Network & Protection Studies

Marketing Material

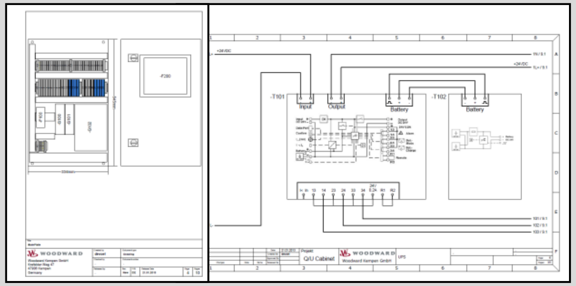
From Product to System up to Solution

Solution

- Network Study
- Remote Access Capability
- Link to superior systems (SCADA) via bus / Ethernet
- Implementation into existing installation / customization
- Commissioning
- etc.

System

- Gen.-Set Control & Protection Panel
- Common Control & Protection Panel
- Protection Boards



Product

- Generator Protection Relay
- Feeder Protection Relay
- Transformer Protection Relay
- Motor Protection Relay
- Interconnection / Mains Decoupling Relay
- etc.

Network Study - Purpose

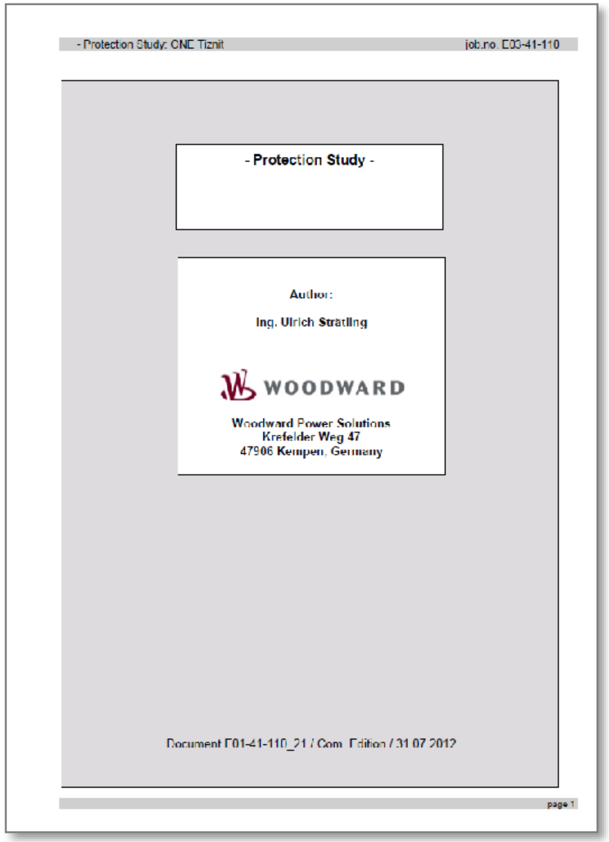
- Dimensioning of Network Elements, e.g.
  - Distribution Systems & Cable and Installation Systems
    - MV switchgears
    - LV switchgears
    - Power Transformers
    - Power Cables
  - Dimensioning Parameters
    - Max. Short-Circuit Current
    - Operation Current

Network Study - Purpose

- Protection of Network Elements, e.g.
  - Network Elements
    - Generators
    - Power Transformers
    - Motors & Feeders
    - Power Cables
  - Dimensioning Parameters
    - Min. Short-Circuit Current
    - Operation Current

Network Study - Content

- Content of a Network Study


- Protection Study: ONE Tiznit job.no. E03-41-110

- Protection Study -

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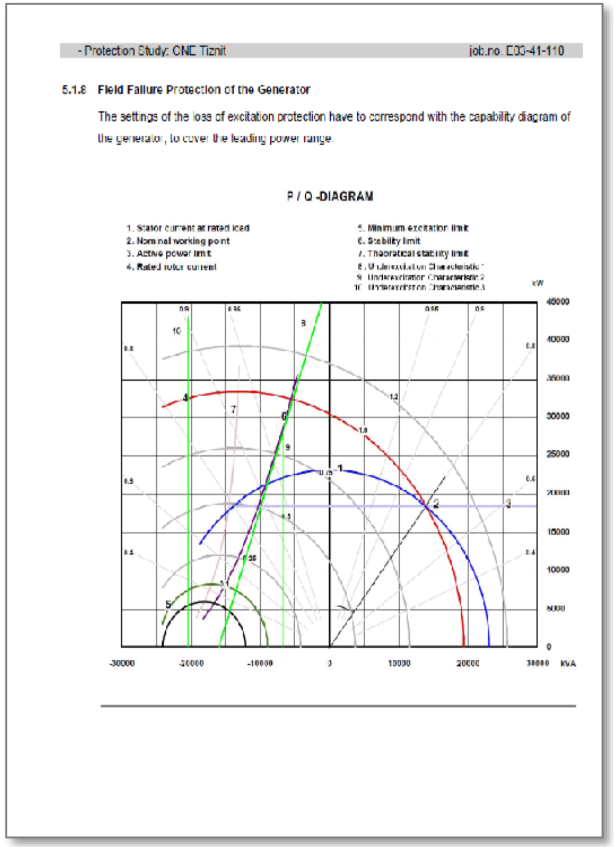
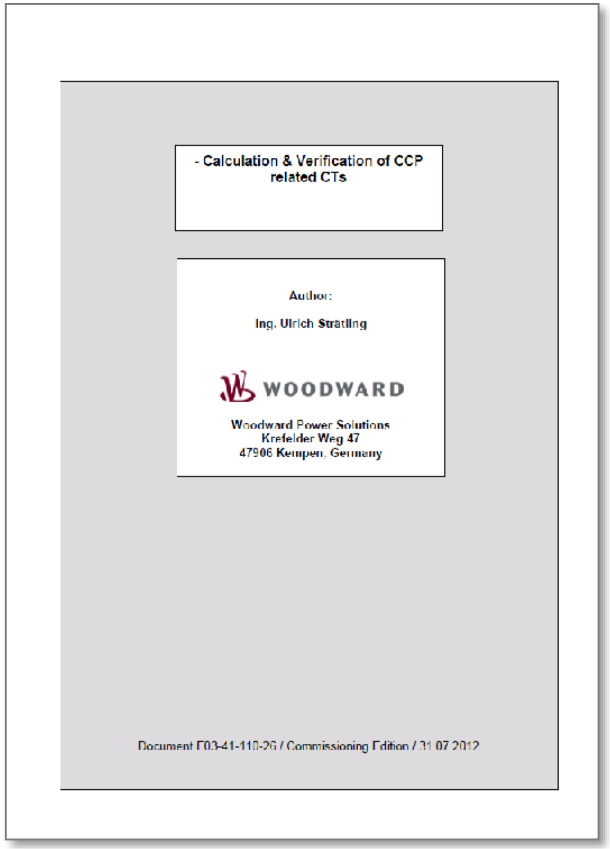

- Protection Study: ONE Tiznit job.no. E03-41-110

5.1.8 Field Failure Protection of the Generator

The settings of the loss of excitation protection have to correspond with the capability diagram of the generator, to cover the leading power range.


- Calculation & Verification of CCP related CTs

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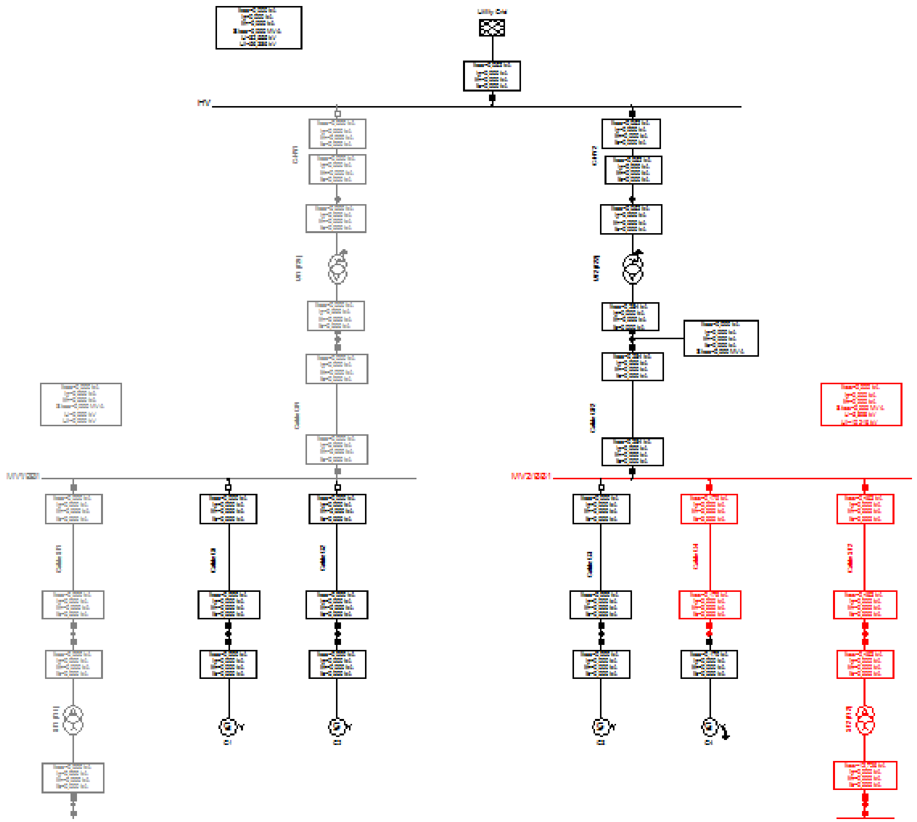
Network Study - Data Input

- Data Collection of Network Elements, e.g.
  - Generators
  - Utility Grid Connection
  - Power Transformers
  - Motors & Loads
  - Cables
- Network Topology

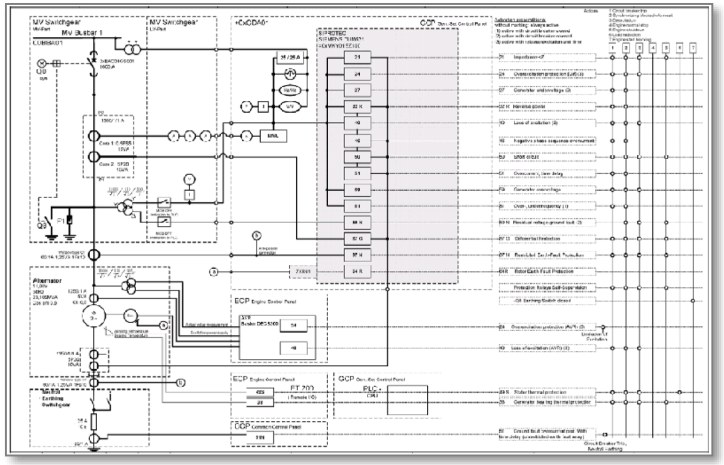


Network Study - Calculations

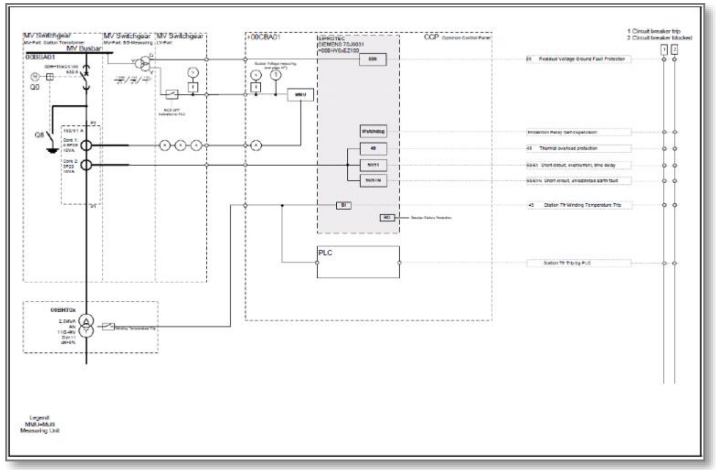
- Load Flow Calculation
    - Result: voltage & load profiles (max. operational current of each network branch)
    - Basis for determination and verification of operating modes
- Short-Circuit Calculation
    - Calculation of max. 3-phase short-circuit current / Calculation of max. 1-phase short-circuit current
        - Result: maximum short-circuit currents at worst case topology
        - Basis for verification of dimensioning of network elements (e.g. switchgears, power transformers)
    - Calculation of min. 2-phase short-circuit current / Calculation of min. 1-phase short-circuit current
        - Result: minimum short-circuit currents at worst case topology
        - Basis for determination of settings of protection devices

Network Study - Protection Functions

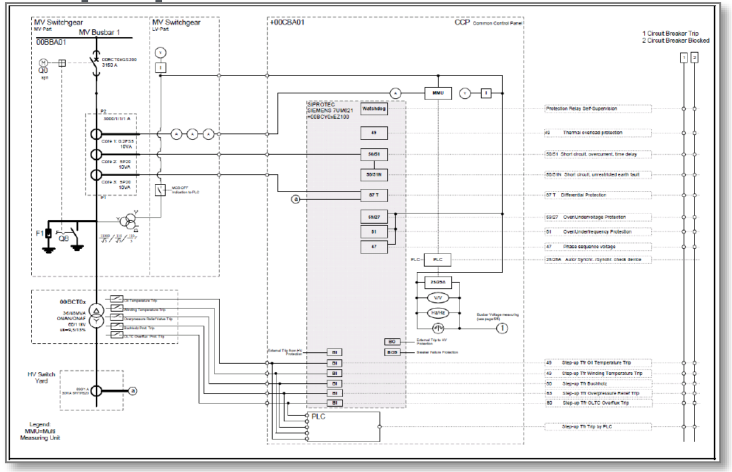
Generator Protection



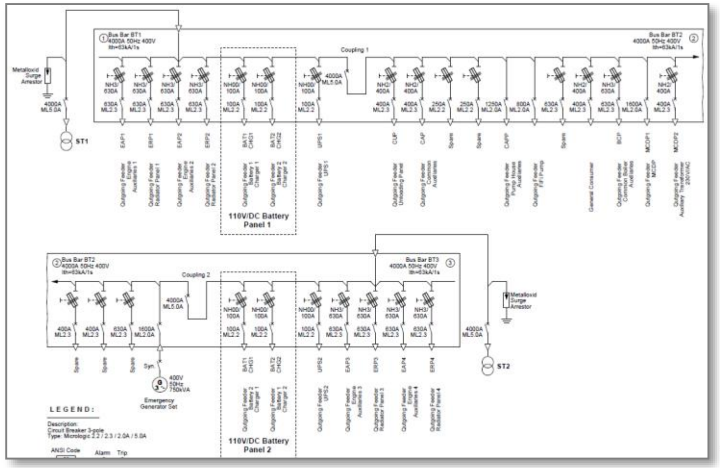
Station Transformer Protection



Step-up Transformer Protection



Main-LV Protection



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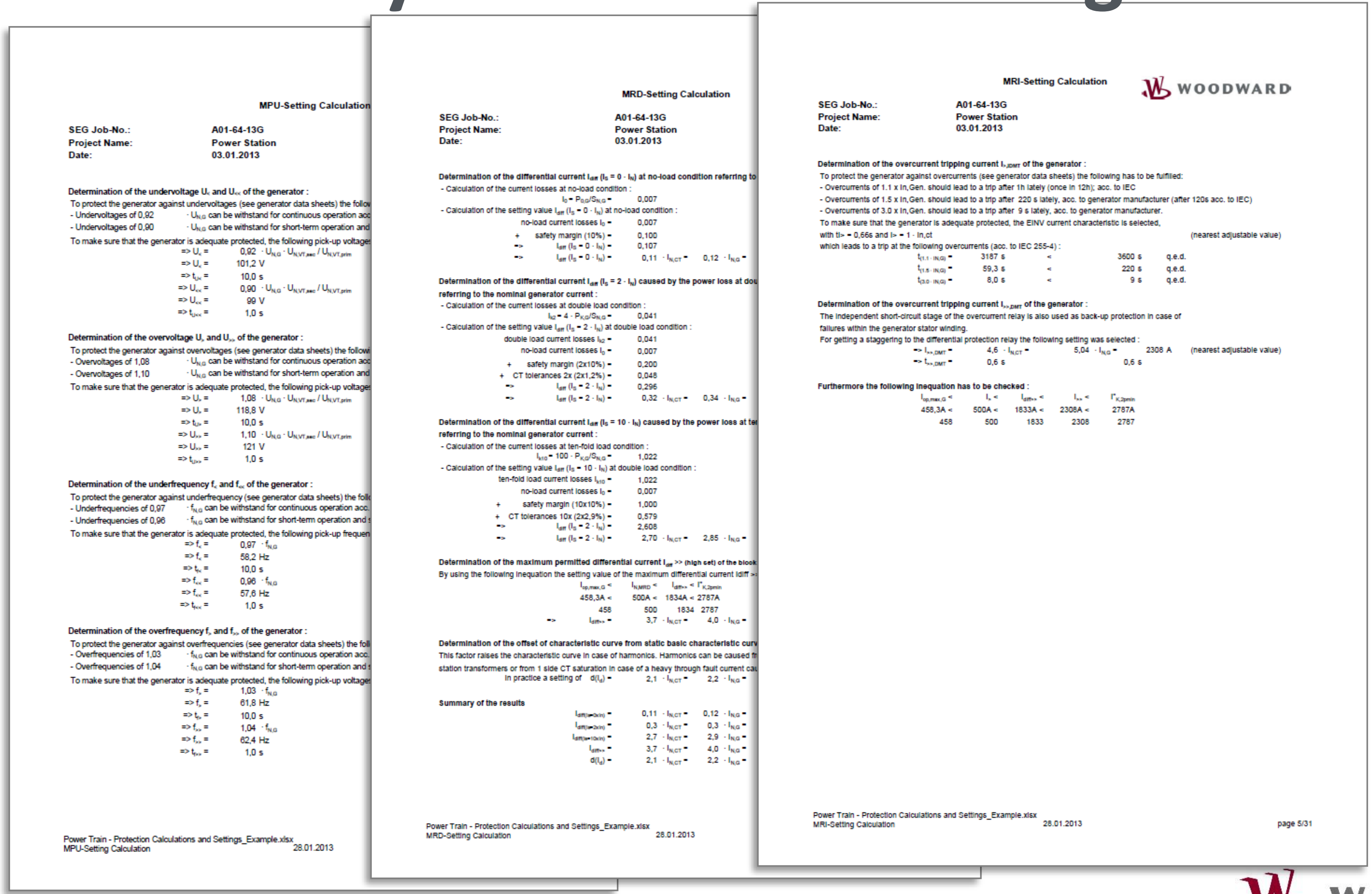
Network Study - Protection Setting Calculation

- Protection device setting calculation, e.g. Generator Protection
    - Generator differential protection
    - Three-phase overcurrent and earth fault protection
    - Stator earth fault at open generator circuit breaker
    - Voltage protection
    - Frequency protection
    - Reverse power protection
    - Negative phase sequence protection
    - Field failure protection
    - Over-excitation protection

Network Study - Protection Setting Documentation



MPU-Setting Calculation

MRD-Setting Calculation

MRI-Setting Calculation

SEG Job-No.:	**A01-64-13G**
Project Name:	**Power Station**
Date:	**03.01.2013**

Determination of the overcurrent tripping current $I_{>,IDMT}$ of the generator :

To protect the generator against overcurrents (see generator data sheets) the following has to be fulfilled:
- Overcurrents of 1.1 x In,Gen. should lead to a trip after 1h lately (once in 12h); acc. to IEC
- Overcurrents of 1.5 x In,Gen. should lead to a trip after 220 s lately, acc. to generator manufacturer (after 120s acc. to IEC)
- Overcurrents of 3.0 x In,Gen. should lead to a trip after 9 s lately, acc. to generator manufacturer.

To make sure that the generator is adequate protected, the EINV current characteristic is selected,
with tI> = 0,66s and I> = 1 · In,ct (nearest adjustable value)
which leads to a trip at the following overcurrents (acc. to IEC 255-4) :

$t_{(1.1 \cdot IN,G)}$ =	3187 s	<	3600 s	q.e.d.
$t_{(1.5 \cdot IN,G)}$ =	59,3 s	<	220 s	q.e.d.
$t_{(3.0 \cdot IN,G)}$ =	8,0 s	<	9 s	q.e.d.

Determination of the overcurrent tripping current $I_{>>,DMT}$ of the generator :

The independent short-circuit stage of the overcurrent relay is also used as back-up protection in case of failures within the generator stator winding.
For getting a staggering to the differential protection relay the following setting was selected :

=> $I_{>>,DMT}$ = 4,6 · $I_{N,CT}$ = 5,04 · $I_{N,G}$ = 2308 A (nearest adjustable value)
=> $t_{>>,DMT}$ = 0,6 s 0,6 s

Furthermore the following inequation has to be checked :

$I_{op,max,G}$ <	$I_>$ <	$I_{diff>>}$ <	$I_{>>}$ <	$I''_{K,2pmin}$
458,3A <	500A <	1833A <	2308A <	2787A
458	500	1833	2308	2787

Power Train - Protection Calculations and Settings_Example.xlsx
MRI-Setting Calculation 28.01.2013 page 5/31

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Network Study - Protection Setting List

Setting List MRI3

Project Name: Power Station | Project Job No.: A01-64-13G

Function Group: =3.GanB | Location: +3Sx.TL | Relay Code: -F9

Relay Function: Overcurrent, Short-Circuit and Restricted Earth Fault Protection | ANSI Code: 51/50/67N

Password: ++++ | Date: 03.01.2013

x = 1-12,
a = A-T, n = 1-2

1. System Parameter

Function	Relay Type: MRI3-IER	Default Settings	Actual Settings
$I_{primär}$ (phase) *Indication as kA*	X	500	
$I_{primär}$ (earth) *Indication as kA*	X	50	
Uprim/Usek (earth)	X	sek	
1:1 / 3pha / e-n	X	3pha	
50 / 60 Hz	X	60	
Indication Pickup	X	FLSH	
Parameter switch/ext.triggering for fault recorder	X	SET 1	

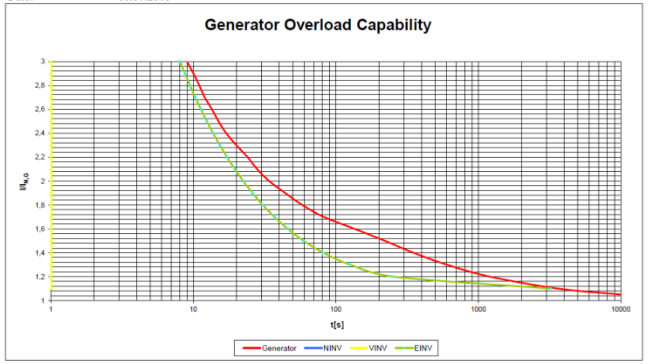
2. Protection Parameter

Function	Relay Type: MRI3-IER	Default Settings	Actual Settings
2 parameter sets	X	set 1	
I> (=xx*IN)	X	1,00	
CHAR I>	X	EINV	
$t_{I>}$ (V) / $t_{I>}$ (R)	X	0,66	
0s / 60s (phase)	X	60	
I>> (=xx*IN)	X	4,6	
$t_{I>>}$ (V) / $t_{I>>}$ (R)	X	0,6	
RCA			
$U_{E>}$	X	11	
$I_{E>}$ (=xx*IN)	X	0,080	
trip / warn	X	Trip	
CHAR I_E			
$t_{IE>}$ (V) / $t_{IE>}$ (R)	X	20,00 / 12,00	
0s / 60s (phase)			
$I_{E>>}$ (=xx*IN)	X	0,30	
$t_{IE>>}$ (V) / $t_{IE>>}$ (R)	X	2,0 / 0,4	
SIN / COS	X	COS	
SOLI / RESI			
Block/trip – time	X	EXIT	
t_{CBFP}	X	EXIT	
RS485 / Slave	X	1	
Baud-Rate (only Modbus Protocol)	X	9600	
Parity-Check (only Modbus Protocol)	X	Even	

Power Train - Protection Calculations and Settings_Example.xlsx
MRI-Setting List 28.01.2013 page 7/11

MRI-Setting Calculation

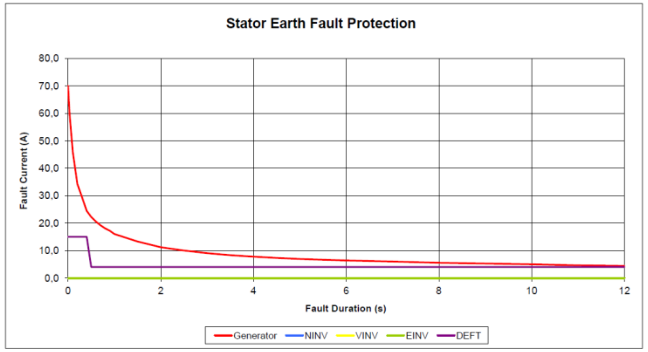
SEG Job-No.: A01-64-13G
Project Name: Power Station
Date: 03.01.2013



Power Train - Protection Calculations and Settings_Example.xlsx
MRI-Diagram I(t) 28.01.2013 page 5/11

MRI-Setting Calculation

SEG Job-No.: A01-64-13G
Project Name: Power Station
Date: 03.01.2013



Power Train - Protection Calculations and Settings_Example.xlsx
MRI-IE Diagram IE(t) 28.01.2013 page 6/11

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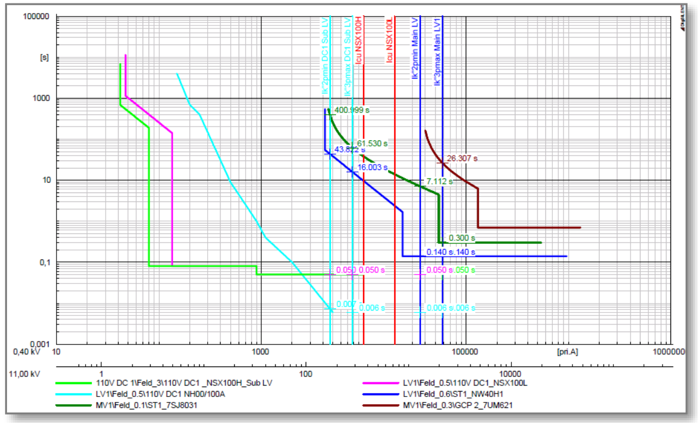
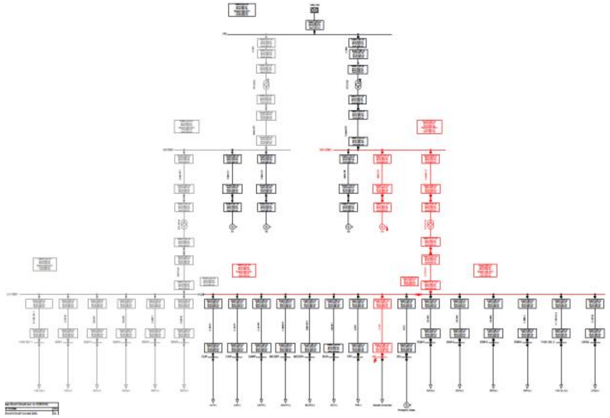
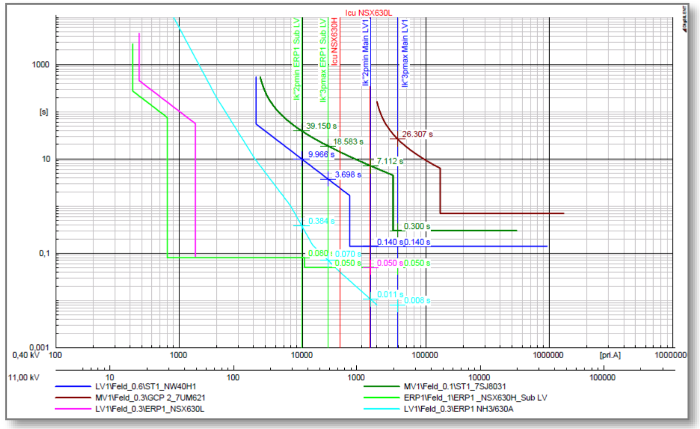
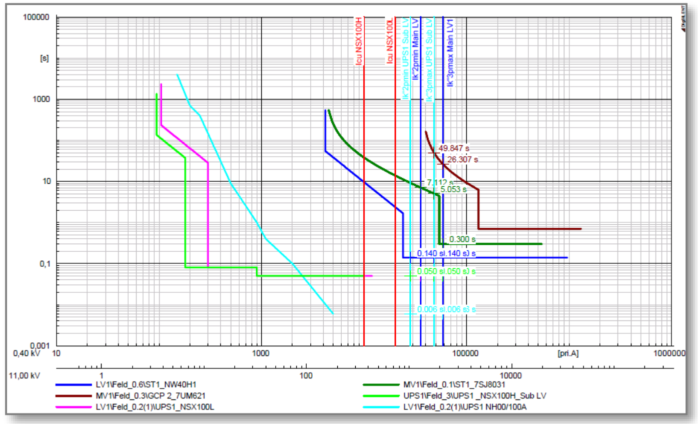
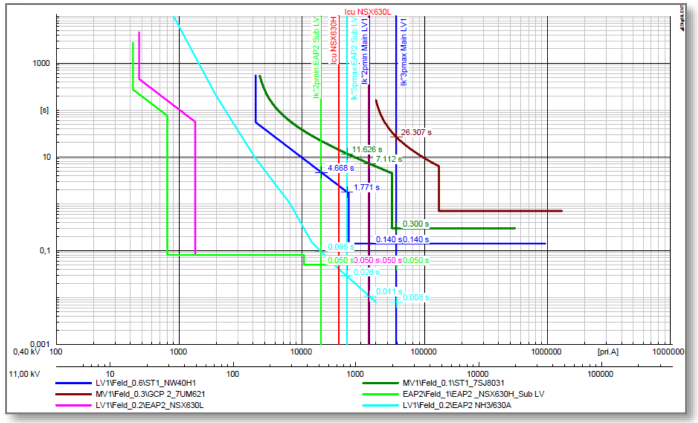
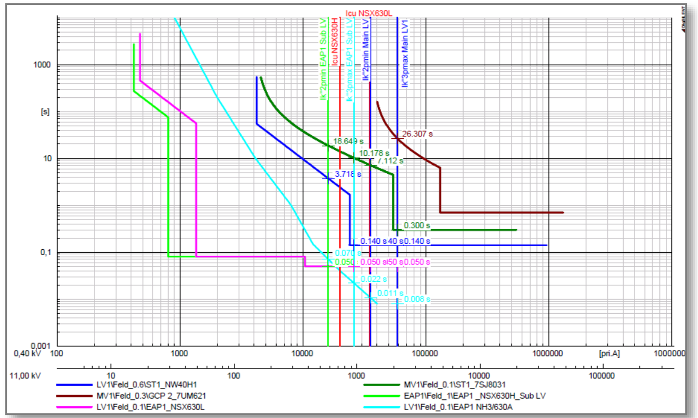
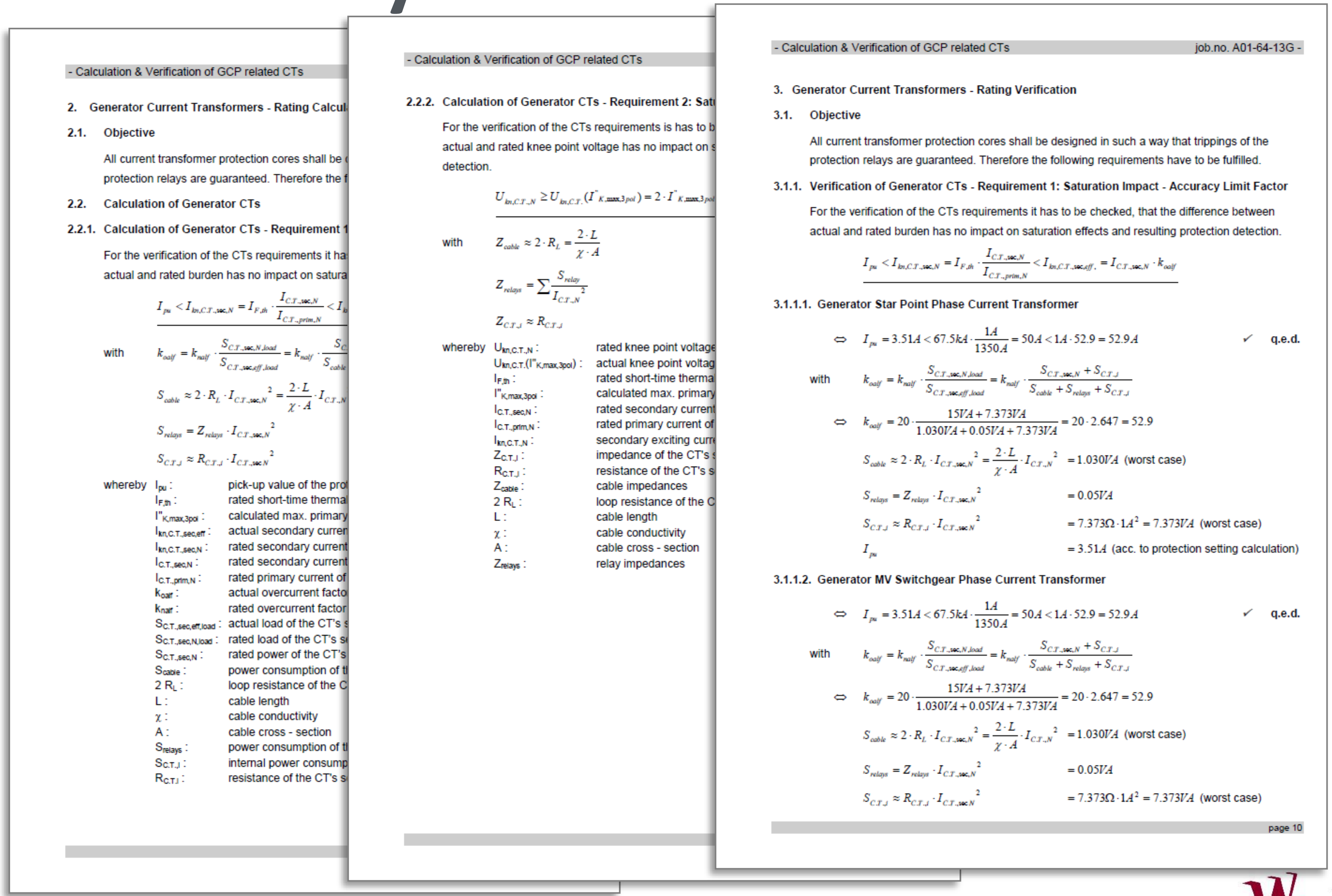
Network Study - Verification of Coordination

- Verification of Selectivity

Network Study - Verification of Current Transformer



- Calculation & Verification of GCP related CTs job.no. A01-64-13G -

3. Generator Current Transformers - Rating Verification

3.1. Objective

All current transformer protection cores shall be designed in such a way that trippings of the protection relays are guaranteed. Therefore the following requirements have to be fulfilled.

3.1.1. Verification of Generator CTs - Requirement 1: Saturation Impact - Accuracy Limit Factor

For the verification of the CTs requirements it has to be checked, that the difference between actual and rated burden has no impact on saturation effects and resulting protection detection.

$$I_{pu} < I_{kn,C.T.,sec,N} = I_{F,th} \cdot \frac{I_{C.T.,sec,N}}{I_{C.T.,prim,N}} < I_{kn,C.T.,sec,eff,} = I_{C.T.,sec,N} \cdot k_{oalf}$$

3.1.1.1. Generator Star Point Phase Current Transformer

$$\Leftrightarrow \quad I_{pu} = 3.51A < 67.5kA \cdot \frac{1A}{1350A} = 50A < 1A \cdot 52.9 = 52.9A \qquad ✓ \quad \text{q.e.d.}$$

with $k_{oalf} = k_{nalf} \cdot \frac{S_{C.T.,sec,N,load}}{S_{C.T.,sec,eff,load}} = k_{nalf} \cdot \frac{S_{C.T.,sec,N} + S_{C.T.,i}}{S_{cable} + S_{relays} + S_{C.T.,i}}$

$$\Leftrightarrow \quad k_{oalf} = 20 \cdot \frac{15VA + 7.373VA}{1.030VA + 0.05VA + 7.373VA} = 20 \cdot 2.647 = 52.9$$

$$S_{cable} \approx 2 \cdot R_L \cdot I_{C.T.,sec,N}^2 = \frac{2 \cdot L}{\chi \cdot A} \cdot I_{C.T.,N}^2 = 1.030VA \text{ (worst case)}$$

$$S_{relays} = Z_{relays} \cdot I_{C.T.,sec,N}^2 = 0.05VA$$

$$S_{C.T.,i} \approx R_{C.T.,i} \cdot I_{C.T.,sec,N}^2 = 7.373\Omega \cdot 1A^2 = 7.373VA \text{ (worst case)}$$

$$I_{pu} = 3.51A \text{ (acc. to protection setting calculation)}$$

3.1.1.2. Generator MV Switchgear Phase Current Transformer

$$\Leftrightarrow \quad I_{pu} = 3.51A < 67.5kA \cdot \frac{1A}{1350A} = 50A < 1A \cdot 52.9 = 52.9A \qquad ✓ \quad \text{q.e.d.}$$

with $k_{oalf} = k_{nalf} \cdot \frac{S_{C.T.,sec,N,load}}{S_{C.T.,sec,eff,load}} = k_{nalf} \cdot \frac{S_{C.T.,sec,N} + S_{C.T.,i}}{S_{cable} + S_{relays} + S_{C.T.,i}}$

$$\Leftrightarrow \quad k_{oalf} = 20 \cdot \frac{15VA + 7.373VA}{1.030VA + 0.05VA + 7.373VA} = 20 \cdot 2.647 = 52.9$$

$$S_{cable} \approx 2 \cdot R_L \cdot I_{C.T.,sec,N}^2 = \frac{2 \cdot L}{\chi \cdot A} \cdot I_{C.T.,N}^2 = 1.030VA \text{ (worst case)}$$

$$S_{relays} = Z_{relays} \cdot I_{C.T.,sec,N}^2 = 0.05VA$$

$$S_{C.T.,i} \approx R_{C.T.,i} \cdot I_{C.T.,sec,N}^2 = 7.373\Omega \cdot 1A^2 = 7.373VA \text{ (worst case)}$$

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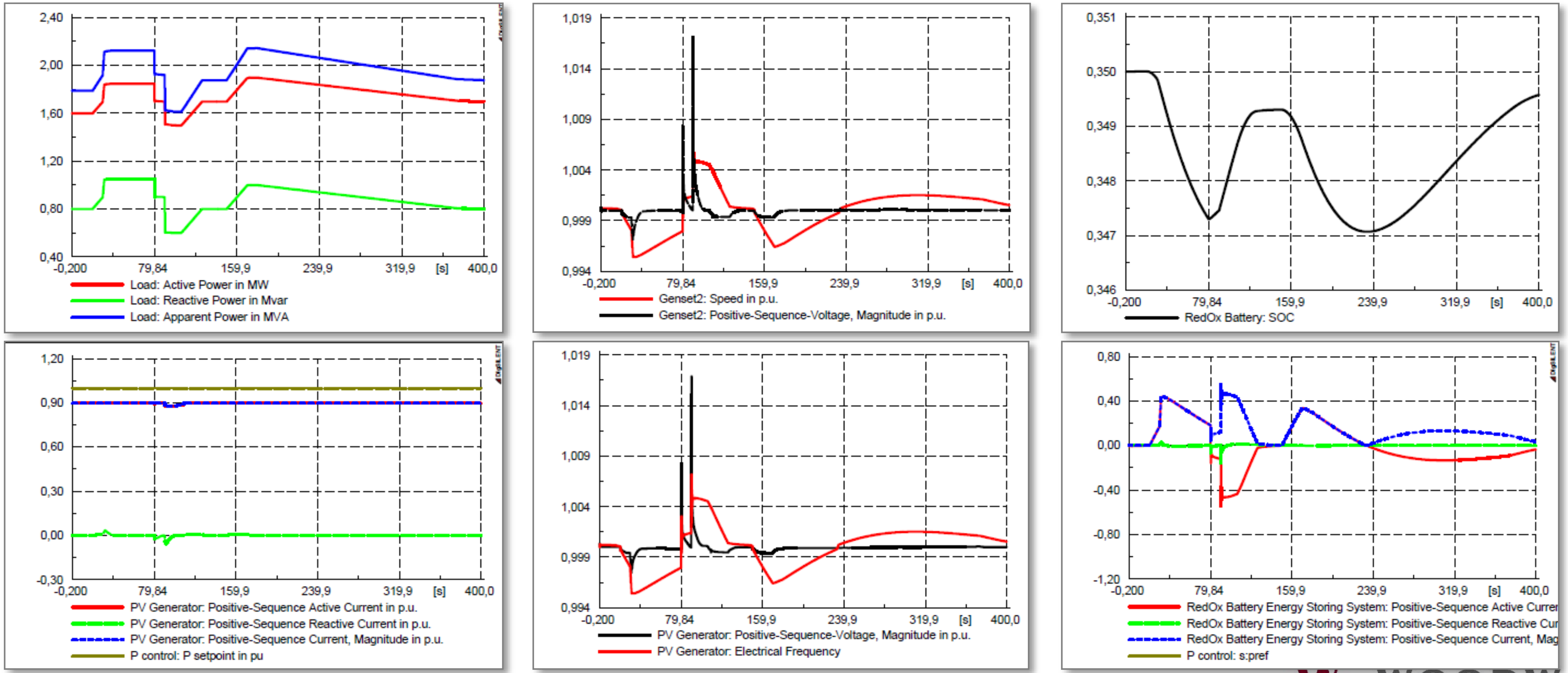
Network Study - Fault Event Simulation

- Simulation of Network Stability / Investigation of Special Events
  (e.g. for critical load steps, loss of generator, loss of power transformer)



Network Study - Some Reference Projects

Project Name	Application	Country	Year
Cementos Progreso SA	Cement Plant	Guatemala	1993
Palma de Mallorca	Airport	Spain	1996
Sharourah Extension	Power Plant	Saudi Arabia	1998
Monte Rio	Power Plant	California	2001
Cap Verde	3x Power Plants	Cap Verde Islands	2001
US Navy Milcon	Naval Base	Bahrain	2002
Sri Lanka	Power Plant	Sri Lanka	2004
Kabul	3x Power Plants	Afghanistan	2007
Collahuasi	Copper Mine (4000m)	Chile	2008
Termomanaus	Power Plant	Argentina	2008
A3	Peak Power Plant	Brazil	2010 - 2011
Rubiales	6x Power Plant	Columbia	2008 - 2011
ONE Tiznit	Power Plant	Marocco	2011
KPS6 - KPS7 - KPS9	Power Ship	Turkey	2009 - 2013
King Abdullah Port	Power Plant	Saudi Arabia	2013
Tabuk Cement	Power Plant	Saudi Arabia	2014
Noonmati PS - Oil India	Crude Oil Power Station	India	2015
Kodda, Desh	2x Power Plants	Bangladesh	2015
Ocensa - Chiquillo	Power Plant	Columbia	2015

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Service & Commissioning: Capabilities

- Erection of Protection & Control System
- Commissioning of Protection & Control System
  - Secondary injection test for validation of protection setting including
    - test of the entire signal chain up to circuit breaker trip test.
    - data logging with Omicron sec. injection test units
    - test reports
- Maintenance incl. Secondary Injection Test
- Retrofit of obsolete Protection Relays & Systems
- Training on Protection & Control Systems
  - On-site training
  - In-house training

Service & Commissioning: Protection Validation

Validation of Protection Settings with secondary Injection Tests on-site.

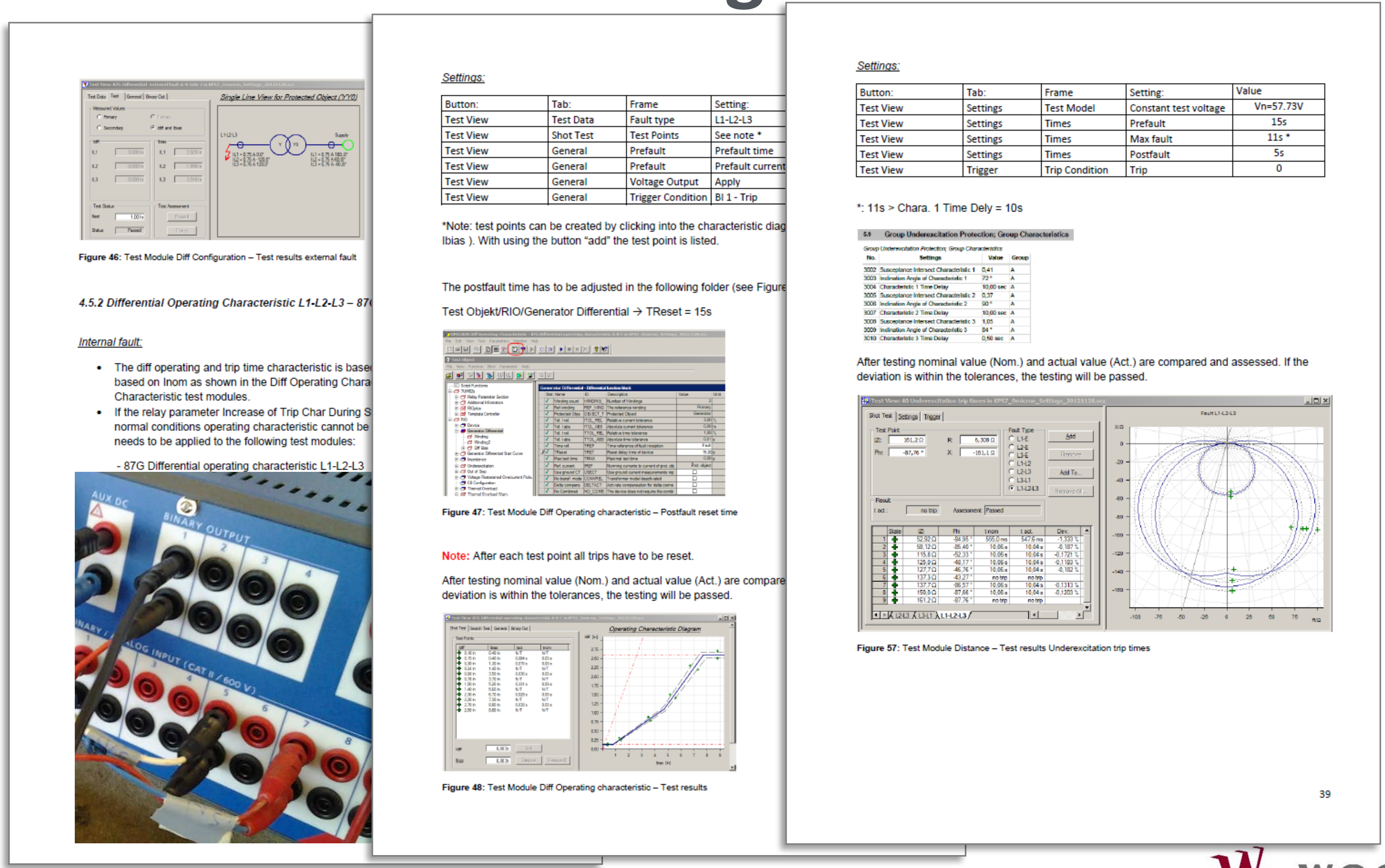

Figure 46: Test Module Diff Configuration – Test results external fault

4.5.2 Differential Operating Characteristic L1-L2-L3 – 87

Internal fault:

- The diff operating and trip time characteristic is base based on Inom as shown in the Diff Operating Chara Characteristic test modules.
- If the relay parameter Increase of Trip Char During S normal conditions operating characteristic cannot be needs to be applied to the following test modules:

  - 87G Differential operating characteristic L1-L2-L3

Settings:

Button:	Tab:	Frame	Setting:
Test View	Test Data	Fault type	L1-L2-L3
Test View	Shot Test	Test Points	See note *
Test View	General	Prefault	Prefault time
Test View	General	Prefault	Prefault current
Test View	General	Voltage Output	Apply
Test View	General	Trigger Condition	BI 1 - Trip

*Note: test points can be created by clicking into the characteristic diag Ibias). With using the button "add" the test point is listed.

The postfault time has to be adjusted in the following folder (see Figure

Test Objekt/RIO/Generator Differential → TReset = 15s

Figure 47: Test Module Diff Operating characteristic – Postfault reset time

Note: After each test point all trips have to be reset.

After testing nominal value (Nom.) and actual value (Act.) are compare deviation is within the tolerances, the testing will be passed.

Figure 48: Test Module Diff Operating characteristic – Test results

Settings:

Button:	Tab:	Frame	Setting:	Value
Test View	Settings	Test Model	Constant test voltage	Vn=57.73V
Test View	Settings	Times	Prefault	15s
Test View	Settings	Times	Max fault	11s *
Test View	Settings	Times	Postfault	5s
Test View	Trigger	Trip Condition	Trip	0

*: 11s > Chara. 1 Time Dely = 10s

After testing nominal value (Nom.) and actual value (Act.) are compared and assessed. If the deviation is within the tolerances, the testing will be passed.

Figure 57: Test Module Distance – Test results Underexcitation trip times

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