

Impact of Widespread Penetrations of Renewable Generation on Distribution System Stability

Tareq Aziz, Sudarshan Dahal, N. Mithulananthan and Tapan K. Saha

School of ITEE

The University of Queensland,

St. Lucia, Qld

Australia

6th International Conference on Electrical & Computer Engineering (ICECE)

December 18-20, 2010

Dhaka, Bangladesh

Outline of Presentation

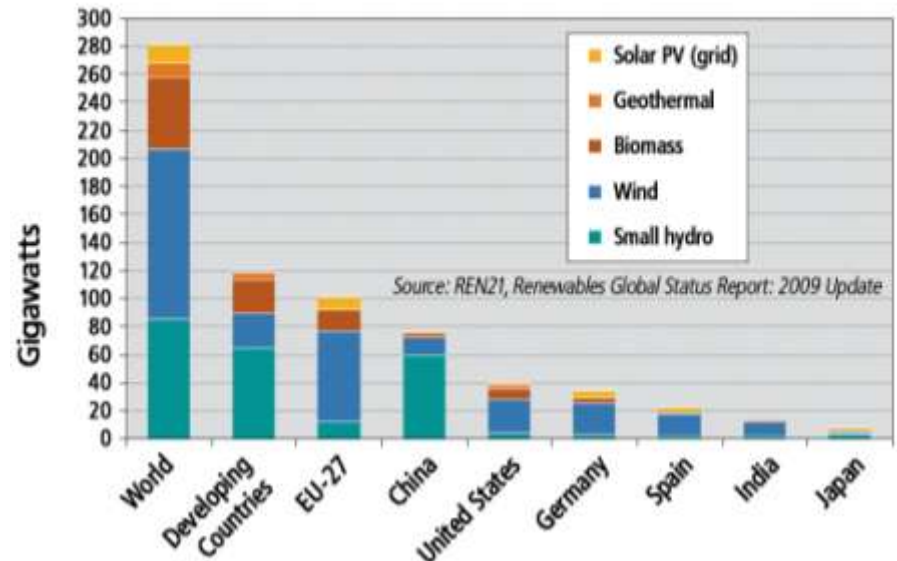
- Renewable generation and present trend
- System Stability & Major Concerns
- Case Studies
- Results analysis
- Summary



Renewable Generation and Present Trend

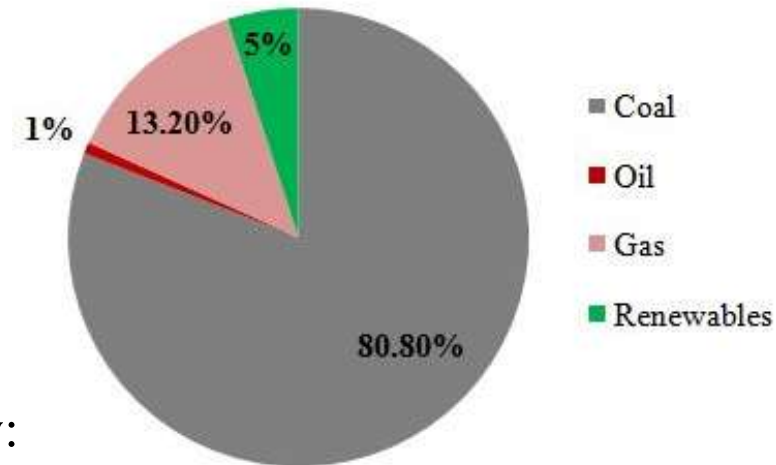
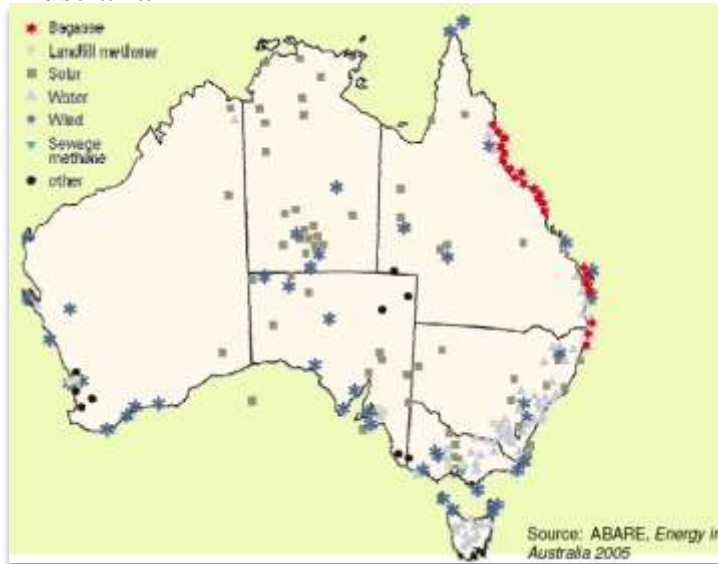
- Environment issue and Kyoto Protocol
- Deregulated electricity market
- Reduction of grid losses
- Less investment cost in line connection
- Efficient asset utilization

Renewable Power Capacities, Developing World, EU and Top Six Countries, 2008



Renewable Generation and Present Trend

Location of major renewable based generation, Australia



Source: ESAA report, 2009

Major Sources of Renewable Energy:

- Hydro
- Bagasse
- Wind
- Solar

System Stability & Major Concerns

- Property of power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance.

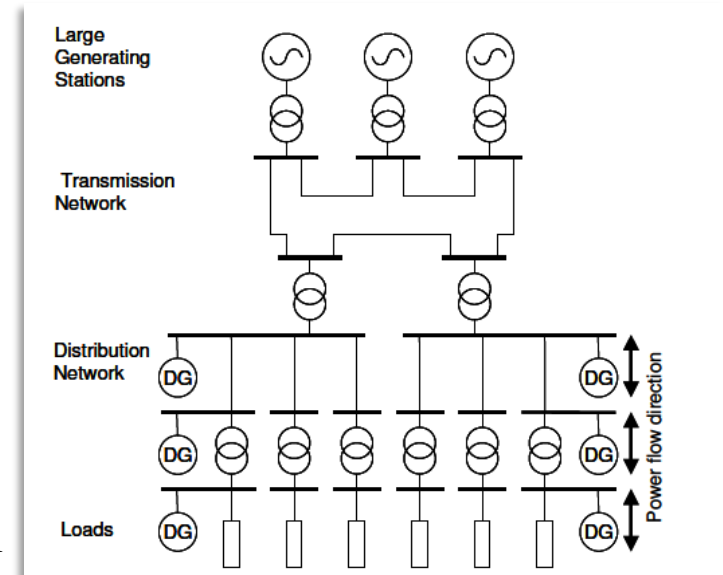
- Differential and Algebraic set of Equations:

$$x' = f(x, y, \lambda, p)$$

$$0 = g(x, y, \lambda, p)$$

- Stability Concerns:

- DG connected to distribution system resulting bidirectional power flow
- Distribution System is no more a passive system
- High R/X ratio of distribution network



Voltage Stability

→ System experiences a state of voltage instability when there is a progressive or uncontrollable decline in voltage magnitude due to a disturbance.

- Power flow studies have been performed with power system algebraic equation for increasing system load.

$$0 = g(x, y, \lambda, p)$$

- All loads are represented as constant PQ load and increased simultaneously according to following relations

$$P_L = P_0(1 + \lambda)$$

$$Q_L = Q_0(1 + \lambda)$$

Where P_0 and Q_0 correspond to the base loading and $(1+\lambda)$ is loadability.

Small Signal Stability

- After a disturbance is cleared, all the oscillatory modes of a system must have a good damping ratio (usually $> 5\%$) to ensure stability.
- Modal analysis was performed to assess existing oscillatory modes, their damping and frequencies.
- Dynamic loadability was assessed considering Hopf bifurcation condition, which is a case when a pair of complex eigenvalues cross the imaginary axis of a complex plane.
- The impacts of increased penetration of DG units were observed for following system parameters:
 - on dynamic loadability
 - on oscillation damping

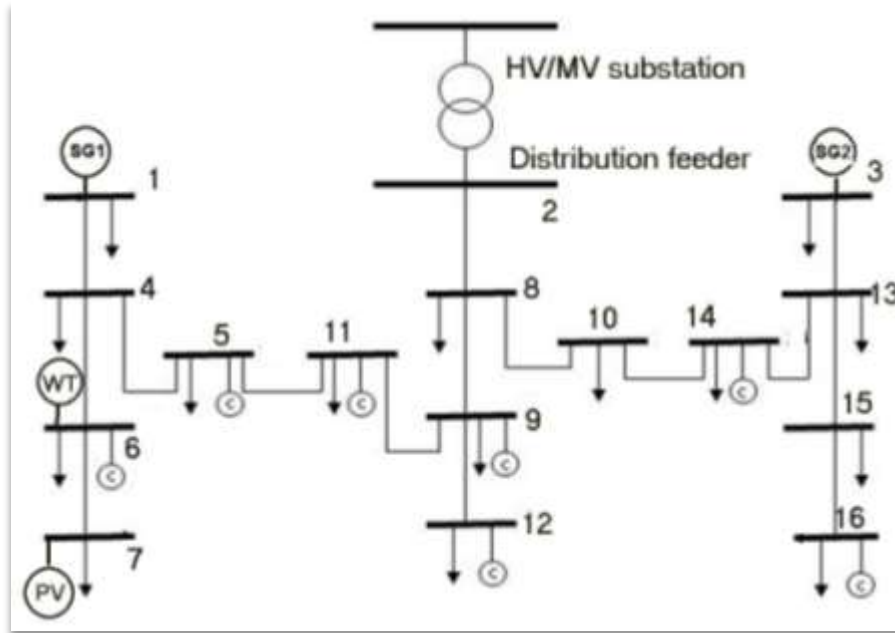
Results & Analysis

Generation Details

Generation type	Electric Machine	Machine Rating	Machine Model
SG1	SG (Voltage controlled)	S= 5MVA Pf=0.8 (lag)	6 th Order
SG2	SG (Pf controlled)	S=5.55MVA Pf=0.9 (lag)	6 th Order
Solar Panel (Aggregated Form)	Photo-Voltaic Static Generator (PV)	S= 1MVA Pf=1.00	Current Source
Wind Turbine	Squirrel-Cage Induction Generator (IG)	P= 2MW	3 rd Order

Results & Analysis

Test Distribution System



23kV 16 bus Primary Distribution System

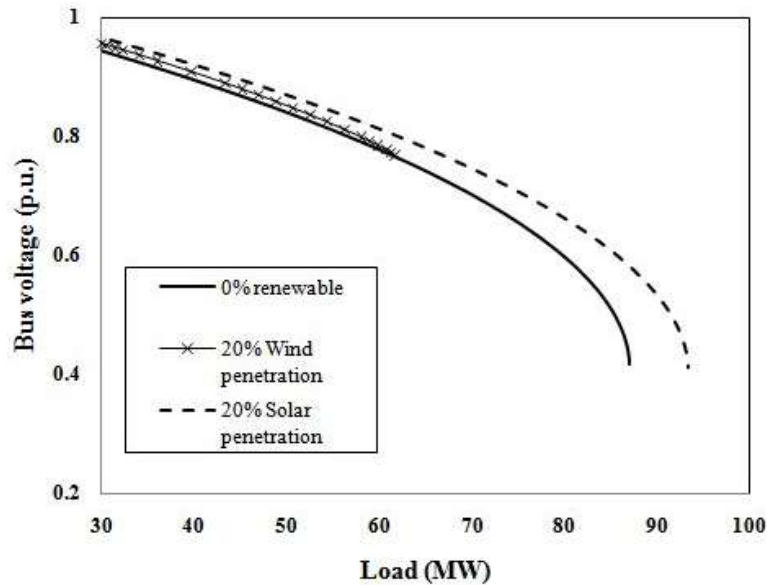
Software tools used

DigSilent PowerFactory 14.0

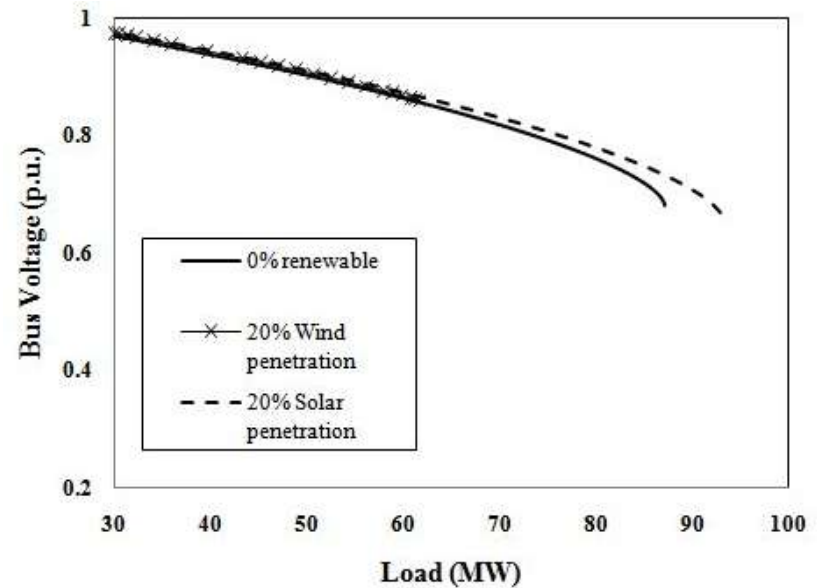
Power System Analysis Toolbox (PSAT)

Results & Analysis

Voltage Stability : P-V curve study



P-V curves for bus 7 with renewable penetration

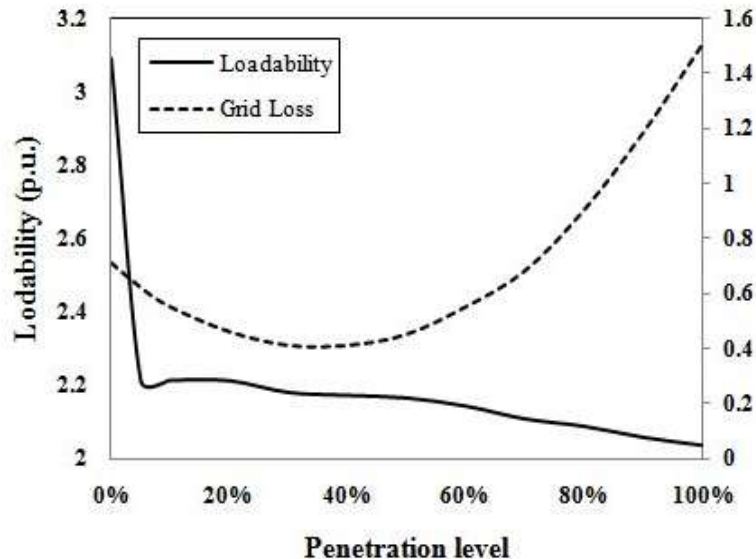


P-V curves for bus 16 with renewable penetration

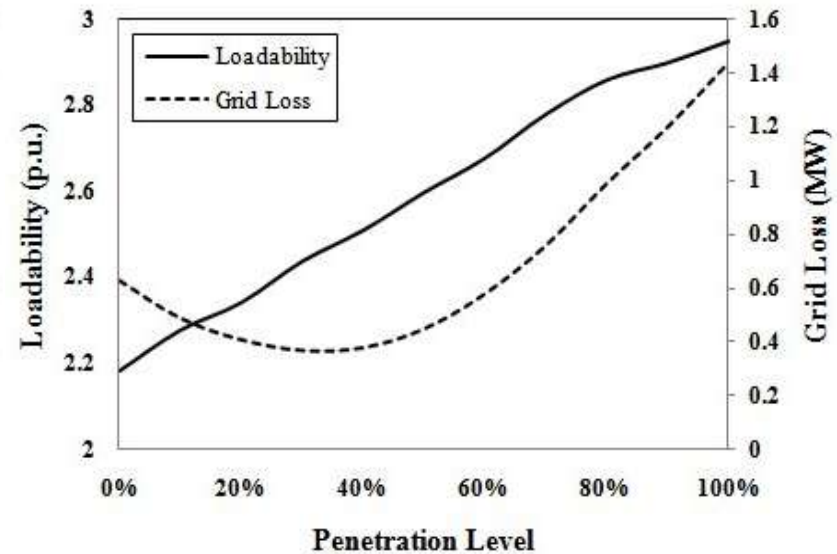
- Maximum loading margin has been found to increase from 87MW to 93 MW with 20% penetration of solar energy
- Loading Margin decreases to 61.73MW with 20% penetration of wind energy.

Results & Analysis

Impact of Penetration on Loadability and Grid loss



Impact of Wind Penetration



Impact of Solar Penetration

- With wind penetration, loadability has been found to be constant at 2.2 up-to 20% of penetration and then declining.
- For solar energy penetration, loadability keeps on improving from 2.2 to 2.95 at 100% penetration.
- Minimum grid loss is found at 30% injection of renewable generation.

Results & Analysis

Oscillatory modes and damping

Modes	Real Part	Imaginary Part	Damping (%)	Frequency
				(Hz)
1, 2	-5.57	20.64	26.1	3.41
3, 4	-4.23	18.15	22.7	2.96
5, 6	-9.81	17.72	48.4	3.23

- Three pairs of oscillatory modes were observed.
- Oscillatory frequencies are around 3 Hz, which is different from a large transmission system, which has frequencies of 0.1 to 2 Hz.
- Damping ratio of oscillatory modes are very good.

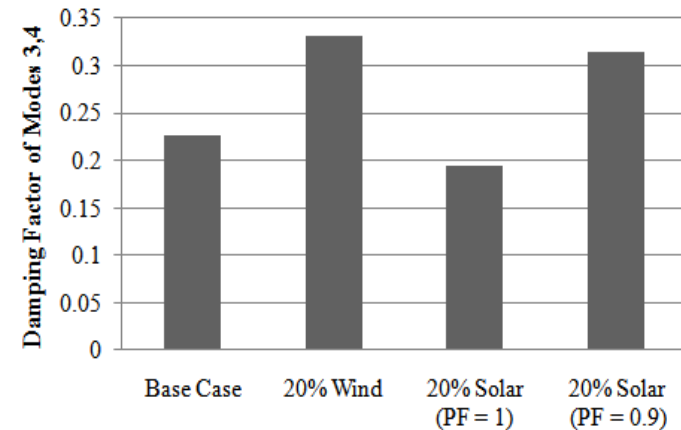
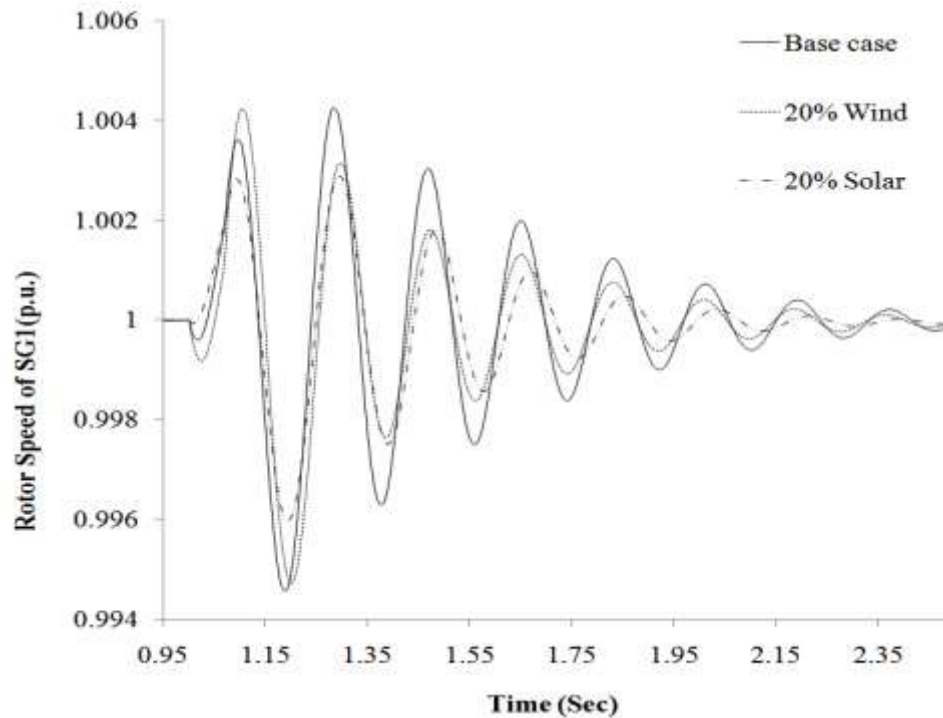
Impact of Penetration on dynamic loadability

	Base case	20% wind penetration	20% solar penetration
Loadability	53.6 MW	44.2 MW	53.6 MW

- Increased wind penetration reduces loadability of a system.

Results & Analysis

Impact of Penetration on damping



- Increasing wind and solar penetration improve time domain response. Hence, stability is improved.
- Increasing wind penetration improves damping ratio of an oscillatory mode.
- Operating solar PV at lower power factor is good for damping.

Conclusions

- In this work, impact of penetration of solar and wind power on stability of a distribution system has been discussed.
- Increasing penetration of solar energy improves system loadability.
- Increasing penetration of wind energy degrades system loadability.
- Grid loss
 - minimum for 20% to 30% penetration of wind and solar.
 - increases after certain level of penetration.
- Modal analysis shows the presence of low frequency oscillations of frequency 3 Hz in a distribution system.
- Damping of low frequency oscillations improves as the wind and solar penetration increases.



Thank You