

GRID CONNECTION ISSUES FOR DISTRIBUTED GENERATION - REVIEW & STANDARDS

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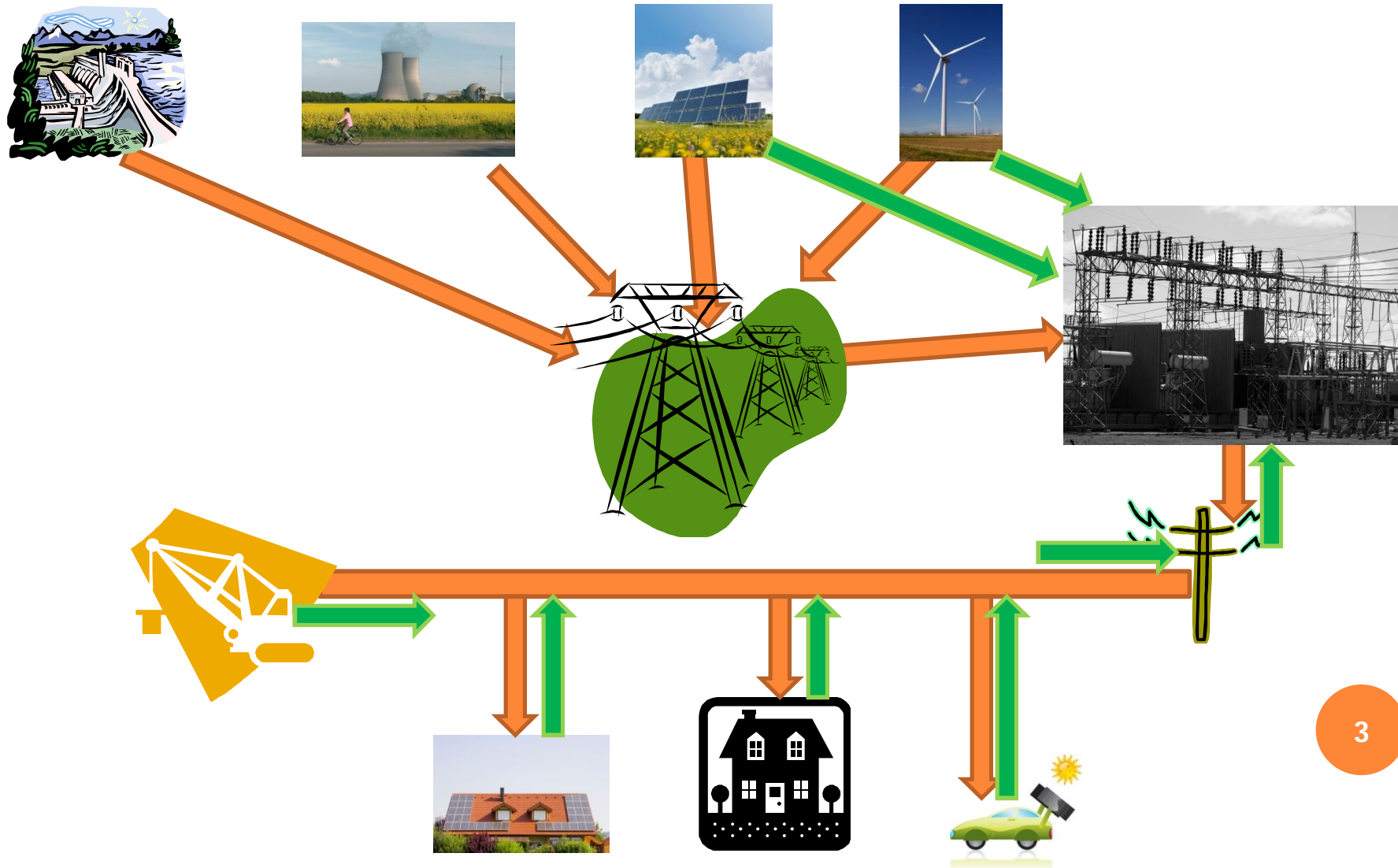
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OUTLINE

- ¢ Introduction
- ¢ Grid connection Requirements – International Std
 - Australia
 - Manitoba Hydro
 - Utilities in USA
 - Comparison with IEEE 1547
- ¢ Summary

MODERN ELECTRICITY SYSTEM



DISTRIBUTED RESOURCE SYSTEM

Fuel Source	Energy Conversion	Interconnection
Sun light	Solar Panel	DC-AC inverter
Hydrogen	Fuel cell	DC-AC inverter
Diesel	Reciprocating Engine	Synchronous generator
Natural gas	Turbine	Synchronous generator
Wind	Turbine	Induction Generator
Biomass	Sterling Engine	Induction Generator

ISSUES WITH DG

- ⌘ Anti-Islanding protection
- ⌘ Auto reconnection after a trip
- ⌘ Short circuit capacity
- ⌘ AC and DC Isolation
- ⌘ Installation safety requirements
- ⌘ Voltage regulation
- ⌘ Harmonics
- ⌘ Flicker, unbalance
- ⌘ Over-voltage from direct/indirect lightning
- ⌘ Transient over-voltage in grid
- ⌘ DC injection and power factor.

STANDARDS AVAILABLE

¢ Australian Standard AS 4777 Parts 1, 2 and 3
(Grid Connection Of Energy Systems Via
Inverters)

¢)



AUSTRALIAN STANDARD – DG VIA INVERTER

Voltage (V)	Time Limit (s)	Frequency (Hz)	Time Limit (s)
$< V_{min}$	2.0	$< f_{min}$	2.0
$V_{min}-V_{max}$	No limit	$f_{min}-f_{max}$	No limit
$>V_{max}$	2.0	$>f_{max}$	2.0

Voltage (V)	Time Limit (s)	Frequency (Hz)	Time Limit (s)
$< V_{min}$	2.0	$< f_{min}$	2.0
$V_{min} < V < 87\%V_n$	1 min		
$87\%V_n < V < 106\%V_n$	No limit	$f_{min}-f_{max}$	No limit
$106\%V_n < V < V_{max}$	1 min		
$>V_{max}$	2.0	$>f_{max}$	2.0

CONNECTION REQUIREMENTS - AUSTRALIA

- ⌘ Impulse voltage withstanding
 - 0.5 Joule, 5kV, 1.2/50 waveform to AS1931 Part 1 or in accordance with IEC 60255-5.
- ⌘ Power Factor
 - Between 0.8 leading and 0.95 lagging for outputs from 20% to 100% of rated VA
- ⌘ Voltage fluctuation and Flicker
 - Equipment shall confirm to AS/NZ 61000.3.3 or 3.5
- ⌘ DC current injection
 - It is recommended to use transformer at output of inverter
 - Shall not exceed 0.5% of its rated output current or 5 mA, whichever is the greater.

CONNECTION REQUIREMENTS - AUSTRALIA

⌘ Harmonics

Current Harmonic Number	Limit based on % of fundamental
3 – 9 th	<4%
11 – 15 th	<2%
17 – 21 st	<1.5%
23 – 33 rd	<0.6%
above 33 rd	<0.3%
Even harmonics	< 25% of equivalent odd harmonics
Total Harmonic Distortion (THD)	<5%

⌘ Harmonics

Duration (Seconds)	Instantaneous Voltage	
	Line-to-Neutral (Volts)	Line-to-Line (Volts)
0.0002	910	1580
0.0006	710	1240
0.002	580	1010
0.006	470	810
0.02	420	720
0.06	390	670
0.2	390	670
0.6	390	670

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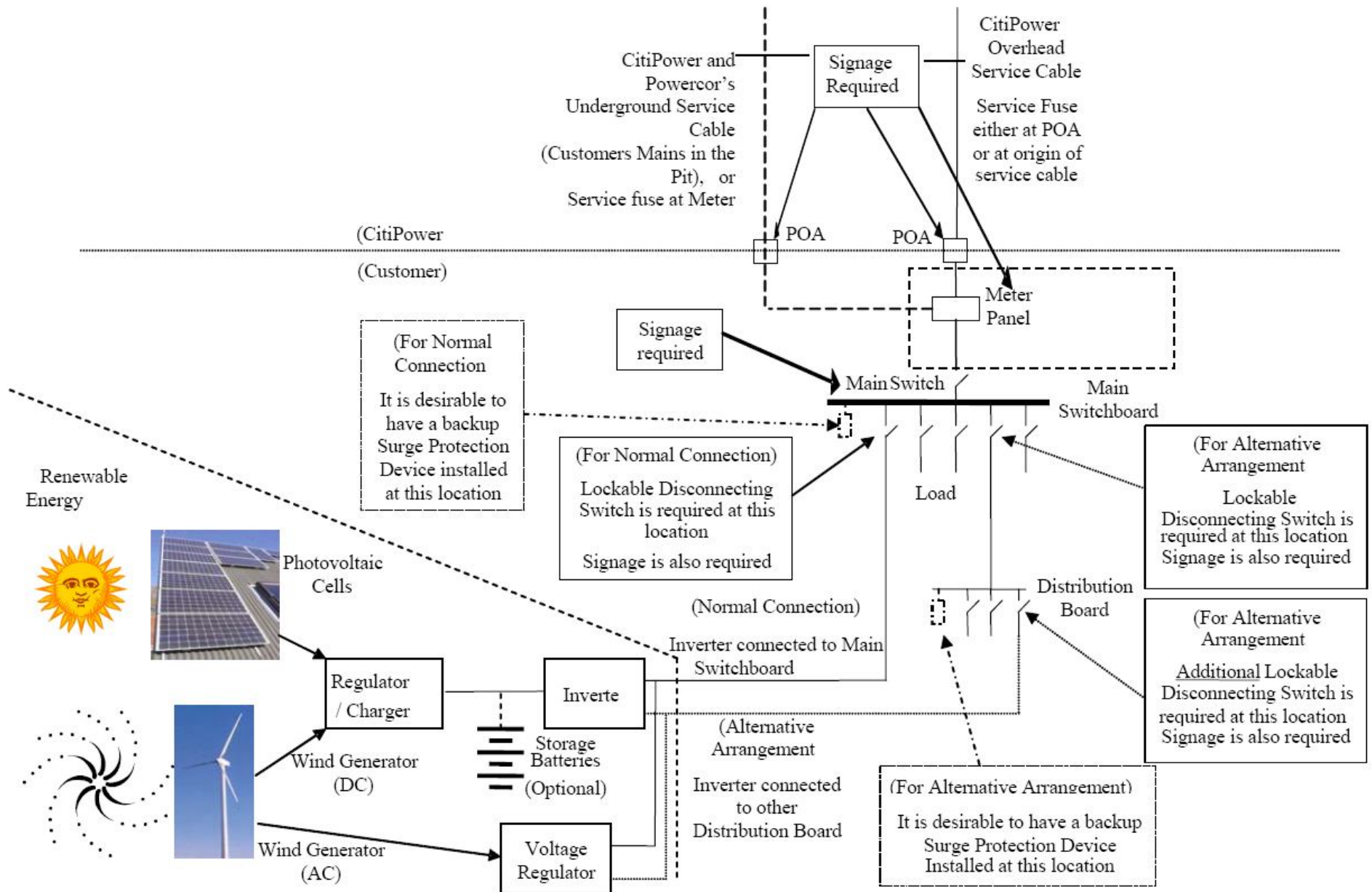
PROTECTION

- ⌘ Over current protection
 - shall operate when the output from the inverter / regulated energy system is greater than 100% of the inverter rating.
- ⌘ Isolate the inverter/DG
 - The supply from the grid is disrupted;
 - Over-Voltage Protection: $V_{\text{grid}} > 265 \text{ V}$ (phase) or 458 volts (line)
 - Under-Voltage Protection: $V_{\text{grid}} < 195 \text{ volts}$ (phase) or 337 volts (line)
 - Over Frequency Protection: $F_{\text{grid}} > 51.5 \text{ Hz}$
 - Under-Frequency Protection: $F_{\text{grid}} < 48.5 \text{ Hz}$
- ⌘ Any one islanding detection technique
- ⌘ The total protection operation and disconnection time shall not exceed 2 seconds after grid failure.

RECONNECTION

- ⌘ Automatic reconnection of inverter / regulated energy system(s) onto the grid shall only occur if:
 - Voltage requirements
 - ⌘ $200 < V_{\text{grid}} < 260$ volts (phase)
 - ⌘ $346 < V_{\text{grid}} < 450$ volts (phase-to-phase);
 - Frequency requirements
 - ⌘ $49 \text{ Hz} < F_{\text{grid}} < 51 \text{ Hz}$
- ⌘ The above conditions have been maintained for a minimum duration of 1 minute
- ⌘ The inverter / DG system and the grid are synchronized and in-phase with each other.

TYPICAL SINGLE LINE DIAGRAM



MANITOBA HYDRO DISTRIBUTION SYSTEM

☪ Scope

Voltage	Generator	Size
Upto 50 kV	Single phase	50 kW
	Three phase	10 MW

☪ Interconnection of inverter-based and generator-based DR systems

POWER QUALITY

⌘ Flicker	Changes/min	$-\Delta V/V$ (%)
	<10	0.4%
	10 to 200	0.2%
	>200	0.1%

⌘ Voltage regulation and power factor

– Sync Generator

⌘ Generator bus voltage set point shall be stable at 95% and 105%

– Inverters

⌘ Power factor to be adjusted to ± 0.90 or better at PCC

⌘ DC current injection: Does not allow any DC offset

⌘ Speed regulation

– Speed regulation with freq as reference is required for large synchronous generators (> 1MW)

POWER QUALITY

¢ Harmonics

$V_{bus} \leq 69kV$						
I_{sc}/I_L	<11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20 - 49	7.0	3.5	2.5	1.0	0.5	8.0
50 - 99	10.0	4.5	4.0	1.5	0.7	12.0
100 - 1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

PROTECTION AT PCC

- ¢ Balanced and unbalanced system faults (i.e. line-ground, line-line, and three phase faults)
- ¢ Frequency variations

Minimum Time	Under Freq Limit	Over Freq Limit
Continuous operating range	59.0 – 60.0 Hz	60.0 – 61.5 Hz
10 minutes	58.7 – 58.9 Hz	61.6 – 62.0 Hz
30 seconds	58.0 – 58.6 Hz	62.1 – 63.5 Hz
Instantaneous trip	< 58.0 Hz	> 63.5 Hz

PROTECTION AT PCC

Under-Voltage/ Over Voltage Protection

PU Voltage	Trip Time
$V \leq 50\%$	Instantaneous
$50\% < V < 90\%$	120 cycles
$90\% < V < 106\%$	Normal Operation
$106\% < V < 120\%$	30 cycles
$V \geq 120\%$	Instantaneous

Islanding is usually not allowed

- Prevent safety hazards created by back feeding isolated portions
- Add redundancy to generator protection internal to DR facility
- Anti islanding protection is to be provided

SYNCHRONIZATION

- Limit values for synchronous interconnection between MG and main grid (Sync generator).

Total DG Rating (kVA)	ΔF (Hz)	($\Delta V\%$)	$\Delta\theta$ ($^\circ$)
0-500	0.3	10	20
>500-1500	0.2	5	15
>1500-10000	0.1	3	10

- Induction generator do not require sync facilities, but they must not violate voltage sag/flicker criteria



STANDARDS FOR INTERCONNECTING DG - USA

- ¢ Utilities in US have different standards
- ¢ IEEE 1547 is believed to be the most general standard
- ¢ Separate standards followed for connecting PV (IEEE Std 929-2000)

SYNCHRONIZATION

- ¢ Re/connection is made when the main grid and MG are synchronized at the PCC in terms of voltage, frequency and phase angle
- ¢ Limit values for synchronous interconnection between MG and main grid.

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THANK YOU

- ⌚ Time
- ⌚ Attention
- ⌚ Patience

⌚ Slides are available at
<http://www.ese.iitb.ac.in/~suryad/publications.html>