DISTRIBUTED GENERATION AND POWER QUALITY

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DISTRIBUTED GENERATION

- Distributed Generation (DG) employs smaller-size generators.
- The electricity is usually generated by low-emission technology like wind, solar PV, fuel cells etc.
- These are distributed through the power system but are concentrated mainly closer to the loads.
ADVANTAGES OF DG

- The customers get the benefit of backup generation improving the reliability of the power supply, possibly at a lower cost.
- The technology can be effectively used for combined heat and power applications.
- DG can enhance the generation capacity of a power system without having an adverse impact on the environment.

DG TECHNOLOGIES

- Reciprocating piston engines,
- Gas turbines,
- Fuel cells,
- Wind turbines and
- Photovoltaic (PV) systems.
RECIPROCATING ENGINE

- Mature technology.
- Most common and least expensive.
- Gas or diesel engines.
- Used for both transmission & distribution applications.
- Usually synchronous generators – induction also possible.
- Efficiency 35 to 40 percent.

GAS TURBINES

- Power range 1 to 10 MW.
- Usually used in distribution networks.
- High speed turbines in the range 8000 to 12000 rpm.
- Usually geared down to 50 or 60 Hz level.
- Natural gas is the most common fuel.
- Various other liquid fuels are also used.
MICROTURBINES

- New technology.
- One-piece turbine with a permanent magnet motor.
- The speed range is between 10,000 to 100,000 rpm.
- Needs power electronics for interfacing.
- Rectifier-inverter combination is required for producing 50/60 Hz ac.

MICROTURBINES (Continued)

- The rating varies between 30 to 75 kW.
- Units in the range 300 to 400 KW are also available (called miniturbines).
- The efficiency is in the range of 25-30%.
- The efficiency can be as high as 60% in combined heat and power (CHP) applications – best suited for this.
FUEL CELLS

- Best suited for CHP and automotive applications.
- Very quiet and has no harmful emissions.
- Since fuel cells produce dc output voltages, inverters are required for interfacing to the ac systems.
- Very expensive – the price will come down when fully adopted by automotive industries.

WIND TURBINES

- A cost competitive means of power generation in coastal areas.
- A group of wind turbines connected together to generate power in the range of 200 to 500 MW in a so-called Wind Farm.
- Large wind farms are connected to transmission grids in places like California.
WIND TURBINES (Continued)

- Wind generation occurs at sparsely populated areas – voltage regulation is often a problem.
- Usually induction generators (squirrel-cage or wound-rotor or doubly fed) are used.
- Non power frequency machines can also be used with an inverter interface.

PHOTOVOLTAIC SYSTEMS

- Well-suited for CHP applications.
- Installation cost is substantial. However once installed the running cost is negligible due to the availability of abundance sunlight free of cost.
- Can only work during the daytime.
- Generates dc power and hence requires inversion.
PQ PROBLEMS DUE TO DG

- Power variations from wind or solar can cause voltage fluctuations.
- Fuel cells and microturbines sometimes do not follow the step change in load well. They need supplementary source such as battery or flywheel storage.
- Inverter connection can lead to harmonics and voltage flicker in distribution systems.

ISSUES FOR DG

- Impact on protection systems.
- Dynamic interaction between generators.
- Conflict in voltage control for generators in proximity.
- Sustained interruptions.
- Harmonics.
- Voltage sags.
**ISLANDING**

*Islanding* can be defined as that operation where a DG maintains the electric supply on a local section of distribution system, which is disconnected from the utility source following an opening of a circuit breaker on a distribution line. This may be caused due to parallel operation of DG units with the utility grid system when the utility grid is removed due to a fault.

**ISLANDING (Continued)**

- DG may continue to support the island as long as the system frequency and voltage are within limits.
- A power-island can be created without the knowledge of the utility personnel and public and hence can be a safety hazard.
- Other issues involved are grounding system, synchronization, orderly restoration of utility supply etc.
VOLTAGE DIP

- One of the main PQ problems.
- Usually caused by sudden load demand, motor start, network fault etc.
- Large motors can cause large voltage dips during starting due to the higher supply impedance of rural networks.
- Solution: DG with voltage control capability.

HARMONIC EFFECTS OF DG

- Harmonic distortions are caused by non-linear loads such as adjustable speed drives, arc furnaces, electronic converters, rectifier loads etc.
- Distributed generators may introduce or reduce the harmonics in the network, depending upon the design of generator and selection of technology.
HARMONICS (Continued)

- Properly designed rotary type generators can generate voltage waveforms that are free of harmonics.
- However, depending on the design of the generator windings (pitch of the coils), core non-linearity, grounding and other factors, they may become a source of harmonics and generate distorted voltage with a significant amount of harmonics.

HARMONICS (Continued)

- Line commutated inverters or SCR type inverters produce high levels of harmonic currents – are rarely used.
- Current practice is to use inverters are designed based on controlled switches (e.g. IGBT).
- These inverters use pulse width modulation to generate clean sinewave voltages that get injected into the ac system.
HARMONICS (Continued)

- PWM inverters are capable of generating a very clean output that is almost free of low-order harmonics.
- PWM inverter based connection is capable of very fast control.
- PWM inverters, in conjunction with passive filters, can keep the voltage at the point of connection totally harmonic-free.

VOLTAGE FLICKER

- A DG installation may increase the flicker level during start/stop or if it has continuous variations in input power because of a fluctuating energy source.
- Squirrel cage induction generators have a high possibility to make flicker level worse because of an inability to actively control terminal voltage.
VOLTAGE FLICKER (Continued)

- In the case of an individual wind and solar energy generator, the output will fluctuate significantly as the wind and sun intensity changes.
- Mitigation approaches for induction generators include reduced voltage starts, as well as speed matching and active or passive reactive power compensation.

VOLTAGE FLICKER (Continued)

- Synchronous generators might require tighter synchronization and voltage matching.
- Inverters might be controlled to limit inrush currents and changes in output levels.
- Energy storage devices such as flywheels, variable speed drives for wind generators or batteries might be used to compensate for fluctuating power levels.
CONCLUSIONS

- DG and its interconnection to the ac power grid is relatively new concept.
- It is also possible to operate a group of DGs in an island – the microgrid concept.
- The DG should preferably comply with IEEE P1574 standard for distributed resources interconnections.