



## System Studies Capabilities

December 2017

Company Number 06086450, registered in England & Wales.

# Introduction

- SPE are Power System Consultants that specialise in High Voltage (HV) systems.
- We can undertake a wide range of power system studies:
  - Load flow studies.
  - Short circuit studies.
  - Harmonic analysis.
  - Protection coordination / discrimination.
  - Arc flash analysis.
  - Motor starting studies.
  - Transient and dynamic stability.
  - Electromagnetic transients:
    - Transformer inrush
    - Insulation coordination
    - TRV switching

# Software

- We own and are experts in operating a large number of industry leading analysis software packages, including:
  - ETAP and Digsilent Powerfactory for power system analysis.
  - EMTP, EMTP-ATP and PSCAD for electromagnetic transient analysis.
  - CDEGS for carrying out earthing studies.
  - AMTECH / Trimble HV Protect, which is often useful for small protection coordination studies
- With the above analysis packages we have the capability of analysing virtually any power system phenomena
- If a specific software package is required, please contact us and we can look at potentially purchasing this software to add to our existing capabilities.

# ETAP & Digsilent Overview

- Powerful industry leading software
- One model used for multiple analysis types
- Capable of modelling distribution systems and large transmission systems
- Multiple scenario and configuration manager
- Undertake a wide range of studies
- Detailed models for
  - Switchgear & circuit breakers
  - Transformers
  - Induction and synchronous motors
  - Generators including Exciters / governors
  - Overhead lines
  - Wind turbines & PV panels
  - CTs, VTs and protection relays
  - AC / DC power conversion
  - Plus much more!!

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# EMTP, EMTP-ATP & PSCAD

- Specialist electromagnetic analysis packages.
- These require very experienced engineers to operate as the level of theoretical knowledge and application is much more complex than DigSilent or ETAP.
- Each phase is analysed individually, to consider full self and mutual couplings.
- Analysis can be set down to nano and pico second level.
- Customised control systems and probes can be inserted to any point in the system
- Models of equipment such as VSDs are built ground-up from their base components.
- These packages are used for studies such as:
  - Transformer inrush
  - Switching transients
  - Insulation coordination
  - Transient Recovery Voltage (TRV) analysis

# CDEGS

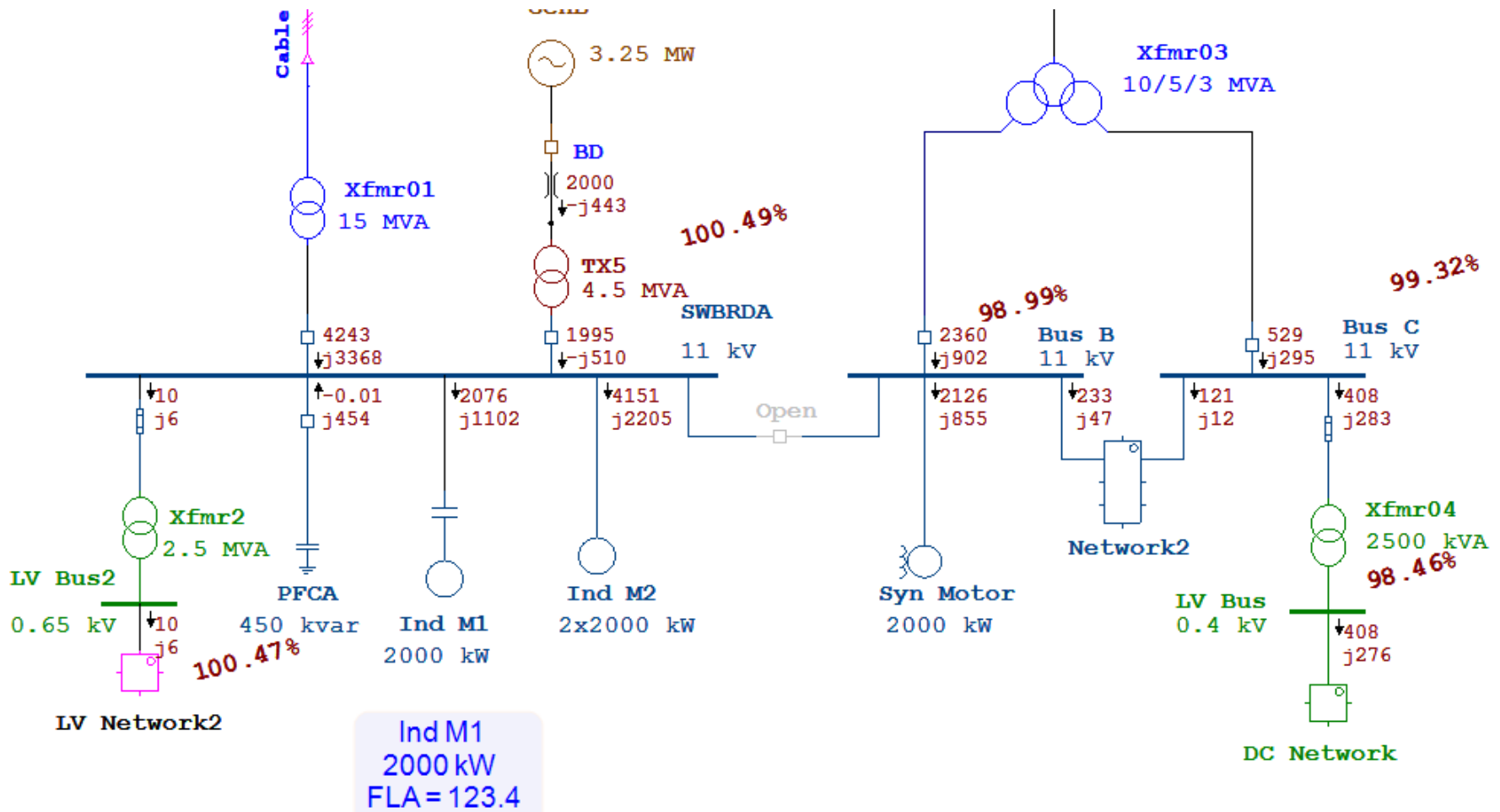
- Specialist earthing analysis package. CDEGS is the industry standard package.
- SPE have licenses for RESAP, FCDIST, MALT, MALZ, TRALIN and SPLITS modules.
- CDEGS allows analysis of any earthing system to calculate key parameters such as:
  - Earth Potential Rise
  - Touch and Step Voltages
  - Tolerable shock limits
  - Induced voltage in nearby pipelines and buried structures
  - Earth fault current distribution in complex networks.

# Load Flow & Equipment Sizing

- Used to validate the basic power system configuration
- Indicate power flows across the system for kW, kVA and kVAR
- Show the system voltage profile
- Select transformer tap settings
- Confirm transformer, switchgear and cable ratings
- Define generator ratings
- Calculate system power factors & need for PFC equipment
- Shows alerts for equipment near capacity and overloaded



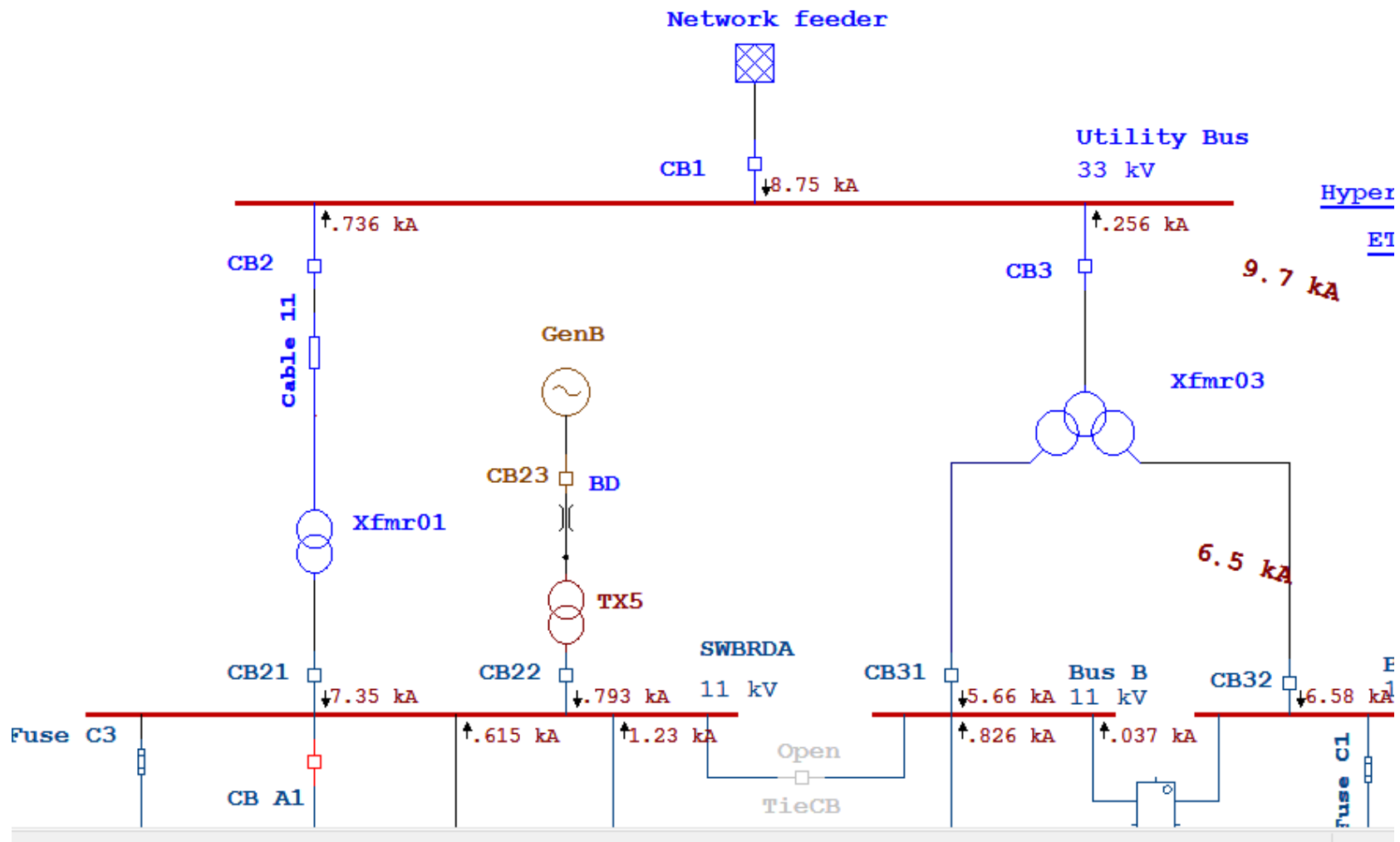
# Load Flow & Equipment Sizing - Sample



# Short Circuit Evaluation

- Studies undertaken to IEC 60909 - equivalent to ENA G74
- Confirm maximum short circuit levels for equipment ratings
- Confirm minimum short circuit levels for protection settings
- Identifies equipment that exceeds its rating
- Multiple fault types
  - 3 phase
  - Phase-earth
  - Phase-phase
  - Phase-phase-earth
- Calculate asymmetric duty and DC component
- More detailed studies possible to IEC 61363
  - AC decrement of generators
  - DC offset
  - Confirmation of fault current passing through current zeroes

# Short Circuit Evaluation - Sample

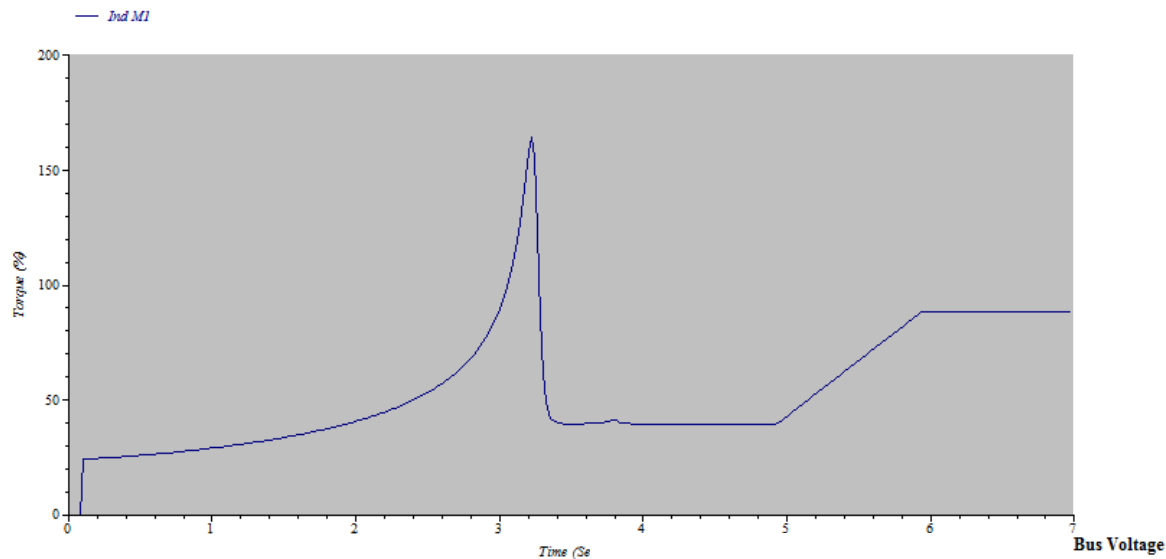


# Motor Starting

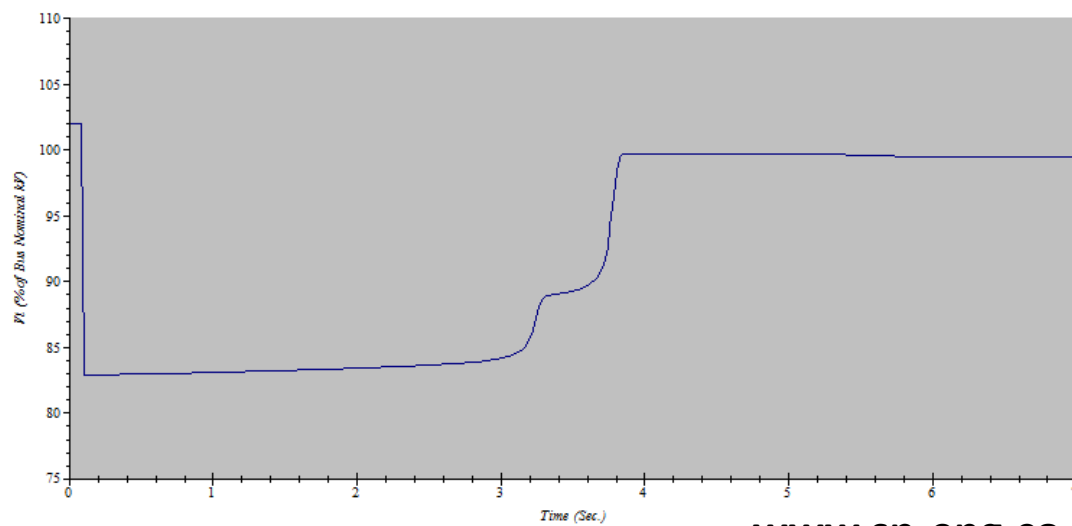
- Motor starting studies can be undertaken statically or dynamically
  - Starting time
  - Torque curves
  - Network voltage depression
- Static Studies
  - Ratio based calculation using short circuit levels
  - Ideal for conceptual design when few details are known
- Dynamic Studies
  - Full modelling of motor type and configuration
  - Full modelling of load torque and inertia details
  - Can model different starting methods: Star-delta, reduced voltage etc..
  - Typical load models included for: Fan, compressor, hoist, pump etc.
  - Considers generators governor and exciter action
  - Graphical representation of motor & load curves

# Motor Starting - Sample

Motor Torque



SWBRDA

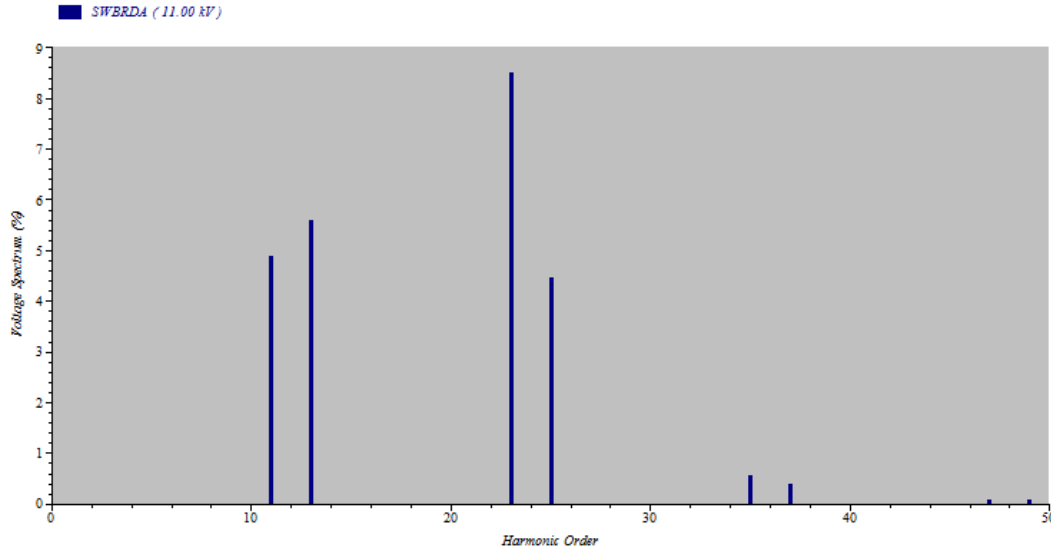


# Harmonic Analysis

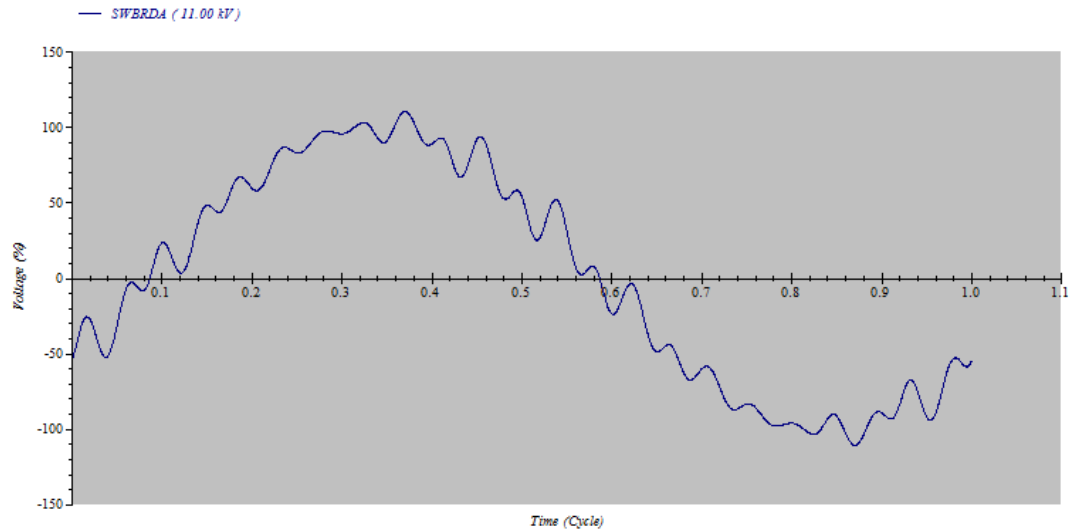
- Used to show compliance with ENA G5/4-1
- Multiple harmonic source models
  - IEEE standards (VSI, LCI, 6-pulse, 12-pulse etc.)
  - Many manufacturer models
- Calculates individual harmonic sources and THD at every required busbar
- Graphical representation of waveform distortion
- Graphical frequency spectrum analysis
- Includes facility to design harmonic filters

# Harmonic Analysis

Spectrum



Waveform



# Reliability Analysis

- Can model all power system elements in availability and reliability figures
- Based on IEEE 493 standard
- Useful for assessing the overall resilience of a power network
- Calculates
  - Failures per year
  - Failure duration
  - Expected Energy Not Supplied
  - Energy Interruption Cost
  - Plus various other metrics



# Reliability Analysis

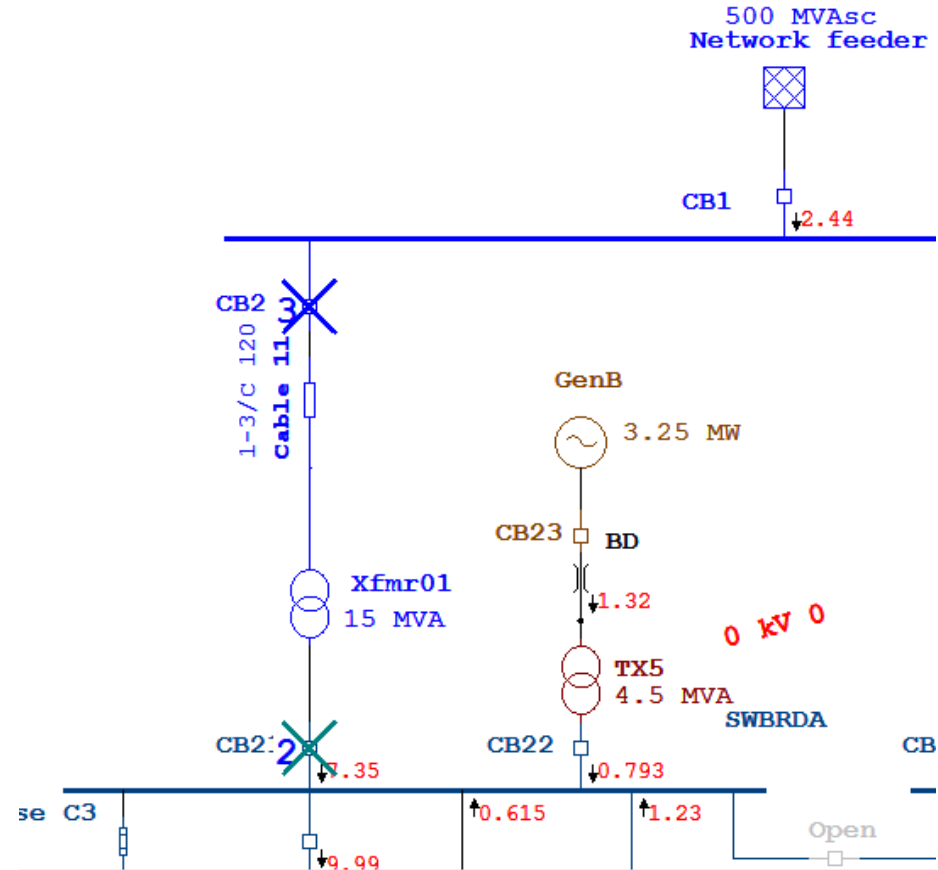
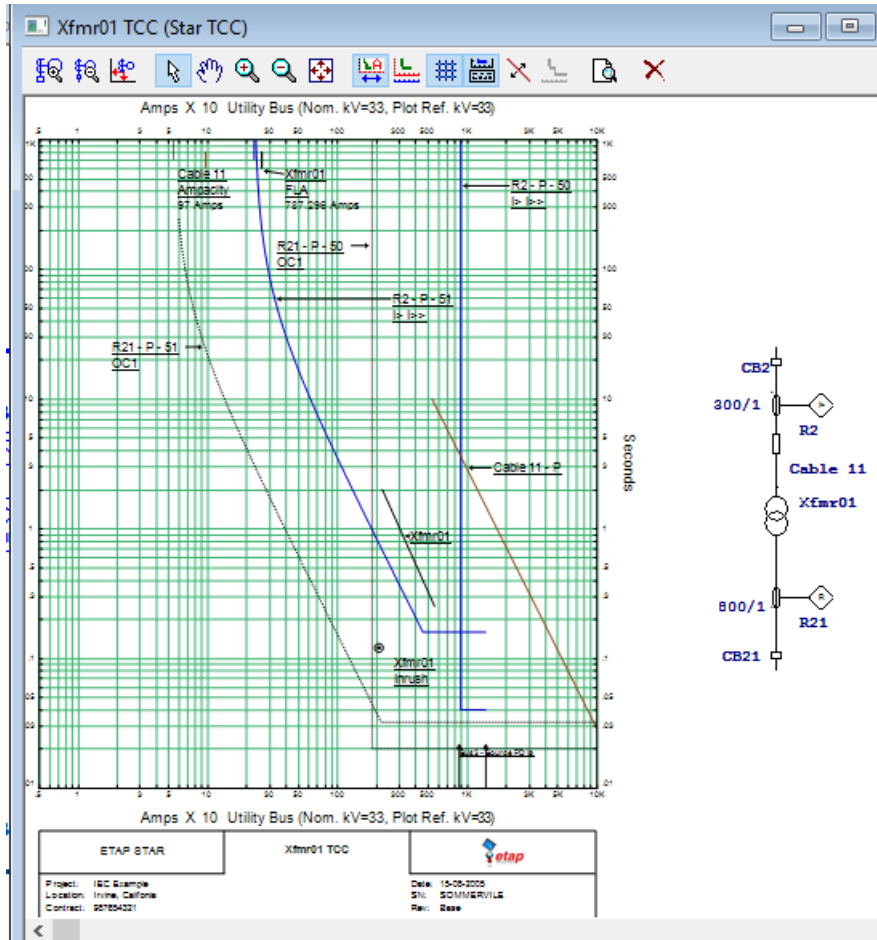
## Load Point Output Report

Bus			Average Interruptin Rate	Average Outage Duration	Annual Outage Duration	EENS	ECOST	IEAR
ID	Load Sector	Connected Bus ID	f / yr	hour	hr / yr	MW hr / yr	\$ / yr	\$ / kW hr
Bus B	N/A		0.0867	122.56	10.6312	22.6045	288407.30	12.759
Bus C	N/A		0.0682	149.26	10.1862	0.0000	0.00	0.000
Bus3	N/A		0.0388	87.23	3.3806	0.0000	0.00	0.000
Bus5	N/A		0.1457	101.88	14.8482	0.1438	0.00	0.000
Bus6	N/A		0.7056	200.90	141.7504	0.0000	0.00	0.000
EmergencySwBrd	N/A		0.2092	109.87	22.9902	9.4786	0.00	0.000
LV Bus	N/A		0.1052	165.22	17.3882	0.0000	0.00	0.000
LV Bus2	N/A		0.1397	101.52	14.1862	0.0000	0.00	0.000
MCC1	N/A		0.1327	147.90	19.6332	4.6431	985.05	0.212
Swbrd2	N/A		0.1082	166.18	17.9882	2.2058	0.00	0.000
SWBRDA	N/A		0.1025	67.90	6.9574	43.3249	328507.40	7.582
Utility Bus	N/A		0.0144	64.93	0.9380	0.0000	0.00	0.000
Mtr6	Agricultural	MCC1	0.1557	136.33	21.2332	2.0725	1065.34	0.514
Ind M1	Industrial	SWBRDA	0.1078	95.48	10.2973	21.3770	162583.40	7.606
Ind M2	Industrial	SWBRDA	0.1025	67.90	6.9574	28.8815	218991.20	7.582
Syn Motor	Commercial	Bus B	0.0882	120.98	10.6762	22.7002	289578.70	12.757
COM_B_Static	None	EmergencySwBrd	0.2092	109.87	22.9902	1.4668	0.00	0.000
COM_A_Static	None	EmergencySwBrd	0.2092	109.87	22.9902	2.0746	0.00	0.000

# Protection Studies

- Allows modelling of complex network protection
- Can model multiple protection elements including CTs, VTs and relays
- Manufacturer relay models
  - ABB, Alstom, Schneider, Siemens, Etc..
- Multiple stages of overcurrent and earth fault coordination
- Advanced protection functions
  - Directional protection
  - Voltage restrained overcurrent
  - Differential protection
- Fault insertion and step-by-step breaker tripping sequence
- Sequence of operation analysis

# Protection Studies - Example



# Arc Flash Evaluation

- Arc fault studies are becoming increasingly common to help increase operator safety.
- ETAP arc-flash is integrated with the protection & short circuit modules and considers actual fault current and protection clearing times.
- Studies evaluate risk to operator for arcing faults.
- Determination of fault clearance time and incident energy calories/m<sup>2</sup>
- Used to determine requirements for Personnel Protective Equipment
- Studies based on IEEE 1584 or NFPA 70

# Arc Flash Evaluation

Project: IEC Example  
 Location: Irvine, California  
 Contract: 987654321  
 Engineer: OTI  
 Filename: EXAMPLE -IEC

**ETAP**  
 12.6.5C

Study Case: Duty909

Page: 1  
 Date: 14-08-2015  
 SN: SOMMERVILE  
 Revision: Base  
 Config.: Normal

This is the remarks first line and it appears in the header of every report.

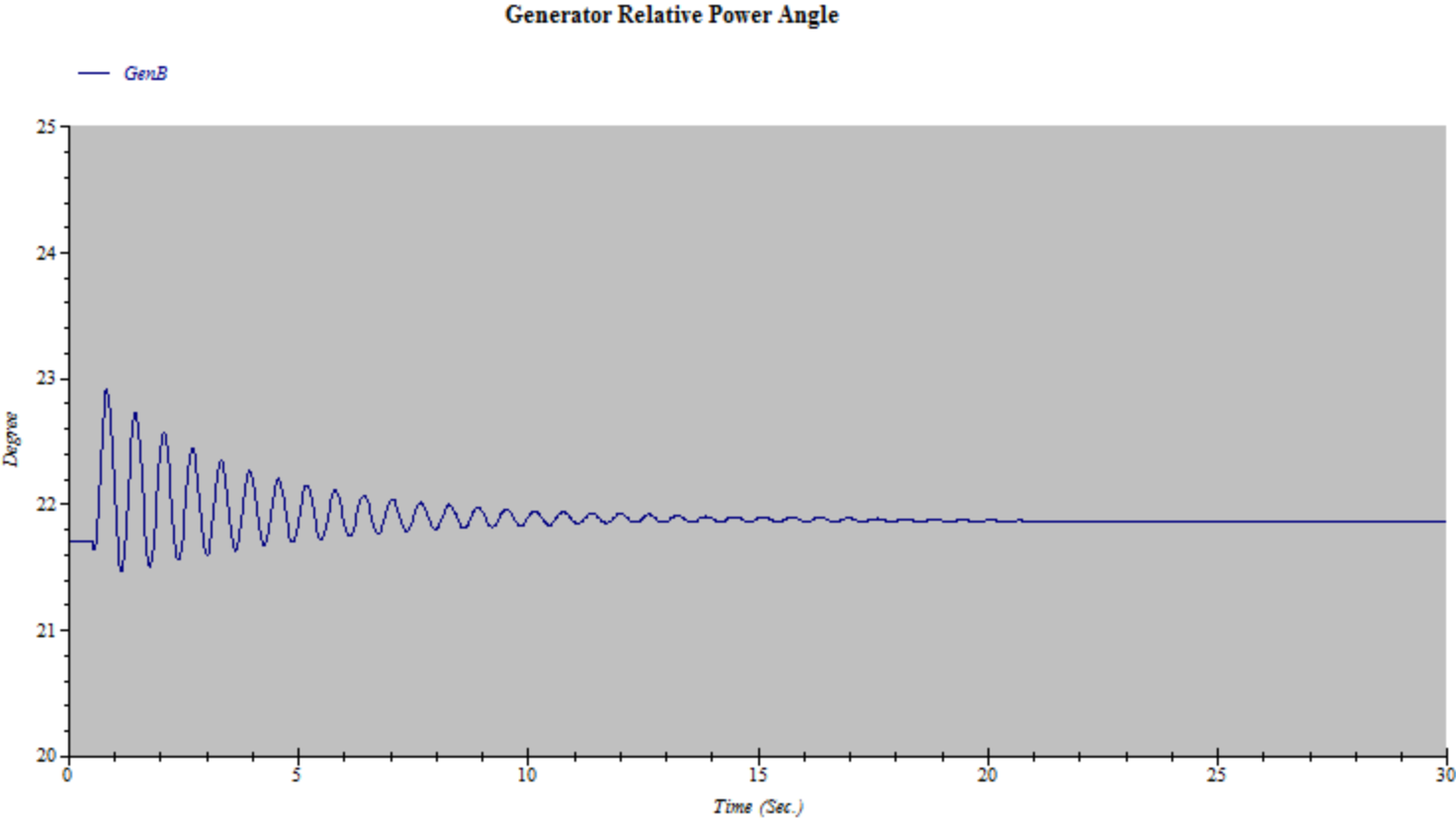
## Incident Energy Summary

Bus			Total Fault Current (kA)		Arc-Flash Analysis Results				
ID	Nom. kV	Type	Bolted	Arcing	FCT (cycles)	Incident E (cal/cm <sup>2</sup> )	AFB (m)	Energy Level	
Bus B	11.000	Switchrack	6.525	6.379	5.000	0.791	0.60	Level A	
Bus C	11.000	Switchrack	6.583	6.435	3.600	0.746	0.56	Level A	
# Bus3	33.000	Other	9.473	9.473	4.750	72.765	3.57	Level F	
Bus5	0.650	Other	17.536	17.421	0.500	204.172	0.33	>Max.	
EmergencySwBrd	0.400	Switchboard	51.106	20.191	3.000	3.506	1.26	Level B	
LV Bus	0.400	Switchboard	51.106	17.162	13.160	12.903	3.06	Level D	
MCC1	0.400	Other	41.775	18.491	17.500	25.052	2.09	Level E	
Swbrd2	0.400	Other	40.904	18.178	11.500	16.162	1.68	Level D	
SWBRDA	11.000	Switchgear	9.987	9.693	69.982	17.406	14.28	Level D	
# Utility Bus	33.000	Open Air	9.739	9.739	15.711	61.861	6.58	Level F	

# Transient Stability

- Used to show any transient event
  - Connection of large loads
  - Loss of main generator(s)
  - Loss of utility connections
  - Trip of main power interconnectors
  - Trip of large motors (load rejection)
- Can be used to define load shedding groups
- Can be used to define motor reacceleration schemes
- Calculate Critical Clearing Times (CCT)

# Transient Stability - Example

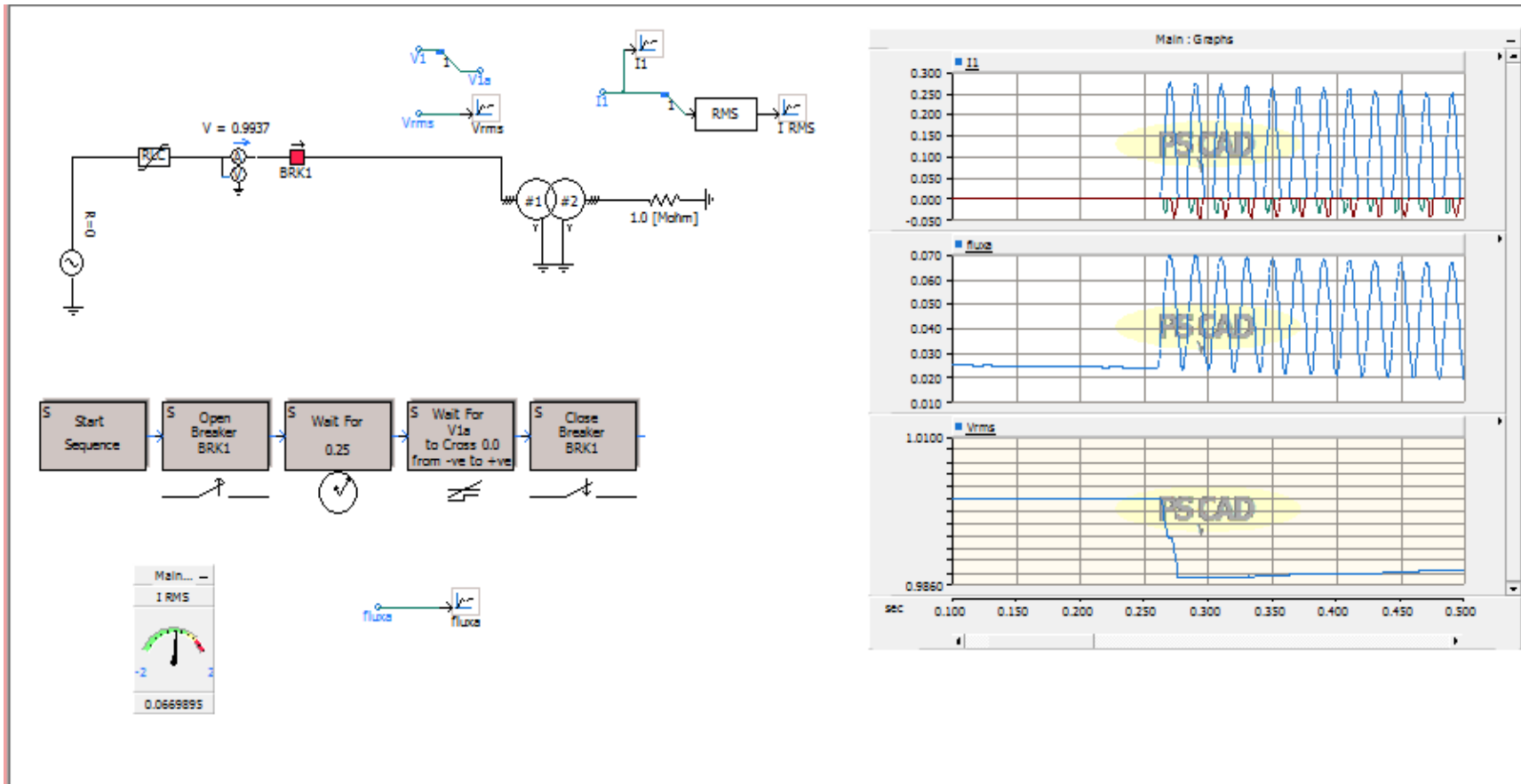


# Transformer Inrush

- Transformer inrush current can cause a significant voltage sag on the network, leading to performance issues.
- DNO's often require energisation studies to confirm the magnitude of the voltage sag.
- ENA standard P28 applies to transformer energisation, and states the total voltage sag should be less than 3%.
- These studies should be undertaken early and not treated as a formality, as problems can be expensive to fix – additional switchgear & PIRs!
- Detailed inrush calculations are difficult and require a lot of information from the transformer manufacturer



# Transformer Inrush - Example

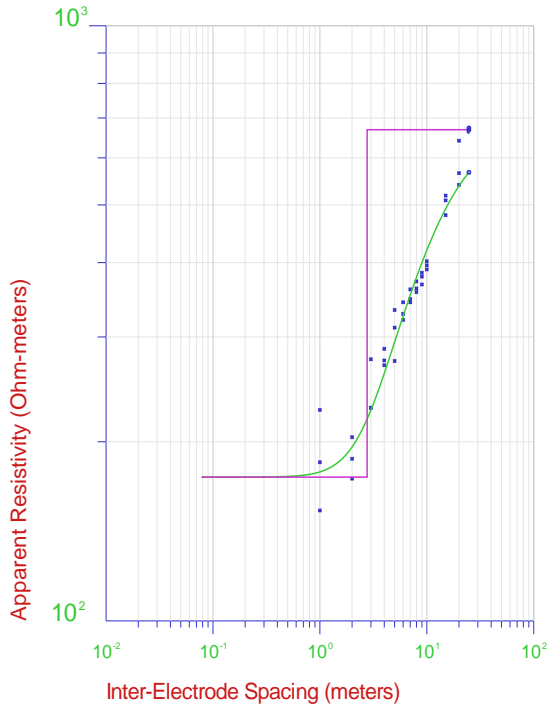


# Earthing Studies

- We undertake studies using the industry standard package CDEGS.
- SPE are familiar with UK, IEC and IEEE approaches.
- CDEGS is an enormously powerful earthing simulation suite that can model virtually any earthing system.
- Different conductor and earth rod models.
- Can construct detailed 3D earth grid to match site layout.
- Multi-layer soil model and modelling of individual soil volumes for bentonite and maronite.
- Can calculate induced voltage in buried pipelines and structures.
- Calculation of actual and tolerable touch and step voltages.
- Considers X/R ratio and fault current decrement.

# Earthing Studies - Example

Metric/Logarithmic X and Y



**LEGEND**

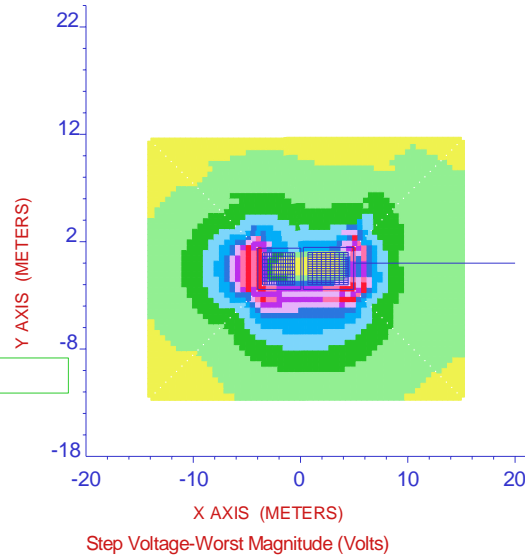
- Measured Data
- Computed Results Curve
- Soil Model

Measurement Method...: Wenner  
 RMS error.....: 7.909%

Layer Number	Resistivity (Ohm-m)	Thickness (Meters)
1	Infinite	Infinite
2	174.4569	2.767606
3	668.9155	Infinite

RESAP-Bonnet Bank >

Single-Electrode/Step Voltages (Spherical)/Worst Spherical (ID/Bwlichgwyt)



**LEGEND**

Maximum Value : 1116.383  
 Minimum Value : 1.866

- < 1116.38
- < 1004.93
- < 893.48
- < 782.03
- < 670.58
- < 559.12
- < 447.67
- < 336.22
- < 224.77
- < 113.32

# Summary

- SPE is a consultancy that specialises in Power System Analysis.
- We operate ETAP, Digsilent Powerfactory, EMTP, EMTP-ATP, PSCAD and CDEGS.
- We can study virtually any power system phenomena.
- Our philosophy is: Your success is integral to our success.
- We pride ourselves on offering accurate and detailed reports with clear advice.
- Our senior consultants are all experienced, degree qualified, chartered engineers.
- We have an innovative business model that keeps prices competitive.
- We can work on a fixed price or reimbursable basis.
- Our website has many additional details: [www.sp-eng.co.uk](http://www.sp-eng.co.uk)

# Questions

- How can we help you?
- Current opportunities?
- Schedule dates to follow up the presentation?