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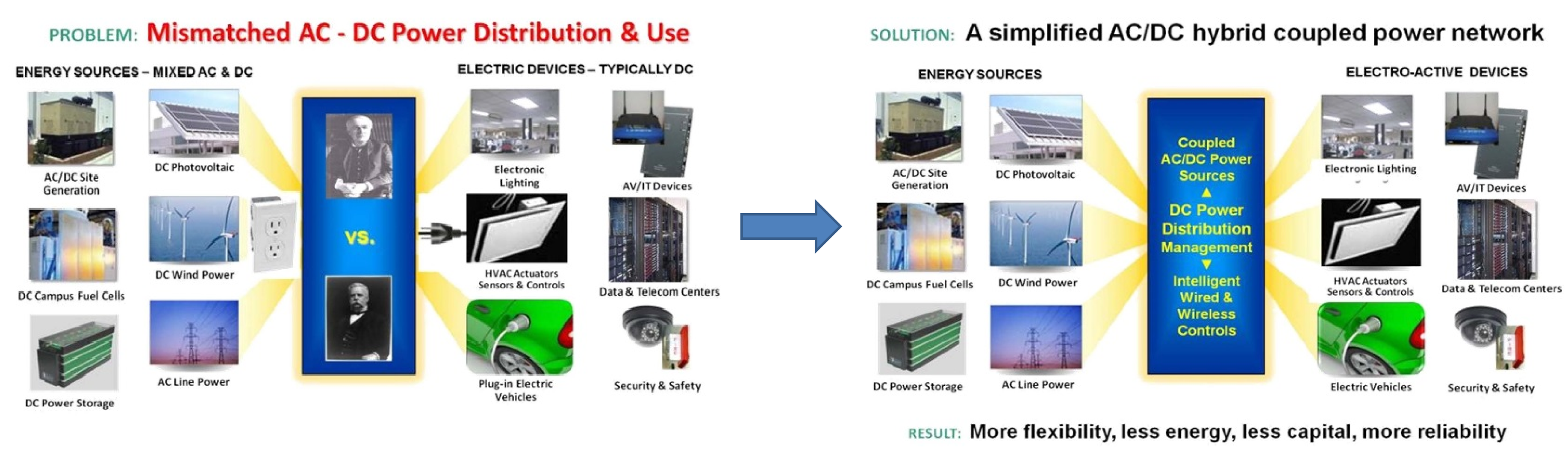
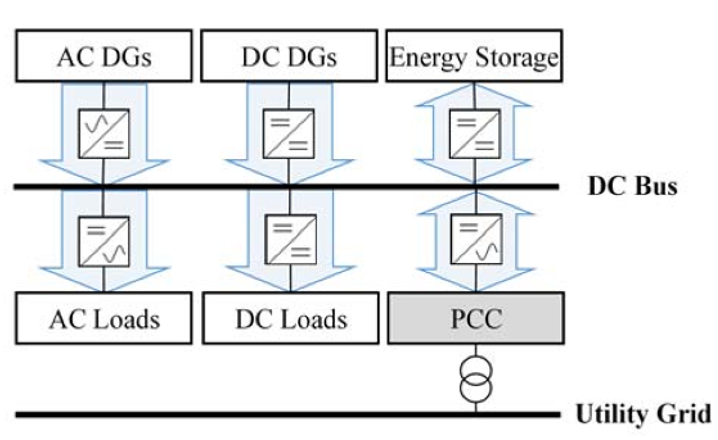
XXX Cycle - II year presentation

Optimal Sizing of Distributed Energy Resources in DC Microgrids

DC Microgrids and hybrid AC-DC Microgrids are gaining interest both in academic and industrial world, due to potential benefits in terms of energy efficiency and capital savings. DIETI Groups ING-IND/32 “Power electronic converters, electrical machines and drives” and ING-IND/33 “Electrical power systems” are enrolled in various research activities related to this area (e.g. Progetto MICCA).



Idea The research activity is focused on the development of methodologies aimed at optimally sizing the Distributed Energy Resources (DERs) included in a DC Microgrid, investigating the economic viability of the microgrid deployment and determining the optimal mix of DERs for installation.



Distributed Energy Resources

- AC and DC Distributed Generators (AC DGs, DC DGs) — *to be optimally sized and operated*
- Energy Storage Systems (ESSs) — *to be optimally sized and operated*
- AC and DC Smart Loads — *assigned, to be optimally operated*

Methodology, Developments, Results

Two distinct methodologies were applied to the problem: 1st: analytical approach 2nd: Mixed Integer Linear Programming (MIP) formulation

Analytical approach

An analytical solution has been found for the optimal sizing of ESSs that minimize network power losses in a DC microgrid.

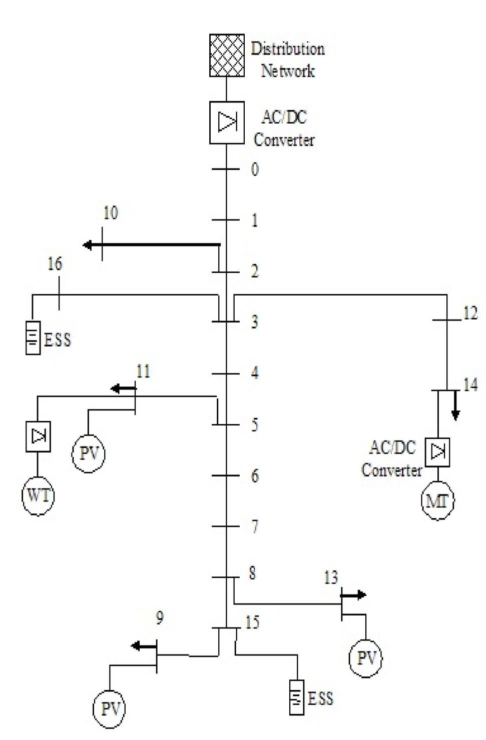
$$\min_{\gamma_1} \int_0^T \mathbf{J}^T \mathbf{R} \mathbf{J}\, dt + \int_0^T \mathbf{J}_{sto}^T \boldsymbol{\Gamma} \mathbf{J}_{sto}\, dt + \Xi$$

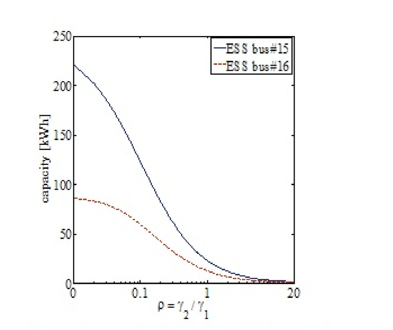
isoperimetric constraint

$$\int_0^T diag(\mathbf{E}_{sto}) \mathbf{J}_{sto}\, dt = 0$$

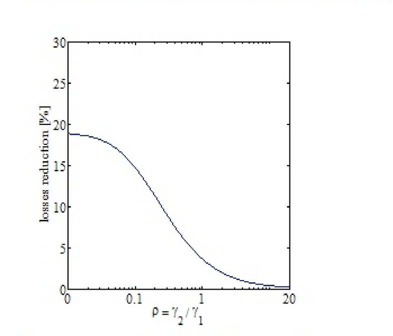
solution

$$\mathbf{J}_{sto} = -\mathbf{B}_1' \cdot \mathbf{K}_1 + \mathbf{B}_2' \left[\int_0^T \mathbf{B}_2' dt \right]^{-1} \int_0^T \mathbf{B}_1' \cdot \mathbf{K}_1 dt$$





Parametric evaluation of the ESS optimal capacity.



Parametric evaluation of the losses reduction.

extract from paper “Sizing energy storage systems in DC networks: a general methodology based upon power losses minimization” (M. Fantauzzi, D. Lauria, F. Mottola, A. Scalfati), submitted for publication on Applied Energy, now under review

MILP problem formulation

A MILP formulation of the DERs’ sizing problem has been developed, aimed at minimizing the Microgrid Total Cost of Ownership (TCO). The output is the optimal size of DGs and ESSs that minimize the TCO over a prefixed time horizon, given microgrid location and fixed load profiles. The procedure is suitable for sensitivity analysis and investigation on effects of uncertain data.

Project lifetime [years]:	*25*			
Loads energy demand (total) [kWh]:	*3,6135E+07*			
Loads energy demand (yearly) [kWh]:	*1,4454E+06*			
Maximum Total Initial Investment:	*€ 10.000.000,00*			
Inverter efficiency:	*€ 0,93*			
	case a: no DG, no ESS	case b: no DG (PV) presence of ESS	case c: no ESS, presence of DG (PV)	case d: presence of DG (PV) and ESS
Total Initial Cost:	€ 88.709,70	€ 2.055.010,00	€ 1.390.950,00	€ 2.260.020,00
Total cost:	€ 9.998.470,00	€ 8.328.390,00	€ 5.535.050,00	€ 4.008.270,00
Annualized cost:	€ 399.939,00	€ 333.136,00	€ 221.402,00	€ 160.331,00
Inverter size [kW]:	177,419	590,023	306,9	177,419
PV system size [kW]:	0	0	412,5	527,2
ESS size [kWh]:	0	3520	0	1179,41
Energy produced by PV system [kWh]:	0	0	3,16E+07	4,04E+07
Energy purchased from the grid [kWh]:	3,89E+07	4,31E+07	2,10E+07	1,19E+07
Energy sold to the grid [kWh]:	0	0	1,40E+07	1,31E+07
Energy for ESS charging [kWh]:	0	2,80E+07	0	9,39E+06
Energy from ESS discharging [kWh]:	0	2,41E+07	0	8,07E+06

MICCA

Microgrid Ibride in Corrente Continua e Corrente Alternata - PON03PE_00178_1

Future developments

Starting from the MILP formulation of the optimal sizing problem, an effort will be made to fully include in it, with adequate precision, some factors crucial in the planning process but often overlooked in existing studies, such as:

- accurate representation of real conditions, which affect the operation financial balance and thus the Microgrid Total Cost of Ownership (TCO);
- presence and optimal management of flexible electrical loads/smart loads, such as EV chargers (that can be used also as storage systems) or different appliances whose running times can be scheduled in given shifting windows;
- effects of data uncertainty on the planning procedure and results: the variety of uncertainties sources (i.e. forecasting errors in loads, variable renewables generation, market prices, unintentional islanding events) requests an optimization framework able to deal with them while preserving computational solvability; different approaches such as Stochastic Optimization (via scenarios generation techniques and scenarios reduction techniques) and Robust Optimization will be investigated.