Some Aspects of Electrical Power System Protection in Underground Mining

Wyee (Mannering) Colliery Drift,
Courtesy of: LDO - LakeCoal

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Conseil International des Grands Réseaux Électriques

Overview of Presentation

Electrical Pwr Sys & Protection:

Part A

1. U/G Mine - Environment for Electrical Equipment
2. Board & Pillar Power Supply
3. Longwall Power Supply
4. Trailing Cable Protection – AS2081 Relays

HB119 - Electrical Protection for Mines & Quarries

Part B

1. Electrical Protection – Challenges

   Consideration of some incidents that have occurred 1995 – 2014.

Part C

1. Key Points
2. References

U/G Mine – Environment for Elec Equipment

Unique Features:

1. The Electrical Engineer is a *"Service provider"* to the Mining Engineer so that ever bigger toys can be run.

2. Robust electrical equipment/electrically powered equipment that is *"used"* by non electrical people. (Identified as fit for purpose.)
3. Continuous installation and retraction environment.
4. Flexibility is Key..install, connect..disconnect..reinstall, reconnect.
5. Reliant on the reticulated Earth Conductors from the Source.
6. *Always Wet with regular human contact* with metalwork/machinery earthed by the trailing cables reticulated earths.
7. Fault Energy in a confined space (if released) likely to contain fuel to propagate an explosion.
8. *"IT Network"*. EFL often 5A for <4000V & <50A for >4000V.
9. CH4 (5-15% explosive range). Dilution the primary management method. Ventilation Fan operation & performance is critical. How Much CH4? =>> LW in Hard Coking Coal @ 800L/s = 69,120m^3
10. Coal Dust.

U/G Mine – Environment for Elec Equipment

Unique Features:

11. Long Cables installed in exposed locations.
12. Specially Designed Trailing Cables for IT Networks AS/NZS 1972.
13. Specially designed AS/NZS 1299 Restrained & AS/NZS 1300 Bolted Cable Couplers.
14. Large machinery manoeuvred in restricted spaces.
15. Humidity >95% most of the time.
16. Large Flameproof Enclosures *(are not & cannot be sealed….have you checked your Closet Camels pre shift.) [Headlights IP56]*
17. Equipment subject to lung effect condensation, water drop corona and corona instigated acidic by-product deterioration.
18. *"Insulator Surface Creepage Distance"* challenges. =>>IEC60815
19. Limited/Tight Space internal to enclosures – E Field Stress Grading Challenges
20. Code C & Code D Overhauls

21. Always remember for the Mining Engineer, Electricity comes in *"Lecky Pipe"* just like water & compressed air.

Board & Pillar (& LW Development) = kW↑

Development & Production :

- Continuous Miner (CM)
- 3 x Shuttle Cars (Some use CM & F
- Section Fan
- Breaker/Feeder
- **Limited Space**
- **Cable Damage**

Board & Pillar					
Year	CMs	S/C	Fan	Bkr/Fdr	Section Txf
1980	372kW	50kW	50kW	50kW	750kVA
1995	542kW	98kW	110kW	110kW	1.5MVA
2014	773kW	220kW	185kW	225kW	2.5MVA
Per Unit	2.1	4.4	3.7	4.5	3.3

Pictures courtesy of: Joy Global

Longwall = kW↑

- DERDS, AFC, Chocks, Pumps
- BSL, Crusher, Mid Block Tripper drive

Longwall					
Year	Shearer	AFC	BSL	Hyd Pumps	Txf 11kV/3.3kV GNAN
1980	1 x 275kW	2 x 250kW	80kW	3 x 75kW	2 x 1MVA
1995	2 x 500kW	3 x 800kW	250kW	3 x 150kW	7.5MVA
2014	2 x 1400kW	3 x 1600kW	355kW	3 x 400kW	7.5MVA + 11kV Starters
Per Unit	10.2	9.6	4.4	5.3	??

Pictures courtesy of: BHPB & Longwall Hydraulics Aust

U/G Coal V's Toyota Corolla

Year	Toyota Corolla
1980	4th Gen KE70 - 1.6L SOHC 58kW 115N-m
1995	7th Gen 1.6L DOHC 84kW 140N-m
2014	11th Gen 1.8L VVTi 2ZR-FE 100 kW 172 N·m
Per Unit	1.7 & 1.5

Pictures & Stats courtesy of: Wikipedia

Power System - U/G Coal

NSP:

-66kV or 33kV 200A Nominal Earth Fault Limited Supply preferred by Coal Mines to manage Step, Touch & Transfer Potential Risks.

-From adjacent operation…Exposure to Open Cut Mine Blasting Vibration…What damage? That is not from us, *that's Moon Rock??*

-Exposure to subsidence from U/G workings

-Does the NSP accept a lower reliability increased outage rate on EFL ring Feeders Supplying Coal Mines?...Full Star Point Shift & Ph-Ph Cross Country Earth Faults…..Utility staff time to find the faults.

Local Generation:

-Weak Infeed challenges for NSP.

-On Site Generation is common.

-X/R Increase for Faults on Colliery Site. Sw Gr Ratings?

-CH4 Drainage Pwr Stations.

-1995 NSW LW Mines in Coking Coal with EDL Installed 54 x 1MW & 40 x 1MW (650,000m^3 CH4 used per day), CH4 of 35 to 40m^3 per tonne of coal mined volume of Gas Liberated = approx 265 million m^3. 35MJ/M^3

-2008 QLD Mine with EDL Installed 15 x 3MW Units.

-Ventilation Air Methane (VAM). Eg 2007 NSW Mine Installed 6MW MEGTEC (0.9% CH4 Concentration

Power System - U/G Coal Longwall

Pit Top (At present):

- 66kV/11kV 2 x 25MVA Txfs
- 11kV Earth Fault Limitation Was 10A… system capacitance has increased…so Now Typically 15A or 25A is required
- Need to manage Step, Touch & Transfer Potential Risks.
- Need to manage Lightning Strike Transfer into U/G Workings
- Bore Hole Cable Drop Down to MainGate Entry 240mm2 XLPE or 300mm2 XLPE

Pit Top (Right Now):

- NSP Applications for a 132kV Supply as a Tee'd Feeder!!....Ahhh No NSP has *"Graded Insulation 132kV Txf Windings"*, Ph-E Rated Insulation & Ph-E Rated Arresters & NEMCO Requirements.
- NSP says….*" Sorry no EFL Supply Available at 132kV "*….Coal Mines to make their own arrangements to achieve Step and Touch Potential plus manage the Transfer Hazards.
- 2 x 40MVA 132kV/11kV Txf

Power System - U/G Coal Longwall

Distribution Network Underground:

-11kV now at limit of Supply Capability (You can only send Amps so far at a set voltage). 33kV in Metal, pecking faults anyone?

-6.6kV not sufficient for a modern Longwall.

-Underground Network Backbone is PILSWA & XLPE Cable 1+Jxl1 (ie jxl not as significant as Overhead Lines)

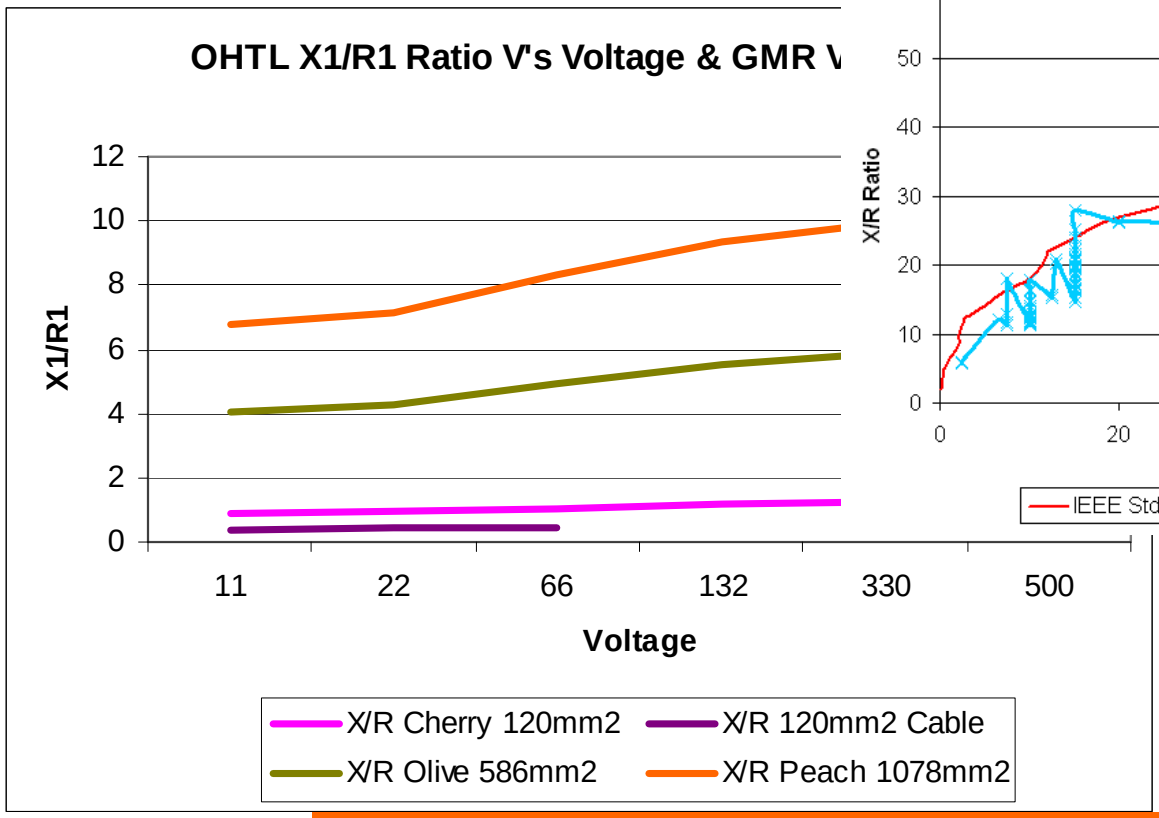
-3.3kV for Most Longwall components. First 11kV AFC installed with Electrical Inspectorate reservations

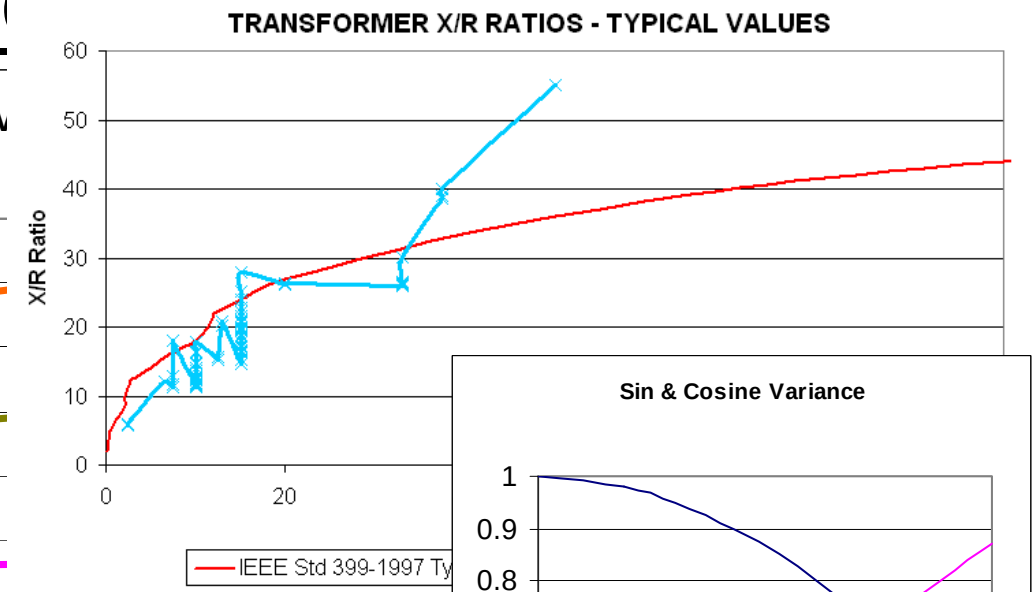
-1.1kV treated like Low Voltage. Plug connectors operated by non electrical staff.

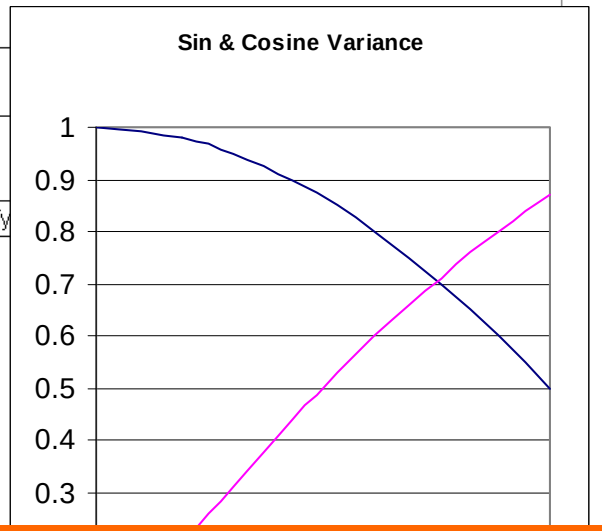
-Pit Top Txf often tapped to 1.05PU and Dev section Txfs tapped to 1.025PU. Under light load/no load conditions voltages float high.

-Overfluxing of cutter head motors rated at 950V has occurred.

Power System – U/G Cost Longwall







N

Vd = (v

+jX cor

Network Contingency Modelling?

Shunt Caps MVAR Out ≈ $(V_A/V_R)^2\ Q_R$

Above Tx Line SIL MVAR Req'd ≈ I^2 JxL

Trailing Cable Protection

AS2081 Relays:

1. Over-current / Overload Protection:

   - Overcurrent Protection 7.5amps to 464Amps in steps ((60 to 116 A in 4A increments x multiplier) Current Multiplier: 1/8, 1/4, 1/2, 1, 2, 4 times
   - Short Circuit Protection: 3 to 10x in 0.5 increments
   - Trip Time: 20, 40, 60, 80, 100, 120, 160mS

2. Earth Leakage Protection:

   - 100-500mA in 50mA increments
   - Time Delay - Instantaneous (<50mS), 100mS then 150mS - 470mS in 40mS increments.)

3. Earth Continuity Protection:

   - Reset if resistance is <45 ohms
   - Trip if resistance is > 45 ohms
   - Shunt Leakage Trip if <1500 ohms
   - Operating Times: 80, 120, 160, 200, 300, 400 and 500mS
   - Pilot Cable Parameters: C <0.3uF, L <10mH, L/R<600uH/Ω.

4. Insulation Test

   - Lockout resistance is selectable at 0.1, 0.2, 0.5, 1, 2, 5, 10, and 15 Meg Ohm

Trailing Cable Protection

AS2081 Relays Continued:

5. Earth Fault Lockout Protection:
   - IS Test
   - Lockout if resistance is: 415V < 4.15k ohms
   - 1000V < 10k ohms
   - 3.3kV < 33k ohms

6. Current Balance:
   - Trip Settings: 5%, 10%, 20%, 50% and off

7. Under-voltage Protection:
   - Selectable from 20% to 80% in 10% increments
   - Trip Delay 800mS

8. Back EMF Timer:
   - Trip Delay Settings: 2, 5, 10 and 20 Seconds

****

9. No Volts Coils

PART B

Electrical Protection – Challenges

- Consideration of some incidents that have occurred 1995 – 2014.

https://www.engineersaustralia.org.au/mining-electrical-and-mining-mechanical-engineering-society

http://cigre.org/
http://cigreaustralia.org.au/

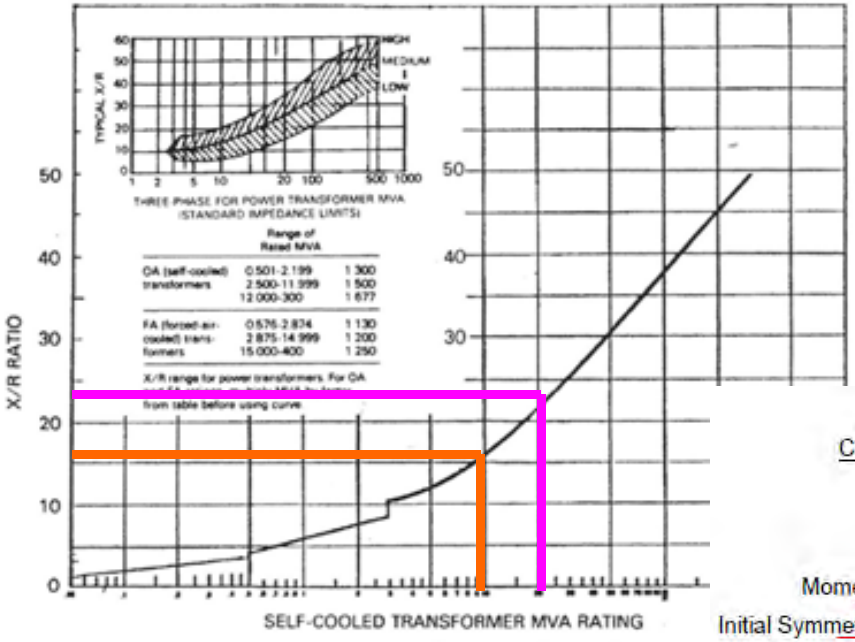
Failure 1

X/R Ratio Increases:

- Larger Txf's = Larger X/R for 3Ph & Ph-Ph Faults
- Adequacy of Sw Gr…Vacuum Bottles don't like heat…a "*Protection Relay 4kA Instantaneous Override Trip*" won't work if the Vacuum Bottles Disintegrate.

X/R Ratio = Tan Theta

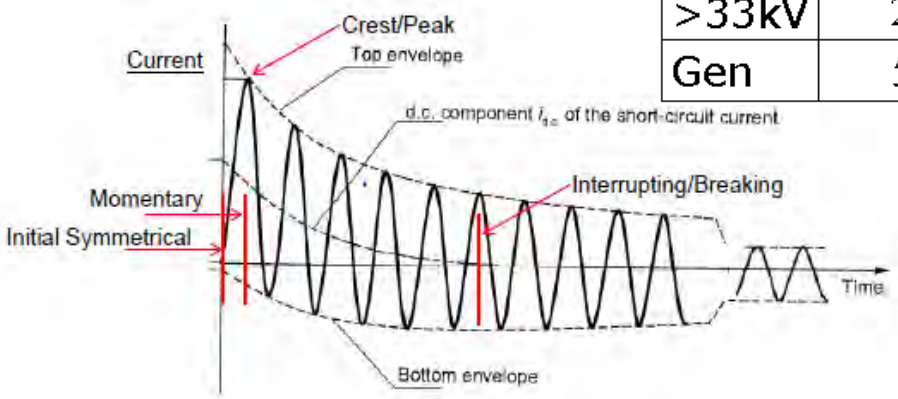
Power Factor = Cos Theta



IEEE Std 399-1997

Figure 1-38—Typical *X/R* ratio of transformers

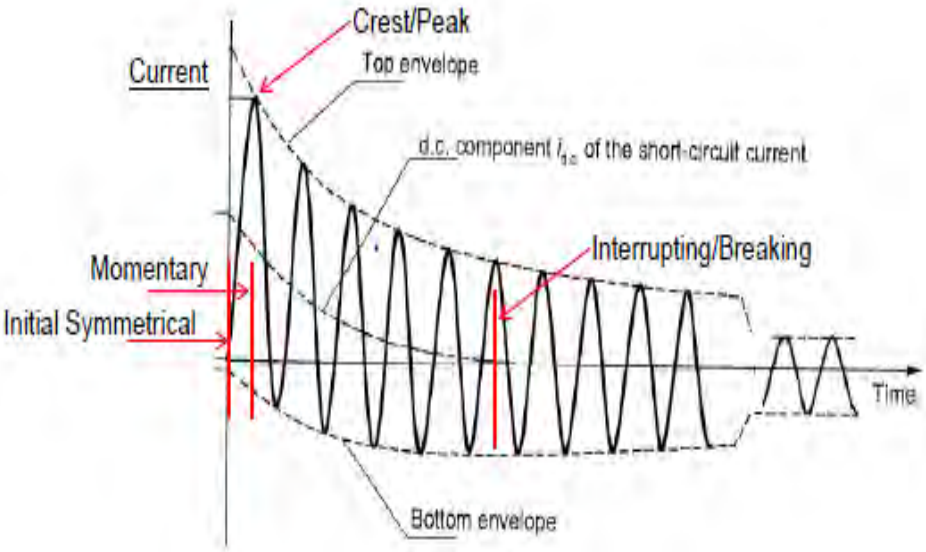
Equip	X/R	PF
LV	5	0.2
LV	6.6	0.15
<33kV	12	0.083
<33kV	15	0.066
>33kV	25	0.04
Gen	50	0.02



Potential Failure

X/R Ratio Increases:

- Flame proof enclosures in Australia are not tested for Ph-Ph Arcing Faults. SIMTARS QLD and Test Safe Londonderry NSW do not have the HV Supply Capability
- NCB UK Harpers Hill had a 6.6kV 50MVA (4.3kA) Arcing Fault Test Supply
- X/R = DC Offset in Fault Current Waveform = Additional Heating internal to the flameproof enclosure during an Arcing Fault



X/R Ratio = Tan Theta

Power Factor = Cos Theta

Equip	X/R	PF
LV	5	0.2
LV	6.6	0.15
<33kV	12	0.083
<33kV	15	0.066
>33kV	25	0.04
Gen	50	0.02

Mine Pwr Sys Exceeds AS4871 Criteria

X/R Ratio Increases:

AS/NZS 4871.1:2010 Pg58 Electrical equipment for mines and quarries

H1.2.8 *Relationship between peak and r.m.s. values for short-circuit current*

The value of peak short-circuit current (peak value of the first loop of the short-circuit current including d.c. component) for determining the electrodynamic stresses shall be obtained by multiplying the r.m.s. value of the short-circuit current by the peak factor (n). Standard values for peak factor and corresponding power factor are given in Table H1.

TABLE H1

PEAK FACTOR

Short-circuit current kA r.m.s.	Power factor cos ϕ	Peak factor (n)
>5 ≤10 (≤3.6 kV)	0.5	1.7
>10 ≤20 (≤3.6 kV)	0.3	2.0
>20 ≤50 (≤3.6 kV)	0.25	2.1
12.5 (>3.6 kV)	0.15	2.5

X/R Ratio = Tan Theta

Power Factor = Cos Theta

Equip	X/R	PF
LV	5	0.2
LV	6.6	0.15
<33kV	12	0.083
<33kV	15	0.066
>33kV	25	0.04
Gen	50	0.02

PF	Peaking Factor	X/R
	1.7	
0.295	1.987	3.238
0.25	2.073	3.872
0.235	2.105	4.136
0.15	2.308	6.591
0.085	2.502	11.72

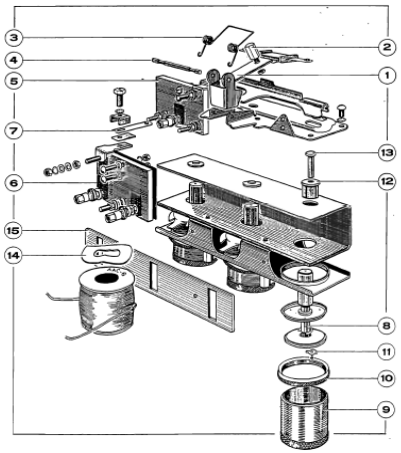
They Still Exist

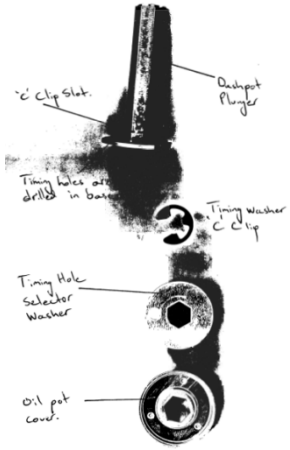
Dashpot Relays:

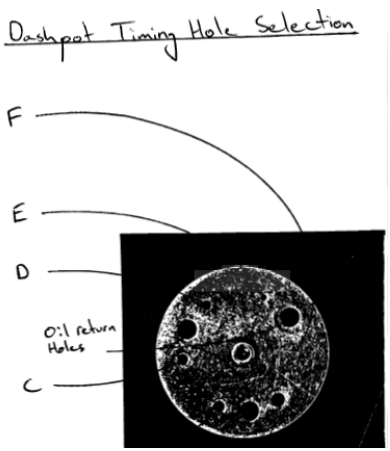
- 11kV O/C Protection??
- Most are a 3 Ph O/C Device.

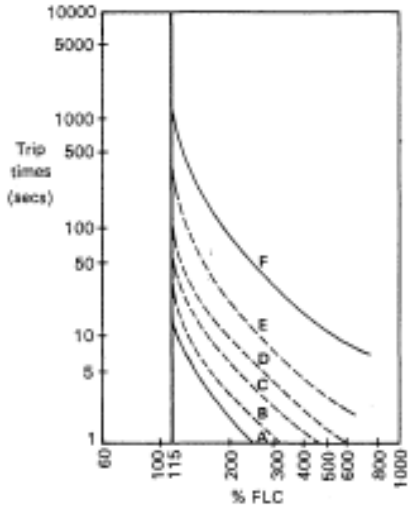
=>> Sounds Good Right?...WRONG

1. Cutler Hammer 1006G introduced October 1970…+ other eg National Benzole R4 Dashpot & CMA Dashpot O/L are Still in use!
2. Everything from grease to 454 crude oil to Brake Fluid…20W50 Std Nat Min Oil, 15W/40 Std Nat Min Oil or 500Cs Silicon Fluid.
3. NO I>> Setting Hopefully Section CB's upstream/Outbye operate.









Challenges

I>> Setting :

Short Circuit Multiple of Setting

Spread Sheet by Brett Roberts Aug-98

Purpose:

To demonstrate the variation of PU multiple of protection Setting with various common types of faults.

3Phase Fault =	**1**	**PU**
Phase to Phase Fault =	**0.866025404**	**PU**

Sqrt(3) =	1.732050808
Sqrt(3)/2 =	0.866025404
1/1.2 =	0.833333333
(Sqrt(3)/2) * (Sqrt(3)/2) =	0.75
1/(Sqrt(3) =	0.577350269
(1/(Sqrt(3)) * ((Sqrt(3)/2))) =	0.5
0.5*((Sqrt(3)/2)) =	0.433012702
0.433*((Sqrt(3)/2)) =	0.375
1/3 =	0.333333333
0.333*((Sqrt(3)/2)) =	0.288675135
0.25 =	0.25
0.25*((Sqrt(3)/2)) =	0.216506351

Suggested Short Circuit Protection/ Instantaneous Settings as a ratio of 3 Ph Flt - Various Sources	**Suggested Setting PU of 3 Ph Flt**	**Effective Multiple of Setting for Different Power System Fault Types (PU of Setting)**				
		3 Ph Flt	**Ph to Ph Flt**	**Arcing Fault 1/Sqrt(3)* Ph to Ph Flt**	**Arcing Fault 0.5* Ph to Ph Flt**	**Arcing Fault 0.43* Ph to Ph Flt**
0.25* Ph to Ph Flt	**0.216506351**	4.6188	4	2.309401077	2	1.732050808
0.25* 3 Ph Flt	**0.25**	4	3.464101615	2	1.732050808	1.5
0.333* Ph to Ph Flt	**0.288675135**	3.4641	3	1.732050808	1.5	1.299038106
0.333* 3 Ph Flt	**0.333333333**	3	2.598076211	1.5	1.299038106	1.125
0.433* Ph to Ph Flt	**0.375**	2.66667	2.309401077	1.333333333	1.154700538	1
0.5* Ph to Ph Flt	**0.433012702**	2.3094	2	1.154700538	1	0.866025404
1/Sqrt(3)*Ph to Ph Flt = 0.5* 3 Ph Flt	**0.5**	2	1.732050808	1	0.866025404	0.75
1/Sqrt(3)*3 Ph Flt	**0.577350269**	1.73205	1.5	0.866025404	0.75	0.649519053
(Sqrt(3)/2)* Ph to Ph Flt	**0.75**	1.33333	1.154700538	0.666666667	0.577350269	0.5
(1/1.2)*3 Ph Flt	**0.833333333**	1.2	1.039230485	0.6	0.519615242	0.45
(Sqrt(3)/2)*3 Ph Flt	**0.866025404**	1.1547	1	0.577350269	0.5	0.433012702

Challenges

I>> Setting Arcing Fault Coverage:

2001 ACARP Study by SIMTARS Pg6

ARC Voltages

6.6kV = 0.2 – 0.45kV

11kV = 0.3 – 0.6kV

22kV = 0.5 – 0.9kV

33kV = 0.7 – 1.2kV

Pecking faults & system capacitance interaction

Short Circuit Multiple of Setting

Suggested Short Circuit Protection/ Instantaneous Settings as a ratio of 3 Ph Flt - Various Sources	Suggested Setting PU of 3 Ph Flt	
0.25* Ph to Ph Flt	0.216506351	
0.25* 3 Ph Flt	0.25	
0.333* Ph to Ph Flt	0.288675135	Most Conservative and covers all scenarios with a good margin. Used by supply Authorities.
0.333* 3 Ph Flt	0.333333333	The closer the suggested setting is to (0.333* Ph to Ph Flt) the more sensitive the protection.
0.433* Ph to Ph Flt	0.375	
0.5* Ph to Ph Flt	0.433012702	
1/Sqrt(3)*Ph to Ph Flt = 0.5* 3 Ph Flt	0.5	"Compromise Setting" to allow mines to operate at extended cable lengths.
1/Sqrt(3)*3 Ph Flt	0.577350269	Less conservative. Borders on being dangerous.
(Sqrt(3)/2)* Ph to Ph Flt	0.75	
(1/1.2)*3 Ph Flt	0.833333333	
(Sqrt(3)/2)*3 Ph Flt	0.866025404	Least conservative. Outright dangerous

Notes:

1) The protection relays used in the mining industry to protect face equipment is typically a 2 phase overcurrent device. Take care when protecting motors as phase failure protection is of use with loss of voltage but not as good at detecting arcing faults within windings.

2) Earth Leakage Protection primary clearance times shall be as short as possible to avoid 1Ph to E faults becoming Ph to Ph Via the cable earth screen.

3) The short circuit/instantaneous setting of a relay typically slows as the fault level multiple of setting approaches 1PU. Typical operation times can increase from 20ms through to 120ms. Relay manufactures should provide in their documentation the relevant test results detailing the relays performance at low multiples of setting value. The question must be asked, when is an instantaneous protection relay not instantaneous?

4) There are a multitude of other factors to be considered in the selection of protection settings including, cold load pick up, equipment thermal damage, allowable current let through, installation conditions of the electrical circuit, allowable withstand currents, voltage level, installation of equipment, cascade protection grading and the protection setting philosophy.

5) Arcing faults are common in the mining industry therefore an adequate margin of safety is required.

Cables are all but a perfect capacitor

=>> A "Pecking Fault" gives you voltage escalation

Problem

I>> Setting not Instantaneous:

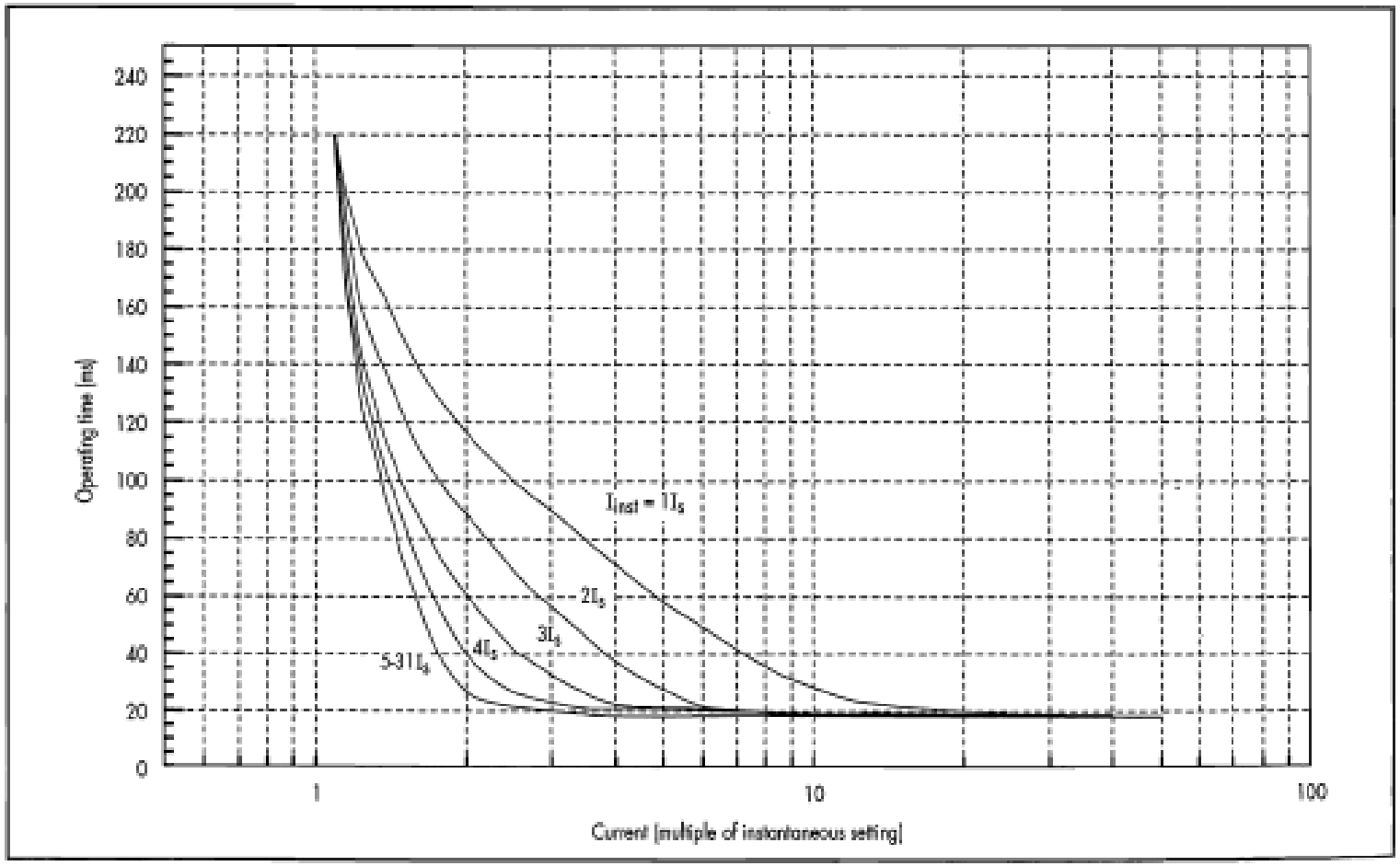


Figure 11: MCGG instantaneous operating times (various settings).

Challenges

I>> Setting not Instantaneous:

- AS2018 Relays not tested for low multiples of I>> Setting?
- When is an I>> Relay not Instantaneous?
- What is an appropriate setting. 0.25x to 0.33x 3Ph Fault Current?
- Large 3Ph Motors and long cables mean the Starting Current approaches 40% of the 3Ph Fault Current…..adequacy of the *"Simple 2Ph Over Current Relays"* used to date in the Australian Industry?
- NCB UK Developed a protection relay that distinguished between motor start currents and short circuits on the basis of Resistive Earth Fault Limitation, a kind of Mho/Distance Protection Relay. AS2081 does not describe this type of protection. Baldwin & Francis marketed this in 1997. USBM has also run projects on this entitled *"Distinguishing Motor Starts From Short Circuits Through Phase-Angle Measurements"*
- *Maybe its time to re-consider the Advantages & Disadvantages of Differential Protection?*

Challenges

AS2081 Relays:

- OEM's like to sell their own relays. SO the same relays end up on 11kV CB on to of Longwall & Development Panel Txfs, at 11kV Section Entry CB's & 11kV M/G Entry CB's

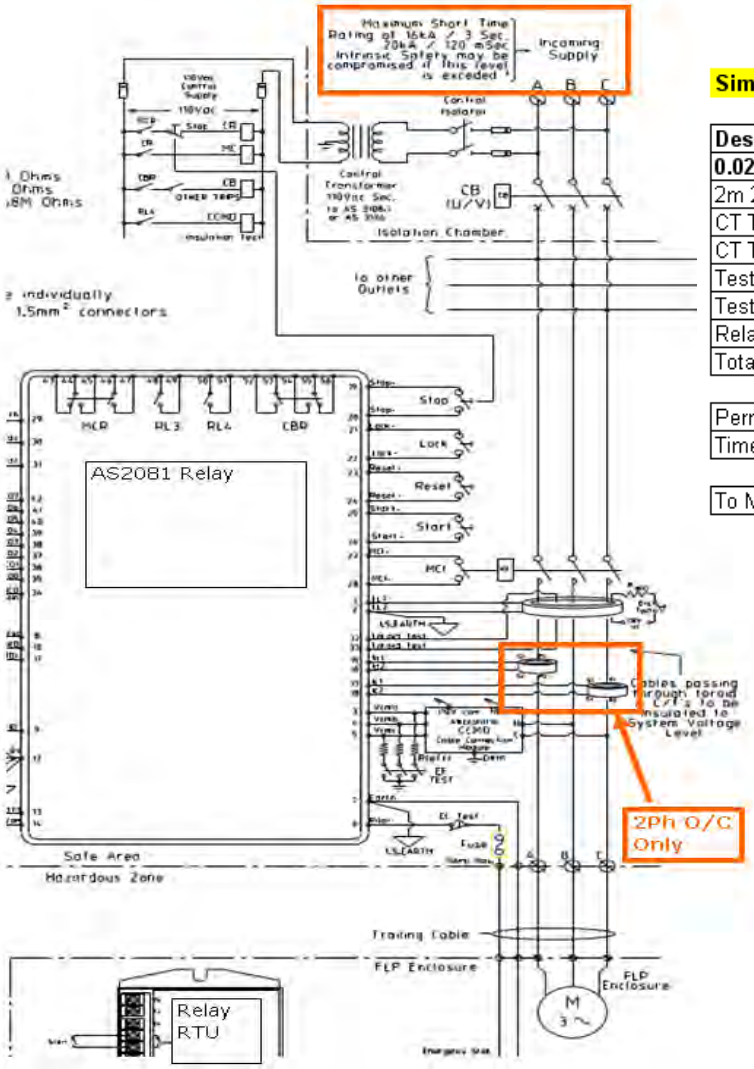
=>> Sounds Good Right?...Well…

1. CT's not Protection Class and have MuMetal Core……just test & plot the secondary excitation characteristic
2. 2 Ph O/C Device. When Ph-Ph fault (ie 0.866 of 3Ph Flt) occurs on secondary side of Delta/Star Txf 0.5PU,0.5PU,1PU results in delay to trip. Clears outbye some 8km away at first 3 Ph Overcurrent Relay…..*the PCC Supply Authority Relays*.
3. MOL Curve is blown out on some so that it is not possible to set below the I^2T Damage curve of some of the individual drive motors.
4. Only the most recent AS2081 relays come with an IEC/BS142 VI type Curve. No Separate Stall Protection Setting.
5. Older relays have no thermal memory and reset instantaneously once current drops *"below pickup"* not useful for pecking type cable faults. (The CDG induction disc relay has advantages).

Challenges

AS2081 Relays:

Over Load CT's -
1000/1 Class 2M.
STC Rating 20kA - 3 Sec.
Note Phasing on Overload C/T's Must be as Shown.



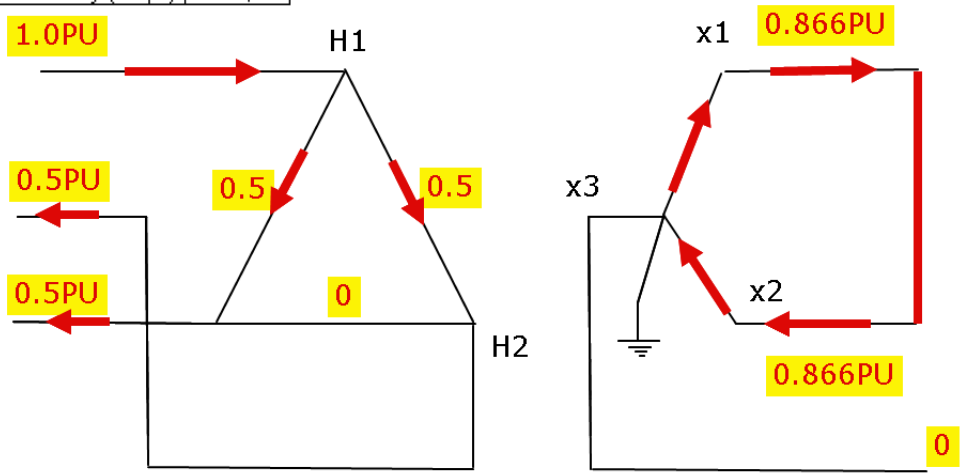
Simplified Assessment

Description	
0.02 PL 20 R2.3	**Ohms**
2m 2.5mm2	0.01482
CT Term	0.05
CT Term	0.05
Test Link Term	0.05
Test Link Term	0.05
Relay	0.2
Total	0.41482

Permissible	2.3Ohms
Times	5.54

To Maintain Accuracy (Amps)	5,545

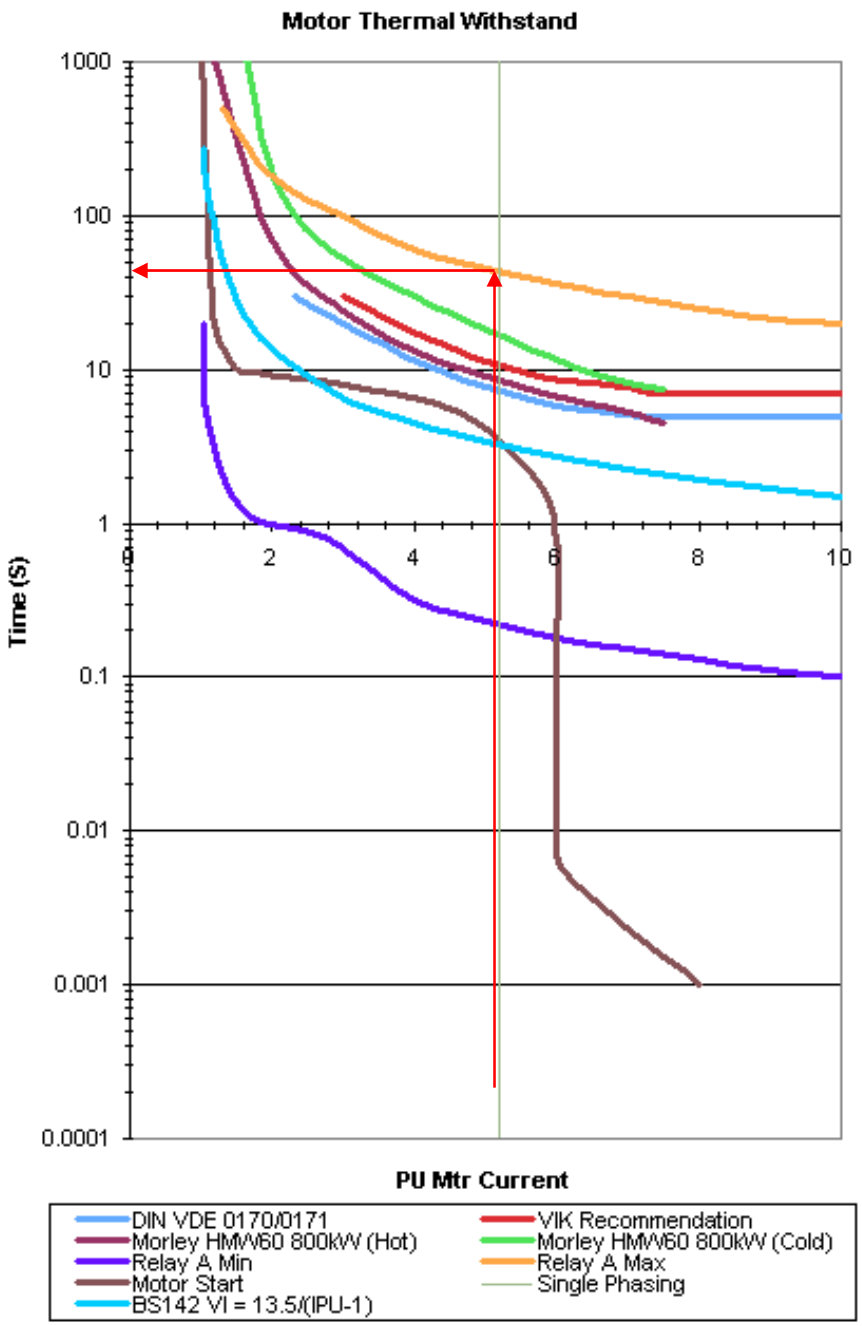
0.866/(Sqrt(3)) = 0.5PU



TRANSFORMER CONNECTIONS
(Per Unit Winding and Line Currents Shown)
Adapted from ANSI/IEEE C37.91

Challenges

AS2081 Relays:

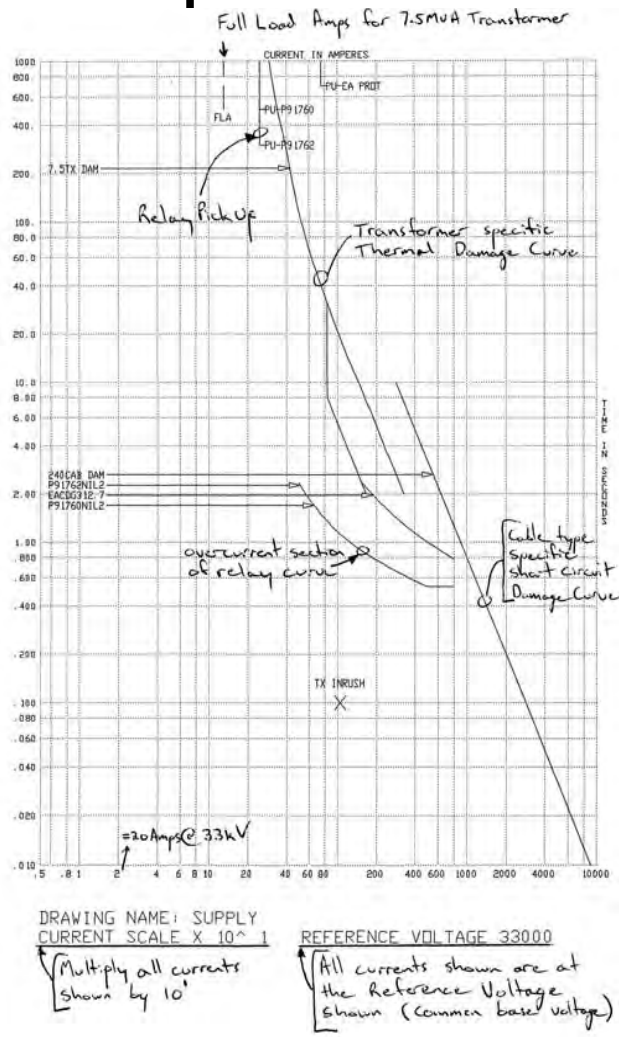


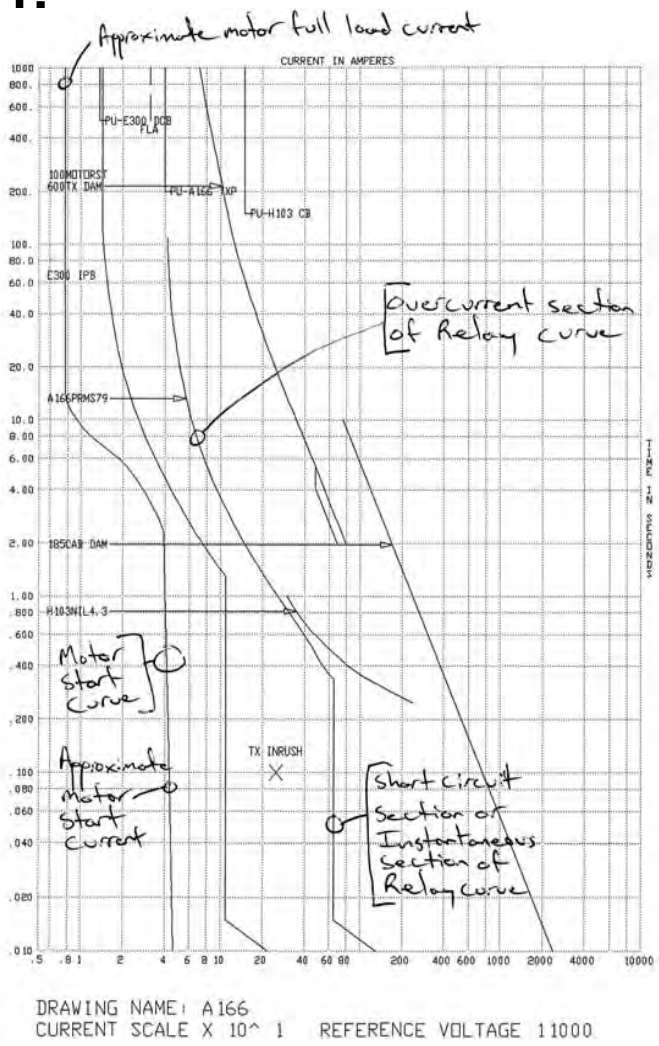
Challenges

Multiple Lines of Protection:

Challenges

Multiple Lines of Protection:

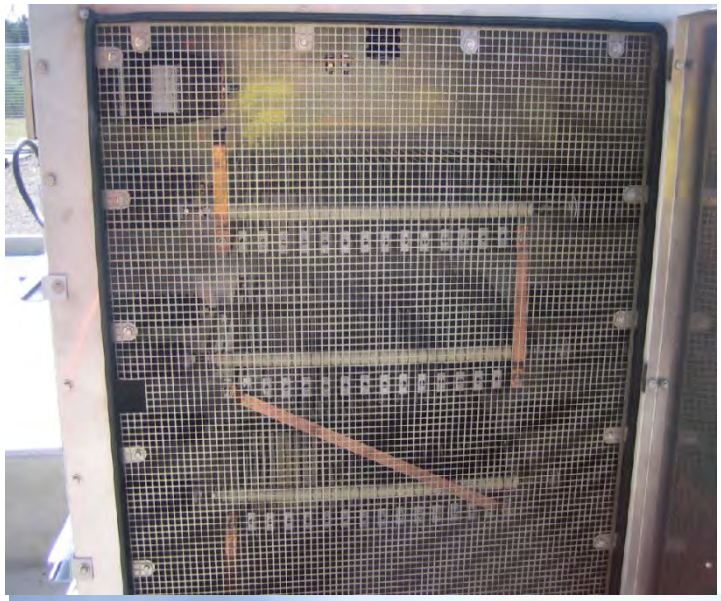


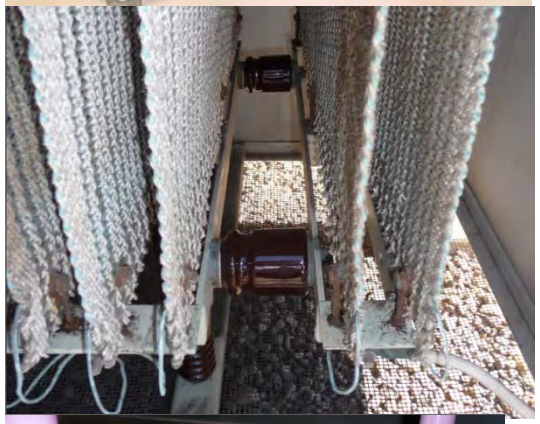


Challenges

<4000Volts 5 Amp Earth Fault

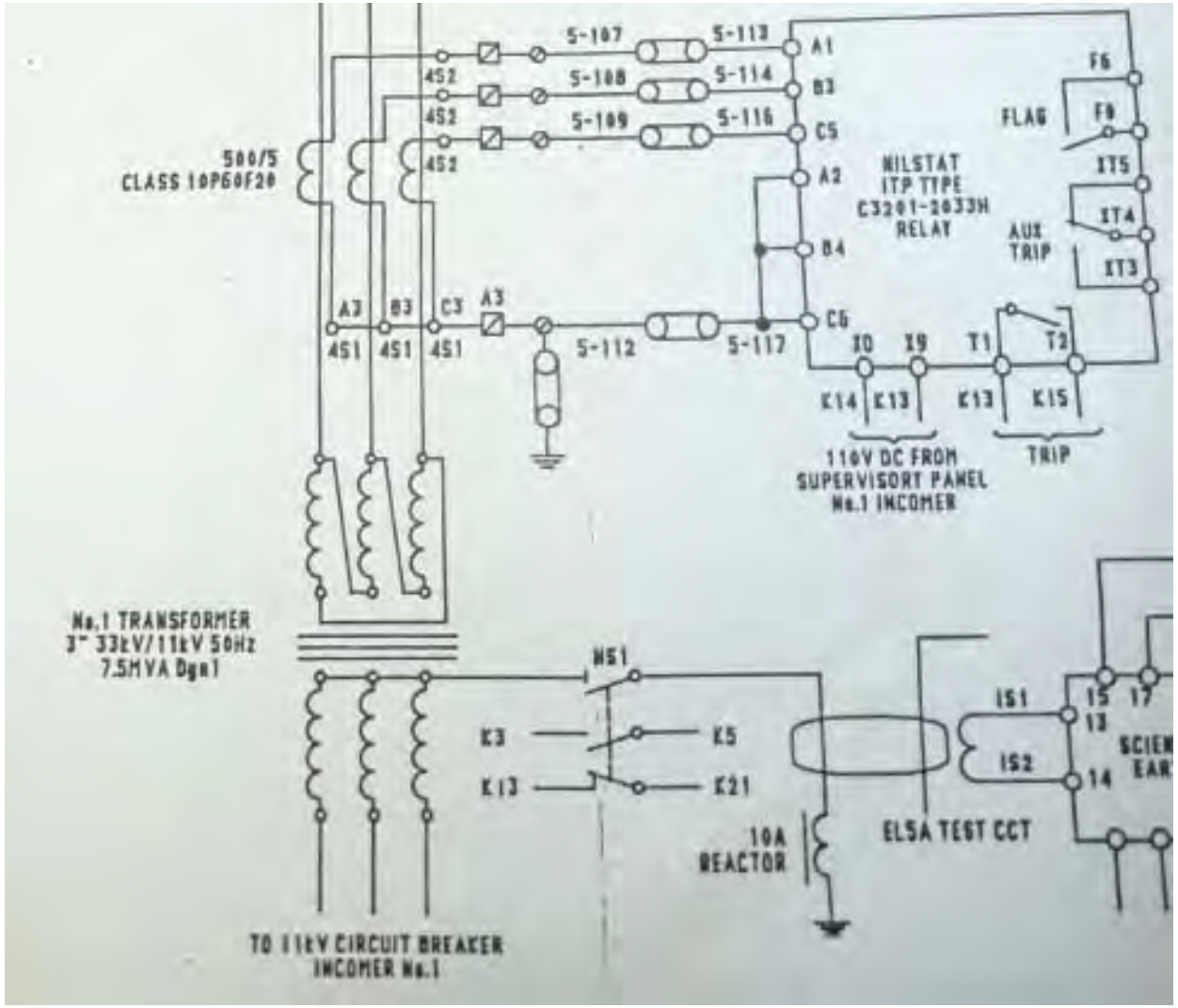
>4000Volts 10-200 Amp Earth Fault





Challenges

11kV 10 Amp Earth Fault Limitation with a **Reactor**



Challenges

Trailing Cables:

- Semiconductive screen

=>> Sounds Good Right?...Consider the following

1. No metallic barrier, cables handled live by staff, cables get pin holes.
2. Discussion on progression of Continuous Miners & Shuttle Cars to 3.3kV Supply & Cables is down right scary.
3. Cable repairs result in compromised insulation systems, next earth fault with full star point shift looks to turn the Ph-E fault into a Ph-Ph cross country fault via the Earth Screen/earth conductors.

   - 120mm2 T241.1 has 3 x 13.75mm2 Earths = 40.25mm2.

     =>> Sounds Good Right?...Well…..

Challenges

120mm2 T241.1 has:

3 x 13.75mm2 Earths

In // only once you get to the couplers

3 x 13.75mm2 Earths = 40.25mm2.

Permissible I^2T for 14mm2

Simplified 3Ph Infinite Busbar F/L

2.5MVA, 1000V, Z = 5.5%

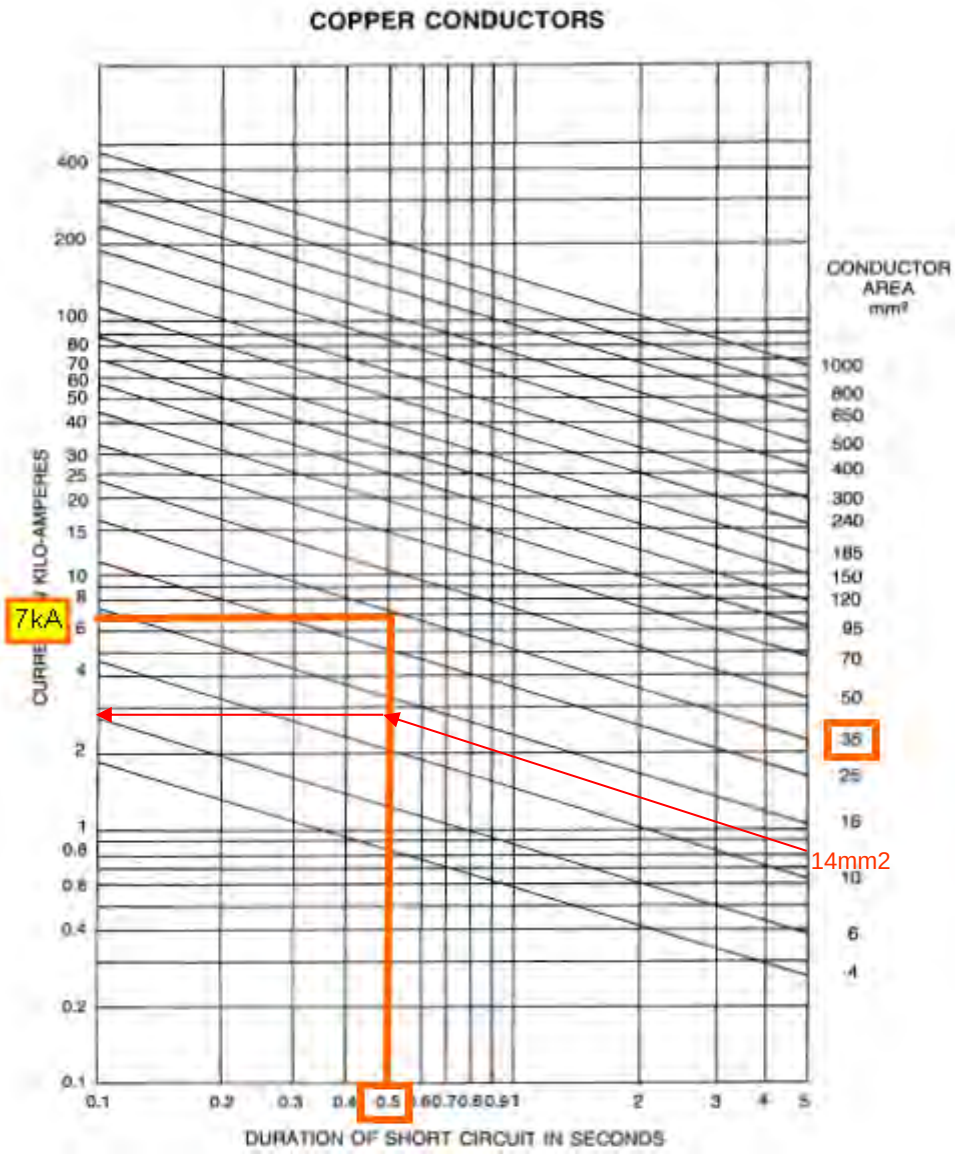
=>> 18 x 1443A = 26.2kA

Assume 80% if Infinite Case

…& Ph-Ph Arcing Fault

0.8*0.866*26.2kA *60% = 10.9kA

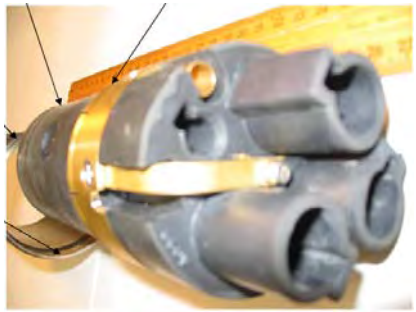
0.8*0.866*26.2kA *50% = 9.1kA



Challenges

Longwall Incident

- 3.3kV Vacuum bottles tried to trip off the “Shearer Locked Rotor Current”, flash at the Longwall Face from the restrained receptacle.
- Lost all U/G Supply



INVESTIGATE Why?

- 3.3kV Vacuum bottles tried to trip off the “Shearer Locked Rotor Current”
- Transient over voltage sufficient create the Ph-Ph Cross Country Fault
- & to then flash over the rear of the Longwall Transformer PCM5 rackable power chassis Busbar connections, Ph-Ph clearances were compromised by connections to star connected reactors installed to perform the AS2081 loss of vacuum protection
- Ph-Ph fault across the rear of the Longwall Transformer went straight through four (4) lines of 2Ph O/C relay protection & cleared 8km away at the first three (3) Phase Overcurrent Relay…..

Challenges

11kV Bolted Cable Adaptor & Coupler

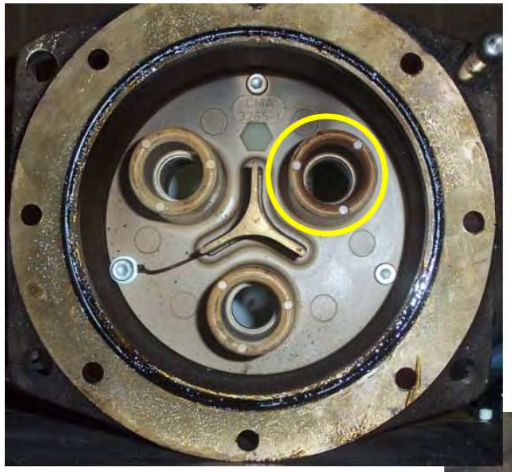
=>> Goes BANG!.... INVESTIGATE Why?

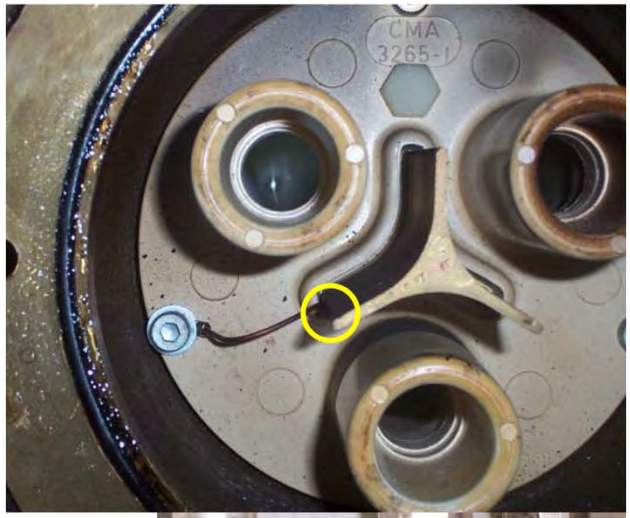
Challenges

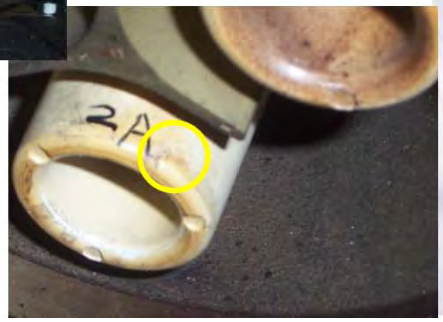
11kV Bolted Cable Adaptor:

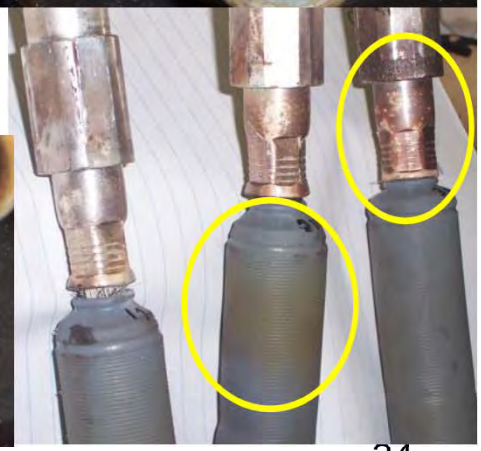
Pre 2004 Design:

1. Thin air wedges, sharp internal metal work, non coaxial E Field Stress Grading
2. Lung effect
3. Corona & PD at Service Voltage
4. Could not Pass BIL / LIWL Test









Challenges

11kV Bolted Cable Plug:

Pre 2004 Design:

1. Thin air wedges, sharp internal metal work, non coaxial E Field Stress Grading
2. Lung effect
3. Corona & PD at Service Voltage
4. No torque wrench, Stainless Steel used as the conductor….

Challenges

11kV Bolted Cable Adaptor & Coupler

=>> Goes **BANG…Here's Why?**

Part C – Summary of The Part B Incidents

1. Vacuum Bottles Disintegrate
2. Arcing Fault Rupture of Flameproof Enclosures
3. Mine Pwr Sys Exceeds AS4871 Criteria
4. Dashpot Relays Still Exist! – Why?
5. I>> Not instantaneous at Low multiples of setting.
6. Delta/Star Txfs and 2Ph O/C Relays produce delay to trip. 1PU fault Current falls in the un-monitored phase.
7. AS2081 relay O/C Curve fails to protect motor.
8. Phase Current Balance “Turned Off”, O/C fails to protect motor.
9. 1Ph-E Pecking fault produces voltage escalation star point shift & insulation failure results in Ph-Ph cross country fault within the hazardous zone.
10. Metering class CT’s subject to saturation result in a delay to trip
11. 2Ph O/C CT’s always in the same phases ensures a protection malgrade with the first 3Ph O/C relay for a Ph-Ph fault on secondary side of a Delta/Star Txf
12. Multiple Lines of Protection often means that a malgrade has to be forced somewhere.
13. Ensure Resistive Earthfault Current is at least 10x the system capacitive current to achieve effective damping & limit the voltage escalation
14. NER continuity & impedance to be Monitored else on undetected failure the Pwr Sys becomes Unearthed, ie an Isolated Neutral System
15. Reactive Earthing to <30% 3Ph F/L is a very bad idea!
16. Trailing Cable individual earths anneal due to passage of Ph-Ph fault current
17. Bolted Cable Couplers and Adaptors not Rated to industry standard BIL/LIWL

Part C – Some Key Points

1. U/G Coal is a unique environment.
2. The Power System for U/G Coal has changed. X/R & F/L.
3. 2 Ph O/C relays are not a great option.
4. Reactive Earthing Limitation to <30% of 3Ph F/L is a very bad idea!
5. Resistive Earthfault Limitation should be 10x the System Capacitive Current to achieve effective damping. Pecking fault escalation.
6. I>> Setting v's F/L requires careful consideration.
7. Protecting Equipment when primary plant detail is lacking. DIN VDE, VIK & IEEE Std399 guidance is invaluable for Equipment Damage Curves.
8. The adequacy of existing equipment should be carefully assessed to ensure it is *"Fit for Purpose".*

Part C – References

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9. IEEE Std 142 - Green Book - IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems

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The U/G Power System

U/G Mining or a Longwall Supply:

- Its not just about the *"Mining Engineer and his ever larger kW toys & t/Hr"*, there are significant Electrical Challenges

Pictures courtesy of: T&I Electrical Inspectorate

Some Aspects of Electrical Power System Protection in Underground Coal

QUESTIONS

g) Colliery Drift,

Courtesy of: LDO -

HB119 -EL023 Committee Project AUSTRALIAN Standards

Brett Roberts – MEMMES Member

MEMMES

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https://www.engineersaustralia.org.au/mining-electrical-and-mining-mechanical-engineering-society

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