Renewable & Sustainable Energy Discussion Forum

ENGINEERING

Technical Considerations when Integrating Renewable Energy into the South African Electrical Utility

Geoffrey Lee

Current Position for Many Renewable Energy Developers

- Decided to become a RE power developer;
- Located suitable sites for building the RE powered generating facility;
- Secured the land through negotiations;
- Submitted EIA's (or in the process of submission)
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- So what must be considered when considering the connection to the utility network?

Points of Discussion Relating to Grid Connections

- Guidelines, Grid Code & DSiEG requirements for Renewable Embedded Generators
- Project phases for connection to the Utility Grid
- Examples of typical connection arrangements
- Examples of typical connection Constraints

Existing Guidelines, Regulations and Position

- **IRP (Integrated Resource Plan)**
- **REFIT**
  - REFIT 1
  - REFIT 2
  - REFIT Project Selection Criteria

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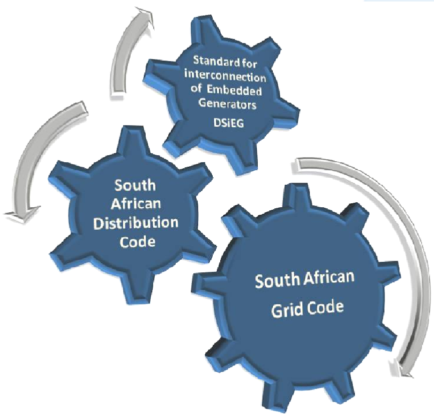
  - REFIT Project Selection Criteria
- The Electricity Regulation Act 6 of 2006.
- The Act requires the Regulator to set guidelines and publish codes of conduct and practice. Examples of such codes of practice are:
  - The South African Grid Code
  - The Distribution Code
- The Act requires utilities to develop standards and guidelines for connecting embedded generators to their networks
  - DSiEG



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RE Generator Connection Requirements

- **Interconnection requirements for Renewable Energy Generators < 1000 MW:**
  - If the local network depends on the EG for voltage support, the connection shall use a minimum of two power lines/routes.
  - Transient stability must be maintained after a successfully cleared single phase fault.
  - If only one line is used for connection – the line must be equipped with circuit breaker bypass facilities at both ends - (SAGC Network Code 7.6.5)

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Generator Connection Requirements

Control Requirements:

- SAGC: Network Code has specific **governing limits**, when EG's are of a nominal capacity greater than **10 MVA**.
- In addition, generators of capacity **larger than 20 MVA** require specific protection.
- All **protection settings** to be applied to the the generators, **which could affect network performance**, are subject to Eskom's written approval.

SAGC

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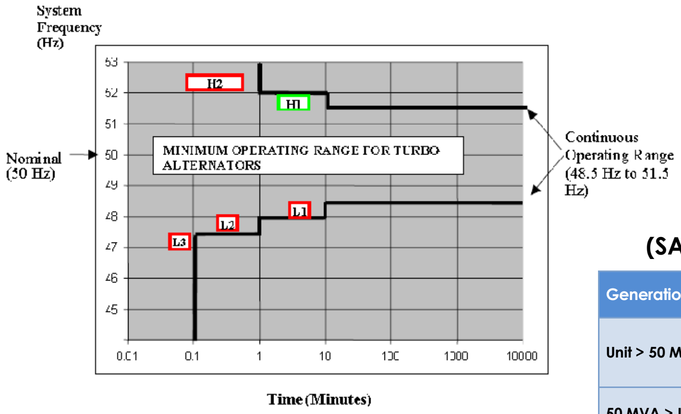
Generation Type:	Operational parameters
Synchronous Generators	Operate Voltage Range: 95 % to 105 %
Induction or Asynchronous generators	Must supply reactive power compensation to a power factor of within ± 0.90
Inverter-type generating equipment	Although most inverters have an operating p.f. range of between ± 0.75, required to adjust to a power factor of within ± 0.90

SAGC

Frequency Operation Requirements



(SAGC Network Code 3.1)

Generation Size:	Governor / Frequency Range
Unit > 50 MVA	48.5 Hz to 51.5 Hz as per Section 3.1.6 (Governing) of the Grid Code
50 MVA > Unit > 10 MVA	Compliance to Section 3.1.6 may not be required, shall be resolved upon consultation with Eskom
10 MVA > Unit	Not required to comply with governing and continuous frequency operational requirements

SAGC

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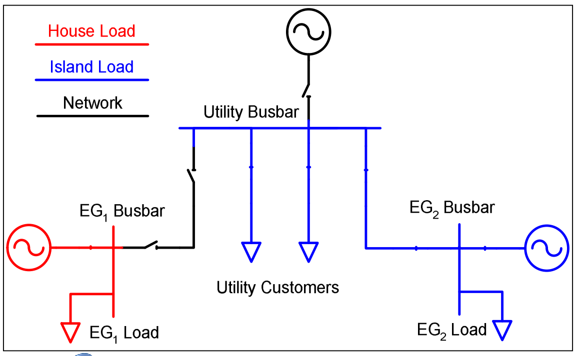
Interconnection Standard - Overview

- **The Standard Prioritises Safety in following order:**
  - Human safety
  - Plant safety
  - Customer supply
- **Eskom DX is responsible for protecting the Network**
  - Utility is held liable for QOS and Damages to customer plant
  - PUC Protection is to be applied
- **EG is not allowed to energise an Islanded network**
- **EG is responsible for protecting & controlling its generator(s)**
  - EG to synchronise
  - EG never to energise dead DX network

Islanding – Loss Of Grid

❑ **Islanding with part of the Eskom network is not permitted.**

- Eskom has no control over quality of supply or network safety when only EG's are connected to the grid.
- The potential exists where an EG can energise a portion of an Eskom network that is not connected to the main grid.



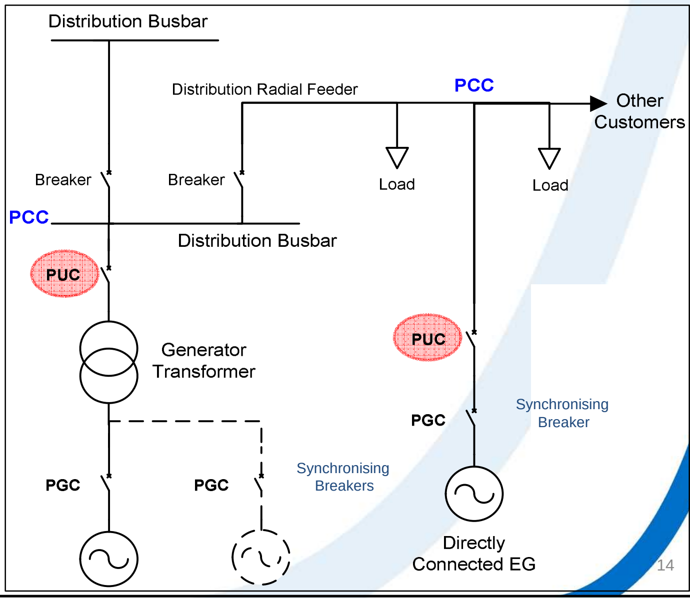
- EG Standard **doesn't** prescribe how EG must operate his own equipment, rather **how to** interconnect to ESKOM network
- Generator shall disconnect from network within 2s upon detection of an island.

Network Connection Points & Node Definitions

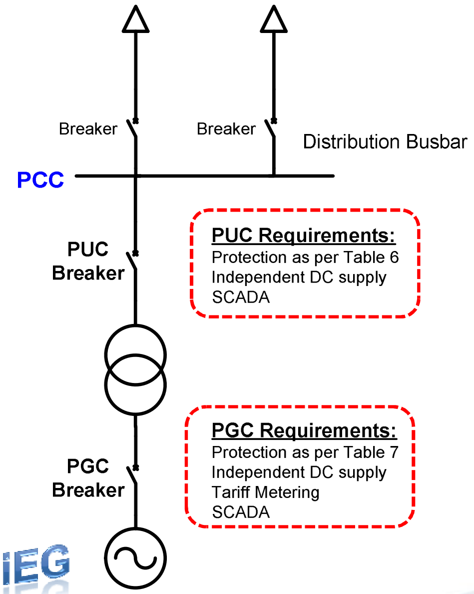
❑ **Point of common coupling (PCC)**

❑ **Point of utility connection (PUC)**

❑ **Point of generator connection (PGC)**



PTMC & DC Requirements



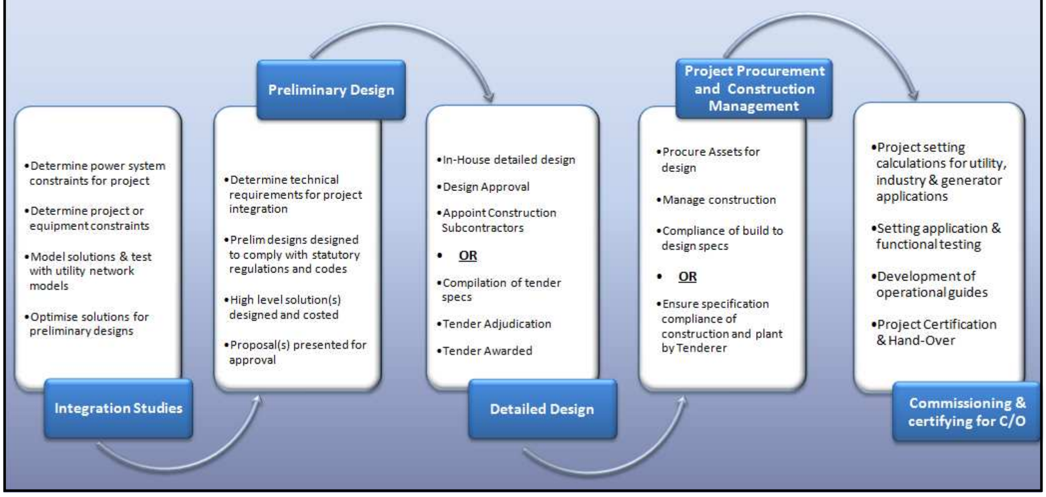
Protection Type (Table 6)	HV	MV
Overcurrent, Earth Fault	Yes	Yes
Sensitive Earth Fault (SEF)	No	Note [1]
Phase Under/Over Voltage	Yes	Yes
Residual Over-Voltage	No	Note [1]
Under/Over Frequency	Yes	Yes
Loss-of-Grid	Yes	Yes
Check Synchronising / Interlocking (Block dead line charge)	Yes	Yes
Reverse Power	Note [2]	Note [2]
DC Failure Monitoring	Yes	Yes

Note [1]: Dependant on Neutral earthing philosophy adopted

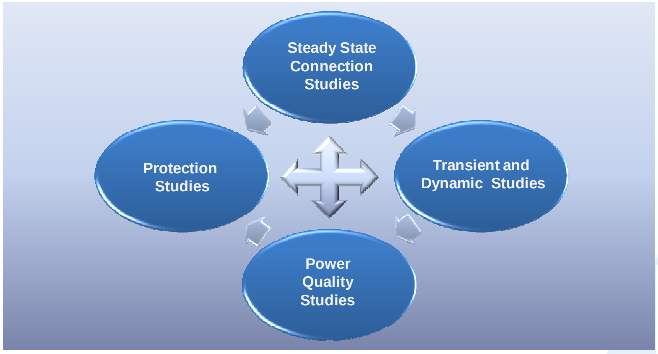
Note [2]: Only if no power is to be exported to the grid

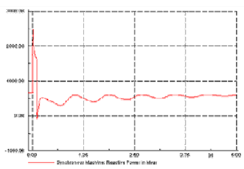
Protection Type (Table 7)
Phase Under/Over Voltage
Under/Over Frequency
Automatic Synchronising
Reverse Power
DC Failure Monitoring
Negative Phase Sequence Overcurrent

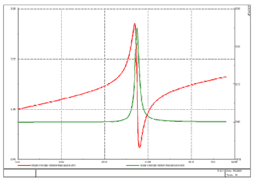
Typical Project Process for a Network Connection

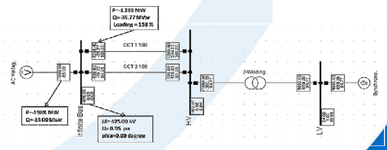


Associated Network Studies Used for Designing the Network Connection









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Typical Examples of a Generator to Utility Network Connection and the Impact on Production Availability

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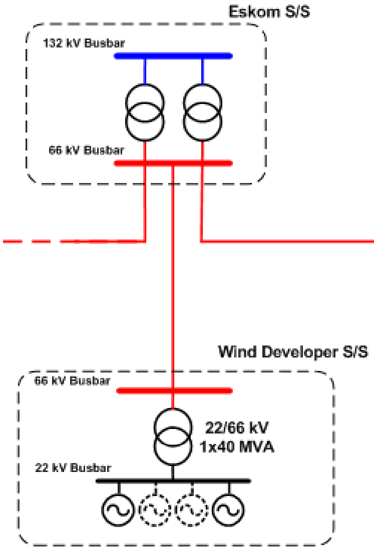
Typical Network Connection Arrangements Option 1



❑ Pro's

- Reduced cost – only one transformer at the Developer substation
- Satisfies Grid Code in terms of the single line to Eskom substation

❑ Con's

- Single contingency loss of output - Transformer not firm
- Single contingency loss of output - Line not firm
- Grid Code requires full transfer capability for line

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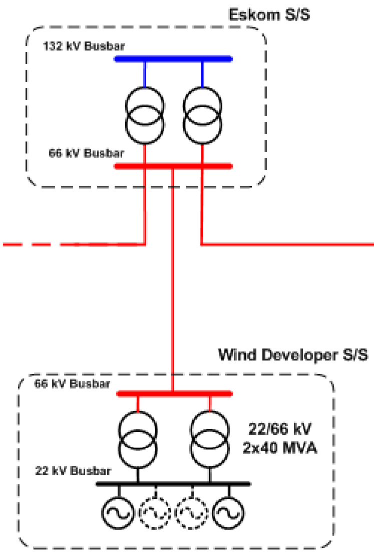
Typical Network Connection Arrangements Option 2



❑ Pro's

- Transformer is firm – production output not lost when one transformer fails
- Satisfies Grid Code in terms of the single line to Eskom substation

❑ Con's

- Single contingency loss of output - Line not firm
- Grid Code requires full transfer capability for line
- Higher cost associated than with option 1

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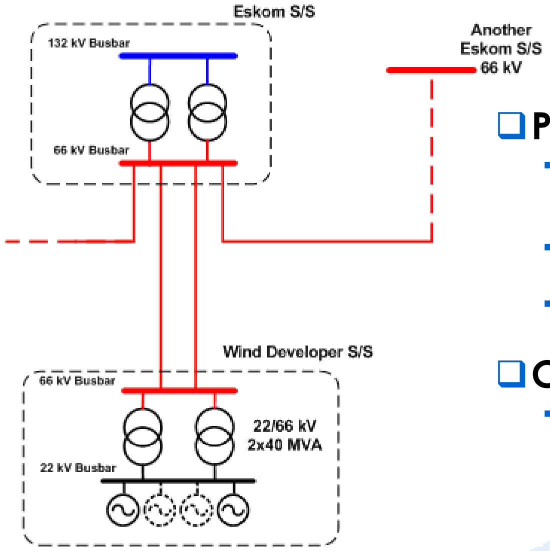
Typical Network Connection Arrangements Option 3



Pro's
- Transformer is firm – production output not lost when one transformer fails
- Line is firm – production output not lost when one line trips
- Satisfies Grid Code in terms of the single line to Eskom substation

Con's
- Most expensive option of the three

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Impact Each Connection Option has on the Production Income

Project Option	Failure Scenario	Power at Risk (MW)	Risk Duration	Potential loss of Income @ R1,25/kWh (Wind)	Potential loss of Income @ R2,30/kWh (CSP Tower)	Potential loss of Income @ R3,13/kWh (CSP Trough)
Connection Option 1	Loss of step-up **Transformer**	40	12 months	R 128,800,000	R 236,940,000	R 322,450,000
	Loss of the **66 kV line** to the Eskom Substation	40	Maximum 3 days	R 1,058,000	R 1,947,000	R 2,650,000
Connection Option 2	Loss of **one** of the step-up **Transformers**	0	0 months	R 0	R 0	R 0
	Loss of the **66 kV line** to the Eskom Substation	40	Maximum 3 days	R 1,058,000	R 1,947,000	R 2,650,000
Connection Option 3	Loss of one of the step-up **Transformers**	0	0 months	R 0	R 0	R 0
	Loss of the **66 kV line** to the Eskom Substation	40	Maximum 3 days	R 0	R 0	R 0

Calculated using a utilisation factor of 30%, a generator availability factor of 98% and different REFIT tariffs

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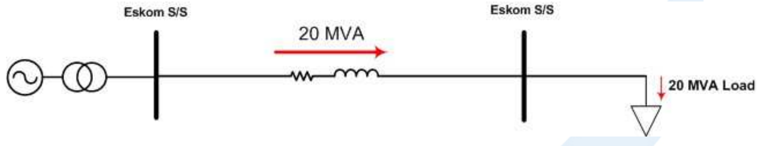
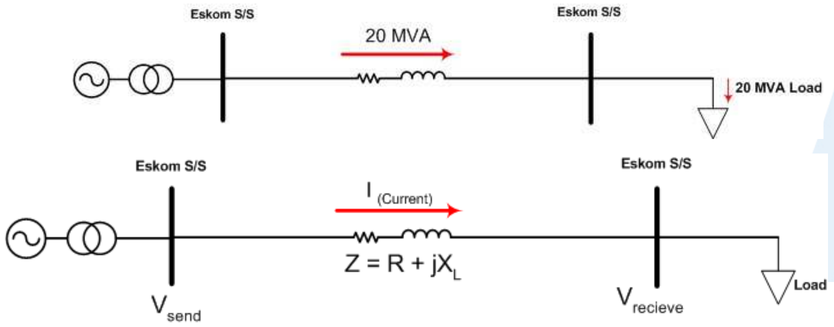
Typical Examples of Network Constraints when Connecting to Utility Networks

Typical Network Connection Constraints

- Simple example of network losses
- Power networks are significantly more complex
- Detailed network simulation studies must be performed when integrating into the larger utility network



Typical Network Connection Constraints



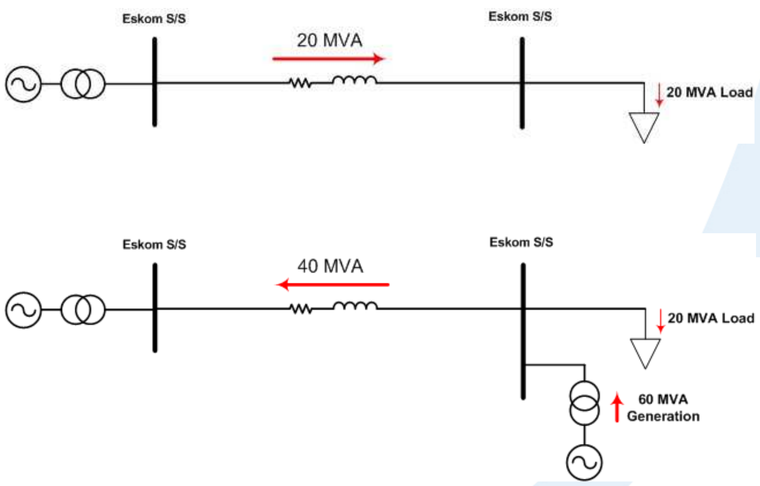
$Power_{loss} = I^2 \times R$

$V_{drop} = I \times Z$

$V_{recieve} = V_{send} - V_{drop}$

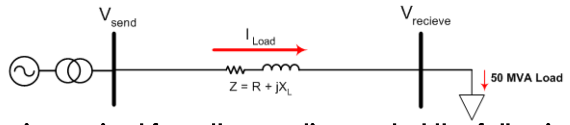
Z is a function of line length

Increased Losses due to RE Generation



The Impact Losses on Voltage Selection

- Using a 40 km long line (hare conductor):



- The following is required from the sending end at the following voltage levels:

Voltage at the Load (kV)	Load Current	Power Loss -Heating (in MW)	Required Sending Power (MW)	Voltage Drop Over Line (in volts)	Required Sending End Voltage (in kV)	Relative Cost of Connection
11	2624	75	125	2957	13.957	Low
22	1312	19	69	1479	23.479	Low
33	875	8	58	986	33.986	Low
66	437	2	52	493	66.493	Moderate
132	219	1	51	246	132.246	High
220	131	0	50	148	220.148	Very High
275	105	0	50	118	275.118	Very High
400	72	0	50	81	400.081	Very High
765	38	0	50	43	765.043	Extremely High

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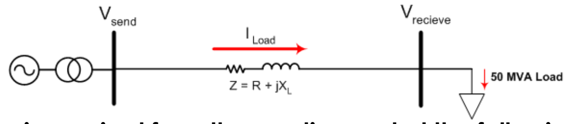

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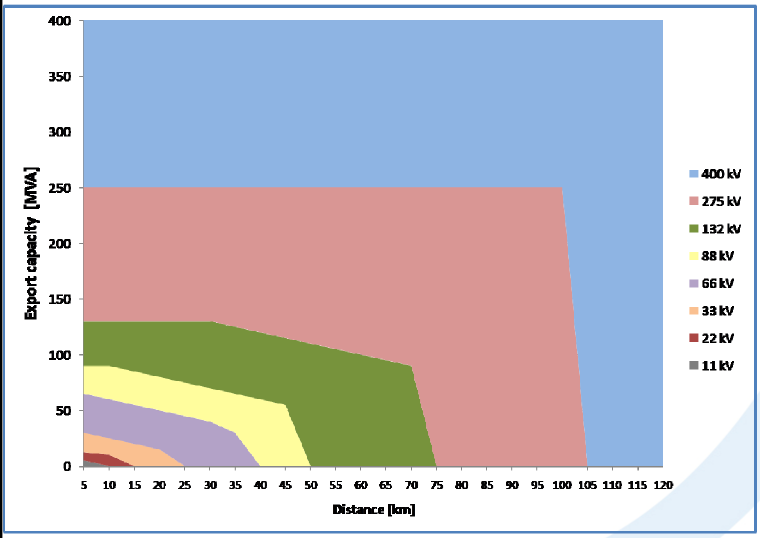
Determining the Connection Voltage Level



- First pass estimation only
- **Network studies** must be used to confirm adequacy of connection
- **Fault levels** must also be obtained through network studies
- Fault levels also have an impact on the connection voltage

Conclusion

- **Grid Codes and the DSiEG have specific network connection requirements.**
- **These requirements need to be integrated into the connection designs from the onset of the project.**
- **Constraints clearly exist when connecting to the Grid**
- **The connection selected is a balance between potential production losses, network losses and project cost – with safety and stability being a given**
- **Studies must be performed during all phases of the Renewable Energy Developer's project to ensure:**
  - Effective & efficient connection
  - Stable transient operation
  - Safety and protection of the expensive plant

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Thank You

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