Optimal control of a Smart Grids Network driven by wind energy

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Outline

- Why Smart Grid?
- Basic Smart Grid
- Key Objectives of Smart Grid
- Approach: Cooperative Network of Smart Grid
- Morocco Smart Grid Network Application
- Conclusions & Future works
Why Smart Grid?

Smart Grid is an emerging technology to provide next generation power grid with major opportunities:

1. Climate: Reduce carbon emissions & contribute to reduce the greenhouse gas

2. Reliability: increase the power quality and its reliability, High penetration of renewable energy sources

3. Economy: boost the economy, enhance the efficiency of energy production by reducing the peak load, create new market of smart grid software and hardware
Basic Smart Grid

- Smart Grid is an emerging technology to provide next generation power grid Smart grid. It is the integration of information and communications system into electric transmission and distribution networks.
Microgrid concept

**Microgrid can operate in both modes:**
- Parallel with the electric network: the microgrid supplies fraction of power demand of the grid
- Autonomous power island: the microgrid must supply 100% of the power to customers

**Advantages:**
- Enhance the robustness of the distribution system
- Facilitate greater use of distributed resources
- Increase energy efficiency
- Enhance the level of local reliability demanded by customers’ loads

**Research question:**
- How local energy storage systems will operate?
- How will be the interaction or the exchange of flows between microgrids?
Basic microgrid

Microgrid concept

- **Energy resources**
  - wind, solar, hydro, waste, ...

- **Storage system**
  - Battery, hydrogen, ...

- **Distributed generator**
  - wind turbines, PV, CHP, fuel cell, ...

- **Control system**
  - control strategies

- **Load**
  - Residential, commercial, & industrial
Challenges & issues

- Develop control strategies to ensure efficient, reliable operation of the microgrid
- Define appropriate policies to enhance the implementation and the use of the microgrid worldwide
- Ensure and demonstrate the economic benefits of the microgrids
- Resolve instability in case of islanded operation due to frequency and voltage variations from intermittent resources
Objectives

- Objective is to present a cooperation of a network of microgrid, and optimize the power flow in each microgrid and among microgrids to:
  - Meet customers requirements
  - Maintain certain constant level in the storage system

- Maintain stable operation of the cooperative network in the presence of intermittent wind power

- Develop & demonstrate the control strategy
**Objectives**

**Problem:**
- Given a set of microgrids in a region, find the optimal power flow exchange in the network and towards the local energy storages.

**Solution:**
- Model the problem as a network of logistic systems
- Find a centralized solution according to an optimal control approach (e.g. based on linear quadratic Gaussian models)

**Hypothesis:**
- connected to the main grid that can provide lacking power; forecast of demand and power production known with an error which is supposed white noise
The optimal control of the problem defined by:

\[ u_t^* = - + \]

\[ K_t \text{ is a } W_x(S-) \text{ matrix given by:} \]

\[ K_t = - + \]

\[ P_t \text{ is a } S- \text{ matrix given by the discrete time algebraic Riccati equations:} \]

\[ P_t = + \]

\[ P_t = \]

\[ K_t^g \text{ is a } W_x(S-) \text{ matrix given by:} \]

\[ K_t^g = + \]

The vector \( z_t^{d2} \) is given by:

\[ z_t^{d2} = + \]

\[ z_0^{d2} = \]

and the vector \( g_t \) is given by:

\[ g_t = - + \]

\[ g_T = \]

The cost function to be minimized is defined:

\[ \min J(z,u) = \left\{ \sum \right\} \]

Each microgrid is supposed to be subject to the following discrete time state equation:

\[ z_{t+} = + + + = - \]

Under the hypothesis of weak control that is when \( N \) tends to the null matrix, the optimal control for the system defined by:

\[ u_t^* = - + \]

\[ Q = \]
Cooperative network of smart grid

Case study: Morocco
Cooperative network of smart grid

Case study: Microgrids configuration

- Three microgrids each one produces power for his local user community, composed by:
  - 500 households
  - Wind turbine
  - Storage system

Proposed connection between smart microgrids
Cooperative network of smart grid

Real consumption of a household in Rabat (4 persons)
Cooperative network of smart grid

Results and discussions

Power balance for different microgrids

ei: power balance in each microgrid
nui: deterministic power balance of microgrid in \([t,t+1)\)
Cooperative network of smart grid

Results and discussions

Trends of the optimal values for the \( u_i = 1, 2, 3 \) elements of the control variables under a cooperative strategy (\( u_{1coop}, u_{2coop} \) and \( u_{3coop} \) in the legend)
Results and discussions

Trends of the optimal values for the state variables, $z^*$ under a cooperative strategy (respectively for microgrids 1,2,3 referred to in the legend as $z_{1\text{coop}}$, $z_{2\text{coop}}$, and $z_{3\text{coop}}$).
Conclusions & future works

The main contributions of the real-time control problem are:

1. The evaluation of the benefits of cooperation among grids

2. The assessment of the benefits to each single grid operation, in terms of integrating a common strategy to face shortage

3. Decentralized control approach of a network of microgrids
Thank you

Questions?