DISTRIBUTED GENERATION (MINI & MICROGRID)
-ISSUES, SOLUTIONS AND REVIEW OF EXISTING SYSTEMS

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NCPRE

Why Distributed Generation?

- Increase in load growth and depletion of fossil fuel
- Proximity of load and source - reduce T&D losses
- Standalone and grid connected systems can be used for augmentation and hence improving power quality and reliability of supply
- Peak operating costs
- Increase system-wide reliability
- Give customer more choices.
- Efficiency of system can be improved by using CHP, co-generation and tri-generation

SOURCES FOR DISTRIBUTED GENERATION

- Wind power
- Natural gas
- Biogas
- Solar thermal
- Solar PV
- Fuel cell
- Combined Heat and Power
- Micro Turbines
- Sterling Engines

MICROGRID

- Microgrid is formed by integrating distributed generators, loads and storage devices
- Operate in parallel to the grid in three modes
  - Grid Connected mode
  - Autonomous power or Island mode
  - Transition between the two above
- No huge investment required for transmission of power
- A stable and controllable microgrid is always an asset to the power system operator
- Provide local voltage support and also increase system reliability

Issues With Microgrids

- Protection
- Synchronization – Reconnection – Restoration
- Islanding
  - Intentional
  - Unintentional
- Power Management
- Power Quality and Reliability
- Storage

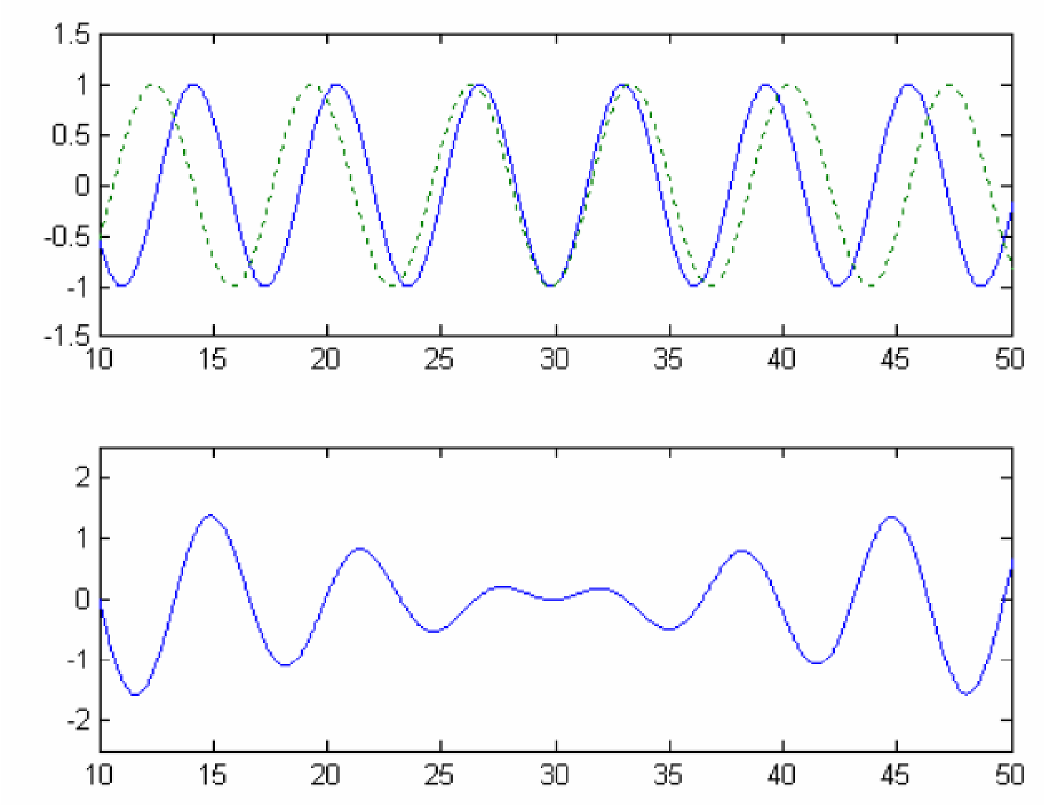
Synchronization

- Re/connection is made when the main grid and MG are synchronized at the PCC in terms of voltage, frequency and phase angle
- Limit values for synchronous interconnection between MG and main grid.

Total DG Rating (kVA)	ΔF (Hz)	(ΔV%)	Δø (^{0})
0-500	0.3	10	20
>500-1500	0.2	5	15
>1500-1000	0.1	3	10

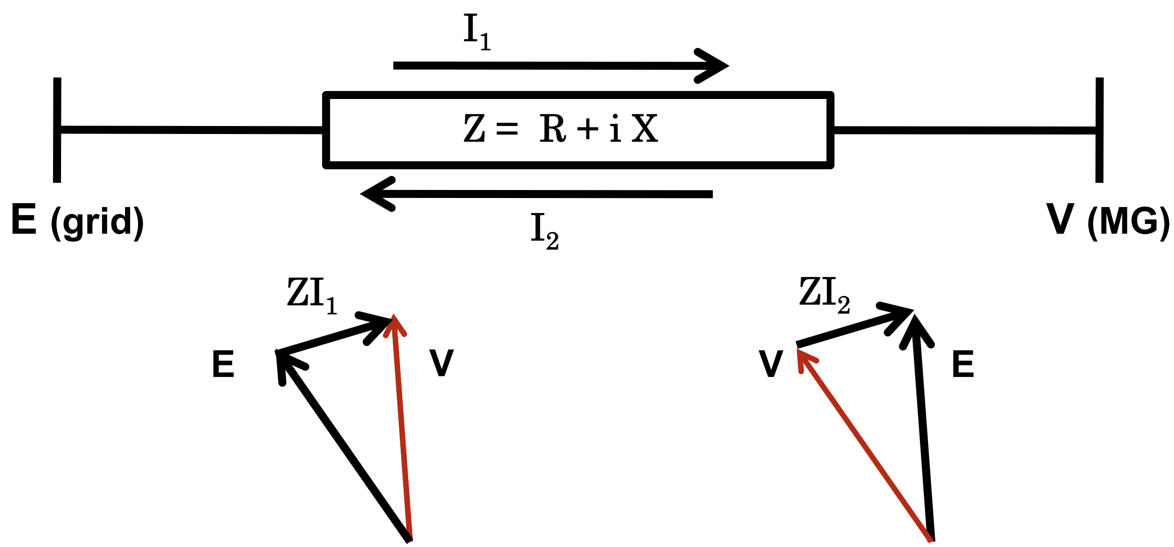
SYNCHRONIZATION

- Frequency is not uniform on both sides
  - The phase angle between E and V is constantly changing from a 0^0 to 180^0.



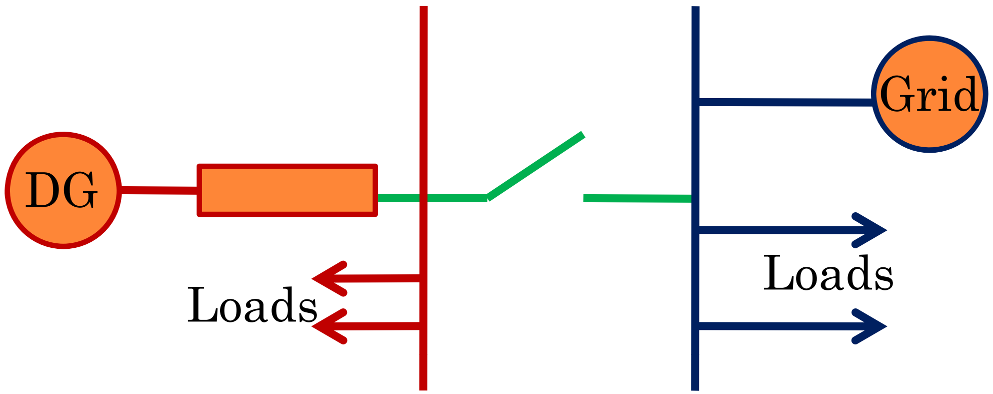
SYNCHRONIZATION

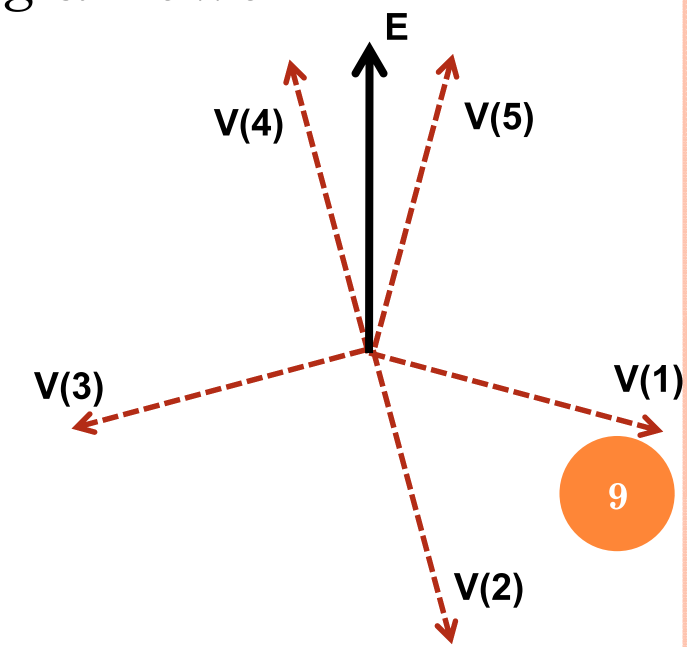
- Closing a switch in a RL circuit with zero initial current
- The relative placement of voltages at the instant of closing decides the direction of current flow



SYNCHRONIZATION

- Conditions for synchronization
  1. Voltage across the switch/contactor must be small
  2. The voltage with higher frequency shall lead the voltage with lower frequency.
- Power flow is always from unit operating at higher frequency to unit operating at lower frequency





ISLANDING –
PLANNED - UNPLANNED

- *"The process whereby a power system is split into two or more segments, each with its own generation. Islanding is a deliberate emergency measure, the result of automatic protection or control action, or the result of human error."* -IEEE Std. 1547
- It can be either be planned or unplanned.
- DERs continue to provide energy to the isolated system after islanding.
- Planned islanding
  - It is possible to have proper load sharing between DGs and loads in autonomous mode
  - Transients can be avoided

ISLANDING – PLANNED/INTENTIONAL

- Frequency of the utility side falls below a threshold
  - Lack of generation on grid side
- Poor voltage quality
  - Unbalance due to nearby asymmetrical loads
- Sensitive loads
  - Last longing voltage dips
- Fault in the system
- Direction of flow of current

ISLANDING – UNPLANNED

- Un-planned islanding
  - It is primarily due to fault in the system, blackouts, voltage drops, short-circuits etc.
- Severity of transients depends on
  - Operating condition before islanding
    - Importing of Power
    - Exporting of Power
    - Floating point
  - Location of disturbance
  - Type of DGs in the microgrid
- Reconnection to main grid is possible when the fault is cleared and system is restored.

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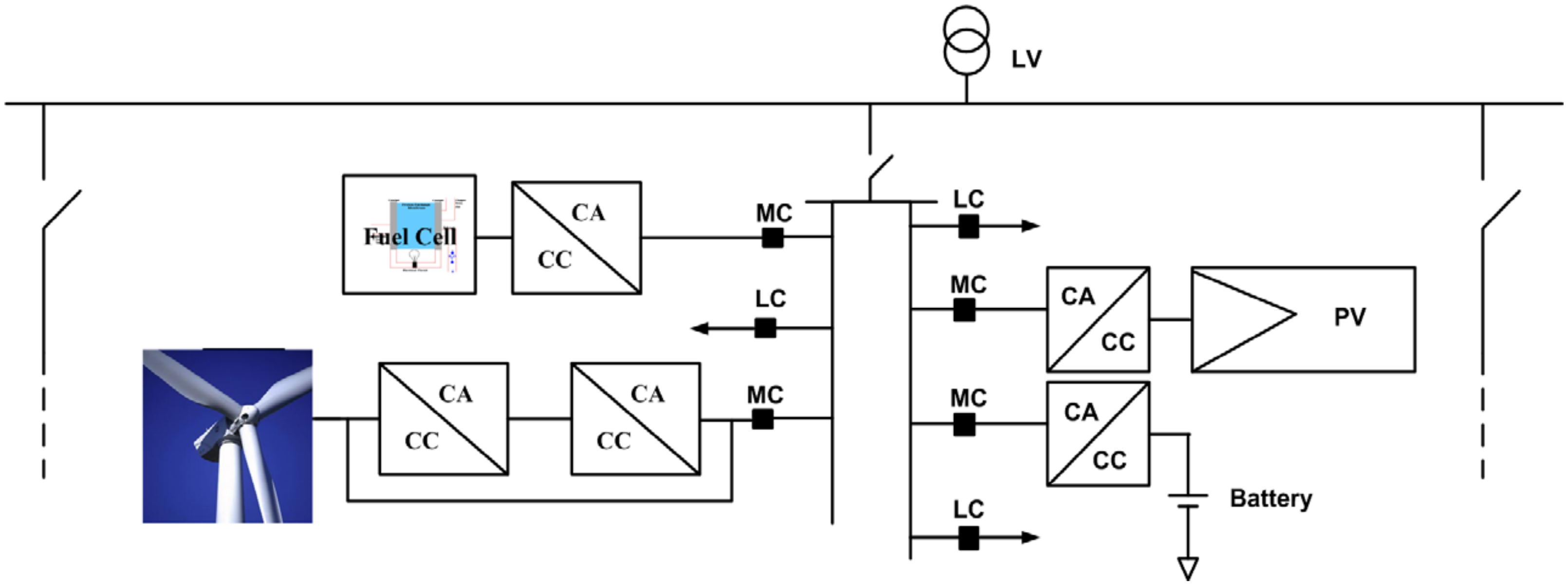
Islanding Detection Techniques

- Passive
  - Under/over voltage
  - Under/over frequency
  - Phase jump detection
- Active
  - Algorithm based on current injection
  - Sandia national laboratory algorithm
- Utility control
  - Island detection by communication signals
  - SCADA – Supervisory control and data acquisition system

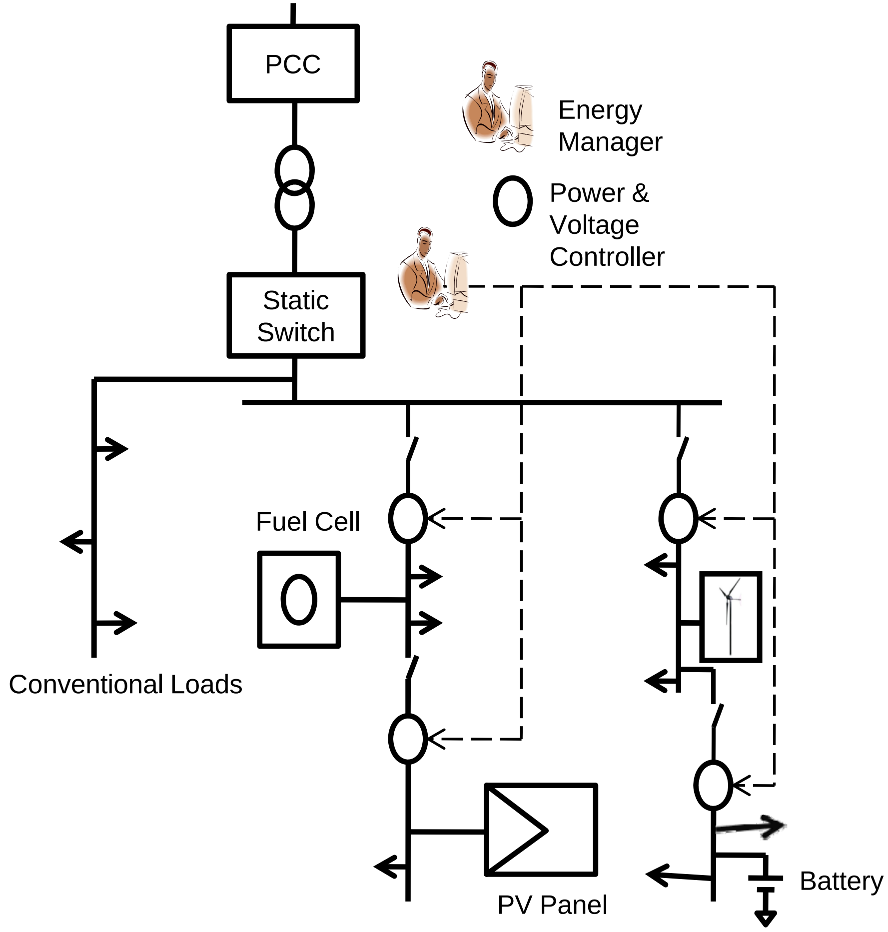
EU MICROGRIDS

- Two level architecture (MGCC &MC)
- MGCC established set points (techno & economical)
- MC & LC execute the set points to obtain regulate active and reactive power and best service respectively



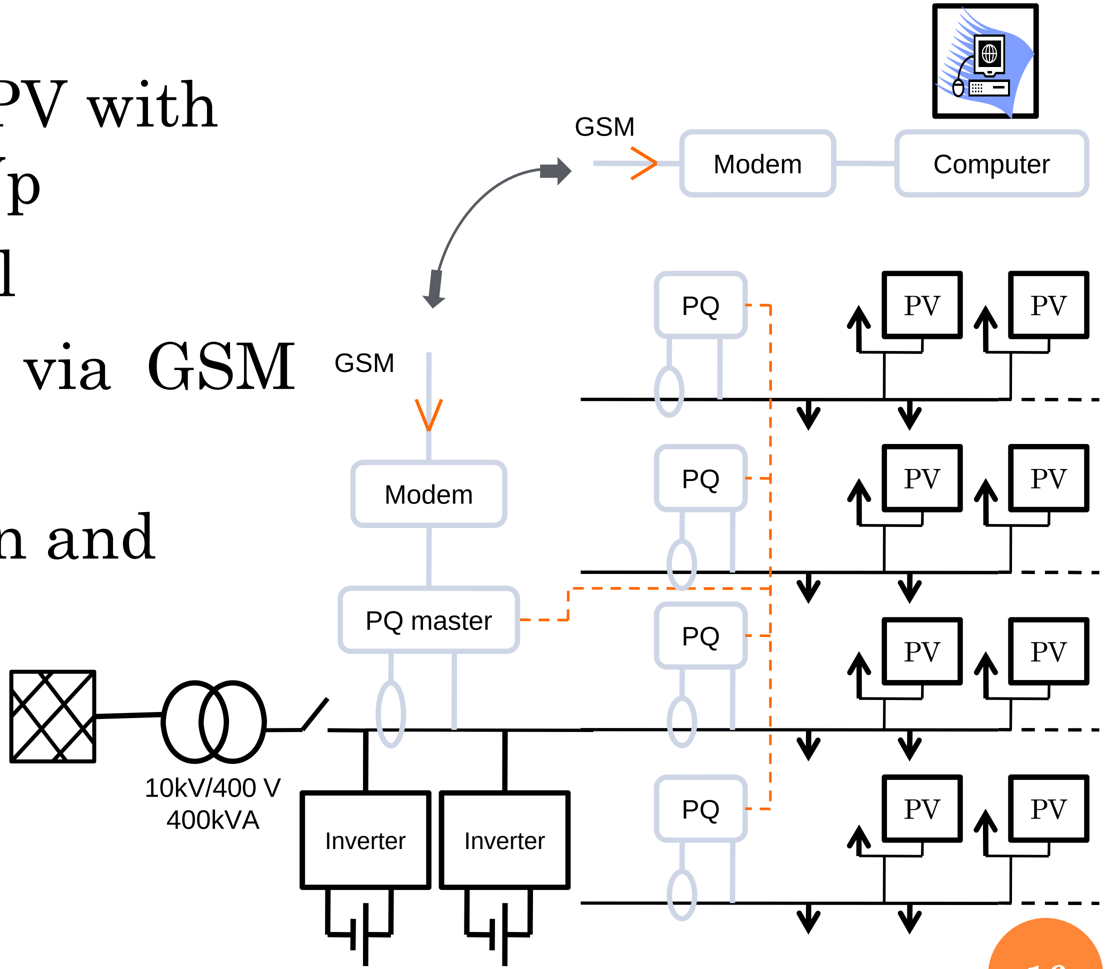
CERTS MICROGRID

- Peer-peer control, any device can connect or disconnect independently
- Operation of generators is locally controlled by droop
- Energy manager is to give initial set points
- High intelligence level is required
- Unit output power control (UPC)
- Feeder flow control (FFC)



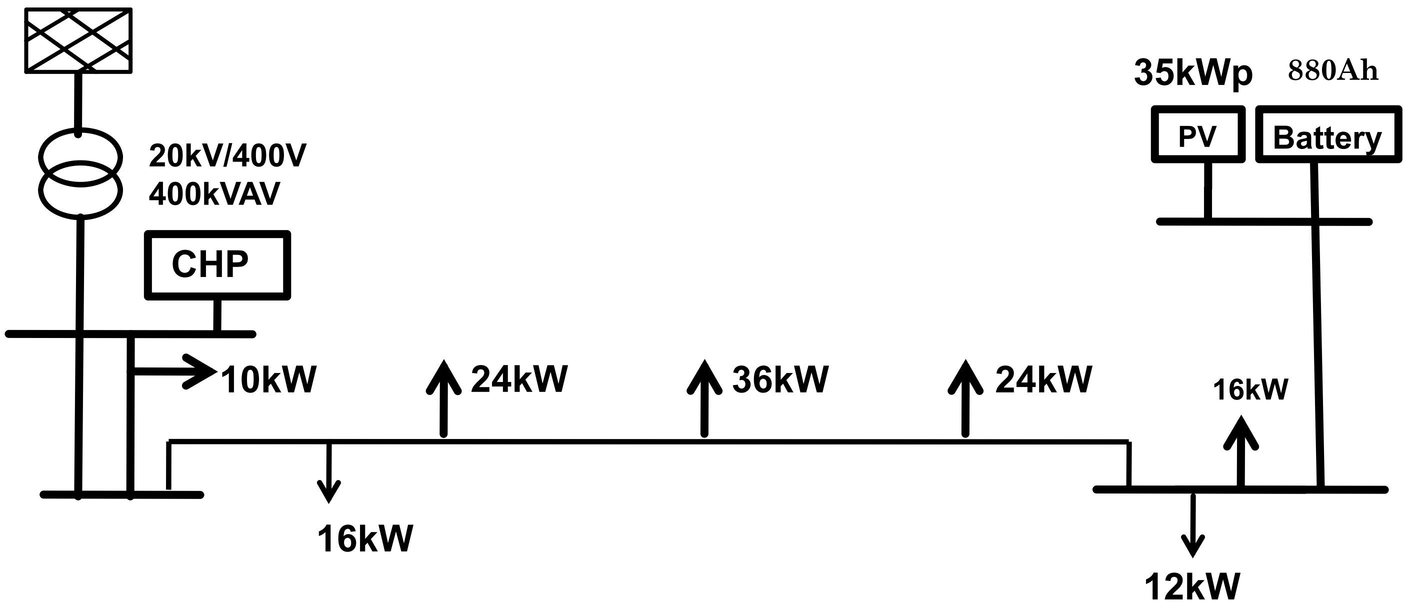
Boston Holiday Park Microgrid – More Microgrids project

- 108 roof top solar PV with capacity of 315 kWp
- Centralized control
- Exchange of data via GSM communication
- Automatic isolation and reconnection



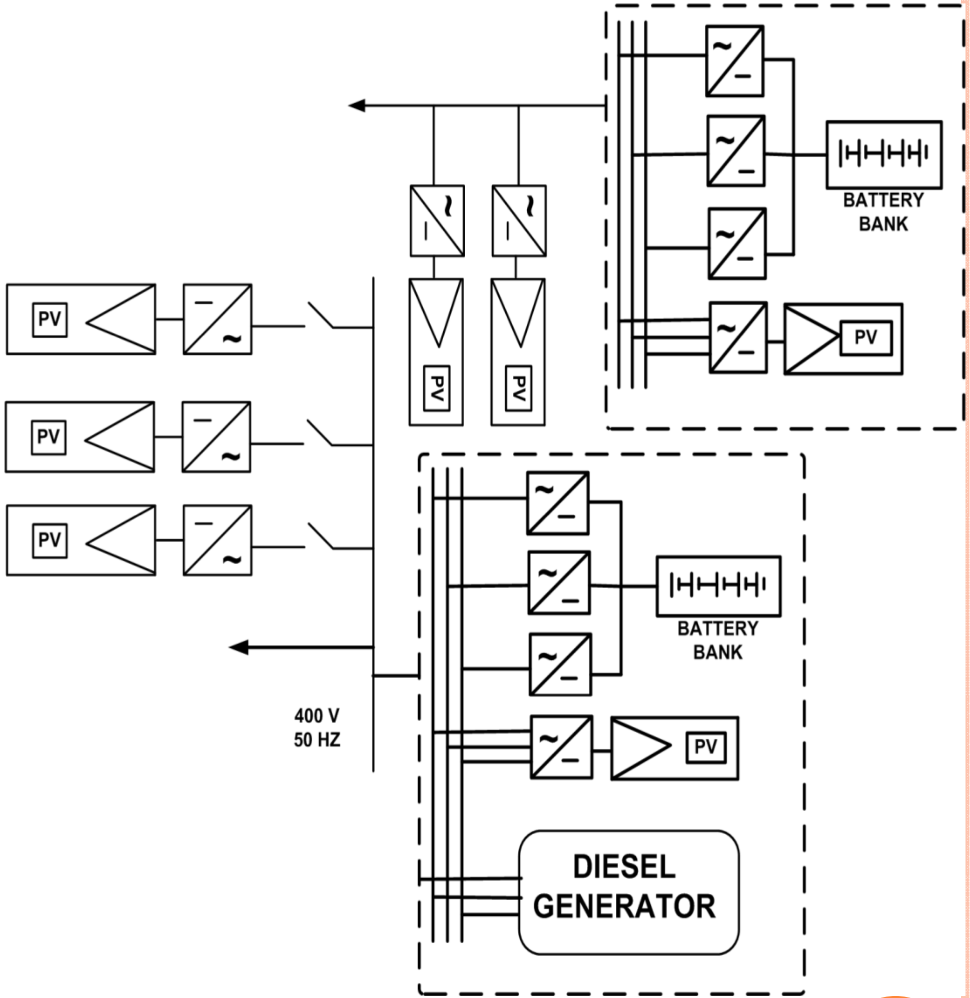
Residential Microgrid of Am Steinweg in Stutensee- Germany.

- 101 apartments are linked to the microgrid with PV and CHP as sources
- System is operated using power flow and power quality management system
  - Centralized controller and several decentralized interface boxes
  - Communication used is TCP/IP



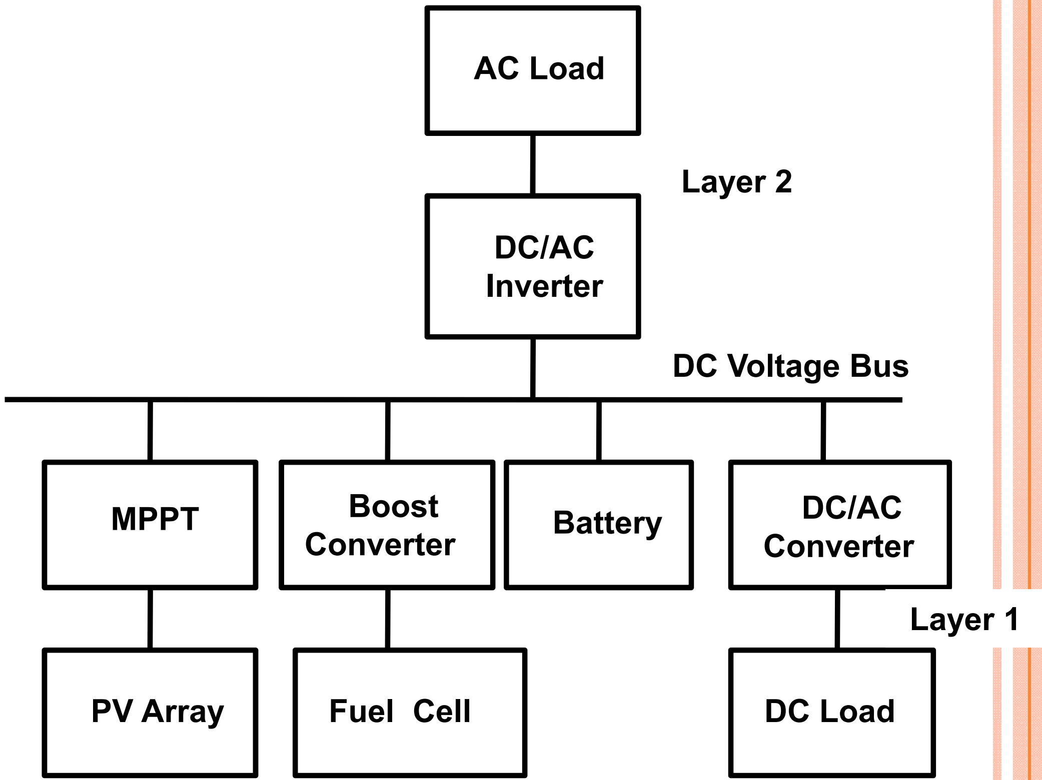
The Kythonos Island Microgrid - Greece

- It electrifies 12 houses having load controllers
- The generation constitute of 10 kW (PV), 53 kWh battery bank, 5-kW diesel generator set and 2 kW(PV rooftop).
- Battery Management
  - When the state of charge of the battery is low, the controllable loads are tripped off thus reducing the consumption
  - when the battery bank is approaching full charge, PV inverters are able to sense this and they continuously de-rate the power outputs



DC LINKED MICROGRID

- PV Control
  - MPPT
  - Battery Voltage Limit
- Battery is responsible for transient operation
- Fuel cell operates in steady state mode
- Fuel cell is turned off when battery is fully charged



Distributed Generation in Sundarbans

	Number	Capacity	Household Benefitted	Population covered
Solar Power Plant	16	1005 kWp	5,010	26,720
Wind Diesel Hybrid System	1	740 kW	1,200	6,000
Biomass Gasifier Power Plant	3	1400 KWe	1,800	10,800

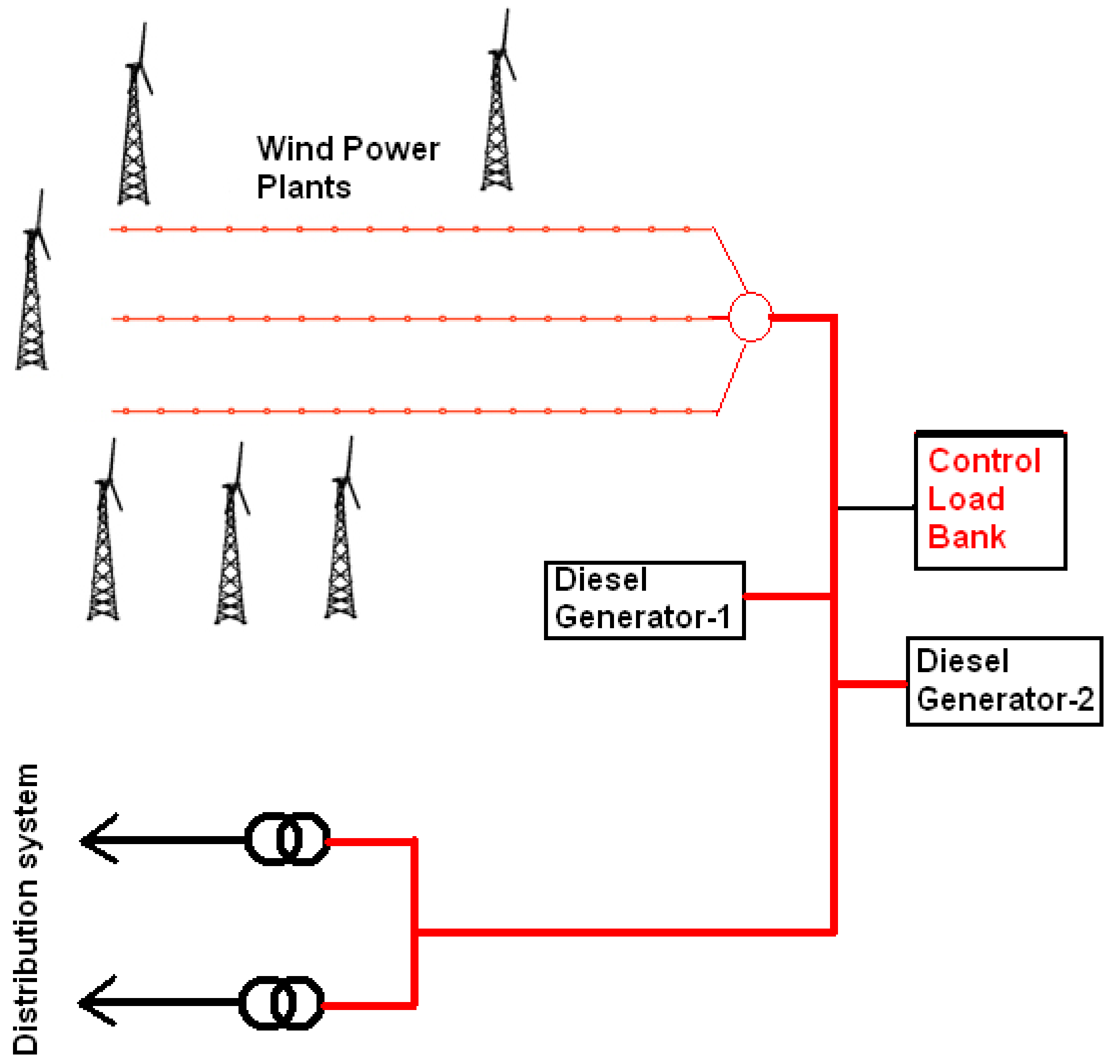
Solar PV Plant in Kaylapara

- Largest off-grid 120kWp solar PV plant in India (2005)
- Plant caters to 500 consumers
- Designed and owned by WBREDA, maintained by BHEL
- 150Wp polycrystalline solar cell, 800 modules
- Distribution line of 3km length, 440V
- Inverter
  - 4x30 kVA (240dc/415vAC), 93% FL efficiency

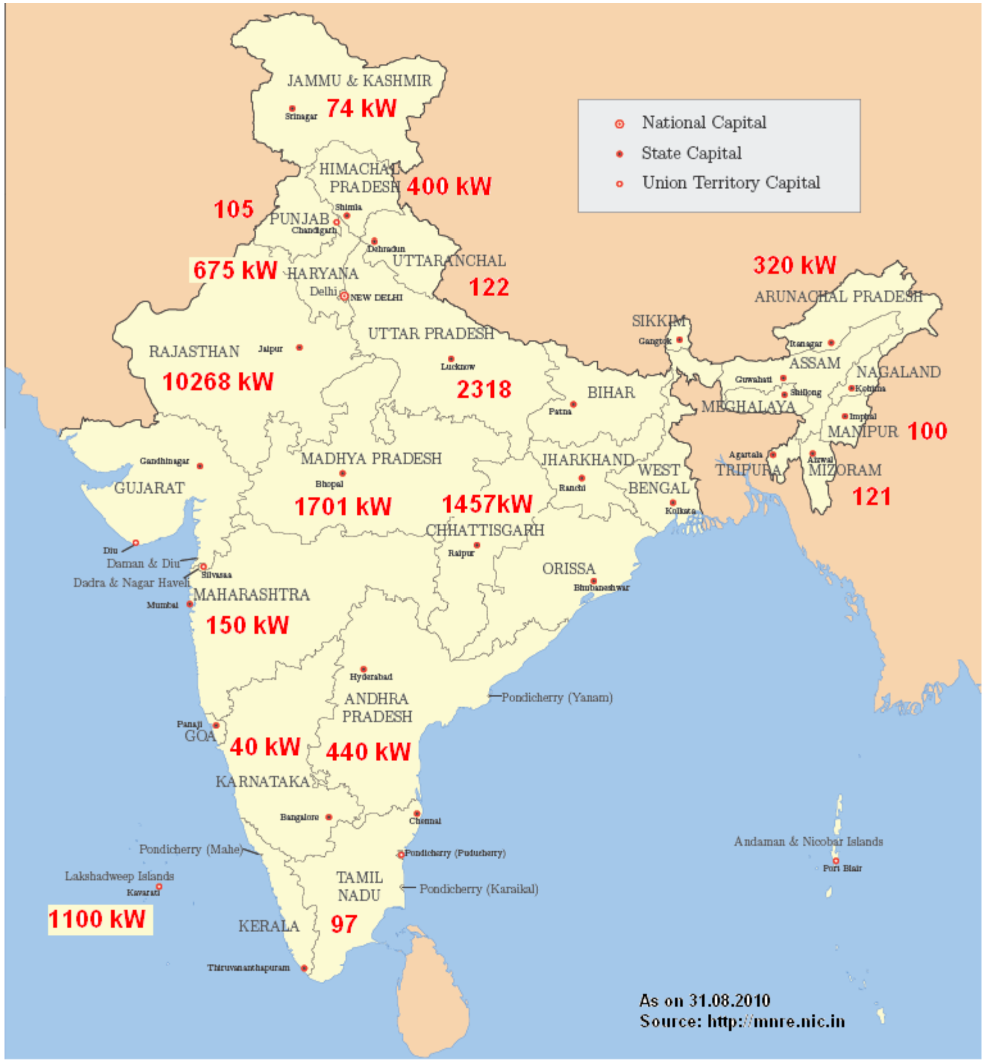
Wind-Diesel Hybrid Power Plant – Sagar Island

- The country's first Wind Diesel Hybrid Project has been set up at Sagar Island of South 24 Parganas District.
- Wind generators (each 55kW) have been installed along with 2 nos. 180 KVA Diesel Generators.
- A controller has been developed to ensure 100% wind penetration in the diesel grid

Wind-Diesel Hybrid Power Plant – Sagar Island



OFF-GRID SOLAR PV POWER PLANTS IN INDIA



Sanctioned/Completed as on 31.08.2010

Power Management in Microgrids

- Grid connected systems
  - DG shall maintain a constant power output as the power mismatch are compensated by the main grid.
- Unit output power control
  - DG is constantly controlled to supply power according to the reference
  - Droop control (P-f) is employed
  - When the load increases, DG output power increases and frequency decreases
- Feeder flow control
  - The power in feeder is manipulated according to flow reference - Feeder droop control
  - When load increases during grid connected operation, the DGs increase output to maintain a constant feeder flow
  - Some of the DGs are excessively loaded during transition
- Mixed control
  - Combination of UPC anf FFC

Droop Control in Microgrids

- Power transfer between two nodes

$$P = \frac{VE}{X_s}\sin\delta \qquad Q = \frac{E}{X_s}(E - V\cos\delta)$$

- Real Power Vs Frequency droop Control

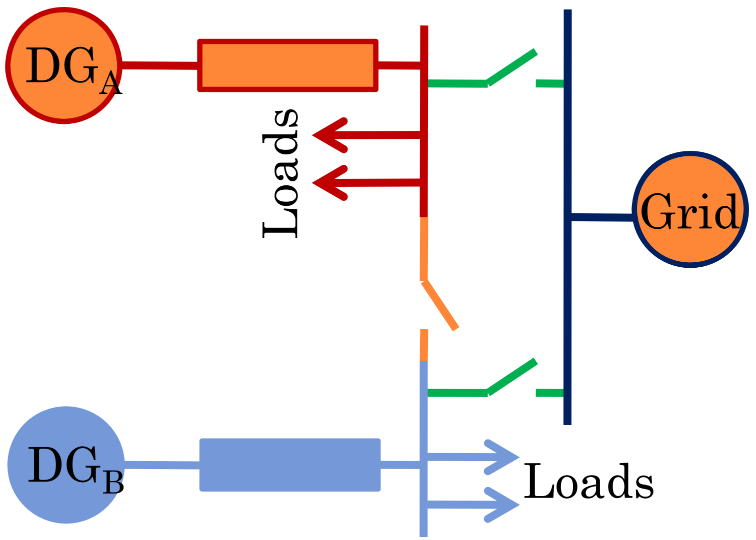
$$f - f_0 = -k_P(P - P_0)$$

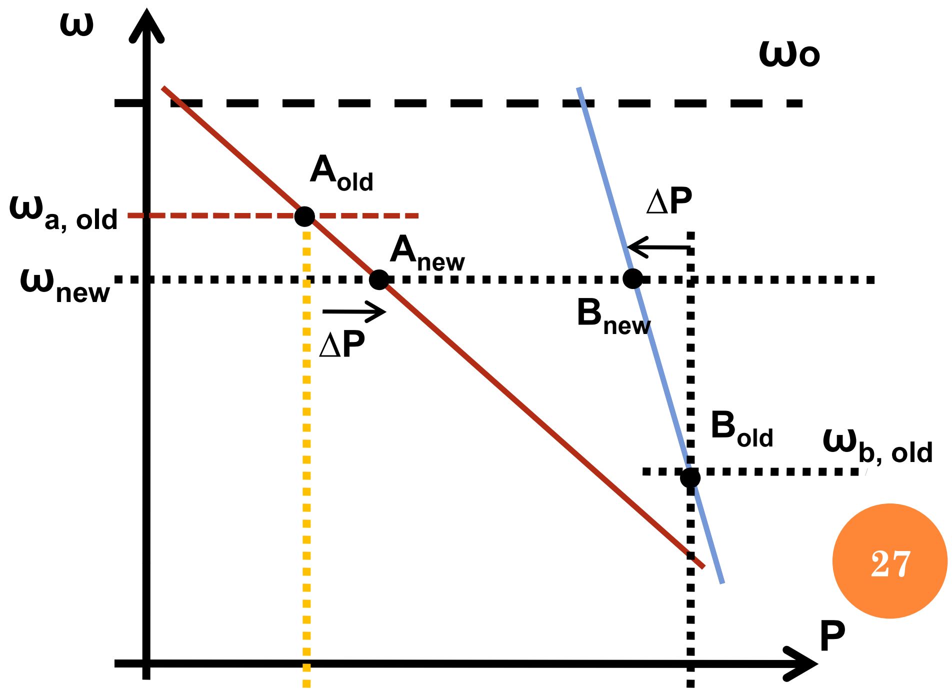
- Reactive Power Vs Voltage droop Control

$$V - V_0 = -k_q(Q - Q_0)$$

Power sharing in DG's

- At steady state, the active power flow is always from the source with higher frequency to the other with lower frequency, before the connection takes place.

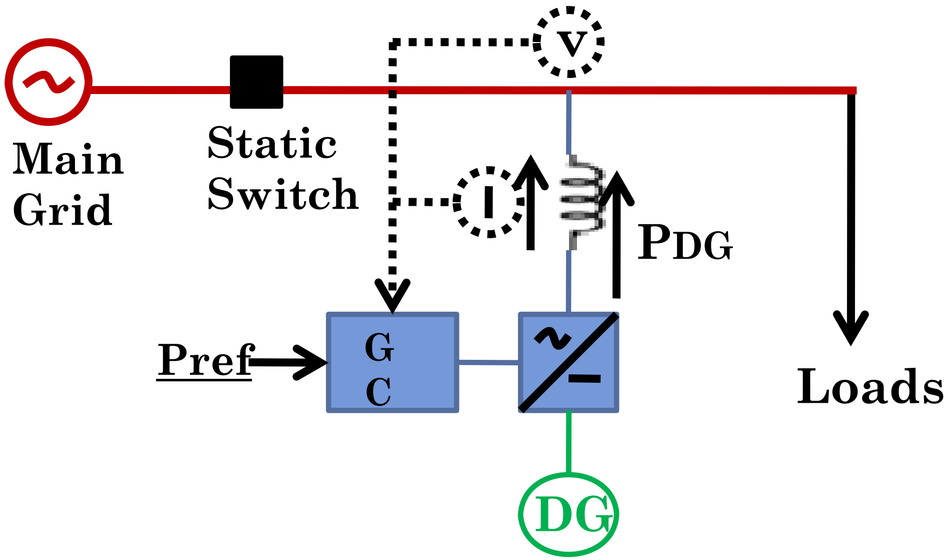


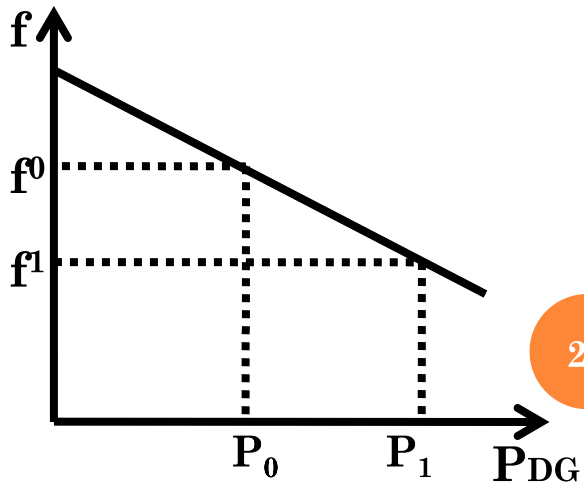


Unit Power output Control (UPC)

- The power injected by the DG is regulated to P_{ref}
- Power injection is calculated from V and I and fed back to the generator controller (GC)
- In autonomous mode, the DG follows (P-f) droop curve to maintain load balance

$$f^{new} = f^{old} - K^{U}(P^{new} - P^{old})$$

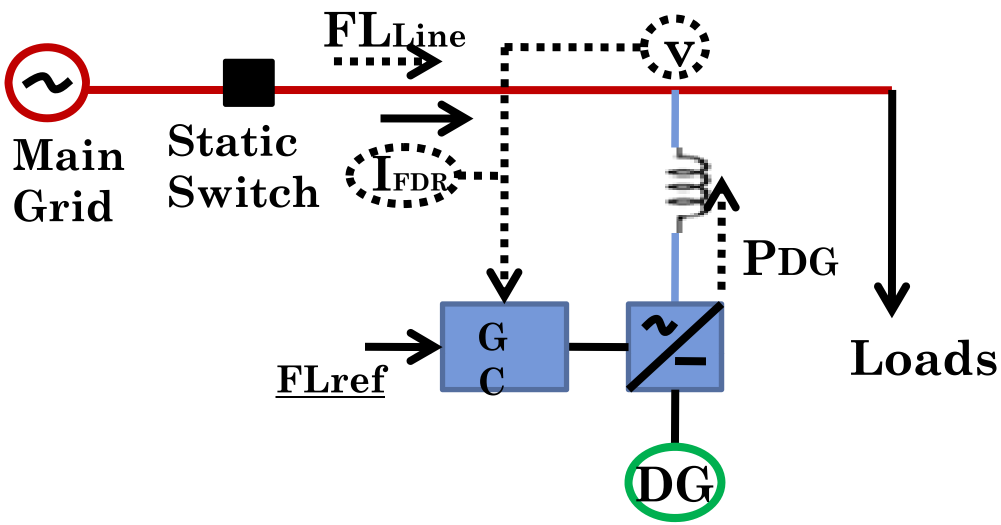


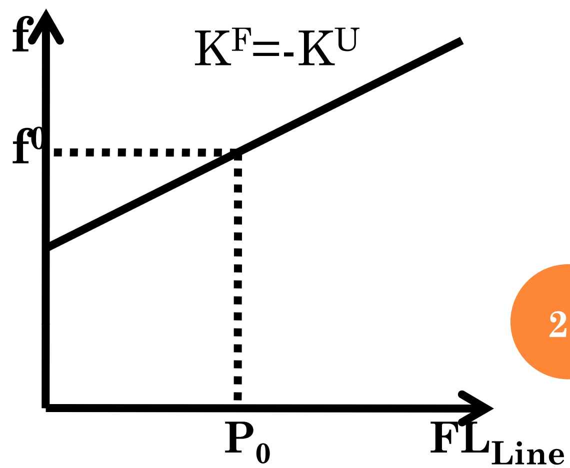


Feeder Flow Control (FFC)

- DG output is controlled to maintain active power flow in the feeder (FL_{line}) constant, irrespective of changes in load
- Microgrid resembles a controllable load from utility point of view.
- In autonomous mode: Flow versus frequency droop characteristic is used:

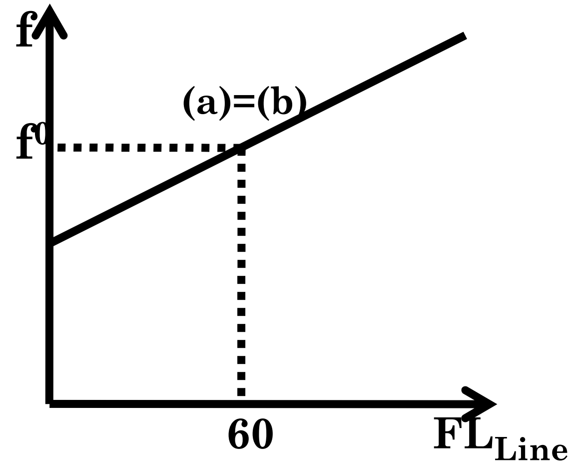
$$f^{new} = f^{old} - K^{F}(FL^{new} - FL^{old})$$

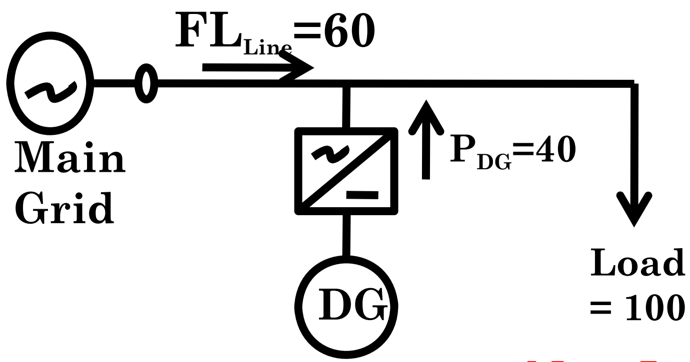




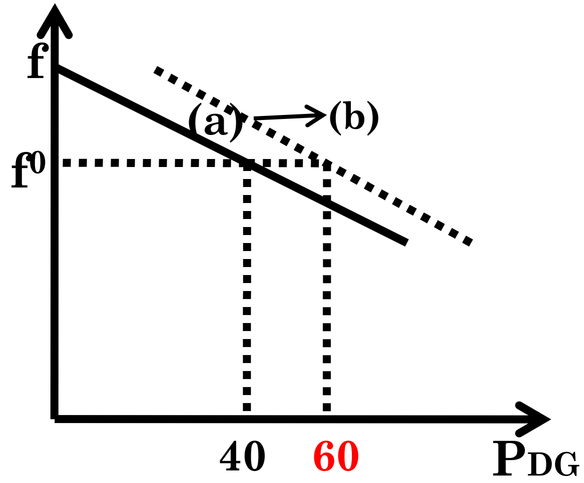
Case A: Load increase - Grid Connected System

- The feeder flow shall remain constant
- The generator (DG) increases its output to cater to the new load requirements



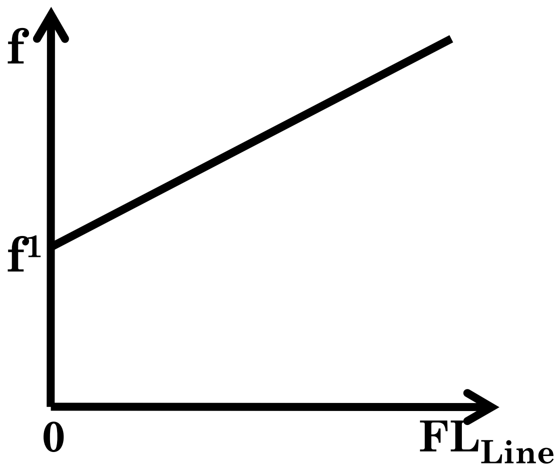


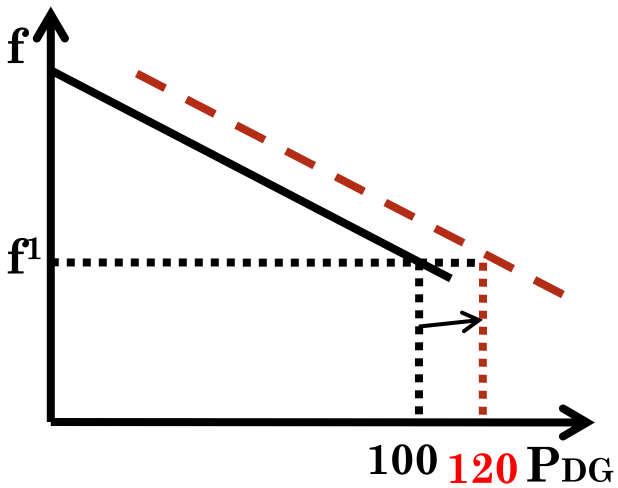
New Load = 120 kW

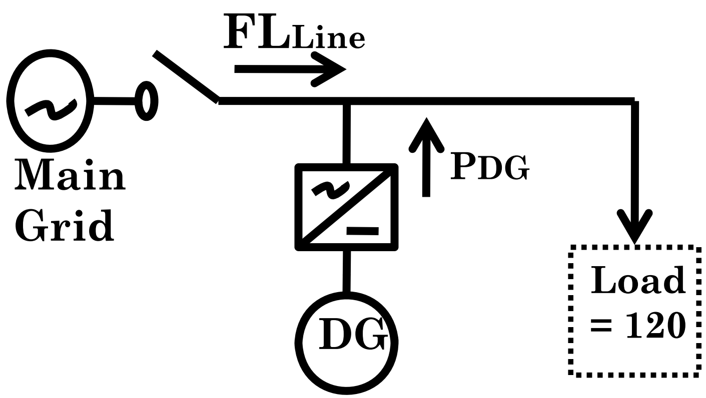


Case B: Isolated System – Load Increases

- During isolated system, frequency changes only if DG cannot maintain feeder flow.
- Feeder flow is Zero, in the case of FFC

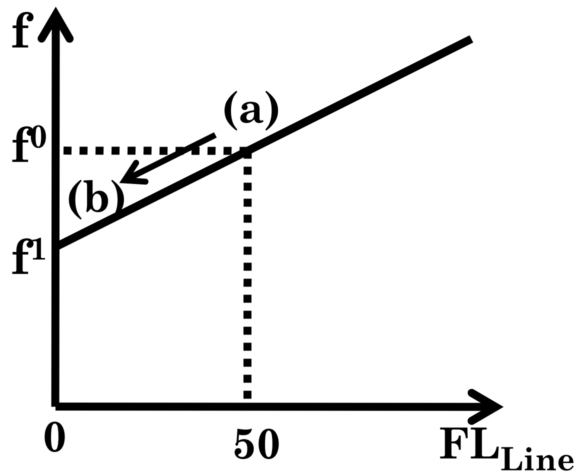


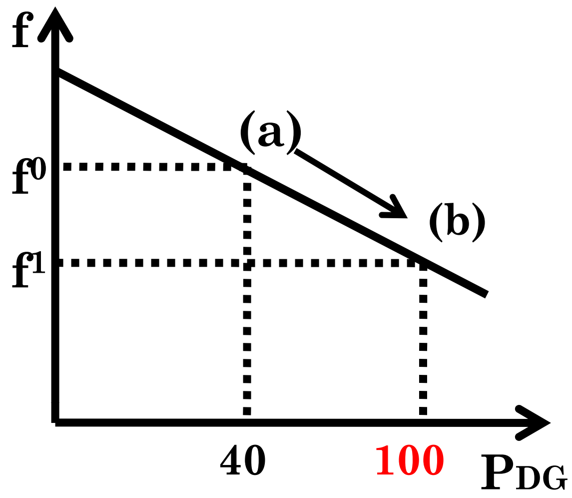


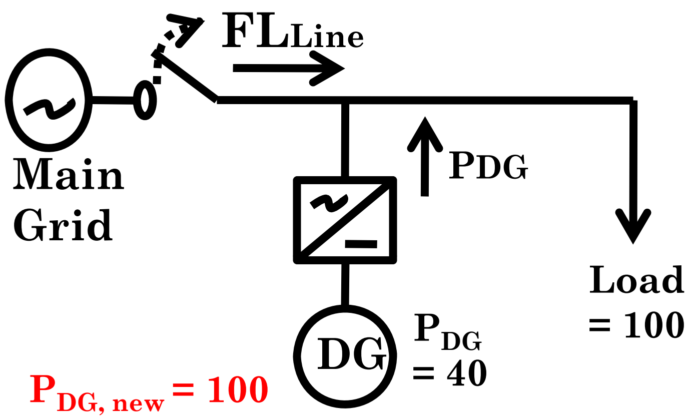


CASE C: LOSS OF MAINS

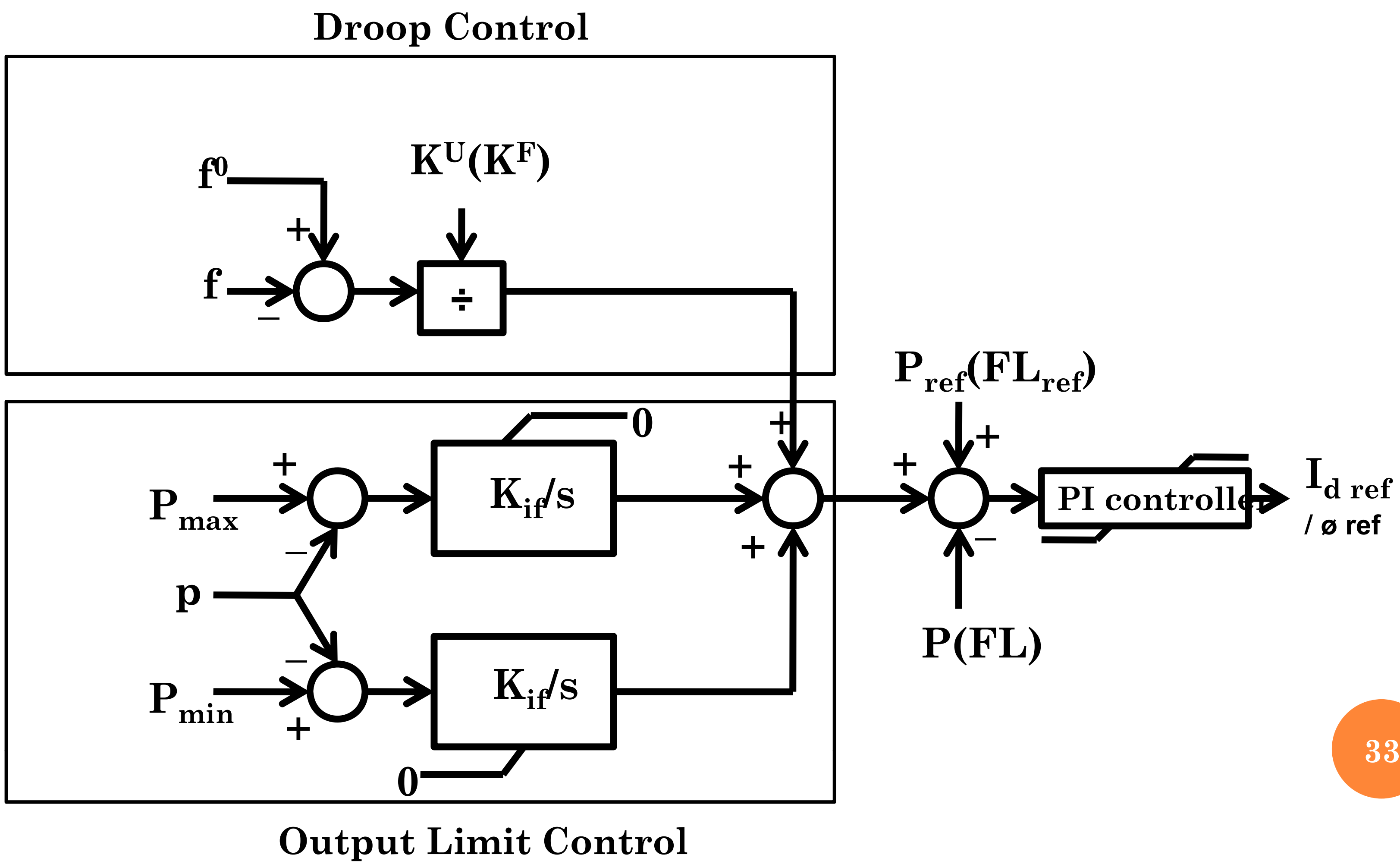
- The feeder flow is zero at this new condition and hence power flow measured by DG is Zero.
- DG increases its output from 40 kW to 100 kW to compensate the decreased feeder flow





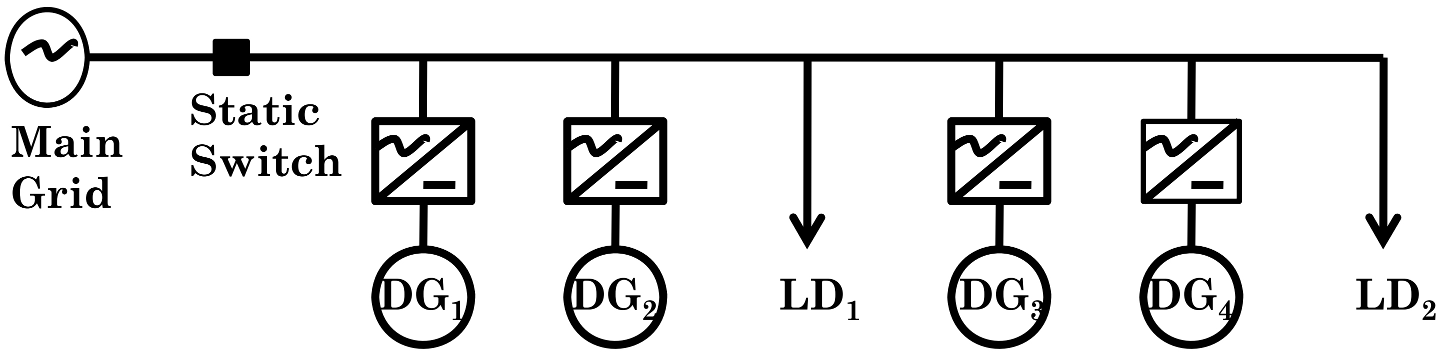


Block Diagram - Active Power Control



POWER SHARING – MIXED CONFIGURATION

- DGs operate in UPC Mode
- DG_1 operate in FFC mode others in UPC mode
- DG_1 and DG_3 operate in FFC and others in UPC mode



ANALYSIS

- Power from grid is constantly changing with load in UPC mode
- When microgrid is isolated, DGs adjust their output until they reach a new steady state - Result in change in frequency
- In Islanded operation, frequency is always changing in UPC mode which is harmful for loads
- In case of microgrid with single FFC configuration, the DG size should be dominant
- The power picked up by the DG's is not uniform

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