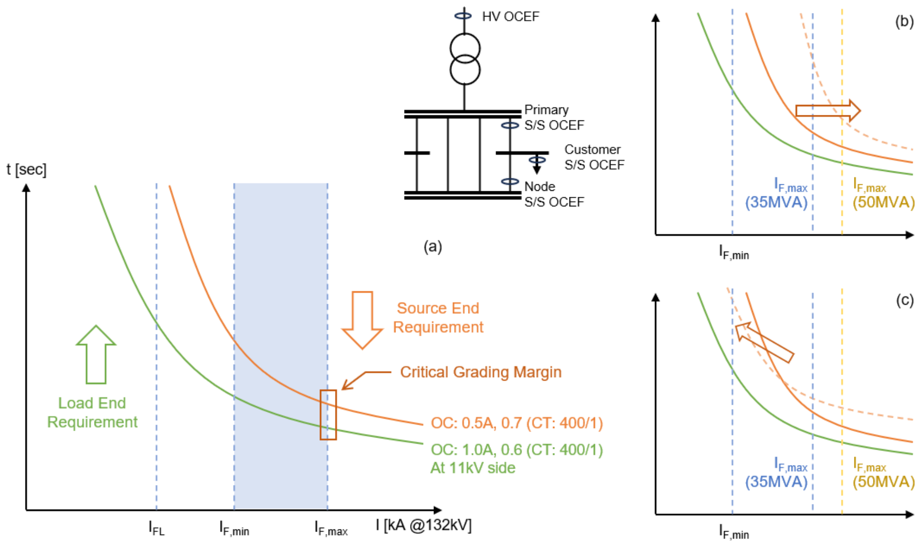


Figure 9: OCEF Coordination Studies in 11kV Legged Ring

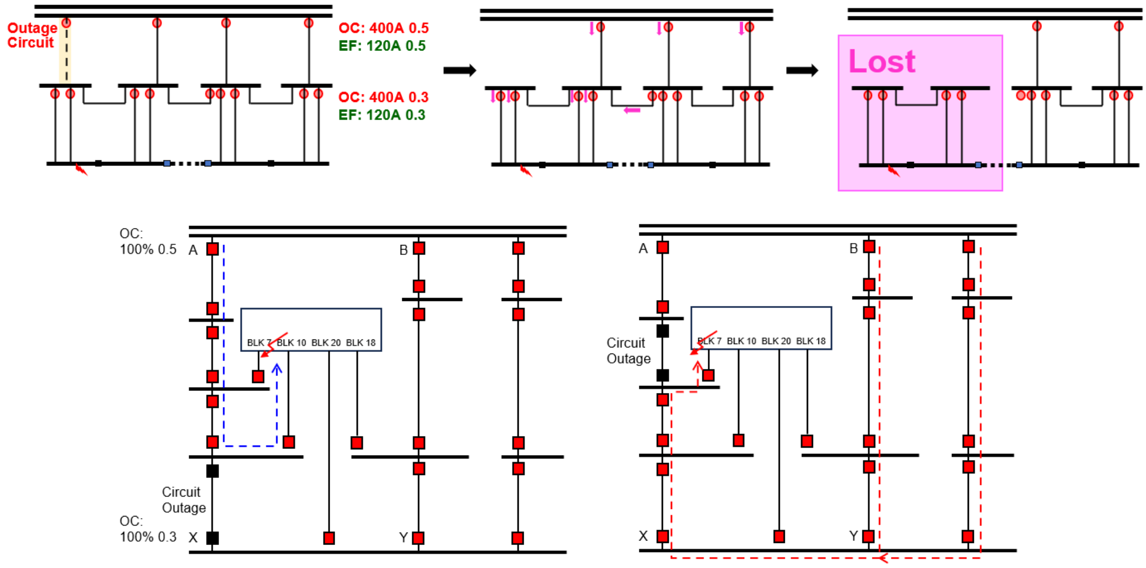
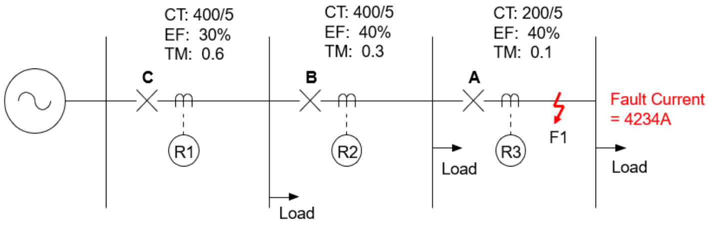


Figure 10: (a) Network with 4 Feeders Supplying Two Sub-Ring (Upper)
(b) Network with RMU Feeders (Lower)

- It often exhibits open circuit fault at which could create an outage to downstream loads at radial feed network. It is often undetectable until any load loss. In legged ring, however, the dual supply with open circuit fault could only lead to a single supply risk. It requires further application, such as broken conductor detection (BCD) applied at OCEF in 11kV primary substation, to detect any abnormal unbalanced load flow, or state estimation facilities to detect any open point in the future.
- OCEF is also gradable for any customer busbar fault at its standard configuration. The node breaker at corresponding leg experiences a current as current sum of the others, hence trips faster, and the primary substation will then trip to isolate the busbar. Yet, in case the fault current is too large such that fault current in each leg already located in the flat region, it is possible to have an additional load loss at the node substation. In case the node substation has a busbar fault, the time multiplier setting at node substation and primary substation allows sequential tripping which embraces selectivity. Any breaker failure possibly due to breaker stuck or trip circuit failure could lead to additional load loss on the node substation.

Figure 10(a) illustrates a network with four feeders supplying two sub-ring, in which the rings are interconnected. With standard OCEF setting, the interconnector should have the same setting as the feeders nearby to split the ring without affecting the others. However, it could lead to a ring loss under fault on outage as the current flows mainly from the interconnectors to the fault point and hence the interconnector must trip faster than the downstream sub-ring feeders. Figure 10(b) illustrates a network with 11kV RMU feeders, illustrated as a block with BLK7 is connected to BLK10, in which OC: 150%, 0.1 is set to allow operational flexibility to supply all loads in the RMU feeders at any source. However, during an outage, circuit outages could lead to different current flow, hence having a network dependent grading threshold. It was suggested to apply a lower OC setting at the RMU feeder to provide enough grading margin.



Operation Time	Substation C	Substation B	Substation A
5A relay + 5A CT	1.14 sec	0.62 sec	0.17 sec
5A relay + 1A CT	2.11 sec	1.24 sec	0.29 sec
1A relay + 5A CT	0.77 sec	0.41 sec	0.12 sec

Figure 11: Operation Time for OCEF with Mismatch CT and Relay

Mismatch in CT and OCEF Relay

CT requirement in protection application is often strict. It often requires an accuracy at a certain accuracy limiting factor (ALF) and denoted in form of 5P10, with a maximum of 5% error at 10 times nominal current for OCEF protection 'P'. Hence, it is assumed with correct conversion ratio at large current and enough burden to supply an OCEF relay. CT often provides 1A at secondary circuit in transmission protection, as it flows through a long lead from switchgear room to protection panels and creates an acceptable voltage drop. In distribution protection, it provides 5A output as it allows better sensitivity and the voltage drop problem is not significant with most CT wirings located within the switchgear panels.

CT for OCEF application often provides flexibility to provide output with half ratio and full ratio connection, and some digital OCEF provides dual CT input for 5A or 1A applications. Hence, mismatch of CT and OCEF relay exists in real applications. It either leads to instability under normal load (5A relay + 1A CT, with 5 times current going into the relay) or leads to sluggish tripping with loss of selectivity (1A relay + 5A CT, with 0.2 times current going into the relay).

It is essential to identify mismatch by test. In case the relay is accidentally connected in a wrong CT input, measurement test by secondary injection at CT terminal as a relay pre-commission test is performed to identify such event. However, to avoid accidental connection to wrong CT input (half ratio to full ratio), it is required to perform primary injection, possibly with leads connected through the CT for ratio test if the CT is exposed as SIEMENS 8DB10 does, or direction injection through panels from one earth to another earth during CT balance tests if the CT is not sealed inside the switchgear as SIEMENS NXPLUS does, to identify such event. It is the difficulties in tests on CT ratios after commissioning. It is noted that the OCEF CTs are shorted and connected with half ratio before energization of the panel, and the ferrule numbers at CT wires could have mistakes as compared to the standard. In case it is a sealed switchgear, and the relay is applied one day after the commissioning, it was advised to check the load measured by relay during on load test as the last step before real applications.

Although mismatch in CT with relay is not preferrable, it once was intentionally applied (1A CT + 0.5A relay) in practice. Due to the large CT ratio (1200/1) as provided by the switchgear manufacturer, and normal EM OCEF relay cannot provide a plug setting as designed (with step of 0.2A), it was designed to apply a 0.5A relay to provide large sensitivity and a finer step on plug setting.

Considerations in OCEF Coordination Studies

It is impossible to have OCEF time multiplier setting increased infinitely to provide enough grading margin, as higher time multiplier implies a longer time to trip, and it cannot provide protection to equipment against damages such as dielectric degradation from thermal breakdown, or low-cycle fatigue with mechanical decomposition due to electromechanical force generated by large current. While it is the protection goal to lower time multiplier with enough grading margin, it is also important to high set enough the time multiplier (or plug setting) to ensure its stability against phenomena such as motor stalling and inrush[6].

Transformer damage curves, as suggested in IEEE C57.109-2018[9], are current-time curve ranged from 2 to 1000 second for overload (< 5 x nominal current) and through fault that a transformer can be able to withstand. Although the damage curve describes the duration a transformer can withstand a fault, it does not mean that the fault does not cause any damage thermally, mechanically, and chemically. It is important to consult the manufacturer on cyclic rating and emergency rating for operation, or else it requires condition monitoring and loss-of-life calculation to ensure it can run in a good condition. Damage curve cannot be validated in test as the effect is aggregated through the transformer lifetime. Instead, it is generated from engineering judgement and historical field experience.

OCEF elements should operate before damage, i.e. below the withstand curve. It is impossible to grade for all extreme case. Protection requirement against mechanical and thermal damage is based on the frequency of through fault and transformer size. To remain its stability while providing enough grading margin and protecting against sustained overload, it is suggested to provide an adaptive OCEF, an IDMT OCEF curve supplemented by a HSOC to protect low current overload, or a thermal overload protection.

It is noted in IEEE 242 that the damage curve is dependent on winding and fault type[10]. The damage curve in Figure 12 assumes a three-phase secondary fault with a wye-wye transformer. In case with a delta-wye transformer which redistributes the current from LV side to HV side in different phase, the curve should be shifted to left by 58% as per recommended, as earth fault at wye side (LV) is reflected to phase-to-phase fault at delta side (HV). Figure 13 illustrates possible conditions with a delta-wye transformer to be considered in OCEF coordination studies.

Transformer inrush upon energization can have a significant impact on the coordination studies in OCEF protection. Inrush currents are high-magnitude, harmonic-rich currents generated

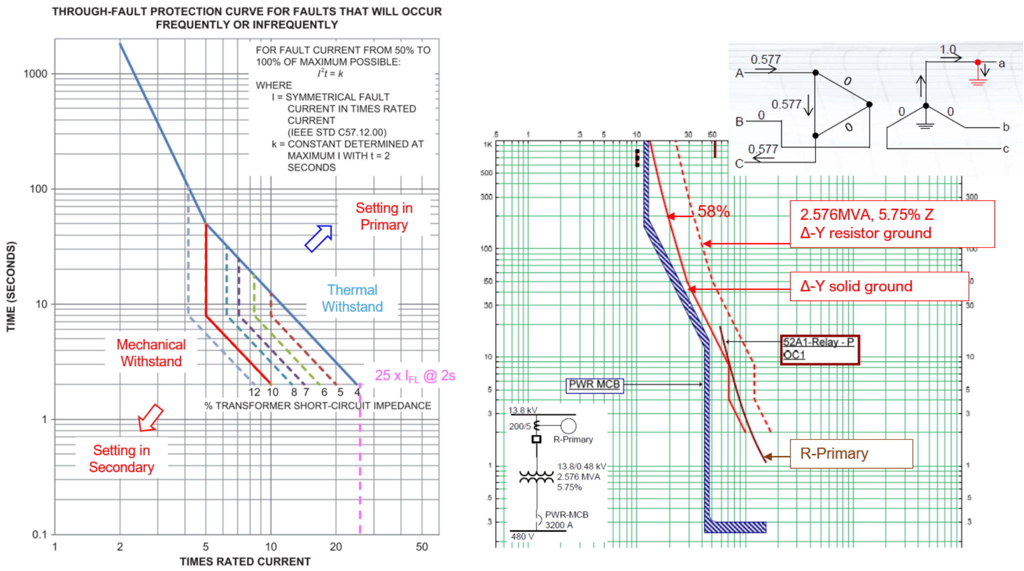


Figure 12: Effect of Transformer Damage Curve to OCEF Coordination Studies

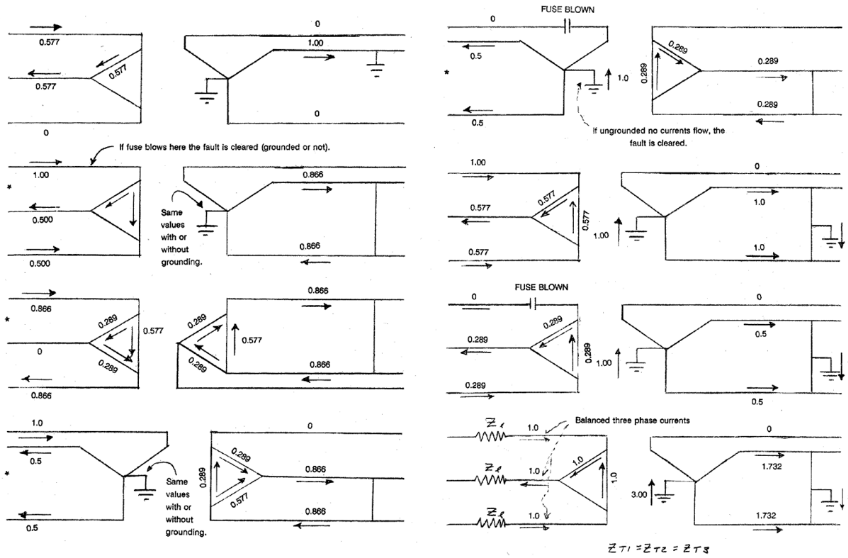


Figure 13: Effect of Transformer Winding to Current Flow and OCEF Coordination Studies

when transformer cores are saturated upon energization. The inrush peak is represented by the equation [11].

$$i_{pk} = \frac{\sqrt{2}v_m}{\sqrt{(\omega L)^2 + R^2}} \frac{2B_n + B_r - B_s}{B_n}$$

It is not required to ensure no operation for current below the peak, as it is impossible to have no OCEF operation below such large value, as the inrush magnitude damped after 0.1s upon energization. There are many factors affecting the magnitude of inrush, including transformer core material, residual flux in the core, point on wave upon energization and any controlled switching available.

To avoid tripping of OCEF upon energization, in which occurred in history that OCEF time multiplier was low set beyond 0.2 as proven protection for energization and tripped the transformer, use of 8 – 12 times of full load current at 0.1s is an empirical approach based on EM relays [6]. A dot represents a typical rms equivalent of inrush from energization to the point in time. PSCAD simulation indicates a large delay constant for inrush upon energization (τ_{inrush} = 10s) and small constant during loaded condition (0.5 < τ_{inrush} < 2.0)[12]. It is common to use the asymmetrical rms value of secondary fault current (1.6 I_{sym}) to establish the instantaneous pickup, but most digital relay filters out DC components and possibly high frequency components.

Motor stalling can have a significant impact on the coordination studies in OCEF protection. When the motor load is increased above its overload region, the motor speed gradually reduces and the motor stalls, i.e. with zero speed (locked rotor condition). During a hot summer night with most citizens switched on their air conditioners, a disturbance could lead to voltage dip and hence the induction motor inside stalls. The motor draws a large stall current, which can be up to 3 – 5 times nominal current for 3 – 4 second in past experience, to build up field for acceleration and the OCEF relay at the incomers of the building triggers and trips the source. It is coined as load rejection.

To provide a longer ride-through for air conditioner stall current and maintain protection coordination between HV (11kV) and LV (380V) with fast clearance to earth fault, it is suggested to

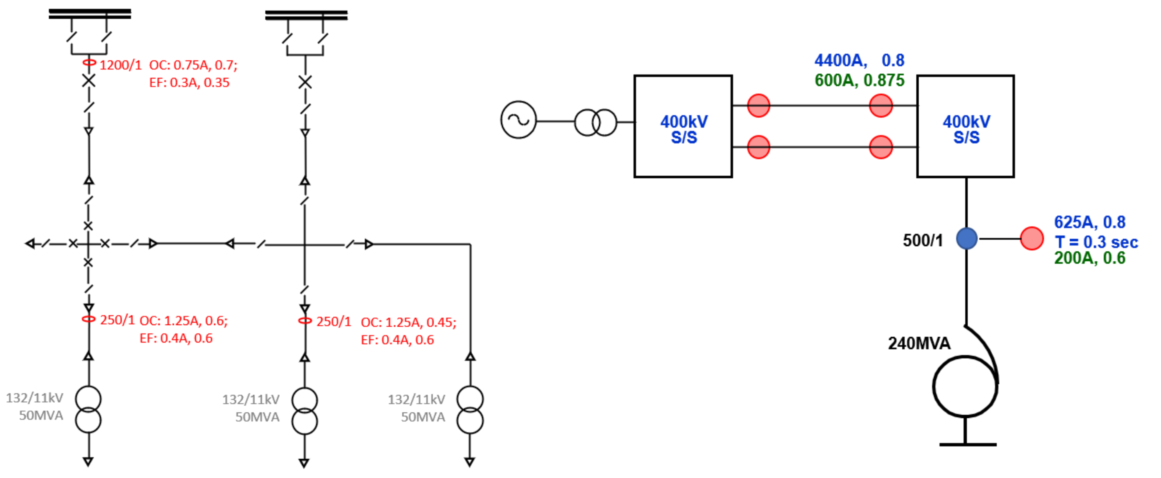


Figure 14: OCEF Protection Applied in Transmission Network – 132kV RMU Circuits and 400/132kV Auto-Transformer

- Raise the existing OC time multiplier setting at the 11kV/380V transformer HV side to NI / 3.0 sec or NI / 1.0 sec.
- Change the existing OC relay characteristics from NI to EI (given that adjustable setting and IDMT characteristics or replacing the existing relay).

It is noted that the upstream OCEF setting is not changed, so the number of special OC setting adopted is limited to 2 relays within a ring leg and 9 relays under a 132/11kV transformer for 35MVA transformer. To avoid inadvertent tripping during hot summer with abnormal supply arrangement (N – 2 outage), it is also proposed to high set the OC plug setting in selected nights.

It is also noted that EM OCEF relay must be set above the asymmetrical rms current, either via the pickup or with a time delay as discussed, and digital relay should have a generous margin such as 2 times locked rotor current even it can perform filtering [6].

OCEF Protection in Transmission Network

In Hong Kong, transmission network in 400kV and 132kV often employs distance zone 2 and zone 3 as remote backup as the plain feeders form a ring structure and it is impossible to perform grading without explicit load flow direction except 400/132kV auto-transformer and 132kV RMU feeders as illustrated in Figure 14 which is designed to have load flow from 400kV to 132kV and from 132kV busbar to RMU and to different transformers in load end respectively.

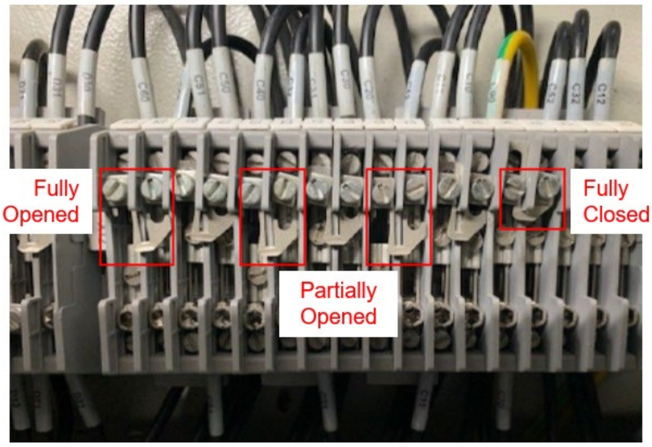
For 400/132kV auto-transformer, as it is possible to have overload, a 2-stage OC is applied. Stage 1 is triggered by an IDMT to trip 132kV CB, and stage 2 is triggered by the IDMT with 0.3 sec delay to trip also 400kV CB. If it is just an overload, tripping 132kV CB could cut off the load and keep the transformer energized, yet it could possibly lead to cascade tripping as the load will be shared by the latter transformer. If the current still exists after cutting off from 132kV side, it is essential to cut off the HV side to isolate the fault, given that the transformer fault is not detected by the two sets of circulating current as its main protection. The transformer OC setting should be larger than 145% of its full load, and it is resulted from coordination studies with 2 x 400kV feeders graded with 6 x 400/132kV transformers.

At the downstream of 400/132kV transformers, a double busbar at 132kV should also provide a remote backup to unclear faults at 132kV circuits. Yet, it is impossible to determine the fault current flow and hence all OC at 132kV bus coupler (BC) and bus section (BS) should have the same DTL setting (2600A, 0.7s), which is to perform busbar splitting. It is useful to 132kV circuit energization without proven protection. The current setting is within minimum fault level and full load current such that it could be triggered in case the downstream fault is not cleared by its main protection, local backup (breaker failure protection with 0.3s delay) and remote backup (distance zone 2 with 0.5s delay). Other than the mentioned backup protection, a system backup protection (SBU) is provided at 400kV plain feeder to protect the system against operation under abnormal condition (e.g. overload) or uncleared fault for long duration which is possibly due to high resistance fault or a fault on a long line such that zone 3 of a short line followed by the long line has insufficient coverage to clear the fault. It was originally built at 1980s, when 400kV network was started to build and the system could be partitioned into 4 groups (Castle Peak Group, Hok Un Group, Tsing Yi Group and China Supply), to separate the system in case of persistent overload.

Incidents in OCEF protection

Although OCEF is the simplest protection to power system, it is often leading to maloperation due to human error. The following cases were real incidents for reference.

- An OCEF relay did not trip upon an overhead line (OHL) fault. Site inspection revealed that the CT shorting facilities at CT terminal block for OCEF protection was not fully opened as shown in Figure 15 such that the CT was thus short-circuit and resulted in no current measured by the protection relay. It leads to a larger load loss without selectivity.
- OCEF protection operated on L2-ph OC and tripped the CB. Without fault point or abnormality identified after OHL patrol, the preliminary finding suggested defective protection relay or CT circuit. Subsequent investigation revealed that CT ratio on site was mismatched with the OCEF setting. Half ratio connection was applied instead of full ratio as illustrated in Figure 16. As a result, current measured by the relay has been twice the actual current and hence current measured



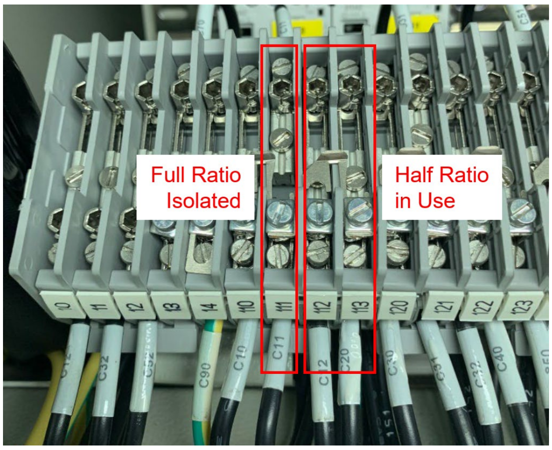


Figure 15: Partial Opened CT Leading to Inoperative OCEF

Figure 16: Wrong Ratio CT in Use

after shifting the normal opened (N.O.) point was larger than the plug setting and hence tripped the circuit.

- After a protection maintenance, a technician accidentally swopped EM-OC relay with EM-EF relay with a lower plug setting. Upon energization, the load current is larger than the EF setting, and the EF relay located at the OC circuitry tripped the circuit.

Conclusion

OCEF is the basic protection to be introduced in all power system course. Its philosophy is easy to understand, and it is applied in all transmission and distribution network worldwide down to customer end in form of fuses and MCB. However, it is difficult to design protection system with graded OCEF to protect every single part of the power system. In fact, it is impossible. This report discusses the practical applications and considerations of OCEF protection to be shared with protection engineers and network designers to reduce load loss as OCEF does as designed.

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Karl M.H. LAI
Department of EEE, HKU
Tel: (+852) 6221 4144
Email: perspect@connect.hku.hk