Hybrid Microgrids as solution for distributed generation and renewable sources (AC/DC study)

Nariman Rahmanov
nariman @ cpee.az

Azerbaijan Scientific Research and Design-Prospecting Power Engineering Institute (PEI)
Azerbaijan Cleaner Production and Energy Efficiency Center
Basic directions of Power System future development

- Increasing of Renewable Sources share to energy producing in Power System.
- Worldwide using Distributed Generation technology.
- Replace small power systems (Micro-GRID) for supplying local far-away consumers.
- Realization of Smart GRID principles in Power System operation.
- Increase DC loads in commercial, industrial and residential applications – creating AC / DC Micro-GRID.
What are MICROGRIDS?

Interconnection of small, modular generation to low voltage distribution systems forms a new type of power system, the Microgrid. Microgrids can be connected to the main power network or be operated islanded, in a coordinated, controlled way.
Technical, economic and environmental benefits

- Energy efficiency
- Minimisation of the overall energy consumption
- Improved environmental impact
- Improvement of energy system reliability and resilience
- Network benefits
- Cost efficient electricity infrastructure replacement strategies
- Cost benefit assessment
Potential for DG to improve service quality

Distribution of CMLs
Network Benefits – Value of Micro Generation

~ .02-.04 €/kWh
Central Generation

~ .03-.05 €/kWh
Transmission

HV Distribution

~ .05-.07 €/kWh
MV Distribution

~ .1-.15 €/kWh
LV Distribution

Micro Generation
Technical Challenges for Microgrids

• Relatively large imbalances between load and generation to be managed (significant load participation required, need for new technologies, review of the boundaries of microgrids)
• Specific network characteristics (strong interaction between active and reactive power, control and market implications)
• Small size (challenging management)
• Use of different generation technologies (prime movers)
• Presence of power electronic interfaces
• Protection and Safety
Micro-GRID Structure with combined AC / DC Network

• Traditionally electrical energy is generated on big power plants in close vicinity of fuel sources and then having been transferred to the centers of consumption. To reduce energy losses power transformers were used to increase voltage level till 220-1150kV and then reduce it on the consumption

• Side to the level of distribution network 35/10/0.4kV. In regional distributive networks power flow usually directed to the one end – from substation to the customer. Network considered as a passive due to absence f sources of electrical energy in it.
DC Sources of Power

- Photovoltaic
- Microturbine
- Wind
- Fuel Cell
- Storage (e.g., Ultra Capacitors)
Most Popular DC users

- CFL bulbs (compact fluorescent lamps)
- LED lamps
- Computers, office equipment
- Commercial and residential electronic equipment
- VFD (frequency controlled motors)
- Data Centers
- PHEV (hybrid electrical vehicle)
DC Micro-GRID

AC Generation
- Utility
- Generator

DC Generation
- Fuel Cell
- Microturbine
- Photovoltaic

DC Bus

Inverter
- AC Loads

AC Load

DC Load
- DC Loads Internet/Telecom
- DC-DC Converters

Storage
- Ultra Capacitor
- Battery
- Fly Wheel
Combined AC / DC Micro-GRID System

- AC Micro-grid
  - Diesel Generator
  - Wind Speed
  - Gear
  - DFIG
  - AC/DC/AC
  - SCIG
  - Tidal Current Speed
  - Gear
  - Utility Grid
  - AC Loads
  - AC Bus

- AC/DC Power Flow Coordinator
  - Bidirectional AC/DC Main Converter
  - DC Bus
  - DC/AC PMSG
  - Wind Speed
  - Solar Irradiation
  - Temperature
  - DC/DC Boost
  - DC/DC
  - Fuel cell Stack
  - DC/AC
  - Flywheel
  - Bidirectional Converter
  - Battery
  - DC Plug-in EV
  - Electric Vehicle (EV)
  - DC Loads

- DC Micro-grid
  - DC Bus
  - DC/AC
  - Battery
  - DC Loads
Modeling and Simulation.

Case 1: Operate in a GRID tied mode.

Transition stage – a Hybrid AC-DC Micro-GRID

On the first stage it is considered to use combined supply of consumers from DC and AC buses.
Modeling and Simulation.
Case 1: Operate in a GRID tied mode.

1.1 Model of analyzed AC-DC Micro-GRID without wind generator
Modeling and Simulation.
Case 1: Operate in a GRID tied mode.

1.2 Hybrid DC-AC Micro-GRID (Load Flow of DC)
1.2 Hybrid DC-AC Micro-GRID (Load Flow of DC) – continuation

- Along with conventional Diesel generator Gen.1 there is a small wind generator WG1 with nominal power 200kW supplying AC load 60KVA (Load2) through AC bus (Bus3).

- On DC bus side (dcBus1) there are PV solar unit with output voltage 200V connected through the booster DC/DC to the dcBus1, 50KW load (dcLoad1), battery (Battery1) and terminal dcBus 8 for charging plug-in electric vehicles (PEV or PHEV).

- There are also converter and inverter for energy exchange between both ac and dc buses.
Modeling and Simulation.
Case 1: Operate in a GRID tied mode.

1.3 No power from AC bus and PV-unit (power entered into the Micro-GRID from E-cars)
1.3 No power from AC bus and PV-unit (power entered into the MicroGRID from E-cars) - continuation

- There is a case 1.2 when on the AC side Wind generator produce no power.

- Some extra power (40kW) pass from DC bus to the AC bus through Inv5 and Grid adds some 15 kW needed by AC Load1.
Modeling and Simulation.
Case 2: Operate in a autonomous mode.

No power from GRID and PV-unit (power entered into the Micro-GRID from E-cars and partially from Diesel-generator Gen.1

Diagram showing electrical system with components like Bus 1, Bus 2, Bus 5, Battery 1, Load 1, PV-solar plant, and various converters and power units.
Modeling and Simulation.

Case 2: Operate in a autonomous mode (continuation).

- The last case is the islanded mode of operation when Micro-GRID is separated from the GRID and PV plant is off.

- AC load (50kW) is getting 40kW from the Diesel generator Gen.1 and 15 kW is coming from dc network.
Barriers on the way for wide range realization of DC Micro-GRIDs

- Fear of changing or fear of something new, non-traditional
- Proved case of DC energy delivering still not much clear
- Most of the used equipment has no compatible input socket to feed from dc power supply
- There are still no standards on safety and protection
- Standard practice on development, implementation and maintenance of DC Micro-GRID is not mature
- Still no standards in the level of voltages
- Induction machines with direct supply from AC terminals – which are the base of most industrial equipment
Advantages of DC Micro-GRIDs

• Not necessary the synchronization of DG networks generators
• Deviation of generated and consumed power may be compensated in Micro-GRID by installation of energy storage units.
• The loads are not impacted by harmonics, voltage sag or swell, non symmetry of phase voltages.
• Voltage quality does not change due to current surge (during commutation of induction containing circuits) or in presence of one phase load or generator.
• DC Micro-GRIDs are more efficient than AC Micro-GRIDs
Conclusion

- A Hybrid AC-DC Micro-GRID can reduce the number of AC/DC or DC/AC converters in AC or DC Micro-GRID.
- A Hybrid AC-DC power supply system concept may be implemented on the base of Micro-GRID with further expansion to the cellular Micro-GRID system.
- A Hybrid AC-DC power supply system increase energy efficiency and improve reliability.
A Tall of Power Outages

Total Annual cost of power outages and PQ disturbances by business sector

Total $119–$188 Billion

$14.3 $6.2 $34.9

Digital Economy Continuous Process Mfg. Fabrication & Essential Services Other U.S. Industry

Cost of:
PQ Disturbance Power Outage

$66.6–135.6
Thanks for your attention