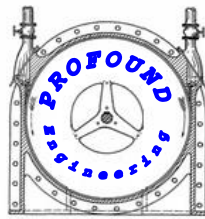




The design of substations for interconnecting power plants to the grid

Presented by: Johan van Zyl Pr. Eng.



What will we discuss?

- Why is this topic relevant?
- What qualifies as a Power Plant?
- Different types of Substations
- Why is there different design criteria for distribution substations to generation substations?
- Legislation affecting generation substations
- Load Flow Studies
- Fault Studies
- Transient Stability Studies
- Protection requirements
- Commissioning



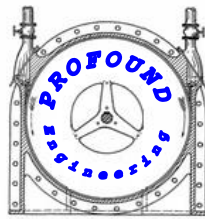
Why is this topic relevant?

- Shortfall of generation capacity
 - Not just a South African problem
- Financing of large power plants
 - Leads to more but smaller power plants being constructed
- Co-generation
- Wind farms
- Own generation

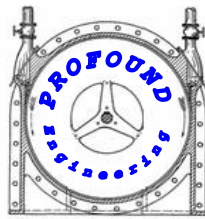
Thermal Power Plants



Co-generation Power Plants



Co-generation Power Plants



Hydro Power Plants



Hydro Power Plants



Diesel Power Plants

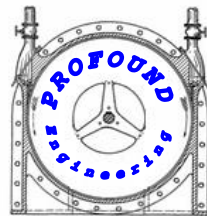


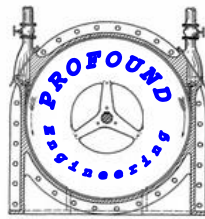
Diesel Power Plants



INTERNATIONAL T&D CONFERENCE ON ADVANCES IN SUBSTATION DESIGN™

Gas Power Plants

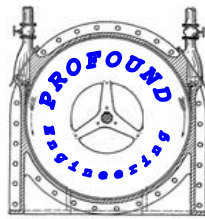




Natural Gas Power Plants



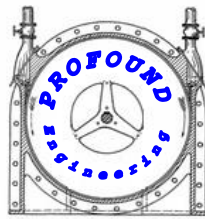
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Different types of Substations



- Any MV (6.6kV – 33kV) switchgear combination
- Any HV (66kV – 132kV) switchgear combination
- Any EHV (275kV – 700kV) switchgear combination



Different types of Substations



Different types of Substations





Why is there different design criteria for distribution substations to generation substations?

Distribution Substations

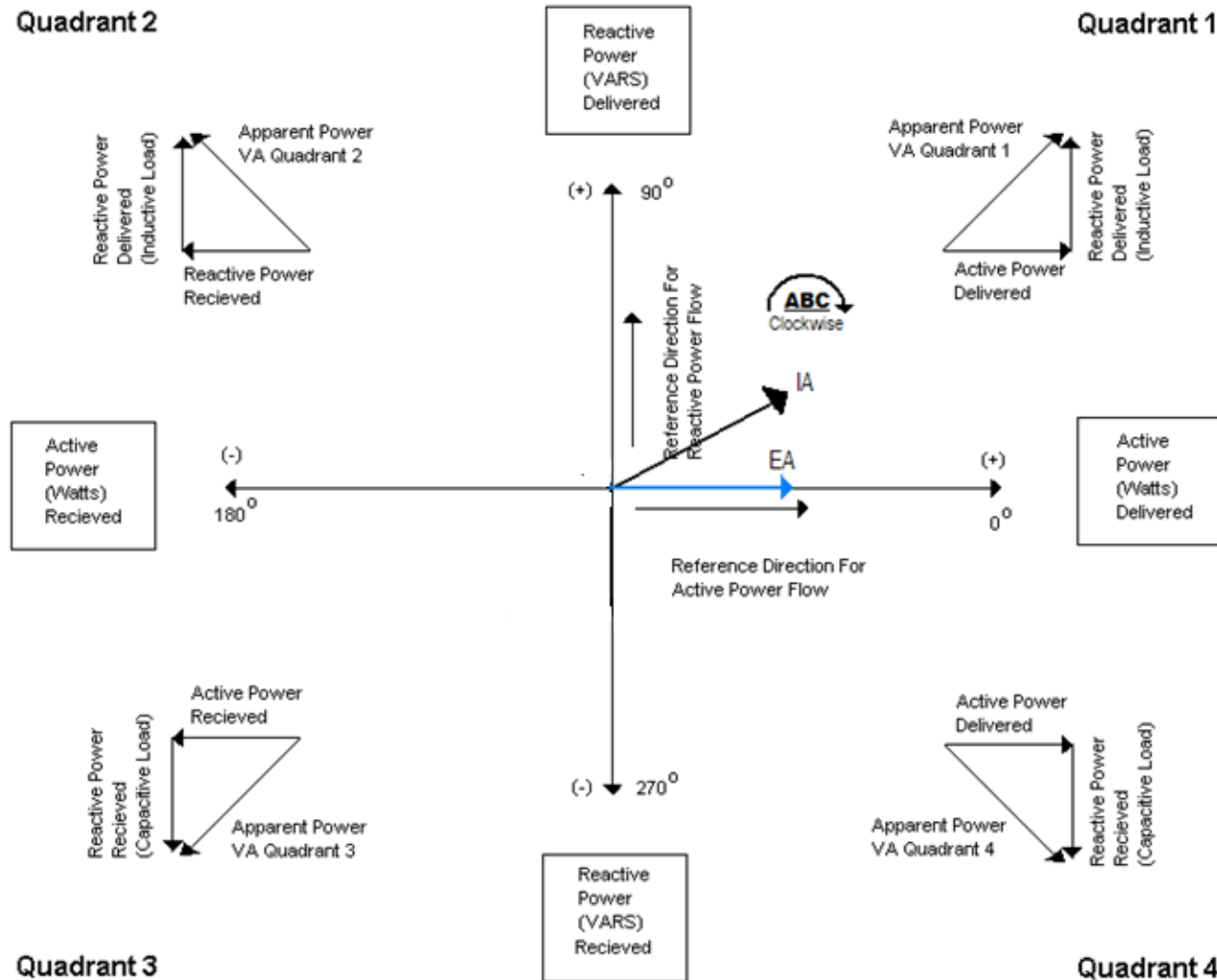
- Interconnects Loads to the Grid
- Current has a one directional flow into the substation
- Power flow can only be in maximum two quadrants

Generation Substations

- Interconnects Generators to the Grid
- Current can flow in both directions; thus in and out of substation
- Power Flow can be achieved in all four quadrants



Why is there different design criteria for distribution substations to generation substations?





Why is there different design criteria for distribution substations to generation substations?

Distribution Substations

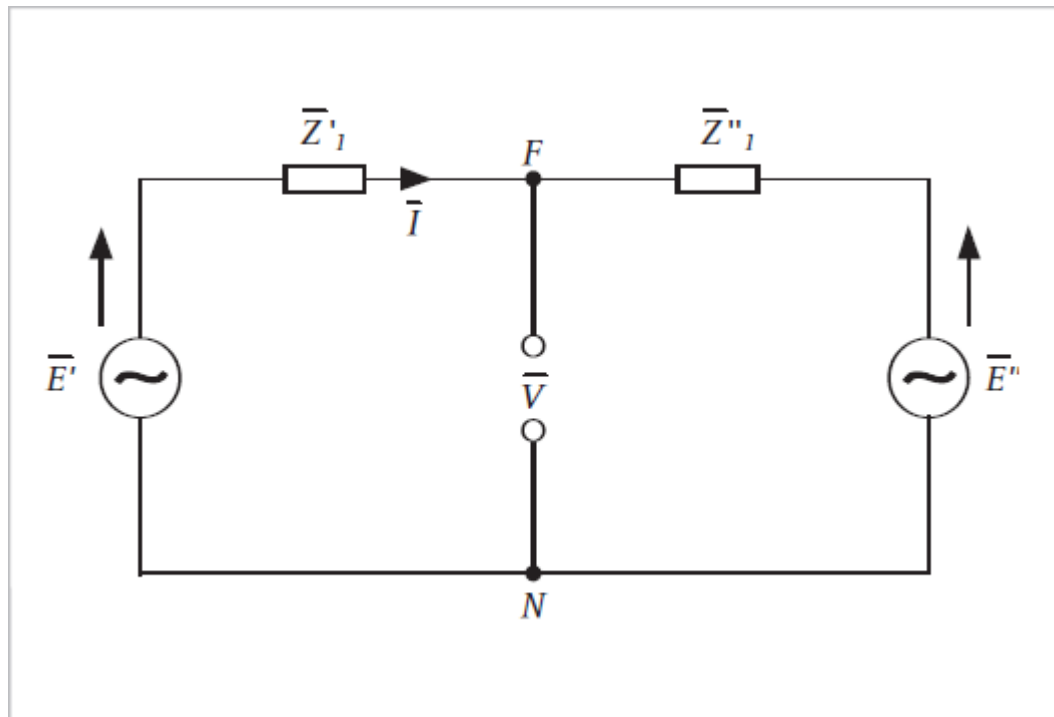
- Fault level dependant on Grid fault level only
 - Fault level depends on the maximum possible current that could flow into the fault from the source (Grid)
 - Fault currents are reduced by the impedance of the Overhead Line, Cables and Transformers feeding the substation

Generation Substations

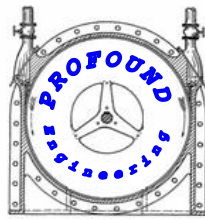
- Fault level is a combination of the Grid and Power Plant fault levels
 - Fault level depends on the maximum possible current that could flow into the fault from the source (Grid)
 - PLUS
 - Maximum possible current from the Generator/s; This current is NOT equal to the Generator Full Load Current (FLC) – typically 6 -8 times FLC



Network with a Fault at “F”



$$\bar{I}_f = -\Delta \bar{I} = \bar{V} \frac{(\bar{Z}'_1 + \bar{Z}''_1)}{\bar{Z}'_1 \bar{Z}''_1}$$



Why is there different design criteria for distribution substations to generation substations?

Distribution Substations

Generation Substations

- On interconnected “Own” or co-generation facilities, this becomes problematic from a protection stability concept.
 - Power plant is not always on while load is on – thus changing fault levels, which complicates protection grading
 - Protection must cater for both scenarios



Why is there different design criteria for distribution substations to generation substations?

Distribution Substations

- Phasing needs to be done once only if correct impossible to close circuits out of Synchronism
- Auto Reclose is fairly simple and multiple shots can be made

Generation Substations

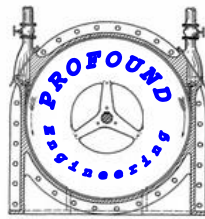
- Circuits can be interconnected out of Synchronism with each other
- Auto Reclosing difficult to achieve since the generators could loose synchronism with Grid

Legislation affecting generation substations



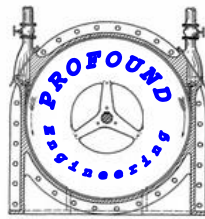
- **South African Legislation**
 - OHS Act 85 of 1993 as amended
 - Grid Code
 - Governance Code
 - **Network Code**
 - Systems Operations Code
 - **Metering Code**
 - Transmission Tariff Code
 - Information Exchange Code
 - Generation Licence
 - Apply with Eskom for Permission to Interconnect to the Grid

Legislation affecting generation substations



- **Network Code**

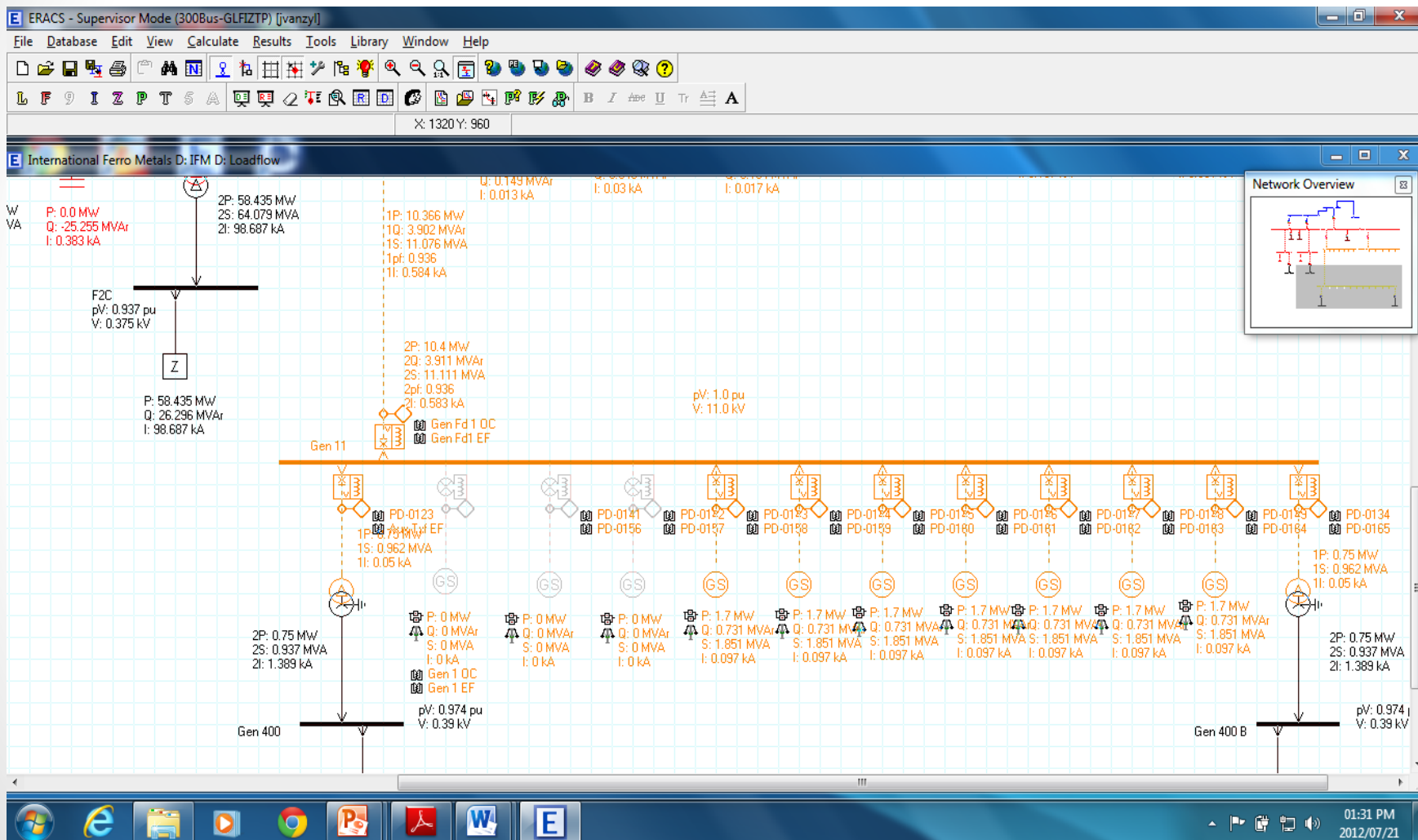
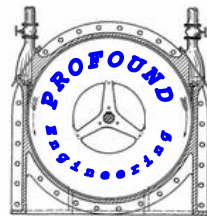
- Service provider design and service level requirements
- Equipment design standards
- Clearances
- CT and VT ratios, accuracies and cores
- Standard busbar arrangements and security criteria
- Motorized isolators
- Earthing and surge protection
- Telecontrol
- Transformer tap change
- Substation drawings
- Recorders
- HV yard breaker operating times and synchronisation facilities
- Fault levels
- Protection requirements

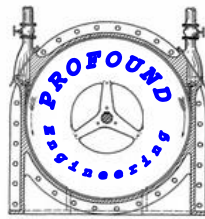


Load Flow Studies

- Selection of transformer tap changer settings
- System voltage profiling
- System loss optimisation
- MW and MVAR power flow analysis
- Equipment loading factors
- Power factor correction location and optimisation
- This information is used for
 - system planning
 - generator operating procedures
 - equipment specification
 - impact load studies
 - circuit reconfiguration studies
 - power generation planning

Load Flow Studies



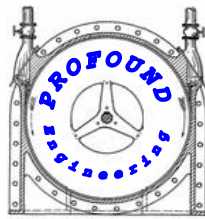


Fault Studies

- Calculation of data for circuit breaker and switchgear ratings (maximum and minimum 3 phase fault currents)
- Calculation of data for relay and fuse selection and setting
- Calculation of motor fault contribution (this is virtually impossible to do manually)
- Calculation of generator fault contribution
- Determination of fault current distribution and busbar-voltage levels during a fault
- Faults to be analysed
 - 3 Phase Faults
 - Phase to Phase Faults
 - Single Phase to Earth
 - Two Phase to Earth
 - Single Phase Open Circuit
 - Two Phase Open Circuit



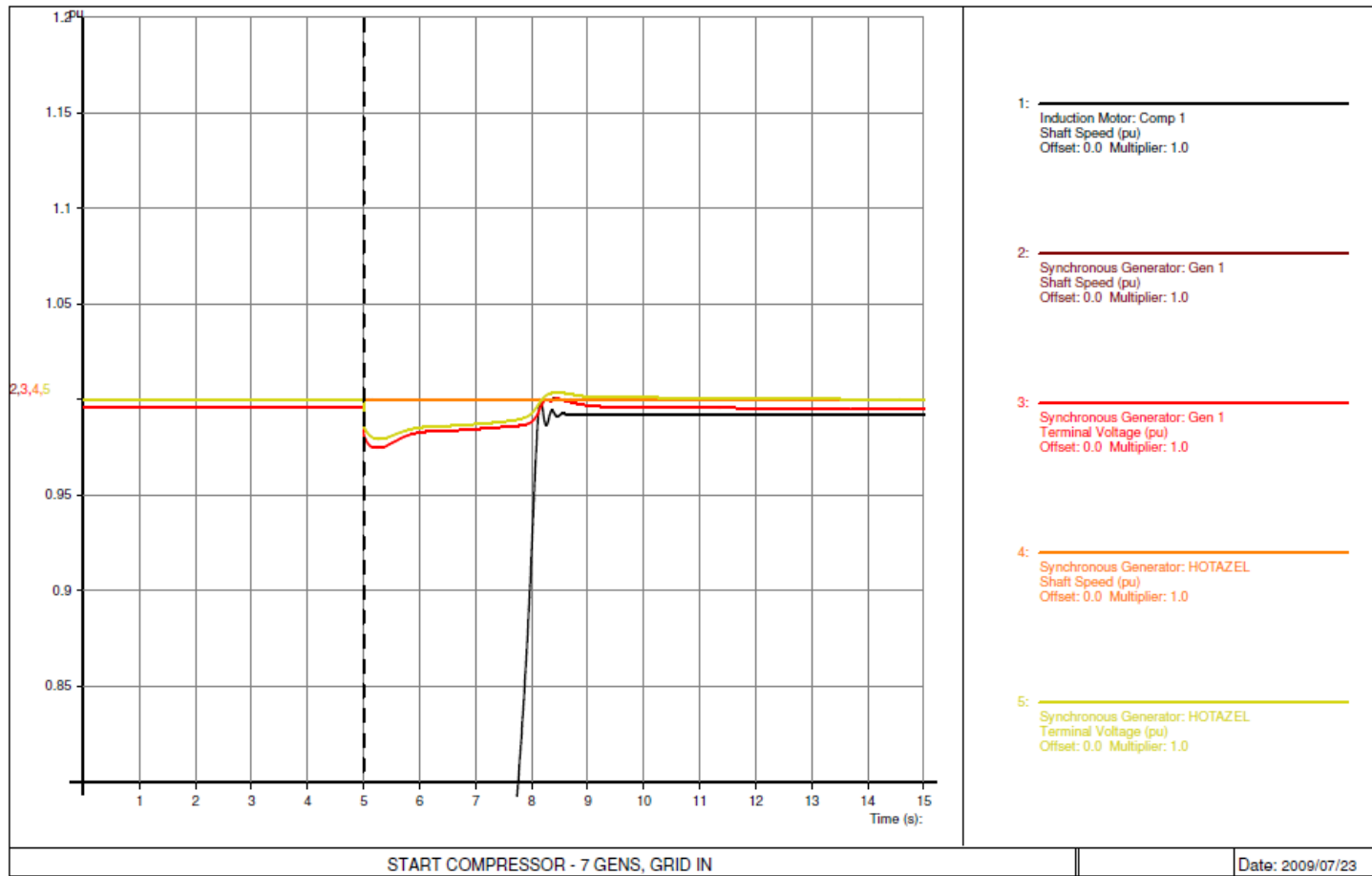
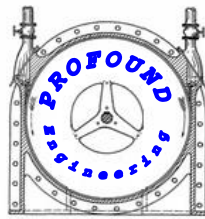




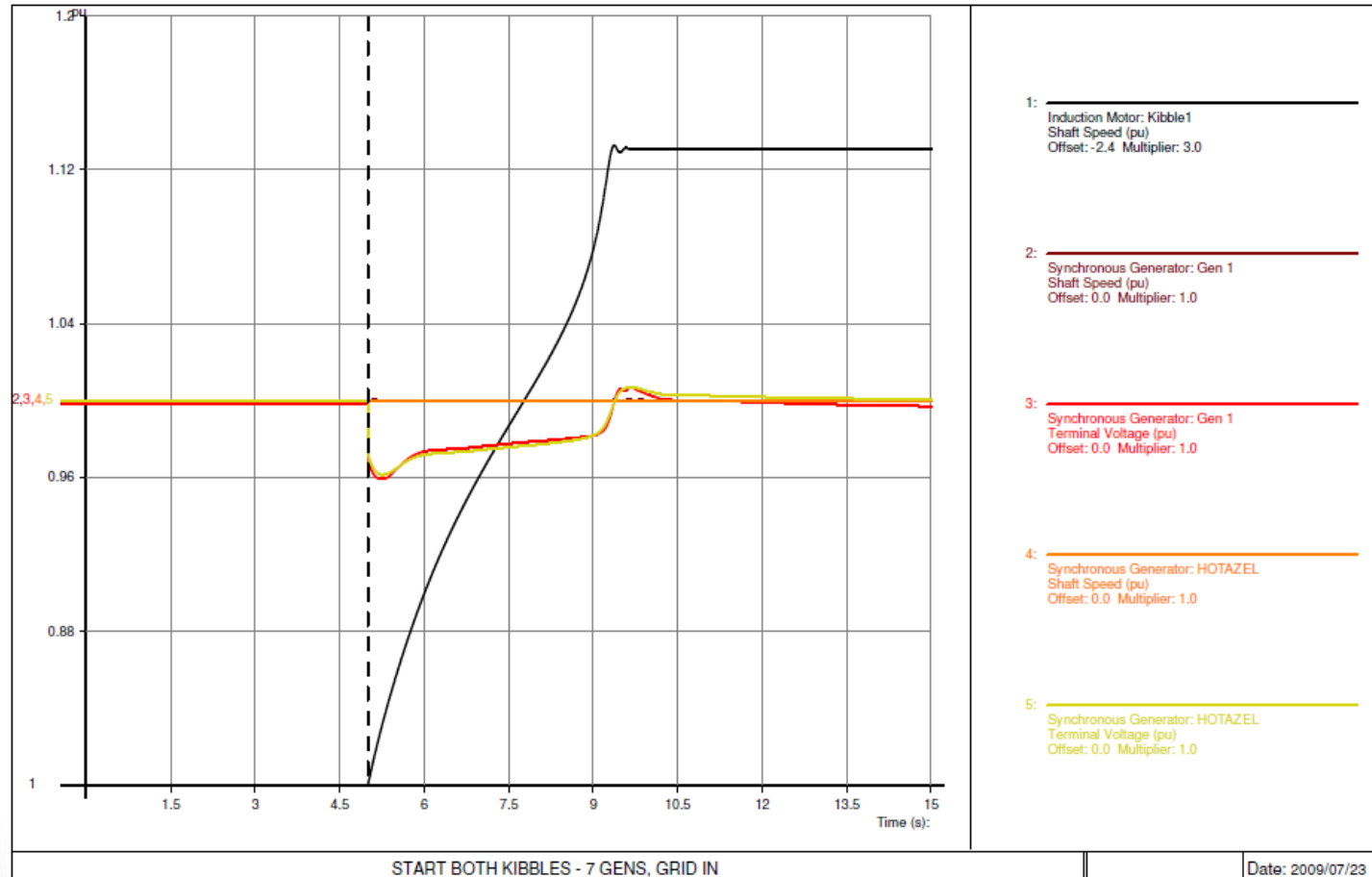
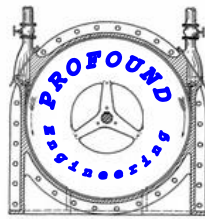
Transient Stability Studies

- Network upset conditions effect on equipment
- Voltage variations during starting and stopping of generators
- Voltage variations under fault conditions
- Voltage variations under starting and stopping of large motors or loads
- Effects on generators for faults elsewhere

Start Compressor with Grid Supply

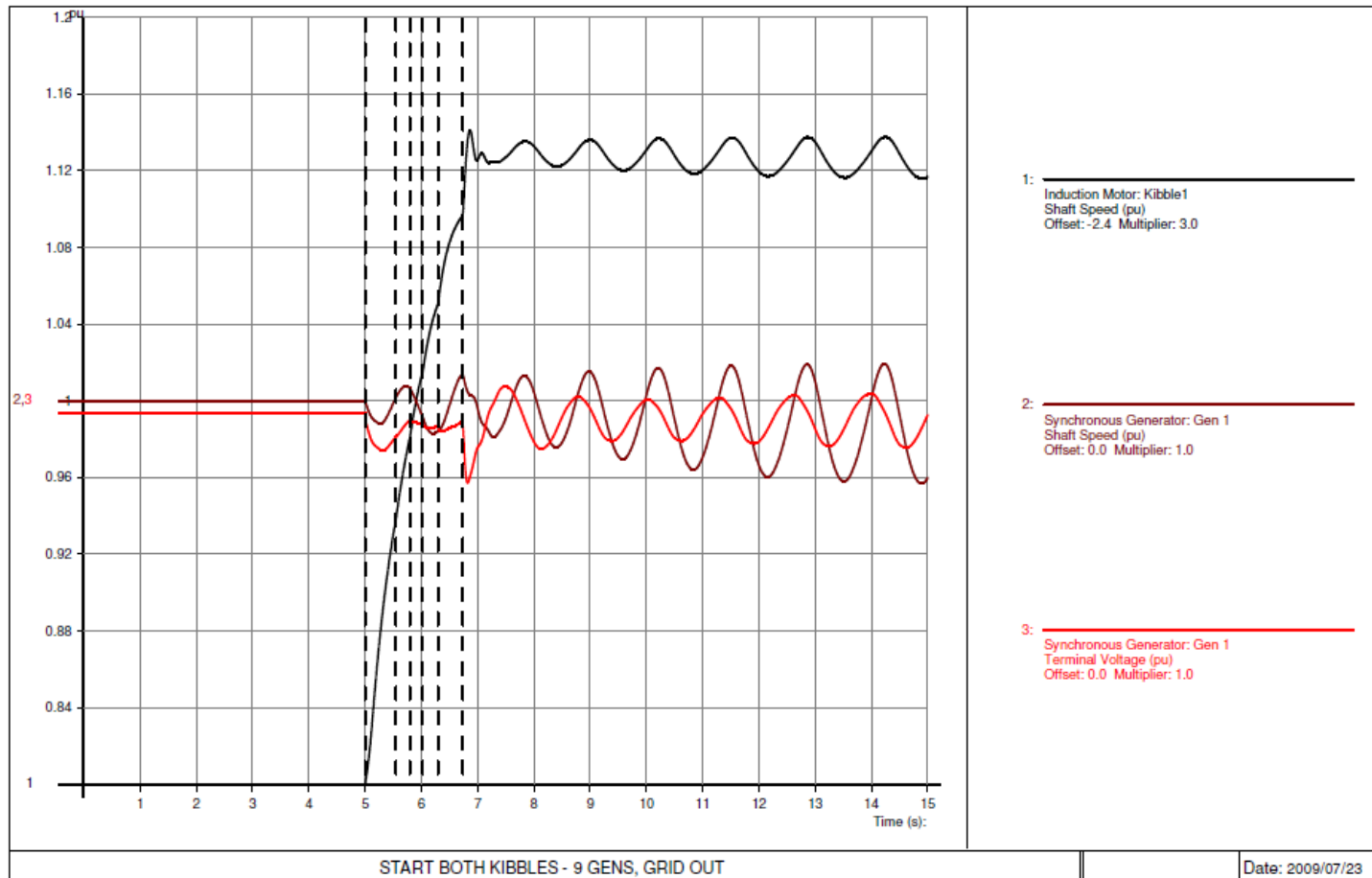


Start Both Kibble Winders with Grid Supply



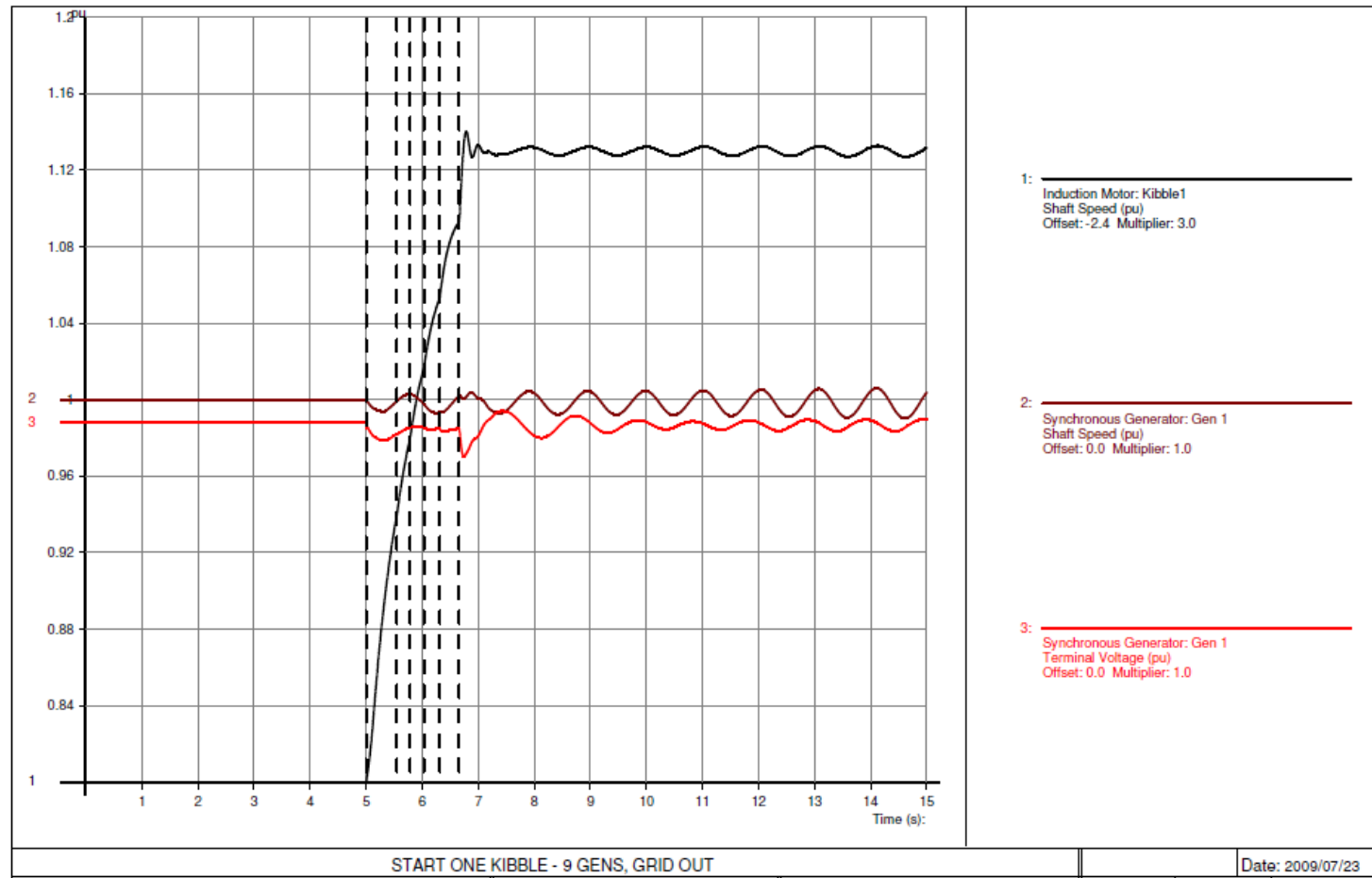


Start Kibbles without Grid



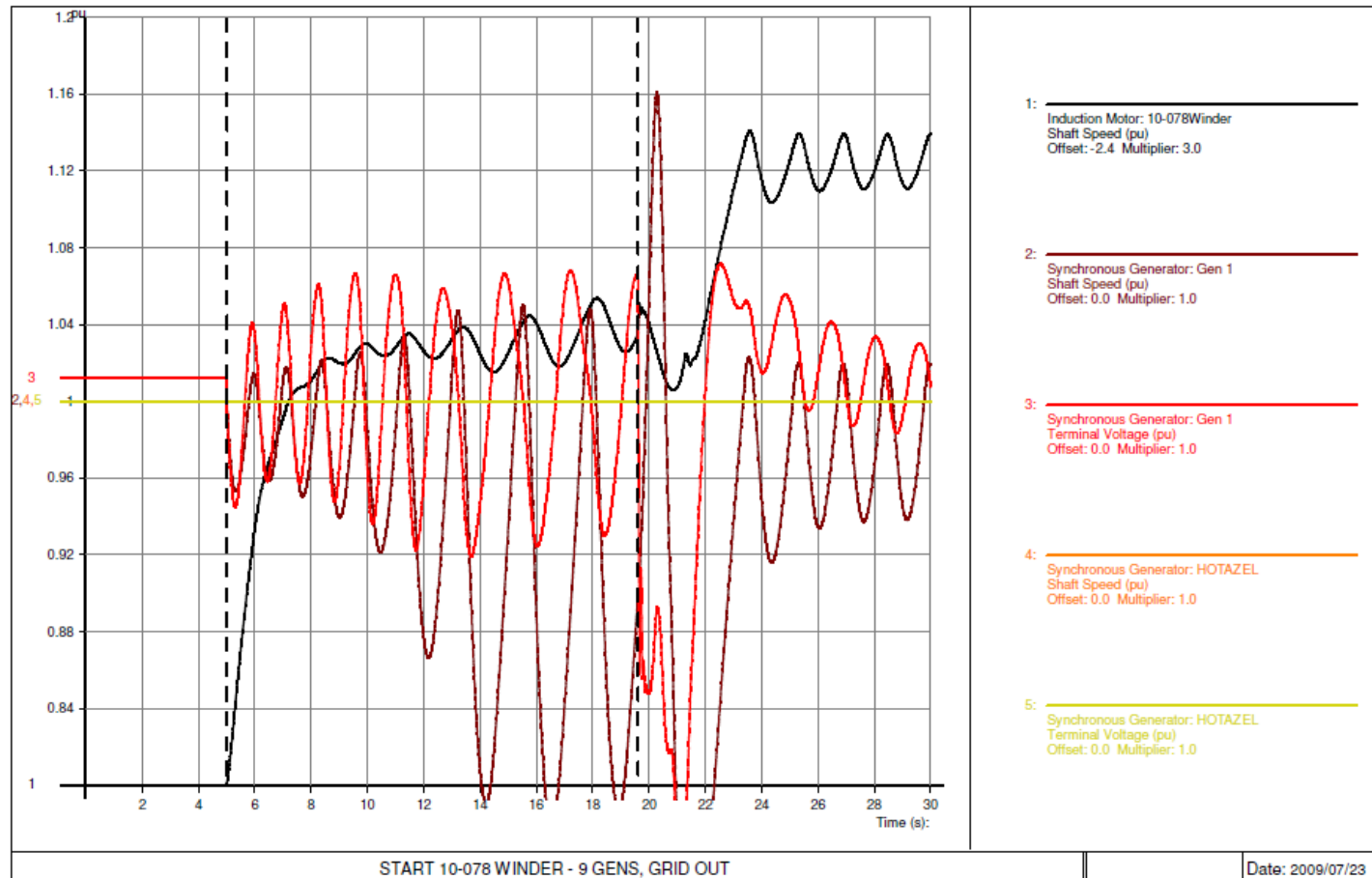


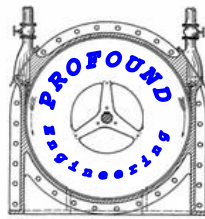
Start one Kibble – No Grid





Start Winder without Grid

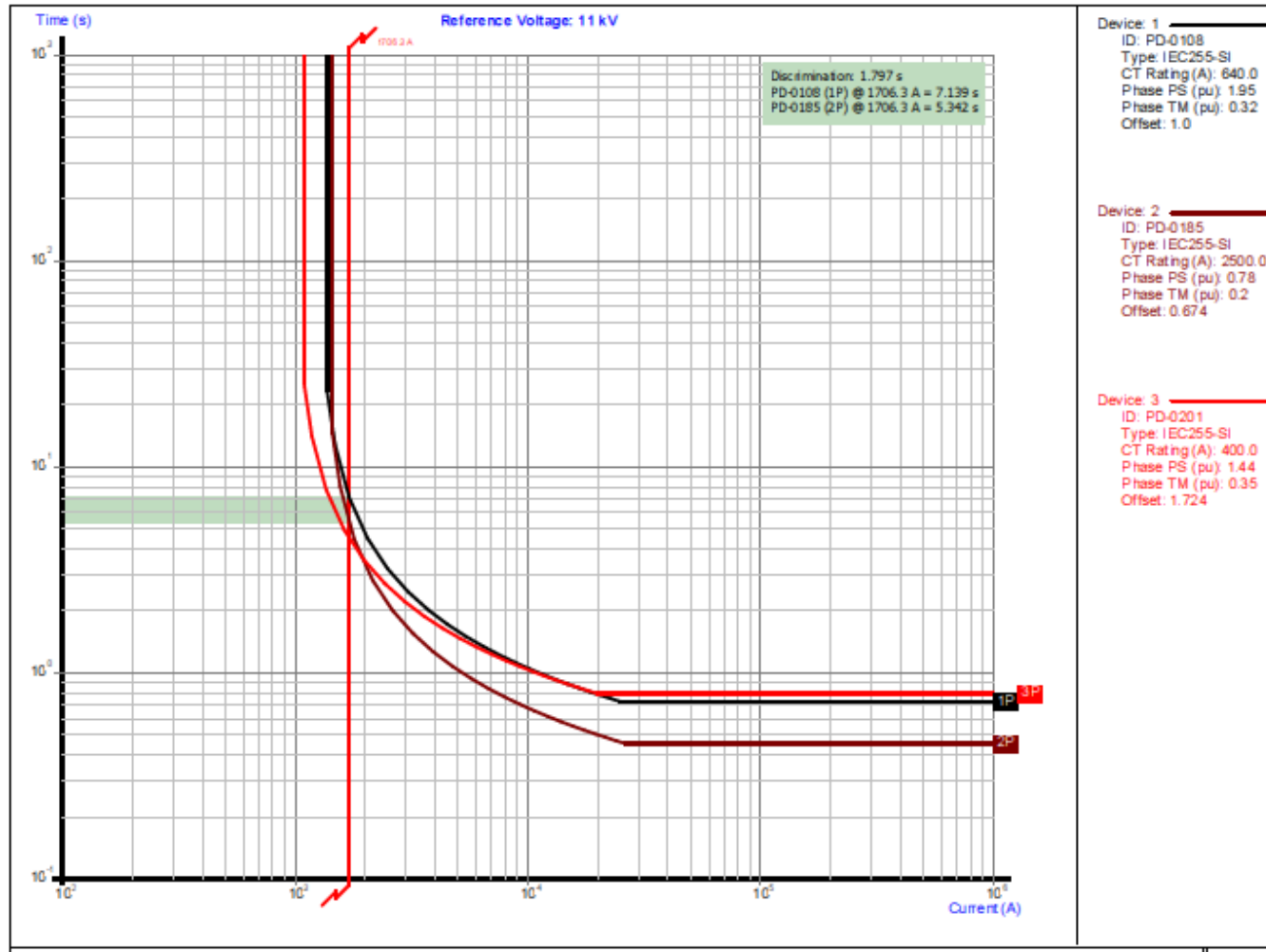
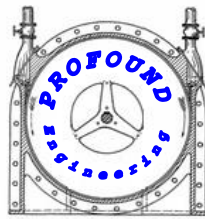




Protection requirements

- Over voltage
 - Under voltage
 - Earth Fault
 - Sensitive Earth Fault
 - Differential Protection (depend on feeders and voltage)
 - Impedance Protection (depend on feeders and voltage)
 - Buszone
 - Directional current flow *
 - Over frequency *
 - Under frequency *
 - Out of Step *
 - Synchronisation *
 - Synch Check *
 - Anti Islanding *
- * Only required for Generation Substations

Protection requirements





Protection requirements

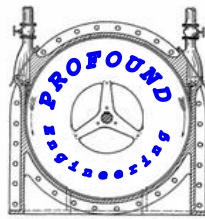
Protection Analyser Results

Network Name: KPLC

Data State Name: Aggreko

Study Name: 1P-E FAULT SURVEY

Fault Type	Fault Location	Fault Cleared	Study Duration (s)	No. of Stages	Minimum Discrimination Time (s)	No. of Saturated CTs	No. of Devices that operated...			No. of Failed Directional Relays	No. of Isolated Busbars
							On Zone 1	On Zone 2 or Higher	Not in Fault Path		
Single Phase to Earth	Busbar with ID EMBAKASI220A	No	14.325	25	0.018	0	0	5	8	0	10
Single Phase to Earth	Busbar with ID EMBAKAS 66-1	Yes	18.295	25	0.019	0	3	5	5	0	10
Single Phase to Earth	Busbar with ID EMBAKAS 66-2	Yes	18.295	25	0.019	0	3	5	5	0	10
Single Phase to Earth	Busbar with ID EMBAKASI220B	No	14.325	25	0.018	0	0	8	5	0	10
Single Phase to Earth	Busbar with ID Embakasi 1A	No	0.573	3	1.22	0	1	0	0	0	0
Single Phase to Earth	Busbar with ID Embakasi 1B	No	0.935	3	1.228	0	1	0	0	0	0
Single Phase to Earth	Busbar with ID Embakasi 2A	No	45.868	25	0.012	0	1	4	7	0	10
Single Phase to Earth	Busbar with ID EMBAKAS 66-3	Yes	18.295	25	0.019	0	3	5	5	0	10
Single Phase to Earth	Busbar with ID Embakasi 3B	No	43.606	23	0.019	0	1	7	4	0	10
Single Phase to Earth	Busbar with ID EMBAKAS 66-4	Yes	18.295	25	0.019	0	3	10	0	0	10



Commissioning

- Need written permission from Eskom to proceed with HOT commissioning
- Must do phasing
- Must check phase rotation on both supply and generators individually
- Must test and proof your synch check and synchronising relays in dry state
- Obviously do all other standard relay injection and functional testing

THE END

