HR EXCELLENCE IN RESEARCH

UNIVERSITÀ DEGLI STUDI DI PALERMO

DEIM – Dipartimento di Energia, Ingegneria della Informazione e Modelli Matematici

Microgrids Optimal Power Flow through centralized and distributed algorithms

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Clean energy in vietnam after COP21
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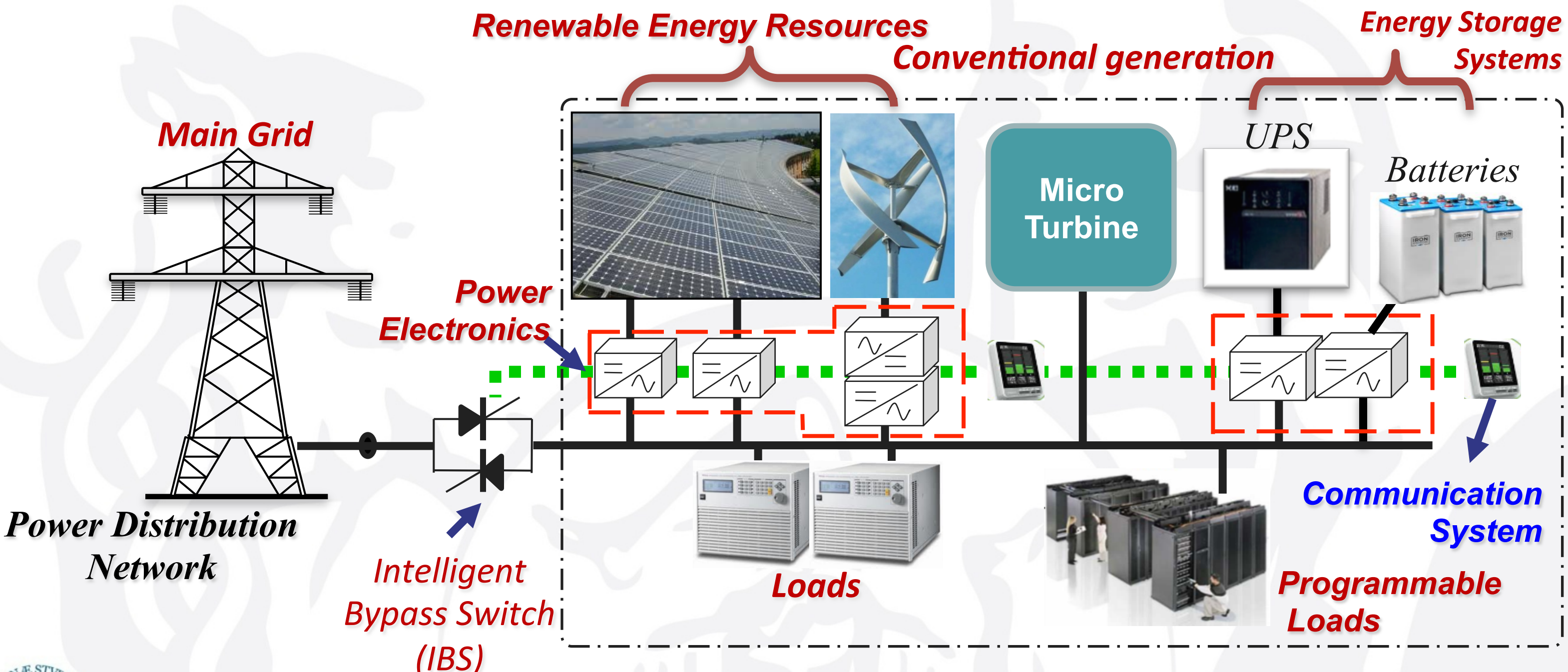
Background

<u>Microgrids</u> are groups of interconnected loads and Distributed Energy Resources, DER, with clearly defined electrical boundaries acting as a single controllable entity as compared to the main grid and can operate in grid connected or islanded modes.

Typical structure of a flexible Microgrid



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Background

Most part of generation units in Microgrids are inverter interfaced units. They are cintrolled by means of a **hierarchical control** architecture implemented through suitable control of Voltage Source Inverters control operating points interfacing ESS (Wind and Solar are in MPPT).

Primary regulation

The droop-control method is often used in this level to emulate physical behaviors that makes the system stable and more damped. It can include a virtual impedance control loop to emulate physical
output impedance.
VIRTUAL INERTIA

Secondary regulation

Ensures that the electrical levels into the MG are within the required values. In addition, it can include a synchronization control loop to seamlessly connect or disconnect the MG to or from the distribution system

Tertiary regulation and EMS are different in grid connected and islanded modes

Background

Most part of generation units in Microgrids are inverter interfaced units. They are controlled by means of a **hierarchical control architecture.**

GRID CONNECTED MG
Tertiary regulation

This energy-production level controls the power flow between the MG and the grid. It may take care of **sharing** the request among generating units, based on COST effective sharing and TECHNICALLY FEASIBLE power sharing

ISLANDED MG
Tertiary regulation

At this level, both COST effective power sharing and **TECHNICALLY FEASIBLE** power **sharing** should be considered, still considering **stability issues**.

Energy management systems optimally **dispatch** the energy resources of the MG

Background

EMS try to compensate load request in each elementary time interval, **since frequency variations and voltage drops depend on differences between production and consumption**:

- **Production follows slowly consumption (when?)**
- **Production is too far from consumption (where?)**

Optimal Power Flow Problem formulation in islanded systems

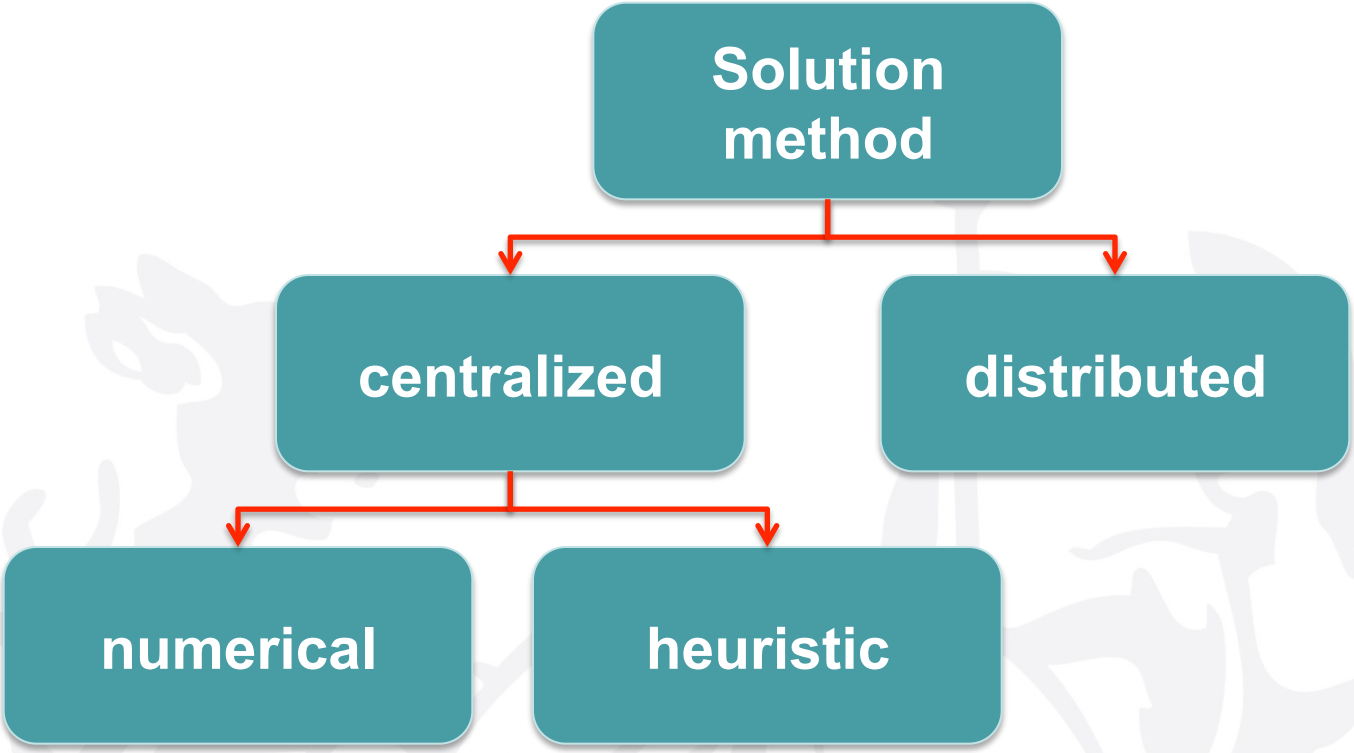
Minimize Losses and/or Costs

Variables: [set points of inverter interfaced units (P,Q); droop parameters of gens]

Under the following constraints:
Load flow equations (f)
Voltage drop below x%
Current in branches below I_{lim}

*If losses are considered, the problem is strongly **non linear** and is not solvable with standard OPF methods. There is no slack bus available, **when the grid is operated in islanded mode**.*

Optimal Power Flow Problem formulation



Optimal Power Flow centralized solution

Centralized solution

numerical

- Uses Lagrange multipliers
- Is iterative
- Is deterministic
- It cannot manage unbalanced loads
- It cannot efficiently account for contraints

heuristic

- Uses GSO
- Is iterative
- It can manage unbalanced loads
- It can efficiently account for contraints

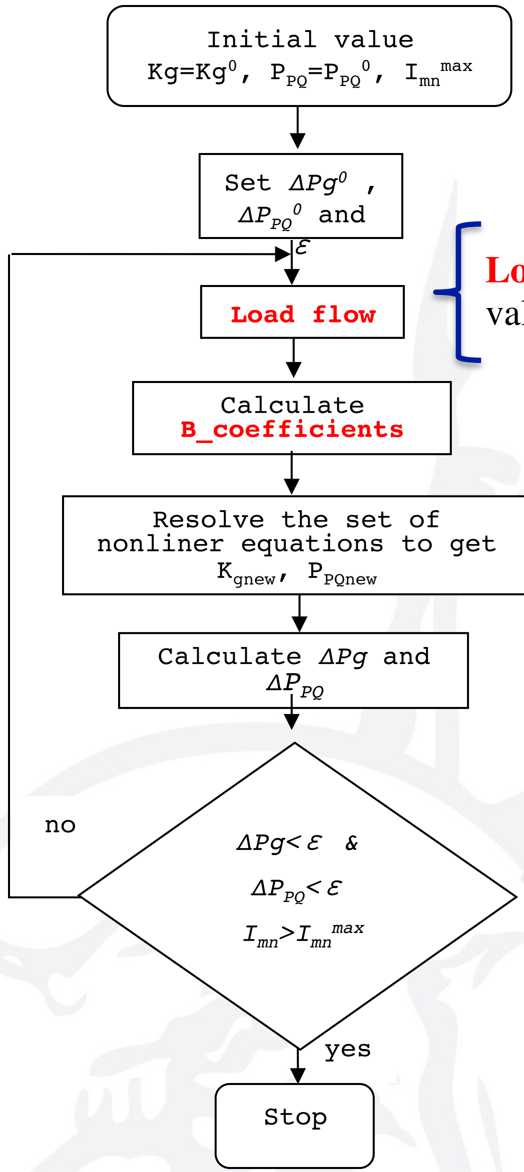
*They both handle **droop parameters** of inverter interfaced units. Loads and generators model accounts for **frequency***

Optimal Power Flow centralized **numerical** solution

Comments

Uses Kron's formula, thus:

- Unbalanced loads cannot be considered
- Reactive generation cannot be accounted for



Load flow is solved for given values of variables

B coefficients are calculated based on LF solution. Ploss is expressed as a function of Pgs

Corrections for variables are calculated to minimize Ploss

Constraints are violated?
Convergence is reached?

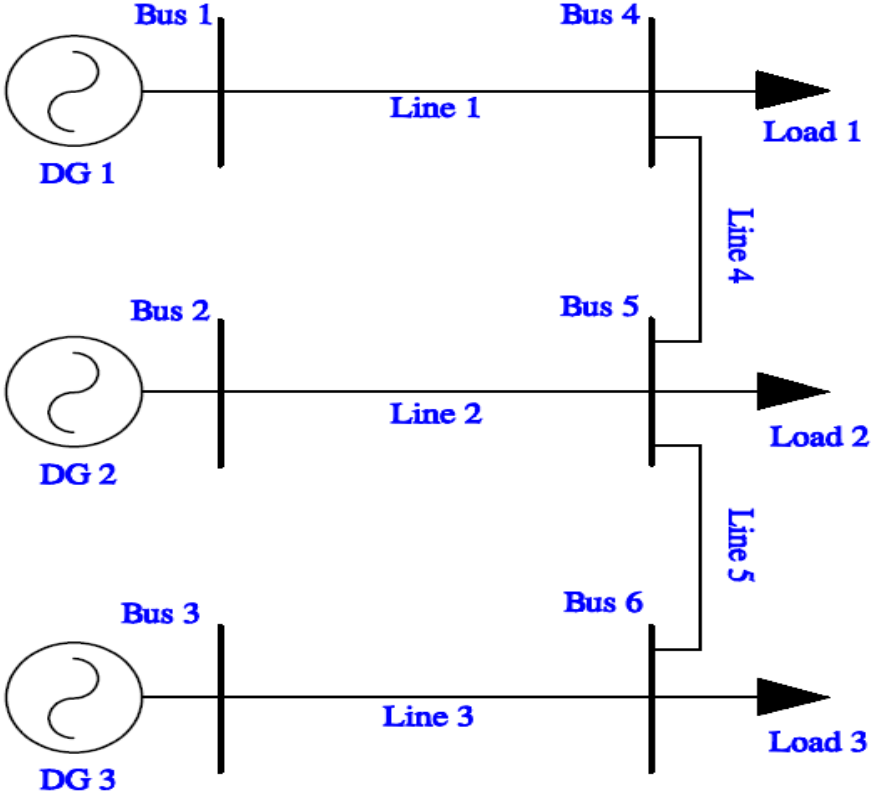
Optimal Power Flow centralized **heuristic** solution

```
Initialize Archive A
           Repeat Until  Termination
Condition
   Do m times
    Step  1:  deterministic  choice
   (selection) of the base vector
    Step  2:  probabilistic  choice
   (selection) of the target vector
   (Roulette  Wheel  technique  based
   on l(t))
    Step 3: recombination
   END m
   Step  4:  create  new  population
(replace A)
       END
  A= archive
  m=archive size
```

Comments

- Unbalanced loads can be considered
- Reactive generation can be accounted for
- Constraints can be included

Test system



G1, G2 and G3 are inverter interfaced units

Results

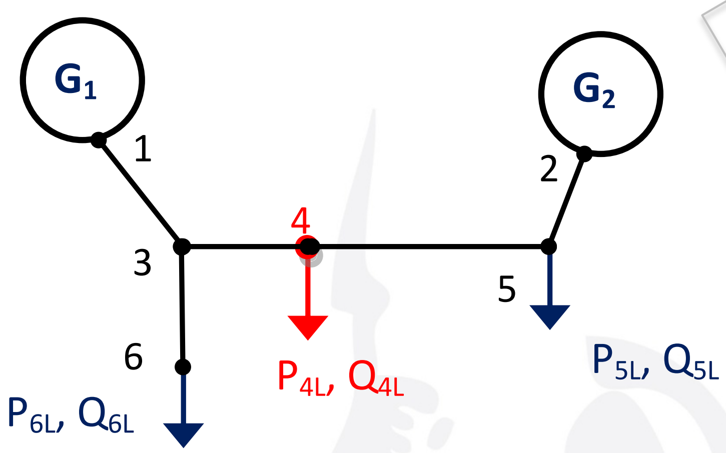
Result of optimal load flow on 6_bus system by Lagrange method taking into account Kgs, pu

KG1	KG2	KG3	Plossmin	f
19.8331	10.3798	22.1034	0.0178887	1.0525

Result of optimal load flow on 6_bus balanced system by GSO Heuristic method taking into account Kgs, pu

Random	KG1	KG2	KG3	Plossmin	f
1	17.8094	8.5080	21.2252	0.0178565	1.0507
2	16.8141	8.0211	20.0541	0.0178565	1.0496
3	20.9933	10.0258	25.0000	0.0178565	1.0536
4	19.5054	9.2860	23.2543	0.0178565	1.0524
5	18.0566	8.5681	21.5628	0.0178565	1.0509
6	20.4090	9.7189	24.3476	0.0178565	1.0531
7	15.1747	7.2123	18.1372	0.0178565	1.0473
8	19.9132	9.5046	23.7349	0.0178565	1.0527
9	18.3848	8.7741	21.9239	0.0178565	1.0513
10	15.5311	7.4100	18.5159	0.0178565	1.0479

Optimal Power Flow distributed Heuristic solution

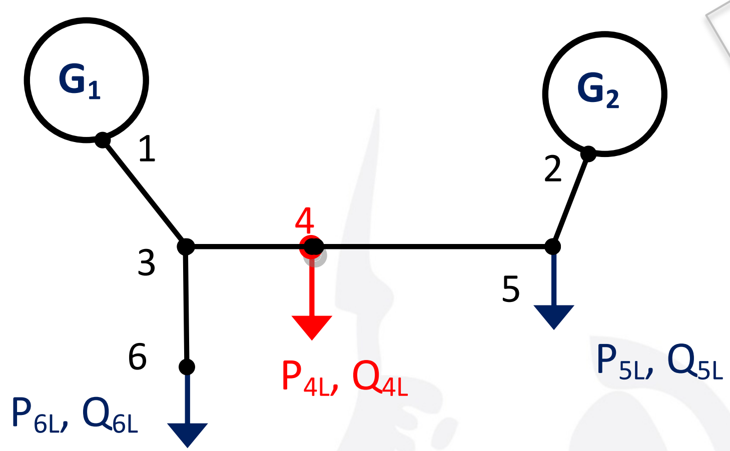


UNDER DEVELOPMENT

3 steps similar to **reinforcement learning**:

1) Power flow tracing
2) Backward phase: Starting from sink buses, go backwards, calculate losses and for each branch produce an elementary correction for the generation bus
3) Forward phase: Starting from generation buses, go forward, calculate upated power losses and generate a correction on soem parameters affecting the search

Optimal Power Flow distributed **Heuristic** solution

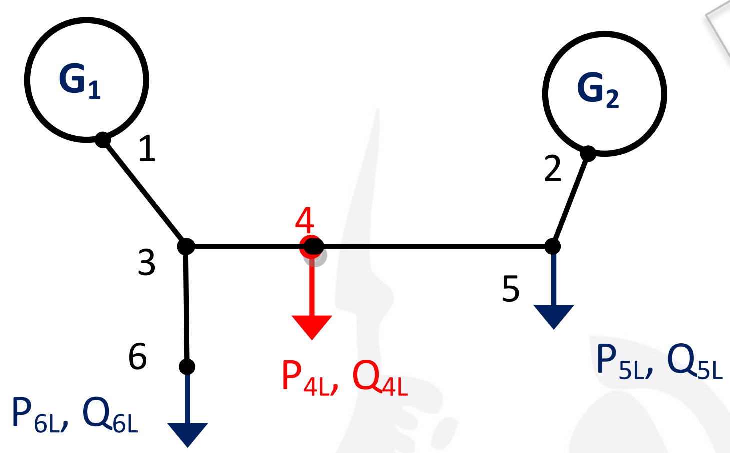


UNDER DEVELOPMENT

WHY?

- It is a *plug and play* solution
- Adjacent nodes exchange local information
- It does not require wide bandwidth communication channels
- It aims at correcting the generators injections according to large loads variations

Optimal Power Flow distributed **Heuristic** solution



UNDER DEVELOPMENT

Generated Power, Learning Proceduce and Ploss of Cases

	Generated Power		Learning Proceduce			Ploss, W
	Pg1, W	*Pg2, W*	*yt*	*W43*	*W54*	
New 0	41721	30000	1	0.84	0.16	1883.33
New 1	40825	26445	1	0.51	0.11	1521.32
New 2	39976	26907	0	0.23	1.04	1502.47
New 3	39158	27388	1	0.23	1.04	1486.53

Weights account for the intensity of the correction produced by the PL calculation on a given branch to the relevant generation source

Both generators reduce their injection because the power losses get strongly reduced.

Conclusions: OPF in microgrids