

Protection of Embedded Generation

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Topics of Discussion

- ◆ **General overview of Generator connection**
- ◆ **Factors affecting protection requirements**
- ◆ **Typical 11kV network protection**
- ◆ **Basic Generator Interconnection protection**
- ◆ **Major Difficulties which arise**
- ◆ **A 415V/11kV and a 33kV connection example**

Connection Overview

- ◆ **Network connections are available from 132kV to 415 volts**
- ◆ **Sub-Transmission connections are complex though causing few problem**
- ◆ **Generally the 415V/11kV export connection is the most problematic**
- ◆ **Typically conversion from standby to parallel operation**

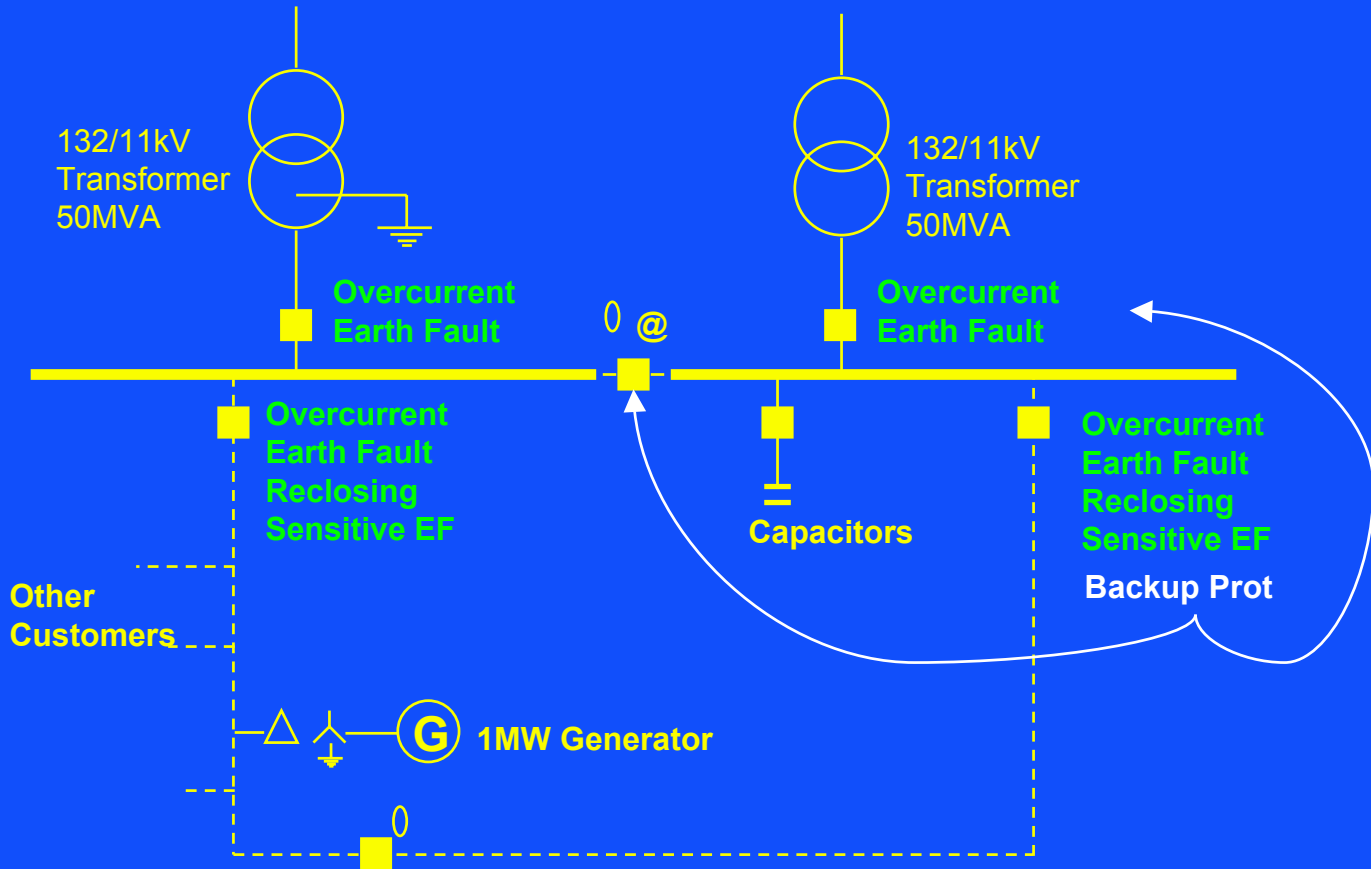
EnergyAustralia Embedded Generation

- ◆ **132kV installation of approx 120MW**
- ◆ **Three 33kV installations comprising a total of twenty 1MW units**
- ◆ **600kW wind generator in the Newcastle Area**
- ◆ **150kW wind turbine at Malabar**
- ◆ **550kW diesel/gas generator in the CBD**
- ◆ **2MW generator in the Ryde area**
- ◆ **2MW generator at Malabar sewage works**
- ◆ **485kW Generator at Cronulla Sewage works**
- ◆ **340kW Generator in the Sutherland area**

Factors Affecting Protection

- ◆ **Export or Non-Export of power to Network and magnitude of flow in each direction**
- ◆ **Generator to maintain a stand-by role for the customer**
- ◆ **Does the increase in fault level adversely affect the customers installation or the network**
- ◆ **Connection network is totally Underground or contains Overhead sections**
- ◆ **Connection to a ringed or radial network**
- ◆ **ETC**

Typical 11kV Overhead Network



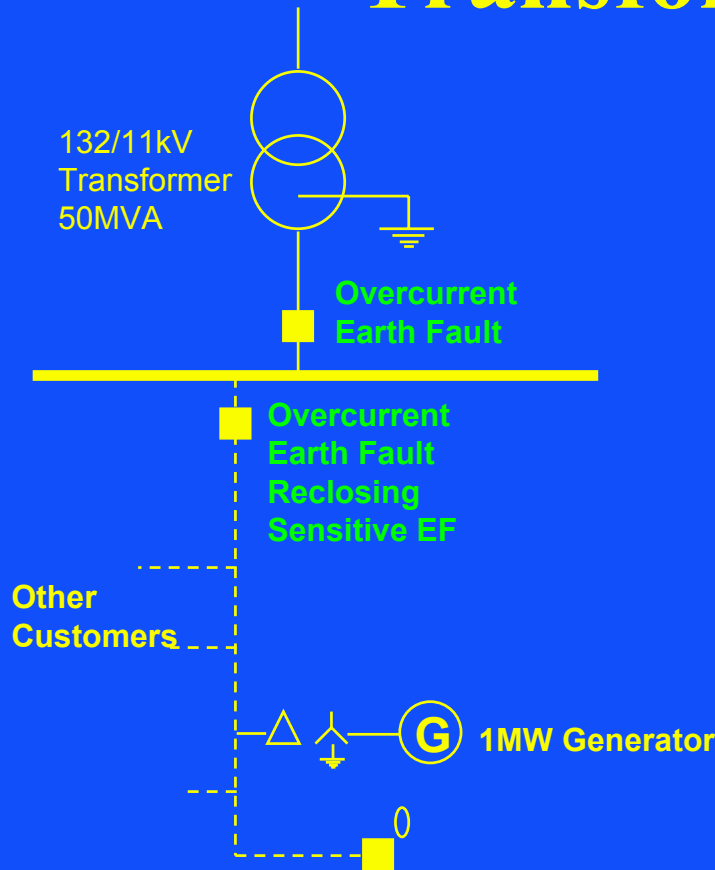
Generator/Interconnection Protection Guidelines

- ◆ **Maintain existing standard of network reliability and security**
- ◆ **Provide reasonable backup provision**
- ◆ **Coordinate with existing network protection**
- ◆ **Use Utility quality devices**
- ◆ **Use dedicated protection devices, not relying on control equipment**
- ◆ **Maintain quality of supply**

Maintain existing standard of reliability and security

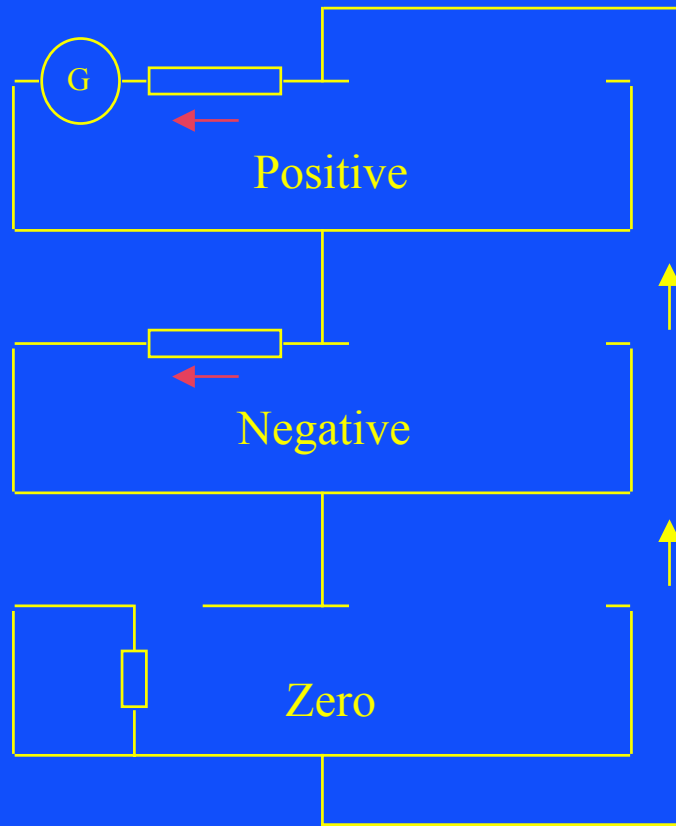
- ◆ **Minimum Interconnection protection**
 - Generator Overcurrent and Earth Fault
 - Possibly df/dt or vector surge protection
 - Residual Voltage Protection on the 11kV side
 - Generator over and under frequency protection
 - Generator over and under voltage protection
- ◆ **Provide Backup by some of the above protections operating into different CBs. Additional backup provided by using relays with multiple functionality.**

Influence of Interconnecting Transformer

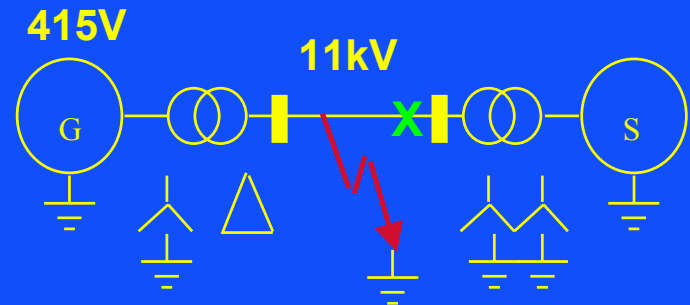


- ◆ **11kV Network must have only one earth point for network protection**
- ◆ **Earth Fault current flow is affected by Tx connections**

Feeder Earth Fault



It is possible to get earth fault current through a delta transformer only while an earth exists on the delta side



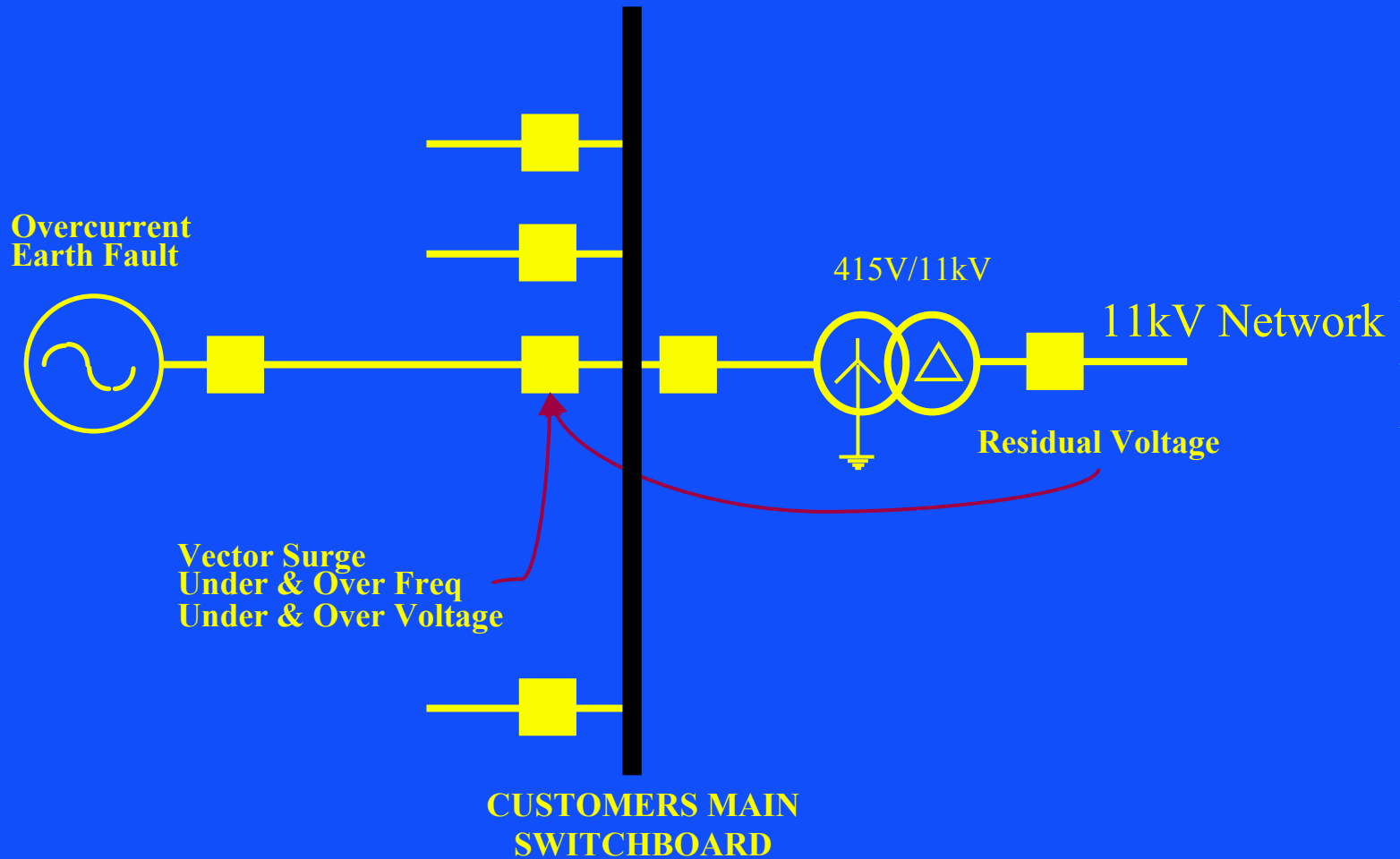
What does this mean?

- ◆ **If the Supply Authority CB opens before the generator CB, the generator will not supply earth fault current and the normal generator protection will not operate**
- ◆ **If the generator is configured to export power it is more likely to continue operation**
- ◆ **If a car hits a pole outside the generator installation, the generator will see little if any network load and the wires may be lying on the ground**

Residual Voltage Protection

- ◆ **This is the only way to sense an earth fault on an unearthed 11kV network**
- ◆ **An open delta five limb suitably rated Voltage Transformer is required on the 11kV side of the installation**
- ◆ **A residual voltage detecting relay is required**
- ◆ **Many suburban kiosks (11kV/415V enclosures) are not designed or able to accommodate the VT**
- ◆ **This can be a very significant cost and may even affect the viability of the project**

415V/11kV Protection Example



33kV Protection Example

Distance
Overcurrent
Earth Fault
Under & Over Freq
Under & Over Voltage
VF Intertrip

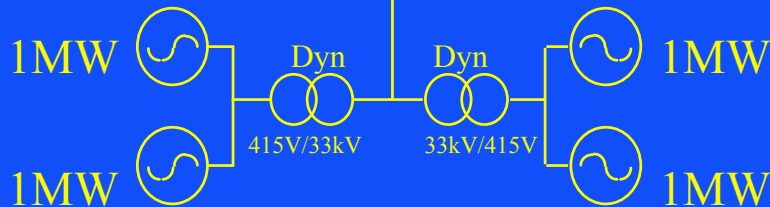
Distance
Overcurrent
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VF Intertrip

Zone Substation

Zone Substation

33kV

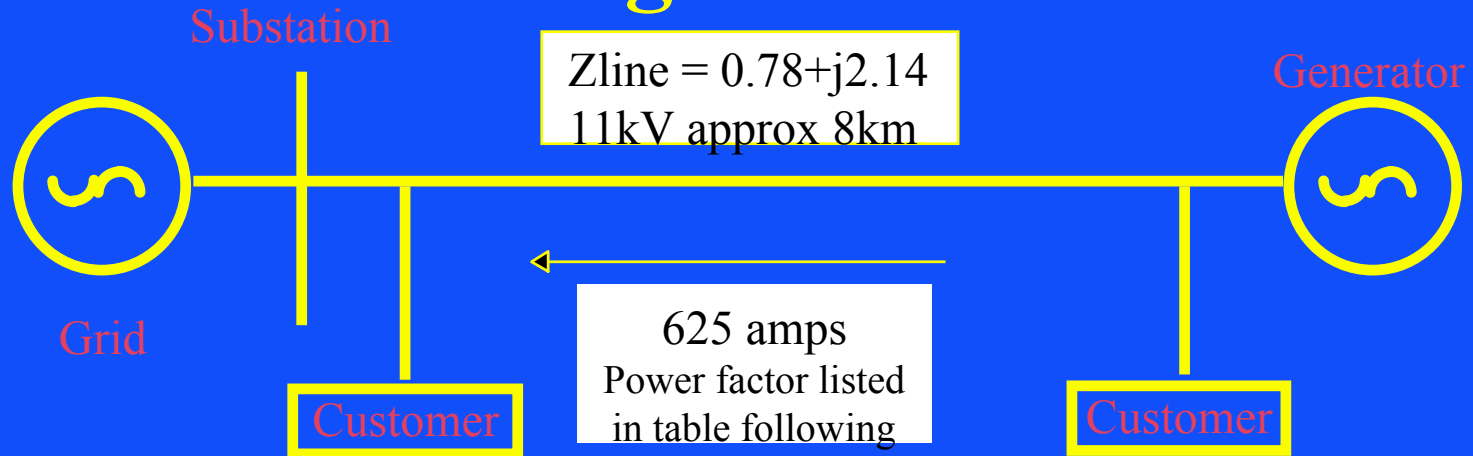
Directional Overcurrent
Non-directional Overcurrent
Earth Fault
Residual Voltage
Under & Over Frequency
Under & Over Voltage
VF Intertrip



**Work out the Protection at
the viability stage.**

Don't leave it too late.

Voltage Control



Generator MVA	Generator MWatts	Generator MVars	Generator Power Factor	Generator Voltage	Zone Voltage
12.0	9.6	-7.2	0.8 lead	11,111	11,440
12.3	11.1	-5.4	0.9 lead	11,384	11,440
13.0	13.0	0	1	12,002	11,440
13.5	12.2	5.9	0.9 lag	12,501	11,440
13.7	11.0	8.2	0.8 lag	12,656	11,440
13.8	9.7	9.9	0.7 lag	12,750	11,440
13.9	8.3	11.1	0.6 lag	12,809	11,440
13.9	7.0	12.0	0.5 lag	12,844	11,440
14.0	5.6	12.8	0.4 lag	12,861	11,440

Power Factor Control

Generator Output Increasing

Volts	Prim. Amps	Phase I lagsV	Power Factor	kW	kVAr	kVA
246	876	40	0.76	495	416	646
246	828	60	0.5	302	531	611
246	720	88	0.04	23	531	531
245	720	90	0.0	-6	529	529
245	678	92	-0.04	-15	498	498
246	684	106	-0.3	-135	486	505
246	684	113	-0.4	-196	465	505

Table shows data taken at customers main switch indicating power flow with supply authority.

