Challenges in system integration of distributed generation with the grid

M. A. Pai

University of Illinois

Urbana, IL 61801

pai@ece.uiuc.edu

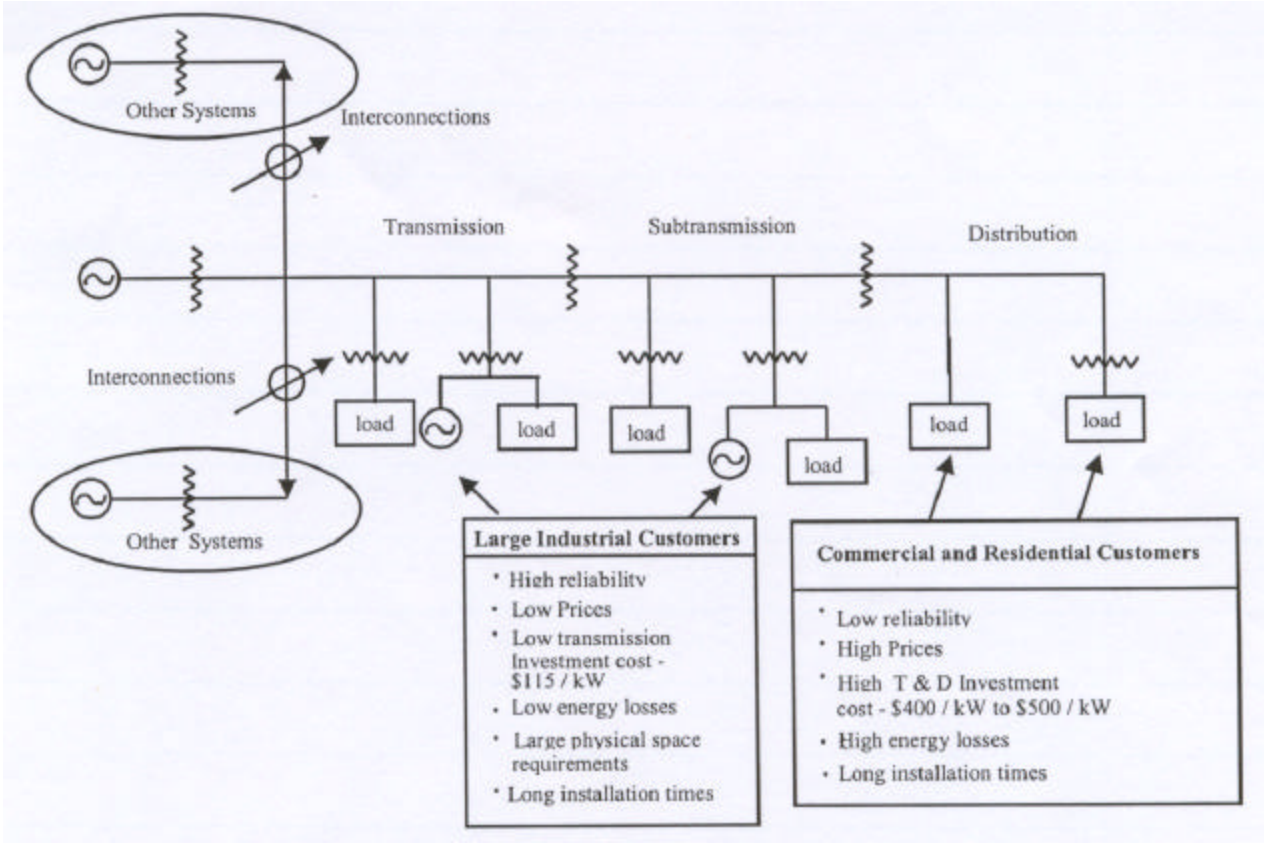
Distributed Generation

- A study by EPRI indicates by 2010 distributed generation (DG) will account for 25 % of the new generation
- Technical, economic, and environmental benefits
- Improved reliability?
  - Utility vs. DG owner opinions differ
- Single line diagram analysis (balanced) vs. three phase modeling (single phase DG, harmonic studies)

Technical challenges

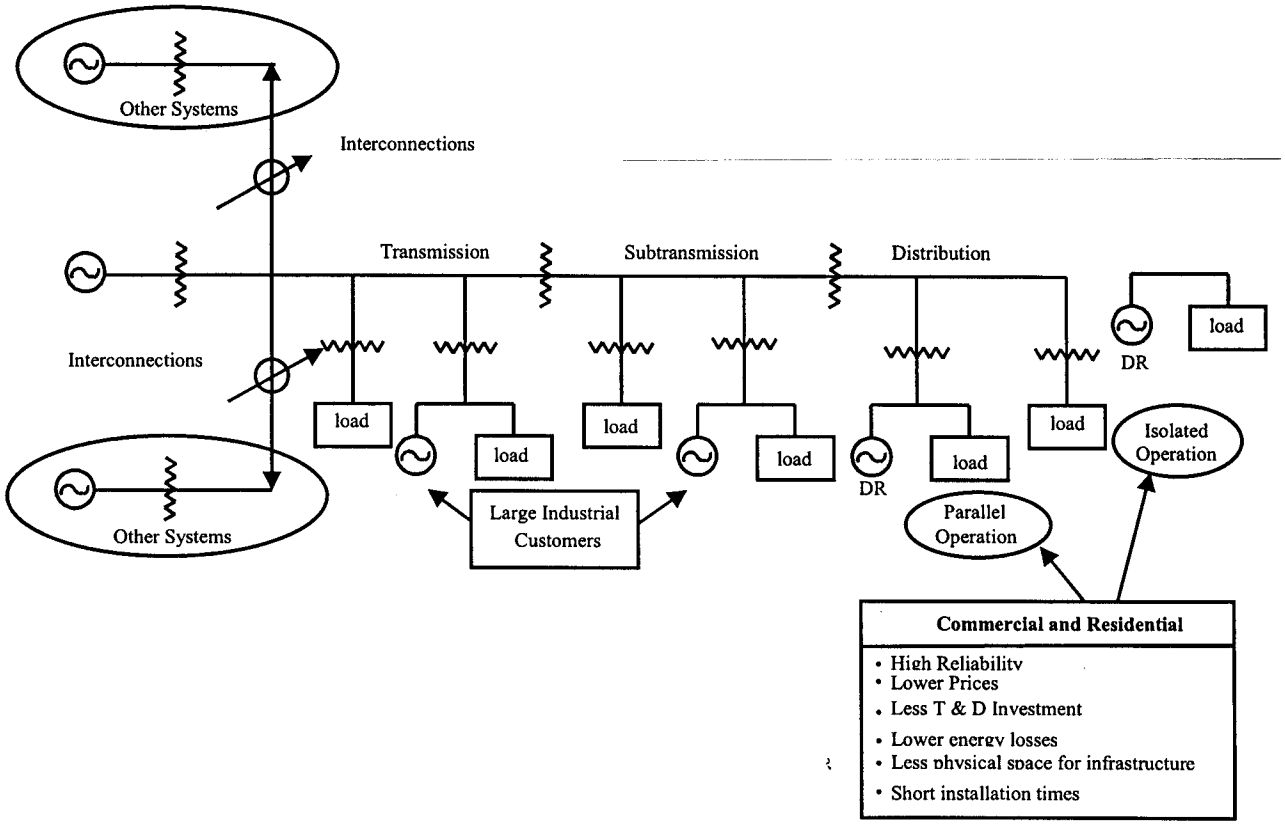
- System interface with the grid
- Operation and control of the DG
- Planning and design
- Interface in most cases involves power electronics except traditional synchronous generators.
- Voltage regulation in addition to tap changing transformer. Overvoltage problems may arise due to an ungrounded DG (wye-delta transformer) connected to three phase four wire system.

Characteristics of traditional central station generation and T&D



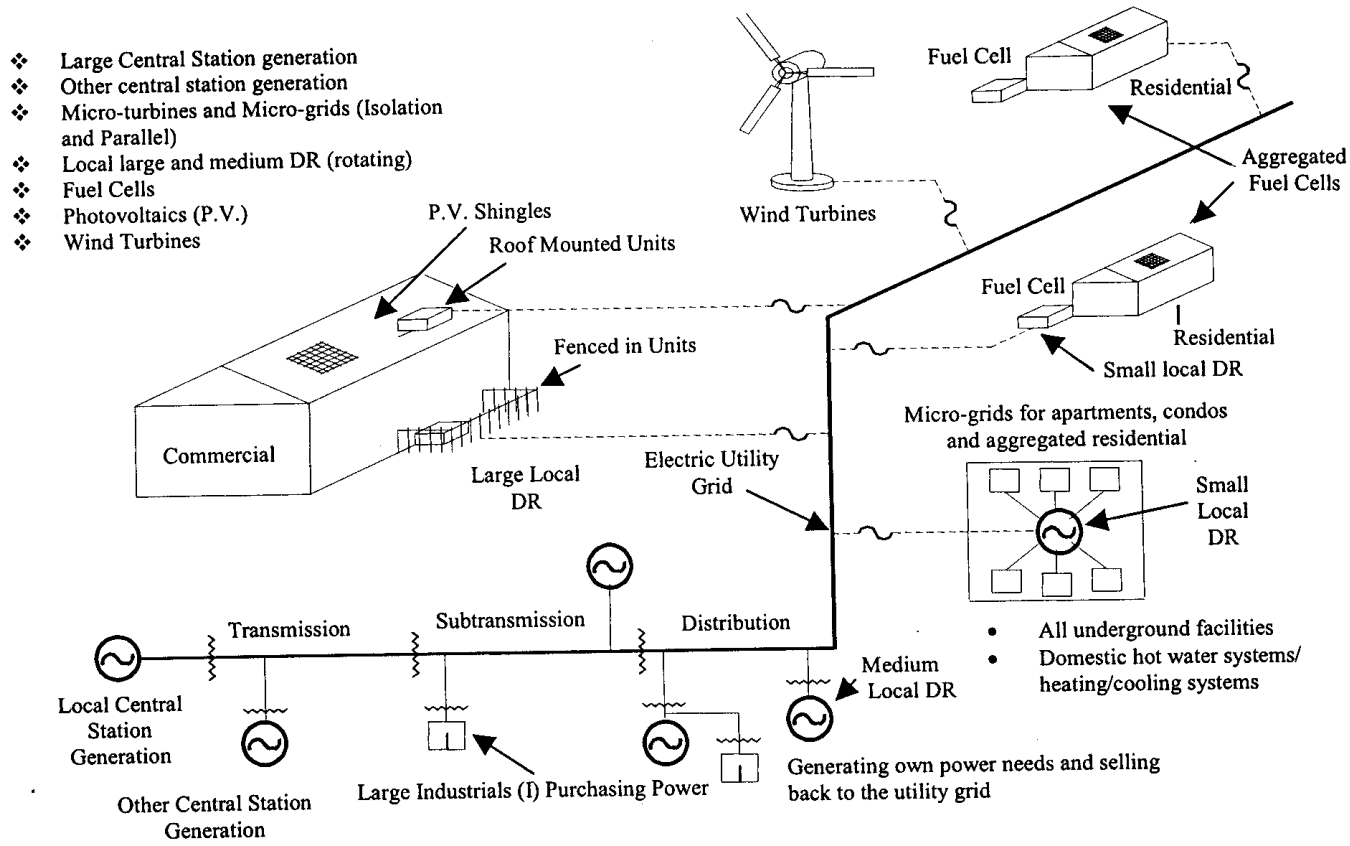
(Murray W David: DG in Power Systems Paper, IEEE PES Summer Meeting, Chicago, IL, July 21-25, 2002)

Characteristics of future central station generation and T&D with DR



(Murray W David: DG in Power Systems Paper, IEEE PES Summer Meeting, Chicago, IL, July 21-25, 2002)

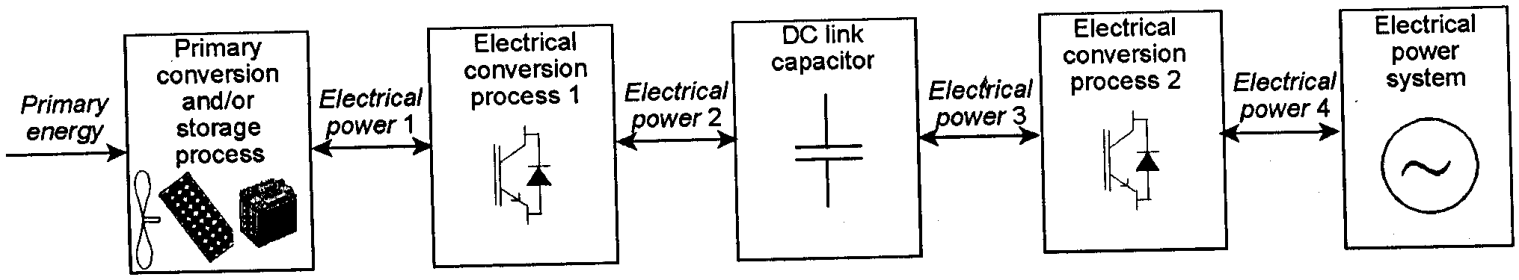
What will the future power system look like?



(Murray W David: DG in Power Systems Paper, IEEE PES Summer Meeting, Chicago, IL, July 21-25, 2002)

Interface with the grid

- Electronically interfaced generators



(Slootweg et al., "Modeling new generation and storage technologies," IEEE PES Summer Meeting, Chicago, July 21-25, 2002)

  - Middle three blocks represent the voltage source converter
- Rotating machine interfaced generators
  - Conventional synchronous generator/turbine representation

Typical interfaces used with DG devices

Type of DR device (prim mover or prime energy source type)	Typical interface device used to convert to prime source to power frequency
Internal combustion engine	Synchronous or induction generator
Combustion turbine	Synchronous or induction generator
Microturbine	Inverter or induction generator
Small hydro	Synchronous or induction generator
Fuel cell	Inverter
Wind turbine	Inverter or induction generator
Photovoltaic	Inverter
Battery, Ultracapacitor, high speed flywheel, or SMES storage devices	Inverter

Power Electronics

(Phillip Barker: Power system modeling requirements for rotating machine interfaced DR, IEEE PES Summer Meeting,Chicago, 2002)

System impact on distributed system

- With low penetration of DG, impact is limited to distributed system
- For example, impact on frequency and stability is low with low penetration
- Become important at higher penetration
- Reduced voltage sags with DG
- Inadvertent islanding

Some DG/P.S. interactions

1. DG interaction with power system protection devices including circuit breakers, reclosers, sectionalizing switches and fuses
2. DG interaction with power system voltage regulation equipment such as LTC transformers, autotransformer type step regulators, and switched capacitor banks

Some DG/P.S. interactions (cont.)

3. DG power quality interactions including harmonic distortion, voltage flicker due to DG output fluctuations, etc.
4. DG islanding response during upstream operation of protection/switching devices and faults on the system
5. Ferroresonance issues and islanding related overvoltages

Modeling studies

1. Short circuit and protection co-ordination
2. Load flow and steady state voltage studies
3. Voltage flicker studies
4. Harmonic studies
5. Islanding response studies
6. Stability and dynamics
7. Ferroresonance