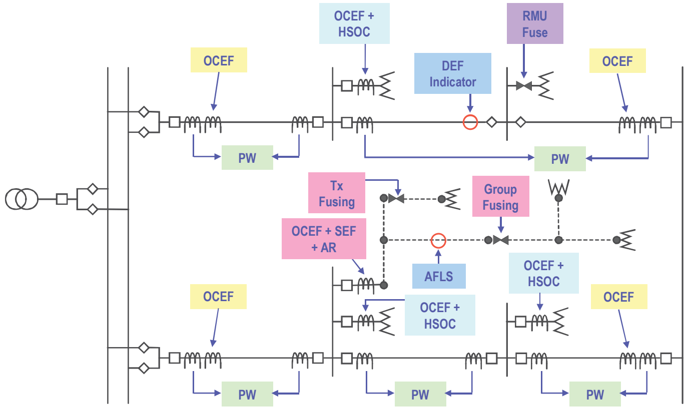
OCEF Coordination and Concerns

Compiled by Karl M.H. LAI

Protection Overview - Distribution



Protection Scheme

- Please name the protection schemes in customer substation by considering
  - Open ring RMU circuit — OCEF at primary S/S, EF indication
  - Close ring feeder circuit — Pilot Wire (PW) / Current Differential (CD); OCEF at some of Interconnectors; DEF indicator at Tee-off RMU; OCEF at Node point
  - 11kV/380V transformer circuit — OCEF, HSOC, Fuse
  - OHL circuit — OCEF, SEF, OHL fuse, AR, Fault indicator-AFLS

OCEF Protection – Applications

- **Main Protection for Distribution System**
  - Distribution transformer
  - 11kV overhead line
  - Busbar and CB of customer substation

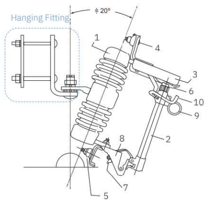
  Graded with LV
  Possibly with Fuses in LV board or
  OCEF at customer incomer

- **Backup Protection in Transmission System**
  - 11kV busbar of primary substation
  - 132/11kV transformer
  - 132kV RMU circuit
  - 132kV transformer feeder circuit
  - 132kV system backup
  - 400kV system backup

LV Fuse – Working Principles

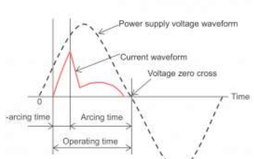
- Made by fusion of one or more of its specially designed and proportioned components
- Breaks current when this exceeds a given value for a sufficient time – thermal effect

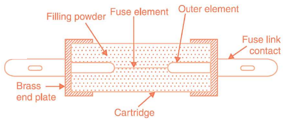
Standard - HRC BS88 or IEC 60269

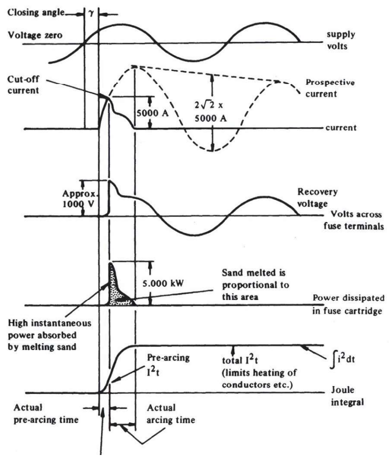


1. Porcelain Insulator
2. Fuse Tube
3. Top Hood
4. Line-End Connector
5. Load-Side Connector
6. Upper Contact
7. Lower Contact
8. Hinge
9. Pull Ring
10. Attachment Hooks

AC circuit

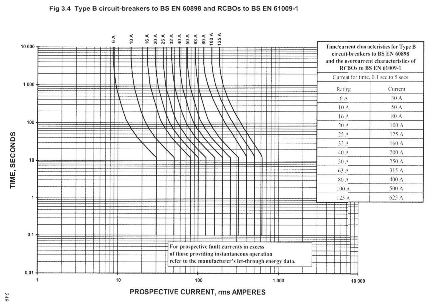


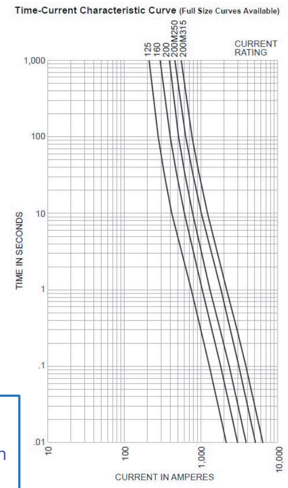




LV Fuse – Working Principles

Require information of
LV incomer OCEF Setting





Grading could be performed based on the characteristic curve
- Source side: Fuse with higher rating (to protect the LV cables)
- Customer side: MCB / Fuse with lower rating (for overload protection of installation wirings

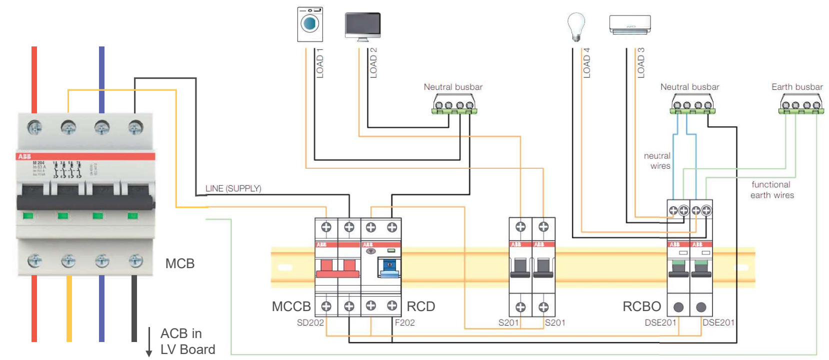
Earth Fault protection to be installed by customers (e.g. Residue Current Device)

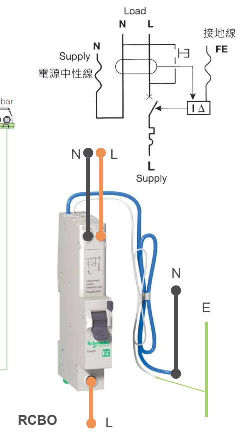
Comparison between Protective Devices

- **MCB** (Miniature Circuit Breaker): **O/C + O/L** (> 100A, characteristics not adjustable)
  - Type B: 3 to 5 times full load current – 0.04 to 13 sec
  - Type C: 5 to 10 times full load current – 0.04 to 5 sec
  - Type D: 10 to 20 times full load current – 0.04 to 3 sec
- **MCCB** (Moulded Case Circuit Breaker): **O/C + O/L** (>1000A, characteristics may be adjustable)
- **RCD** (Residual Current Device): **E/L** (> 30mA, difference between L and N, = RCCB)
- **ELCB** (Earth Leakage Circuit Breaker): **E/L** (< 30mA sec, connected with L, N and E)
- **RCCB** (Residual Current Circuit Breaker): **"水總"** RCD + MCCB [= ELCB in Japan]
  O/C + O/L + E/L (rated < 100A, interrupting < 18kA)
- **RCBO** (Residual Circuit Breaker with Overload): **"老鼠尾"** RCD + MCB
  O/C + O/L + E/L (rated < 1kA, interrupting < 18kA)

[Note: Additional neutral to drain out triplen harmonics, may lead to failure of megger test]

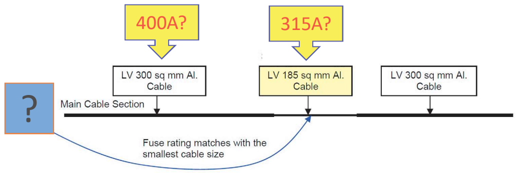
Comparison between Protective Devices





Fuse Selection in LV Network

- Fuse Operating Time of 5 seconds
  → Maximum Conductor Temperature under short-circuit condition in 5 seconds is limited to
  → XLPE insulation would be deteriorated if 250ºC exists for more than 5 seconds



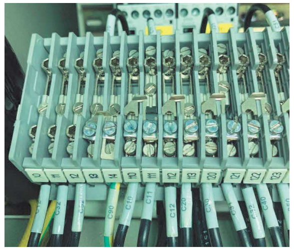
Standard LV Cable	Standard Fuse Rating (A)	Maximum Cable Length Based on 5-second Fuse Operating Time (m)
300 sq mm Al	400	380
	315	500
	200	900
	100	2,000
185 sq mm Al	315	300
	200	580
	100	1,380
95 sq mm Al	200	280
	100	770
25 sq mm Cu	100	240

(PS-TG-0325 : Technical Guideline for LV Cable Network Improvement and Specific Design Considerations)

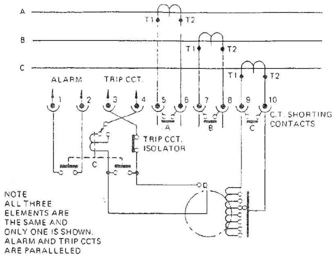
OCEF Protection – Introduction

CT Output
- Types of CT – 5P10, 5P20
- Output – L_1, L_2, L_3 (R, W, B)

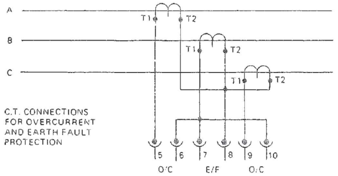
Relay Connection
- 3 x OC vs 2 x OC + 1 x EF

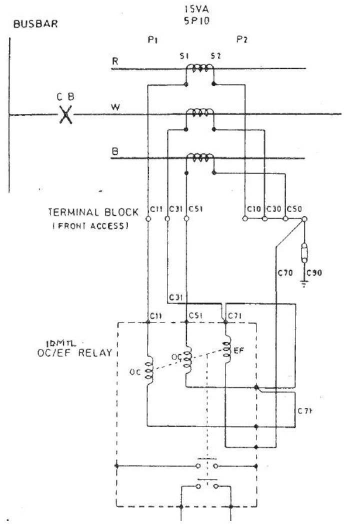


3 x OC



2 x OC + 1 x EF





OCEF Protection – Introduction

- Elements that can detect under different fault types

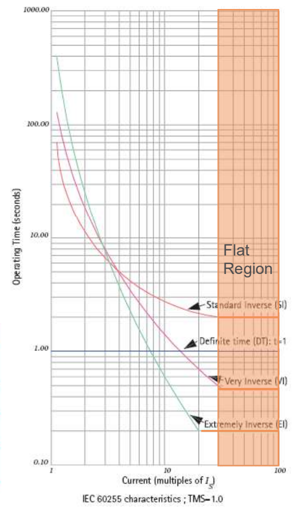
Fault Type	OC (L1)	OC (L3)	EF (N)
L1-L2	X		
L2-L3		X	
L2-E			X
L1-L3 / L1-L2-L3 / L1-L2-L3-E	X	X	
L1-E / L1-L2-E	X		X
L3-E / L2-L3-E		X	X
L1-L3-E	X	X	X

OCEF Protection – Introduction

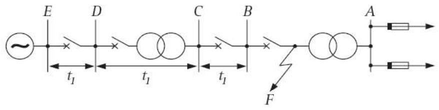
- Earth Fault Relay
  - Earth fault is the most frequent of all faults
  - Earth fault current is usually limited in magnitude by the neutral earthing impedance, or by earth contact resistance
  - Advantage: Provide more <u>sensitive</u> protection against earth faults
  - Setting: 30%-40% I_{FL} or $I_{EF(min)}$

Relay Characteristic	Equation (IEC 60255)
Standard Inverse (SI)	$t = TMS \times \frac{0.14}{I_r^{0.02} - 1}$
Very Inverse (VI)	$t = TMS \times \frac{13.5}{I_r - 1}$
Extremely Inverse (EI)	$t = TMS \times \frac{80}{I_r^2 - 1}$
Long time standard earth fault	$t = TMS \times \frac{120}{I_r - 1}$

Relay characteristics to IEC 60255



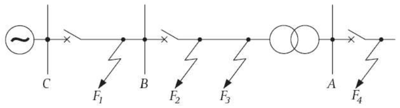
OCEF Protection – Grading



Principles of time/current grading

Discrimination by time

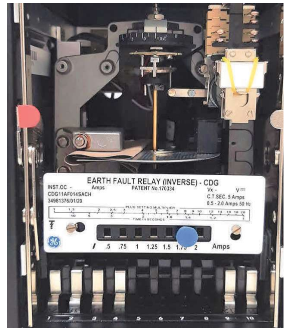
- Disadvantage:
  Longest fault clearance time occurs for fault in section closest to the power source



Discrimination by current

- Advantage: Fast operation (instantaneous)
- Disadvantage:
  Cannot distinguish a fault at F1 and a fault at F2
  Difficult to coordinate (source dependent)
- Application:
  Appreciable impedance between 2 circuit breakers (e.g. transformer, motor)

OCEF Protection – Grading



Principles of time/current grading

Discrimination by Time and Current

(e.g. Inverse Time Overcurrent Characteristics)

- Advantage
  - Faster operating times for relays nearest to the source, where the fault level is the highest
  - Possible to increase the number of breaker in series without increasing the time setting of relays at power source
- Setting of inverse definite minimum time overcurrent relay (IDMT overcurrent relay)
  - Relay Characteristics
  - Current Setting
  - Time Setting

$$\boxed{t = \mathrm{TM} \times \frac{\beta}{\left(\frac{I}{I_0}\right)^{\alpha} - 1}}$$

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

OCEF Protection – Grading

Principles of time/current grading

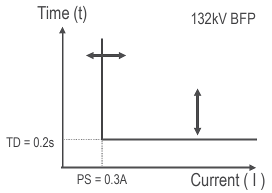
Discrimination by Time and Current

<u>DTL (Definite Time Lag)</u>

2 independent settings:

- Current setting (P.S.)
- Time delay setting (T.D.)

e.g. HSOC (as unit protection of HV cable)
SEF (as a detection element)

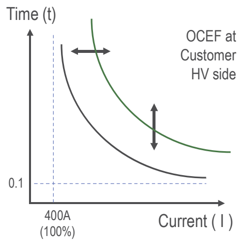


<u>IDMTL (Inverse Definite Minimum Time Lag)</u>

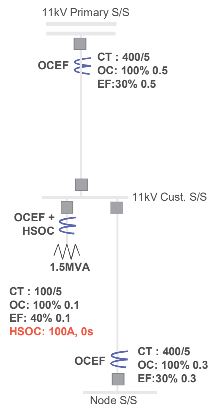
2 dependent settings:

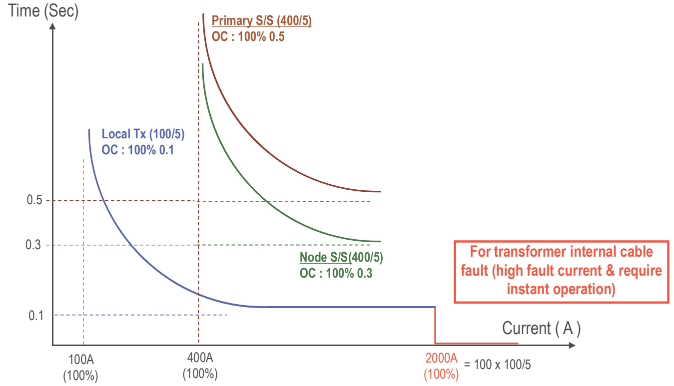
- Current setting (P.S.)
- Time multiplier (T.M.)

e.g. OCEF



OCEF Protection – Grading



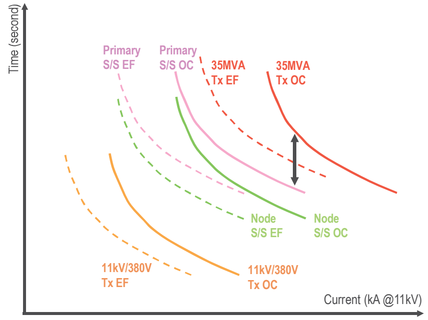


OCEF Protection – Grading

Grading Margin Consideration (EM Relay)

Circuit breaker time	= 0.10 sec
Error allowances	= 0.15 sec
Relay overshoot time	= 0.05 sec
Safety margin	= 0.10 sec
Total	0.40 sec

For Digital Relays, Grading Margin can be reduced to 0.25 – 0.3 sec.



IDMTL OCEF 過電流及接地(繼電)保護

	PHASE 相位	SETTING 定值 P.S. 插頭值	SETTING 定值 T.M. 時間倍值	CREEP 蠕變 (A)	OPERATE 操作 (A)	RESET 復歸 (A)	OP.TIME 操作時間 AT 2 x P.S. (T.M. x 10SEC.)
TYPE 種類: RATING 額定值: 2stage OC/EF CDG	R Ø 紅	1.25	0.8	1.300	1.349	1.175	7.4525
	*Y Ø / EF *黃/接地	– / 0.4	– / 0.6	0.409	0.421	0.381	5.9995
	B Ø 藍	1.15	0.8	1.260	1.323	1.105	7.4525

OCEF Protection – Operation Time

$$\text{Fault Level [MVA]} = \frac{\text{Rating[MVA]}}{\text{Impedance[\%]}}$$

	Rating [MVA]	Impedance [%]	Fault Level [MVA]	Fault Current [kA]
1 x 35MVA	35MVA	28%	125MVA	6.56kA
2 x 35MVA //	35MVA	28%/2 = 14%	250MVA	13.12kA
1 x 50MVA	50MVA	27%	185MVA	9.72kA

$$\text{Fault Current [kA]} = \frac{\text{Fault Level [MVA]}}{\sqrt{3} \times \text{Rated Voltage[kV]}}$$

Siemens 7SJ602 Digital Relay [h = 0.14, k=0.02; SI]

Node S/S (CT: 400/5)
OC: 100%, 0.3
EF: 30%, 0.3

$$0.3 \times \frac{0.14}{\left(\frac{6561}{400}\right)^{0.02} - 1} = 0.73$$

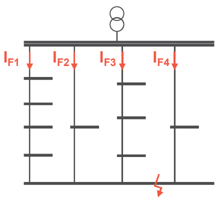
$$\text{Cal. Op. Time (T)} = \frac{\text{h x Time Multiplier}}{\left(\frac{\text{Fault Current}}{\text{Current Setting}}\right)^{k} - 1}$$

For 1x 35MVA Tx :

	Fault Current [A, primary]	Op Time [sec]
1 Leg	6561A	0.73
2 Leg	3280A	0.98
3 Leg	2187A	1.22
4 Leg	1640A	1.47
5 Leg	1312A	1.75

OCEF Protection – Operation Time

No. of Legs Increases, Operation Time of OC Increases



Op Time [sec]	Primary S/S, without Node S/S — NI, OC = 100%, 0.3, EF = 30%, 0.5: 1x 35MVA Tx OC	1x 35MVA Tx EF	2x 35MVA Tx OC	2x 35MVA Tx EF	1x 50MVA Tx OC	1x 50MVA Tx EF	Primary S/S, With Node S/S — NI, OC = 100%, 0.5, EF = 30%, 0.5: 1x 35MVA Tx OC	1x 35MVA Tx EF	2x 35MVA Tx OC	2x 35MVA Tx EF	1x 50MVA Tx OC	1x 50MVA Tx EF
1-Leg	0.73	1.13	0.68	1.13	0.68	1.13	1.22	1.13	1.13	1.13	1.13	1.13
2-Leg	0.98	1.13	0.73	1.13	0.82	1.13	1.63	1.13	1.22	1.13	1.37	1.13
3-Leg	1.22	1.17	0.86	1.13	0.98	1.13	2.03	1.17	1.43	1.13	1.64	1.13
4-Leg	1.47	1.3	0.98	1.13	1.14	1.13	2.45	1.3	1.63	1.13	1.91	1.13

4.1.2 Assuming 11kV feeder circuit C.T. ratio being 400/5, the maximum number of parallel circuits must not exceed :

Tx. Capacity	Max. No. of parallel feeders
Less than 20MVA	2
20 MVA	3
35 MVA	4
40 MVA	5
50 MVA	6

Source End Requirement

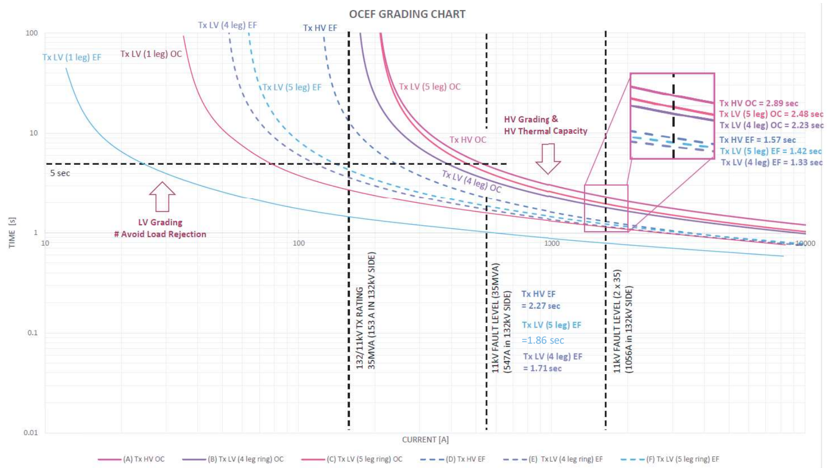
One 11kV feeder circuit having C.T. ratio of 800/5 and plug setting of 100% should be considered as two 400/5 circuits when applying this rule.

Node S/S

NI, OC = 100%, 0.3, EF = 30%, 0.3

Op Time [sec]	1x 35MVA Tx OC	1x 35MVA Tx EF	2x 35MVA Tx OC	2x 35MVA Tx EF	1x 50MVA Tx OC	1x 50MVA Tx EF
1-Leg	0.73	0.68	0.68	0.68	0.68	0.68
2-Leg	0.98	0.68	0.73	0.68	0.82	0.68
3-Leg	1.22	0.7	0.86	0.68	0.98	0.68
4-Leg	1.47	0.78	0.98	0.68	1.14	0.68

OCEF Protection – Operation Time



OCEF Protection – Operation Time

Op Time [sec]	1.5MVA Tx (200/1), No 2x 500A Fuse — NI, OC = 50%, 0.1, EF = 20%, 0.1						1.5MVA Tx (200/1), with 2x 500A Fuse — EI, OC = 50%, 0.3, EF = 20%, 0.1					
	1x 35MVA Tx		2x 35MVA Tx		1x 50MVA Tx		1x 35MVA Tx		2x 35MVA Tx		1x 50MVA Tx	
	OC	EF	OC	EF	OC	EF	OC	EF	OC	EF	OC	EF
1-Leg	0.23	0.23	0.23	0.23	0.23	0.23	0.06	0.02	0.06	0.02	0.06	0.02
2-Leg	0.23	0.23	0.23	0.23	0.23	0.23	0.06	0.02	0.06	0.02	0.06	0.02
3-Leg	0.23	0.23	0.23	0.23	0.23	0.23	0.06	0.02	0.06	0.02	0.06	0.02
4-Leg	0.23	0.23	0.23	0.23	0.23	0.23	0.06	0.02	0.06	0.02	0.06	0.02

Op Time [sec]	OHL (200/5) — NI, OC = 100%, 0.1, EF = 40%, 0.1					
	1x 35MVA Tx		2x 35MVA Tx		1x 50MVA Tx	
	OC	EF	OC	EF	OC	EF
1-Leg	0.23	0.23	0.23	0.23	0.23	0.23
2-Leg	0.23	0.23	0.23	0.23	0.23	0.23
3-Leg	0.23	0.23	0.23	0.23	0.23	0.23
4-Leg	0.23	0.23	0.23	0.23	0.23	0.23

No sharing of fault current due to increase the no. of leg.

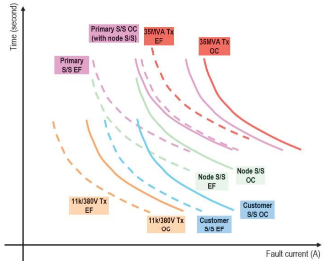
⇩

Operation time of OCEF keeps constant

OCEF Protection – Setting

Standard Protection Settings in 11kV Distribution System (PS-TG-0094 / 2)

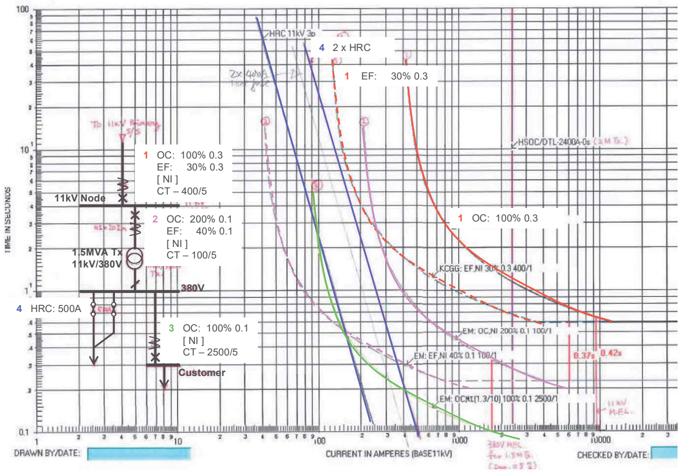
With reference to the TG, what is the setting at 11kV T2H CB panel connected to 11kV Cct for RMU tee Tx?



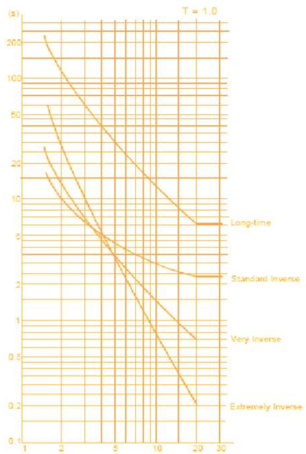
Location		CT Ratio	Relay Characteristic	OC setting P.S.	OC setting T.M.	EF setting P.S.	EF setting T.M.
At 11kV primary substation	supplying ring circuit without node substation	400/5A	Normal Inverse	100%	0.3	30%	0.5
		*800/5A	Normal Inverse	100%	0.3	30%	0.5
	supplying ring circuit with node substation	400/5A	Normal Inverse	100%	0.5**	30%	0.5**
		800/400/1A	Normal Inverse	100%	0.5**#	30%	0.5**#
At Node substation		400/5A	Normal Inverse	100%	0.3**	30%	0.3**
At 11kV T2H CB panel connected to 11kV circuit for RMU tee transformer ***	Merlin Gerin	400/1A	Normal Inverse	150%	0.1	30%	0.1
	Siemens	400/1A	Normal Inverse	150%	0.1	30%	0.1
	Oil Type	400/1A	Normal Inverse	150%	0.1	30%	0.1

- The OC protection at the T2H panel (400/1A, 150% 0.1, NI) can grade with upstream 11kV ring OCEF protection (400/5A, 100% 0.3, NI) with 2 legs or above. If only 1 leg is left, there will be loss of discrimination for fault current less than 750A (11kV).

OCEF Protection – Setting

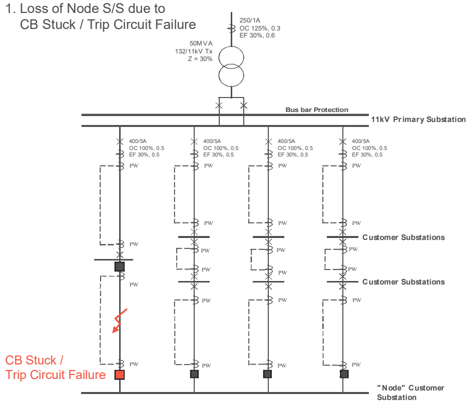


Any advantages to apply EI curve instead of NI curve?

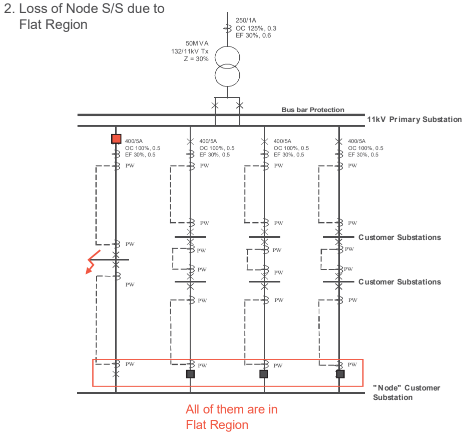


OCEF at 11kV Node Substation

1. Loss of Node S/S due to CB Stuck / Trip Circuit Failure

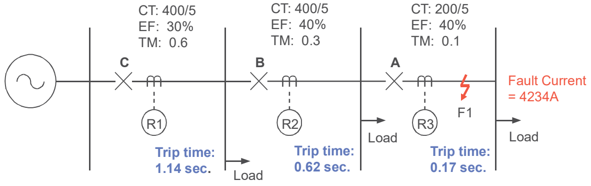


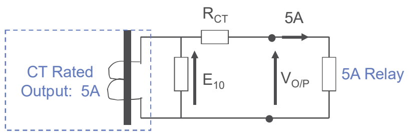
2. Loss of Node S/S due to Flat Region



OCEF Grading – Mismatch in CT and OCEF Relay

Grading between Standard Inverse Relays





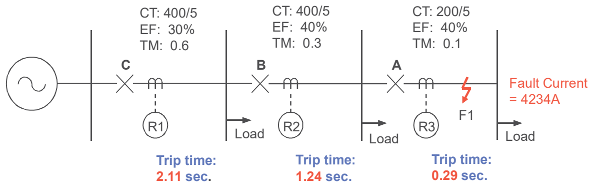
$$t_A = 0.1 \times \frac{0.14}{\left(\frac{4234}{200 \times 0.4}\right)^{0.02} - 1} = 0.17\text{sec}$$

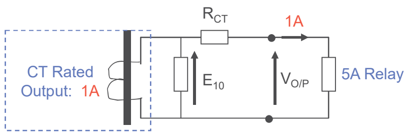
$$t_B = 0.3 \times \frac{0.14}{\left(\frac{4234}{400 \times 0.4}\right)^{0.02} - 1} = 0.62\text{sec}$$

$$t_C = 0.6 \times \frac{0.14}{\left(\frac{4234}{400 \times 0.3}\right)^{0.02} - 1} = 1.14\text{sec}$$

OCEF Grading – Mismatch in CT and OCEF Relay

- Less Current Output than Expected [1A CT to 5A Relay] → Lower Sensitivity / Failure in Sensitivity





$$\frac{\text{CT Output}}{\text{Relay Input}} = \frac{1}{5} = 0.2$$

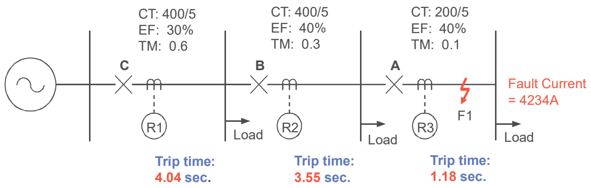
$$t_A = 0.1 \times \frac{0.14}{\left(\frac{4234 \times 0.2}{200 \times 0.4}\right)^{0.02} - 1} = 0.29\text{ sec}$$

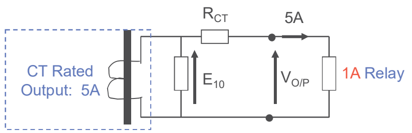
$$t_B = 0.3 \times \frac{0.14}{\left(\frac{4234 \times 0.2}{400 \times 0.4}\right)^{0.02} - 1} = 1.24\text{ sec}$$

$$t_C = 0.6 \times \frac{0.14}{\left(\frac{4234 \times 0.2}{400 \times 0.3}\right)^{0.02} - 1} = 2.11\text{ sec}$$

OCEF Grading – Mismatch in CT and OCEF Relay

- Higher Current Output than Expected [5A CT to 1A Relay] → Tripped under Normal Load / Failure in Stability





$$\frac{\text{CT Output}}{\text{Relay Input}} = \frac{5}{1} = 5$$

$$t_A = 0.1 \times \frac{0.14}{\left(\frac{90 \times 5}{200 \times 1.25}\right)^{0.02} - 1} = 1.18\text{ sec}$$

$$t_B = 0.3 \times \frac{0.14}{\left(\frac{180 \times 5}{400 \times 1.25}\right)^{0.02} - 1} = 3.55\text{ sec}$$

$$t_C = 0.6 \times \frac{0.14}{\left(\frac{280 \times 5}{400 \times 1.25}\right)^{0.02} - 1} = 4.04\text{ sec}$$

OCEF Grading - Considerations

1. Curve Shifting

   Shifting allows relay operation with a common current basis (maximum).

   Shift Factor (SF) =

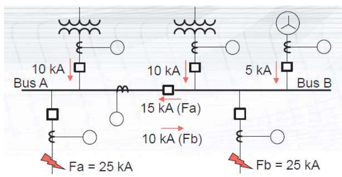
$$SF = \frac{\text{Bus Fault}}{\text{Relay Current}}$$

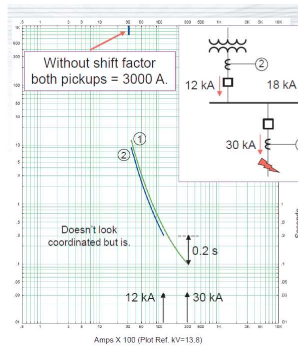
<u>Example</u>

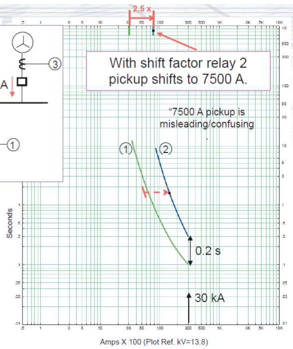
Transformer Relay SF = 30 / 12 = 2.5

Generator Relay SF = 30 / 18 = 1.67

Feeder Relay SF = 30 / 30 = 1.0

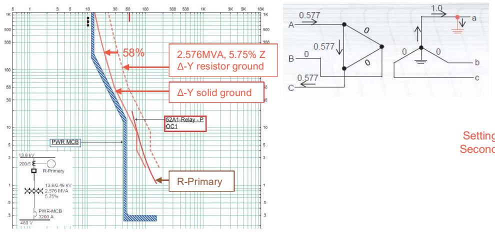


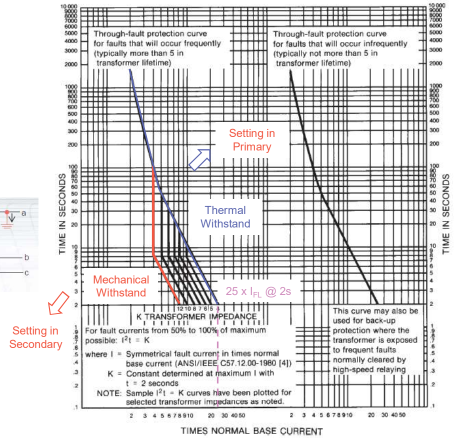




OCEF Grading - Considerations

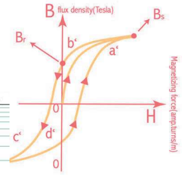
2. Transformer Overload Protection
   - Withstand curve defines thermal and mechanical limits of a transformer experiencing a through fault.
   - Requirement to protection for mechanical damage is based on frequency of through faults & transformer size.
   - Transformer damage curve is shifted 58% to the left to ensure protection for delta-wye transformer.



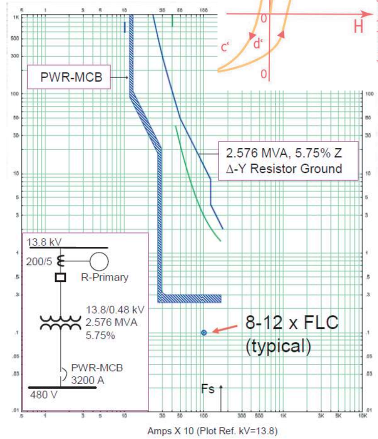


OCEF Grading - Considerations

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



3. Inrush Current
   - Use of 8 -12 times I_{FL} @ 0.1 s is an empirical approach based on EM relays (based on a 1944 AIEE paper)
   - The inrush is not over at 0.1 s, the dot just represents a typical rms equivalent of the inrush from energization to this point in time.
     [Note: PSCAD simulation indicates a large decay (τ_{inrush} = 10s) during energization, and 0.5 < τ_{inrush} < 2.0 during loaded condition]
   - The primary relay instantaneous (50) setting should not trip due to the inrush.
   - It was common to use the asymmetrical rms value of secondary fault current (1.6 x I_{sym}) to establish the instantaneous pickup, but most modern relays filter out the DC component.

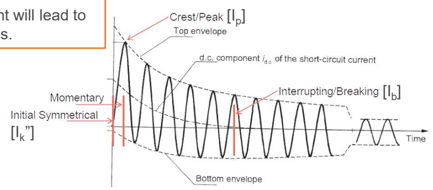


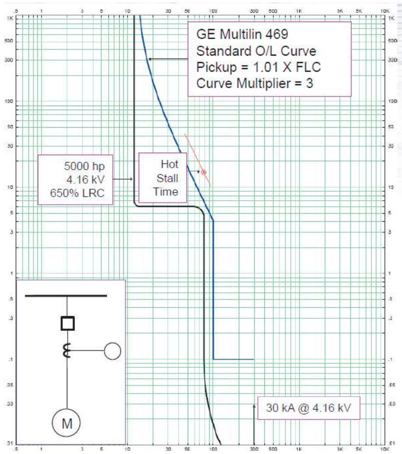
OCEF Grading - Considerations

4. Motor Stall Current
   - Electromechanical relays must be set above the asymmetrical rms current, either via the pickup or with a time delay.
   - Modern relays with filtering can ignore the asymmetrical current, but it's advisable to include a generous margin such as 2 x LRC.
   - Note – undervoltage protection (27) needed to trip motor on loss of power.
5. Fault Current Options

Use of Momentary/ Initial Symmetrical current leads to conservative coordination time interval (CTIs).

Use of Interrupting Current will lead to lower, but acceptable CTIs.

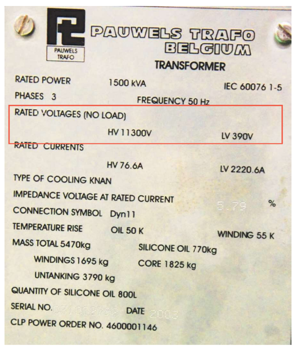




Effect of Delta-Star Transformer in LV (1)

Question:

Will fuse burnt at HV side leads to improper operation of OCEF protection?



PAUWELS TRAFO BELGIUM

TRANSFORMER

RATED POWER 1500 kVA IEC 60076 1-5

PHASES 3 FREQUENCY 50 Hz

RATED VOLTAGES (NO LOAD) HV 11300V LV 390V

RATED CURRENTS HV 76.6A LV 2220.6A

TYPE OF COOLING KNAN

IMPEDANCE VOLTAGE AT RATED CURRENT %

CONNECTION SYMBOL Dyn11

TEMPERATURE RISE OIL 50 K WINDING 55 K

MASS TOTAL 5470kg SILICONE OIL 770kg

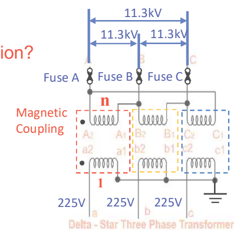
WINDINGS 1695 kg CORE 1825 kg

UNTANKING 3790 kg

QUANTITY OF SILICONE OIL 800L

SERIAL NO. DATE

CLP POWER ORDER NO. 4600001146



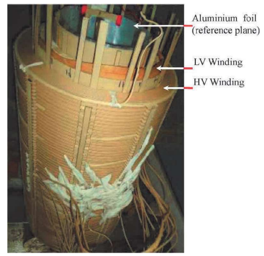
Number of Turns

$$n = \frac{11.3\text{kV}}{\frac{390\text{V}}{\sqrt{3}}} = 50.19 \text{ or } \approx 50$$

$$n = \frac{11.3\text{kV} \times \sqrt{3}}{390\text{V}} = 50.19$$

Rectangular Cross-section

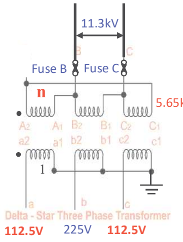
Circular Cross-section



Effect of Delta-Star Transformer in LV (2)

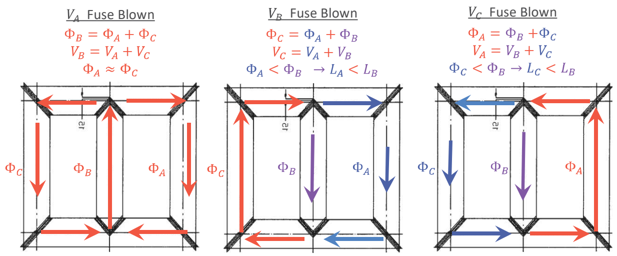
- Ideal Case with VT Fuse (A) Burnt

Ideal Case	Va	Vb	Vc
V_A Fuse Blown	112.5V	225V	112.5V
V_B Fuse Blown	112.5V	112.5V	225V
V_C Fuse Blown	225V	112.5V	112.5V



- VT Fuse (A) Burnt with Reluctance Effect

Ideal Case	Va	Vb	Vc	Remarks
V_A Fuse Blown	V_{a1}	225V	V_{c1}	$V_{a1} \approx V_{c1} \approx 112.5$
V_B Fuse Blown	V_{a2}	V_{b2}	225V	$V_{b2} > V_{a2}$
V_C Fuse Blown	225V	V_{b3}	V_{c3}	$V_{b3} > V_{a3}$

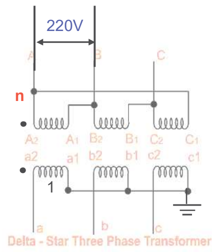


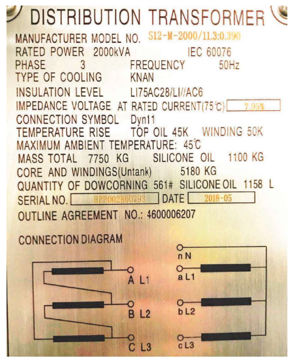
Effect of Delta-Star Transformer in LV (3)

- VT Fuse (A) Burnt with Reluctance Effect

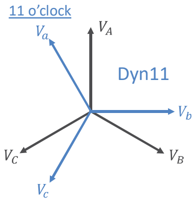
Ideal Case	Va	Vb	Vc	Remarks
V_A Fuse Blown	V_{a1}	225V	V_{c1}	$V_{a1} \approx V_{c1} \approx 112.5$
V_B Fuse Blown	V_{a2}	V_{b2}	225V	$V_{b2} > V_{a2}$
V_C Fuse Blown	225V	V_{b3}	V_{c3}	$V_{b3} > V_{a3}$

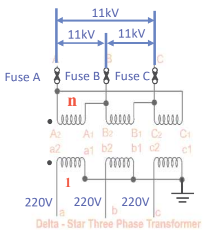
Site Measurement	Va	Vb	Vc
V_{BC}	2.49V	4V	1.55V
V_{CA}	0.87V	3.15V	4V
V_{AB}	4V	3.36V	0.65V





Effect of Delta-Star Transformer in LV (4)





Normal Condition

- Voltage Conversion

$$V_A = \frac{11kV}{\sqrt{3}}\angle 0^\circ \qquad V_B = \frac{11kV}{\sqrt{3}}\angle -120^\circ \qquad V_C = \frac{11kV}{\sqrt{3}}\angle 120^\circ$$

$$V_a = \frac{V_A - V_B}{n} = 220V\angle 30^\circ \qquad V_b = \frac{V_B - V_C}{n} = 220V\angle -90^\circ \qquad V_c = \frac{V_C - V_A}{n} = 220V\angle 150^\circ$$

- Current Conversion

$$I_a = I_a\angle 30^\circ \qquad I_b = I_b\angle -90^\circ \qquad I_c = I_c\angle 150^\circ$$

$$I_{AB} = \frac{I_a}{n}\angle 30^\circ \qquad I_{BC} = \frac{I_b}{n}\angle -90^\circ \qquad I_{CA} = \frac{I_c}{n}\angle 150^\circ$$

$$I_A = I_{AB} + I_{AC} = I_{AB} - I_{CA} \qquad I_B = I_{BA} + I_{BC} = -I_{AB} + I_{BC} \qquad I_C = I_{CB} + I_{CA} = -I_{BC} + I_{CA}$$

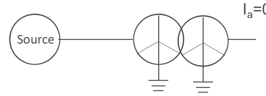
$$= \frac{I_a}{n}\angle 30^\circ - \frac{I_c}{n}\angle 150^\circ \qquad = -\frac{I_a}{n}\angle 30^\circ + \frac{I_b}{n}\angle -90^\circ \qquad = -\frac{I_b}{n}\angle -90^\circ + \frac{I_c}{n}\angle 150^\circ$$

By Kirchhoff's Current Law

1. Each phase of primary current contains 2 phases of secondary current
2. This technique is useful to analyse imbalance 3-phase load in secondary side, especially fault analysis in LV side.

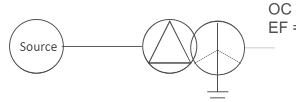
Effect of Delta-Star Transformer in LV (5)

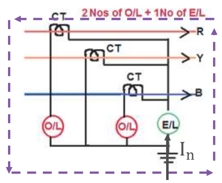
Setting Example at HV Side
Rating = 11kV/380V, 1.5MVA
Full Load at HV side = 78.7A
Full Load at LV side = 2272.7A
CT Ratio: 100/5
Relay: Normal Inverse OCEF
OC = 100% 0.3 (100A or 5A)
EF = 40% 0.1 (40A or 2A)



Imbalance load at LV side:
I_a=0, I_b=0, I_c=2272∠120° A

VS

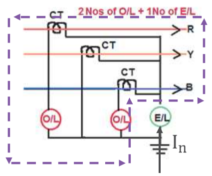




Imbalance load at HV side:
$I_A = 0$, $I_B = 0$, $I_C = 78.7\angle 120^\circ$ A

The earth fault relay current:
$I_n = I_a + I_b + I_c$
Relay mal-operate if $I_n > 40A$

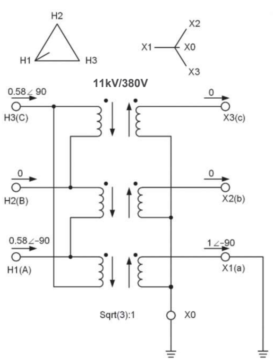
The transformer may be tripped by earth fault relay due to imbalance load such as incorrect setting.

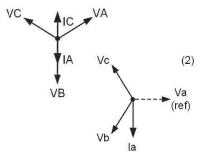


Imbalance load at HV side:
$I_A = 45.44\angle -30^\circ$A, $I_B = 0$,
$I_C = 45.44\angle 90^\circ$ A

The protection scheme remains stable although it is subjected to imbalance load. (due to delta wye transformation)

Effect of Delta-Star Transformer in LV (6)

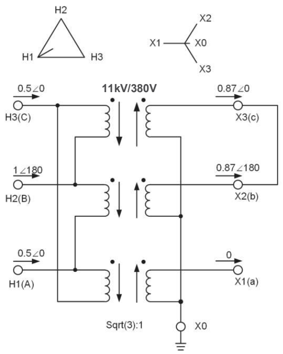


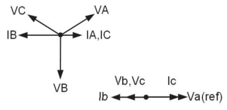


LV Ground Fault

Conversion Factor
LV : HV = 1 : 0.58/n

e.g. LV = 40kA (AG Fault)
HV = 40kA x 0.58/28.9
= 0.80kA (A, C)





LV Phase Fault

Conversion Factor
LV : HV = 0.87 : 1/n

e.g. LV = 40kA (BC Fault)
HV = 40kA x 1/ 28.9 / 0.87
= 1.59kA (B)

Note:
1. For three phase fault, LV = 40kA, HV = 40kA / 28.9 = 1.38kA
2. All LV fault are cleared with OC elements in HV side, as LV EF current cannot go through HV side with delta wye transformation.

OCEF – Application in Transmission

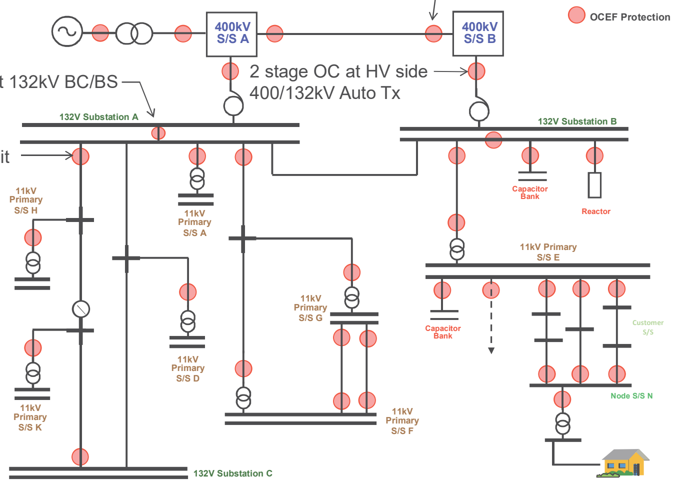
System Backup at 400kV feeder

DTLOC at 132kV BC/BS

2 stage OC at HV side
400/132kV Auto Tx

132kV RMU circuit
132kV transformer feeder circuit

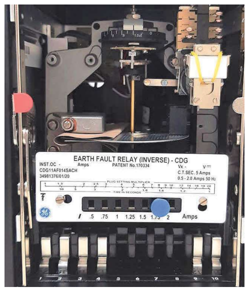
Note:
132kV Plain Feeder does NOT have OCEF as backup due to impossible grading.



OCEF Protection Relays

From Electromechanical Relays

2TJM10



CDG

To Digital Relays

Note –
Digital Relays also mimic the behavior of rotating disk in EM relay.

Function of Digital OCEF
1. Low burden
2. Flexible characteristic
3. SOE
4. Recorder
5. Watchdog

Summary

- OCEF element is often employed as main protection in distribution network (e.g. customer BB), and backup protection in transmission network (e.g. 132kV RMU feeder). It could be a non-unit protection with grading (with IDMT), or a unit protection (with DTL).
- LV Fuse are often the first line in OCEF Grading. It operates with thermal effect, considering the total energy (through arcing and pre-arcing time), hence it could be operative under several overloads or spiky loads. Its characteristics is an extreme inverse in OCEF Grading. When there are two fuses operating in parallel, its effect in grading chart is equivalent to two times current of the original. LV Fuse should be selected to be operative within 5 seconds.
- To provide discrimination (or time coordination) between levels, grading is required. IDMT (normal inverse) characteristics are employed. Between curves, at least 0.4 sec grading margin is required. IDMT has a flat region in which the relay work faster, hence a DTL HSOC is needed to provide instant trip for large current. Other than OCEF grading, short circuit limit as upper limit and stalling or inrush current at downstream as lower limit should be considered.
- With legged-ring design in 11kV network, increases in legs can lead to larger operation time due to current sharing. In grading, it is required to consider the fastest operation (most current flows in same leg), leading to indiscriminative operation, or the slowest operation (current distributed evenly), leading to further raising upstream OC setting.
- Mismatch in CT with OCEF relay can either lead to loss of stability in normal load (CT > relay), or loss of dependability (CT < relay). Yet, it is possible to employ lower setting to provide higher sensitivity with larger plug setting.
- Unlike wye-wye transformer, delta-wye transformer does not have unstable issue with unbalance load. However, it does lead to a conversion factor and earth fault in LV could only be operative with HV OC elements as zero-sequence current at LV side does not flow back to HV side.