# Impacts of wind and solar integrations on the dynamic operations of distribution systems

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# Presentation Outline

- Introduction.
- Test System and Modelling.
- Grid Interconnection Requirements.
- Case Studies
- Conclusions

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# Introduction

- DG is getting popular due to its environmental benefits.
- Most utility electric power systems are not designed to accommodate active generation and energy storage at the distribution level.
- Traditionally, distribution network design did not need to consider issues of stability as the network was passive.
- Transient voltage stability of distribution systems can also limit DG integrations in weekly coupling systems.

# Objective

- Compare the DG integration level with different control modes.

- Integration limitation due to transient voltage instability.

- Comparisons of dynamic performance and CCT of DFIGs, DDWGs and PV generators.

- Impact of energy storage on islanding of distributed systems

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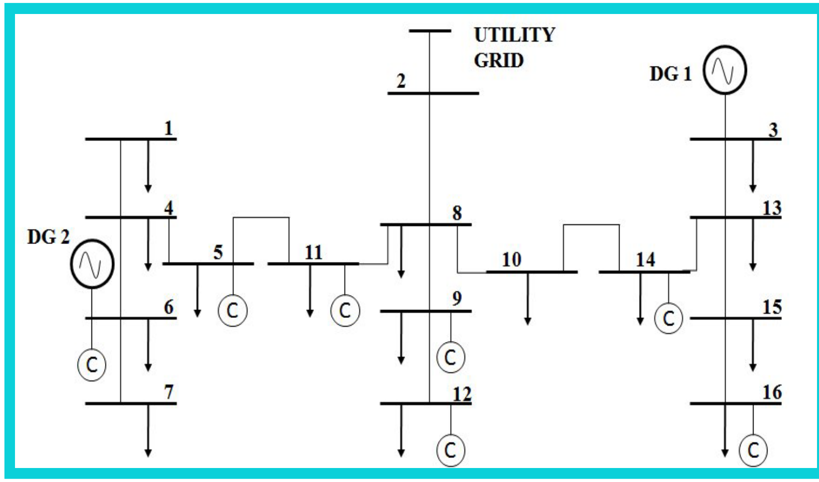
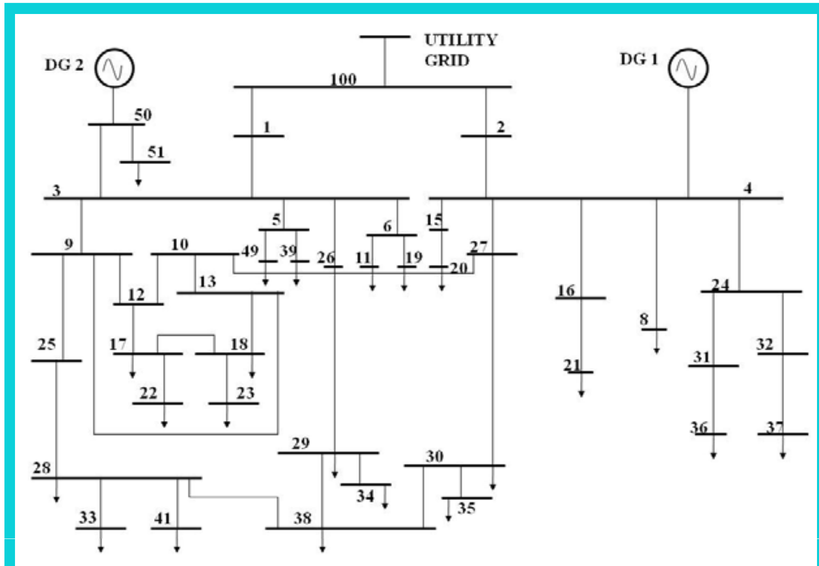
# Test Systems & Simulation Tool




- 23kV radial distribution system with 16 nodes
- Total load  28.7MW , 9.48MVAr
- Treated as commercial feeder




- Mesh distribution system with 43 nodes & five different levels of voltage -69kV, 13.8kV, 4.16kV, 2.4kV and 0.48kV.
- Total load  21.76MW, 9MVAr
- Treated as industrial feeder
- 20 dynamic IM load

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# DFIG

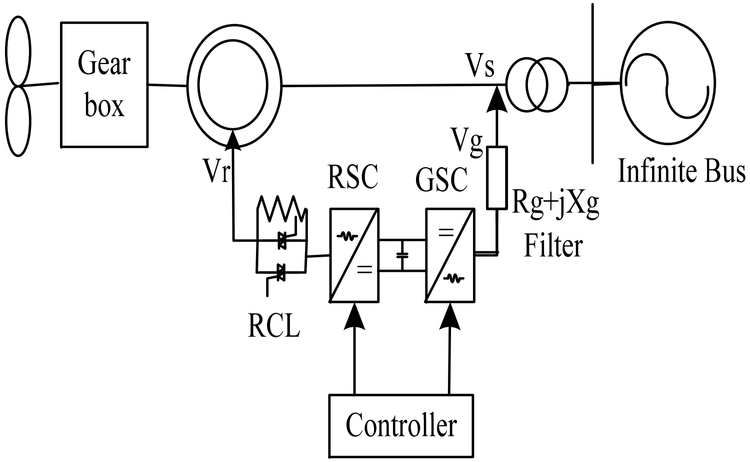
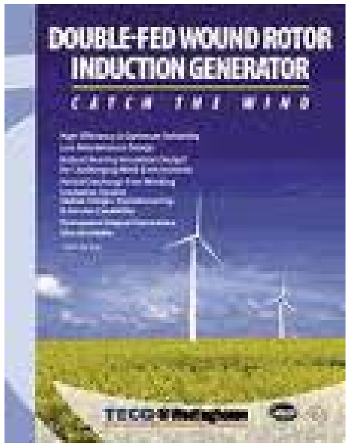



Fig. Schematic diagram of DFIG.

Source Wikipedia



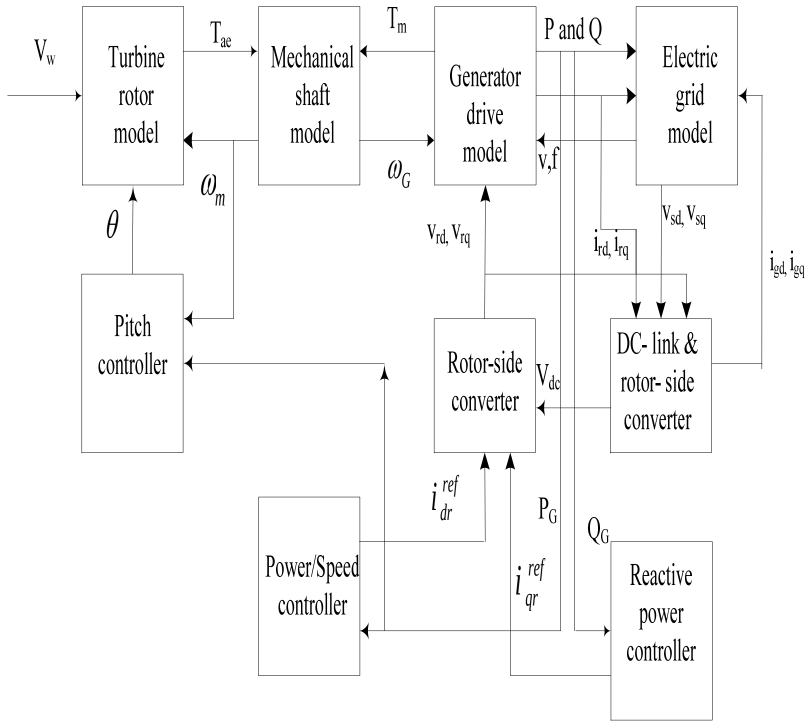
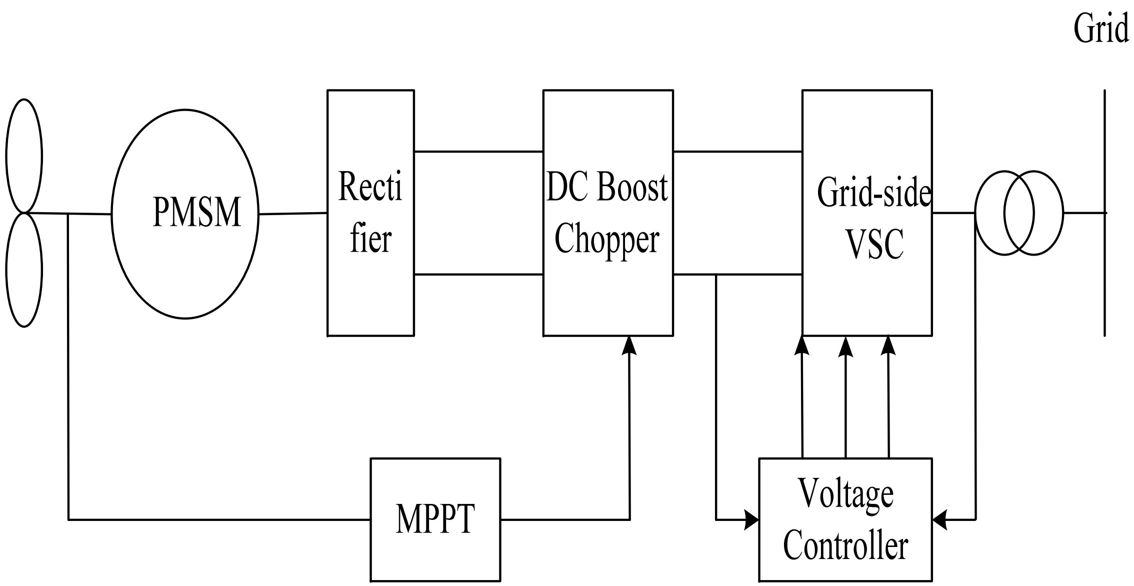




Fig. Block diagram of DFIG wind generation system

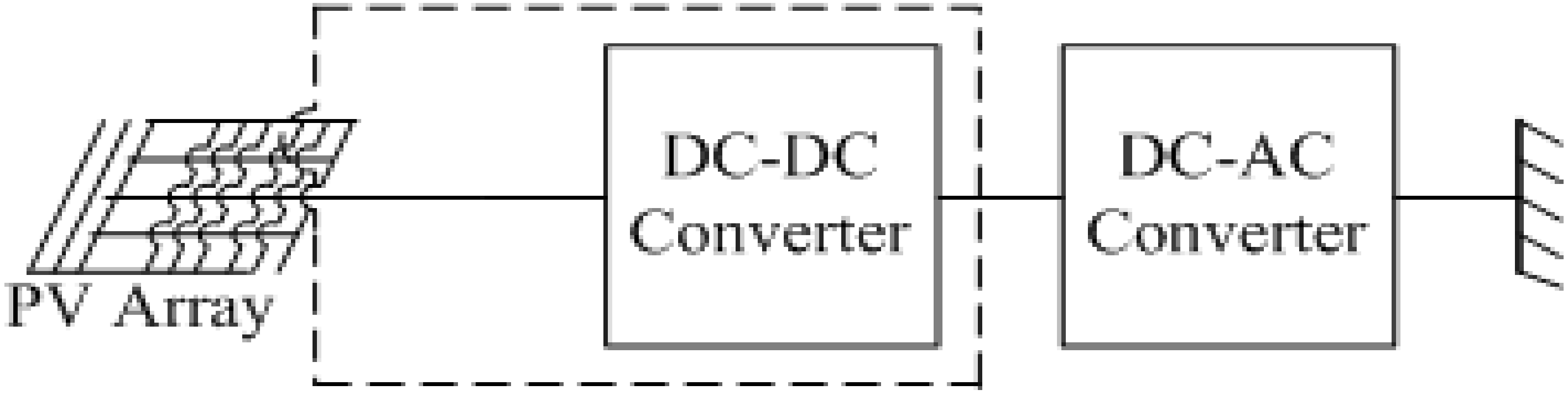
# DDWG




Schematic diagram of DDWG

Source Wikipedia

# PV




# Grid code requirements

(i) DG bus/ PCC should remain within the range of ±10% of nominal voltage;

(i) DG terminal voltage should return to acceptable range within 2 s of occurring fault;

(ii) Minimum damping ratio is 5% which means that in 3 oscillation periods the amplitude is damped to 32% of its initial value;

(iv) During transient period maximum rotor current is 2 pu and DC link voltage is 1.2 pu of the nominal voltage;

# Case Studies

(i) Integration level with steady-state voltage control capability of DG units;

- DG units without a voltage control capability (operated at a unity power factor, as suggested by IEEE 1547).
- DG units with power factor control mode.
- DG units with voltage control mode.

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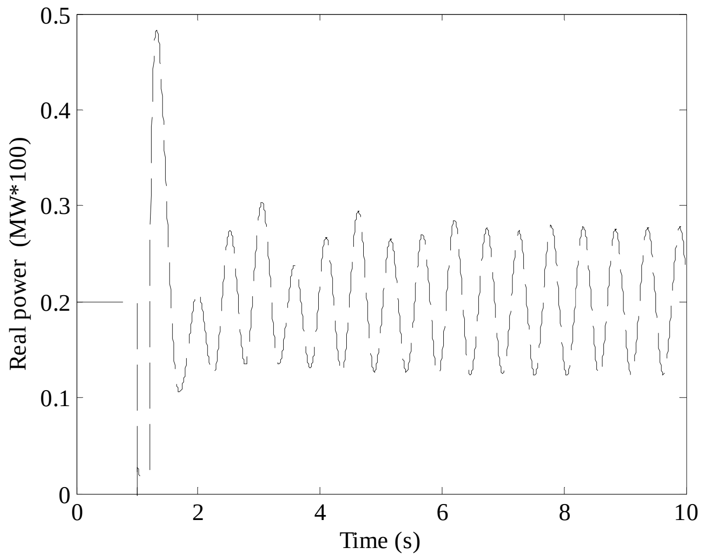
# Integration Level

| Control modes | Bus 1 (MW) | Bus 3 (MW) | Bus 6 (MW) |
|---|---|---|---|
| No control (unity pf) | 9.15 | 7.75 | 12 |
| Power factor | 12.5 | 11.5 | 18.5 |
| Voltage | 15.75 | 13.5 | 20 |

- The penetration level can be increased by 54.16% and 66.67% at bus 6 if the DG units are operated at the power factor and voltage control modes, respectively.

# Transient voltage instability

- A wind farm of capacity 20 MW and comprised of DFIGs can be accommodated at bus 39 without violating the voltage constraint in the mesh system.



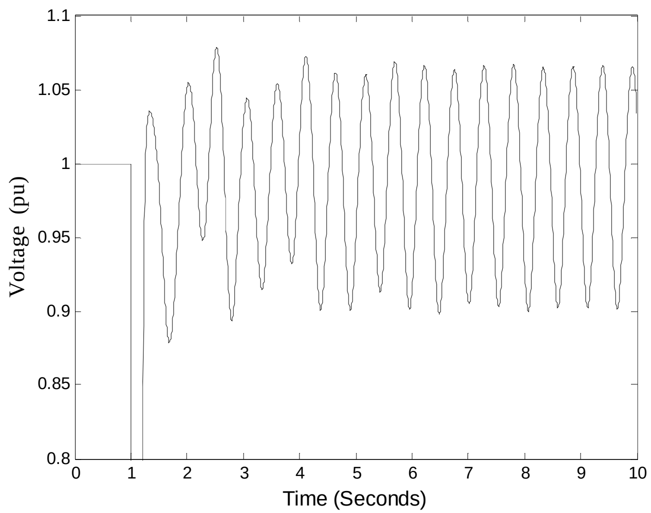




Fig. Real power and terminal voltage of DFIG

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# Comparisons of DFIGs, DDWGs and PV generators

- The DDWG provides better performances in terms of overshoot and settling time than do the DFIG and PV generator.

- During the post-fault phase, the DDWG takes 0.02~s to recover the voltage to the nominal value whereas the DFIG and PV generator take 0.10~s and 0.18~s, respectively.

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# Comparisons of DFIGs, DDWGs and PV generators

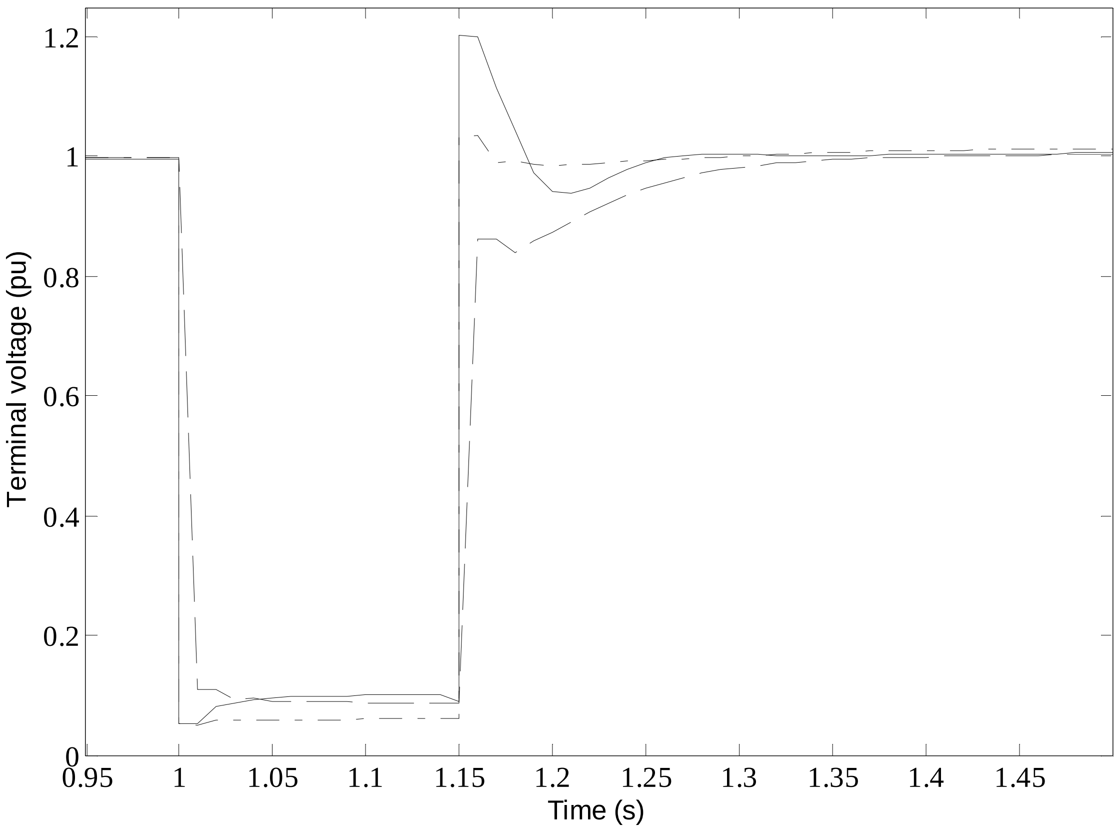


Fig. Terminal voltage for three-phase fault at bus 7 (solid line PV, dashed line DFIG and dash-dotted line DDWG )

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# Effect of islanding on dynamic performance

(i) DG units with no control (unity pf), (ii) DG units with voltage control capabilities and (iii) DG units integrated with a 2~MWh battery energy storage system.

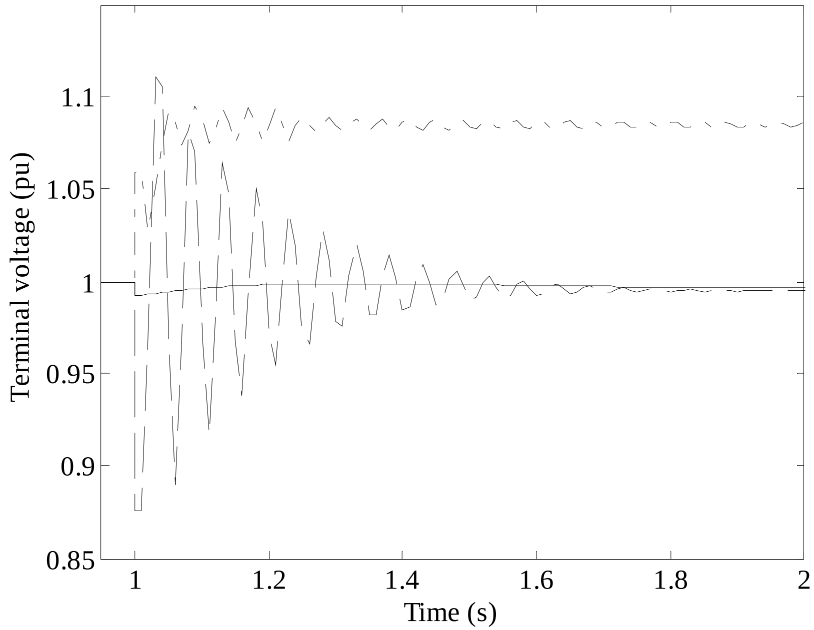


Fig. Terminal voltage of DG2 during islanding (Solid line battery storage, dashed line voltage control and dash-dotted line without voltage control)

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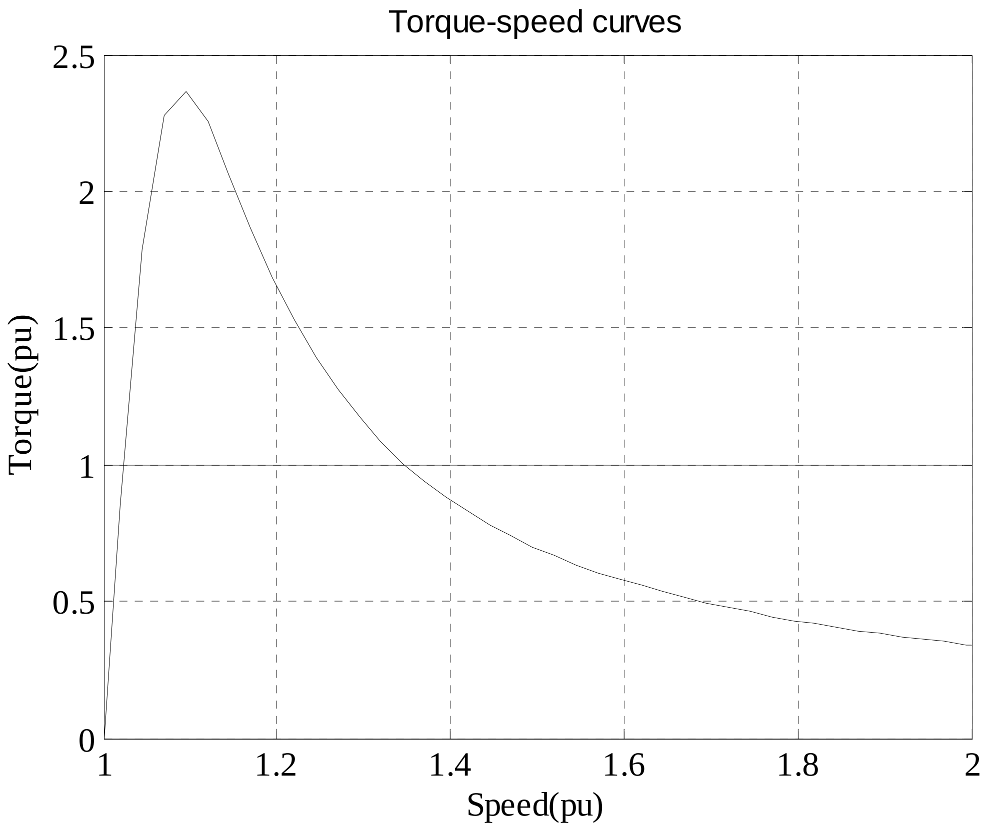
# FRT scheme comparisons

- The CCT is first estimated by using the following equation and then its exact value is determined from simulations;

$$\dot{s} = \frac{1}{2H_g}\left(T_m - T_e\right)$$

$$t_c = \frac{1}{T_m} 2H_m (s_c - s_0),$$

| Index | DFIG | DDWG | PV |
|---|---|---|---|
| CCT | 3.75s | 4.15 s | 3.56 s |

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# Interactions among DG units

- In this paper, all the dynamic responses of controllers are coordinated and simulations are carried out with: (i) DFIGs only; (ii) DFIGs and PV generators; and (iii) DFIGs, PV generators and DDWGs

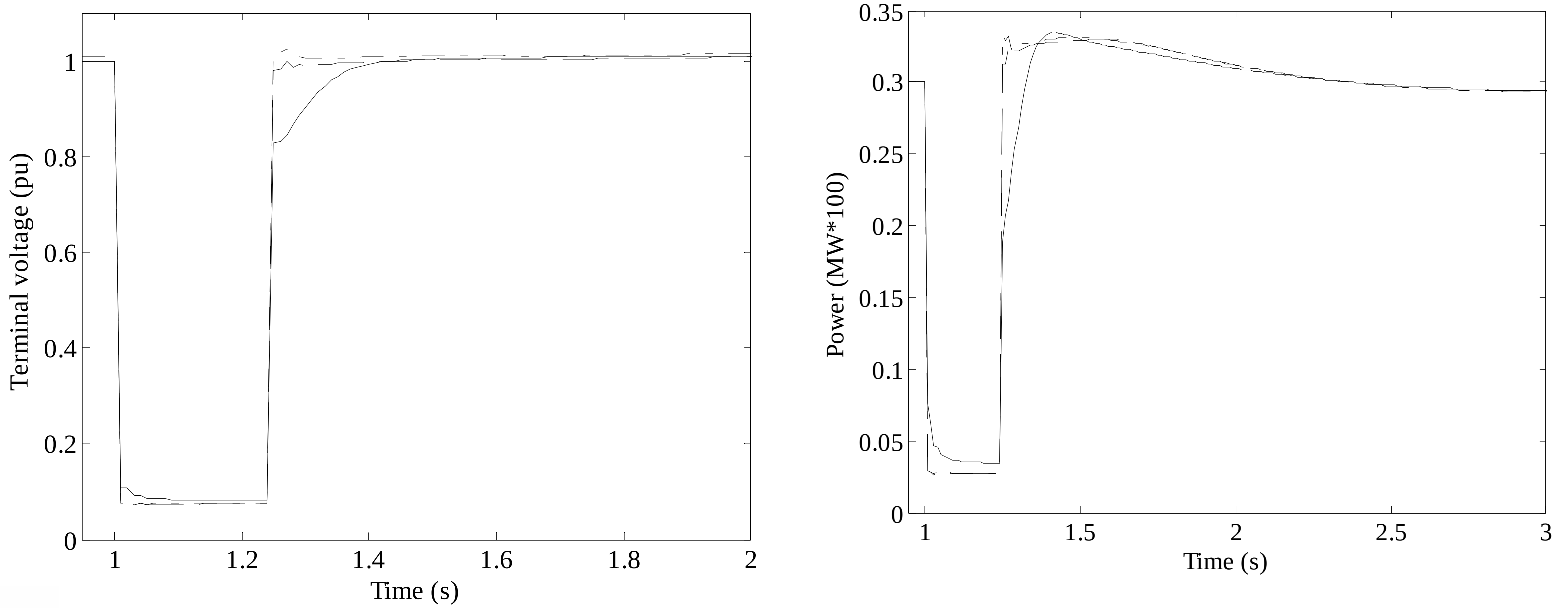


Fig. Voltage and Power (solid line DFIG only, dashed line DFIG+PV and dash-dotted line DFIG+PV+DDWG)

# Conclusions

- DG integrated with a voltage control capability can mitigate voltage rise problems and consequently enhance penetration levels.
- Transient voltage instability may also limit DG integration in a stressed system.
- A DG based on power electronics and equipped with a coordinated control enhances both the damping and voltage stability of a power system.
- BESS can ensure smooth transition from grid connected to islanding of DG units.

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# Thank You

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