Analysis of Coupling Dynamics for Power Systems with Iterative Discrete Decision Making Architectures

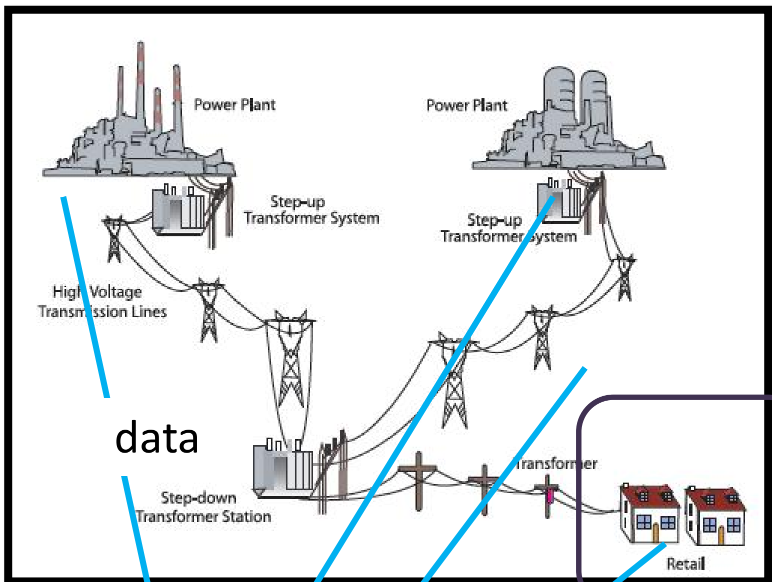
FESC Workshop Presentation, May 21, 2015

Zhixin Miao
Assistant Professor
Smart Grid Power System Lab
University of South Florida
http://power.eng.usf.edu

UNIVERSITY OF SOUTH FLORIDA
COLLEGE OF ENGINEERING

Why Distributed Control?

Conventional OPF:
All data is assumed available



data

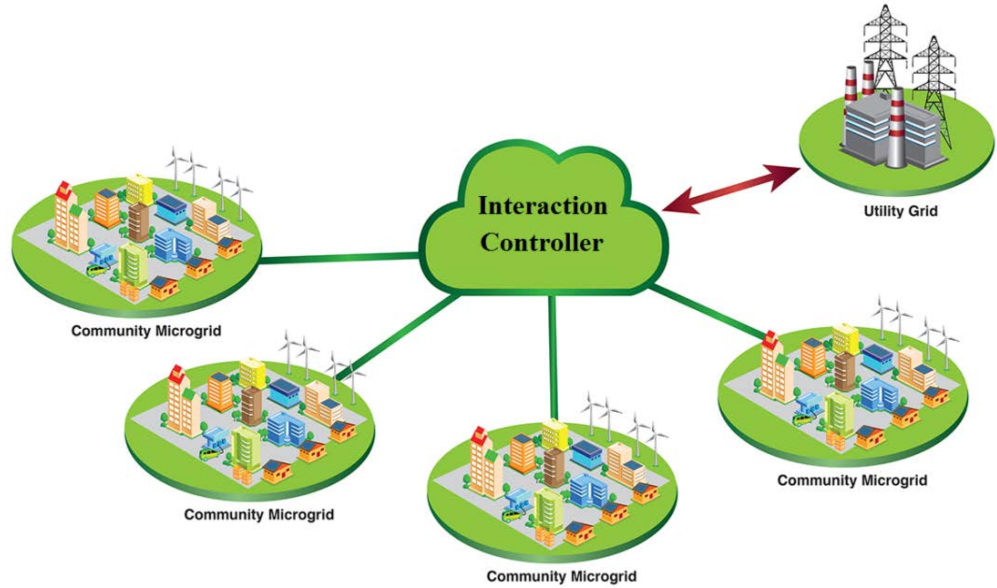
data

Microgrids' Privacy preserving

Massive Data Communication

Centralized Operation Center

Large dimension optimization Problem

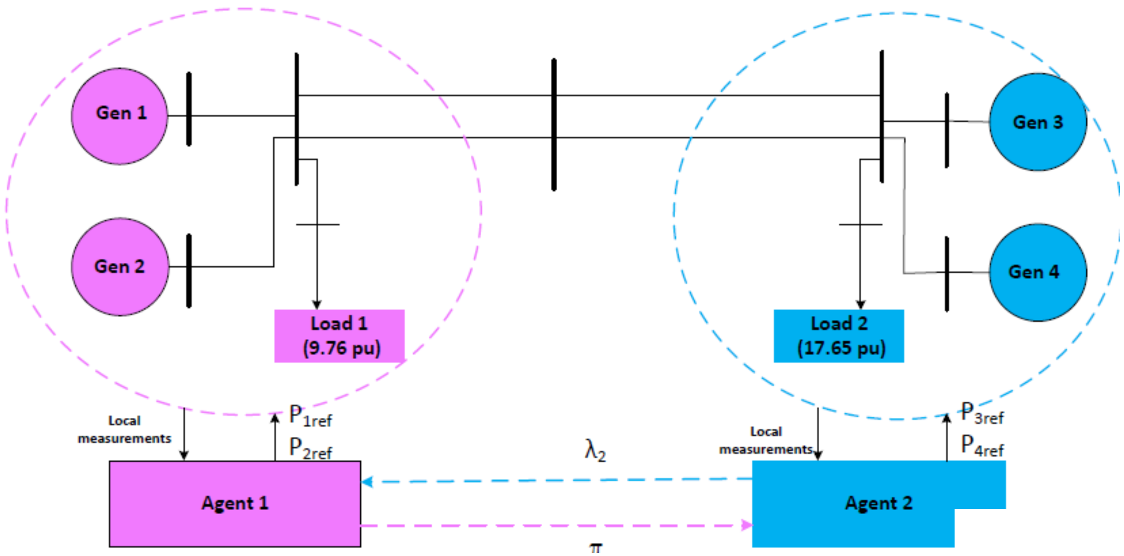


Multi-agent & Distributed optimization via Decomposition & Iteration

Time step of iteration is short.

May cause interactions with power system dynamics

How to analyze coupled system dynamics?

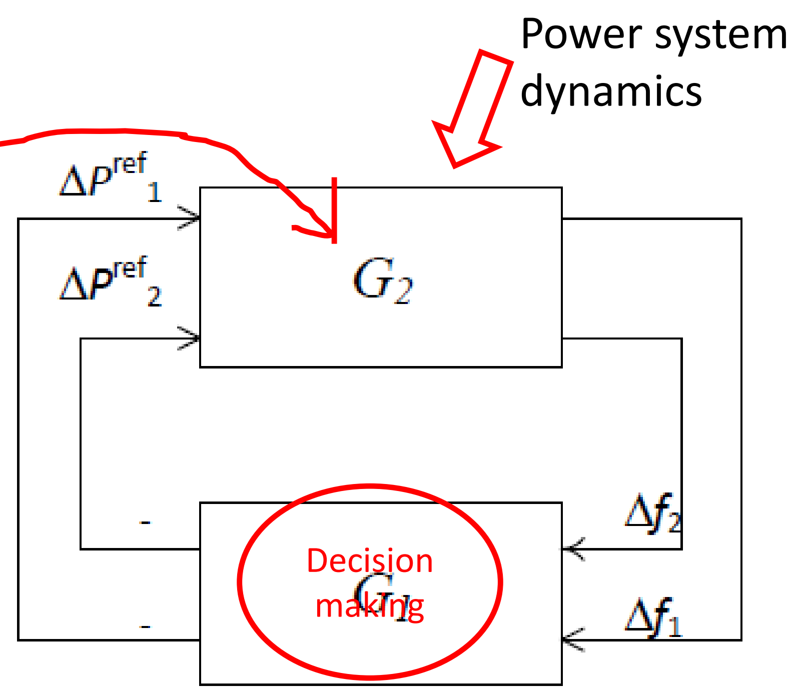


Approach:

- Approximate discrete decision making to continuous dynamics

Power system dynamics: continuous.
Decision making: every 10 seconds, an iteration.

$$\Delta\delta_1 = \frac{(M_1 s^2 + D_1 s + T_1)\Delta P_{m1} + T_1 \Delta P_{m2}}{(M_1 s^2 + D_1 s + T_1)(M_1 s^2 + D_1 s + T_1) - T_1 T_2}.$$



Approximate iterative procedures by continuous dynamics

Solve an economic dispatch problem using consensus + subgradient algorithm

$$\begin{aligned} \min \quad & C_1(P_1) + C_2(P_2) \\ \text{subject to:} \quad & P_1 + P_2 = D_1 + D_2 \end{aligned}$$

It's dual problem:

$$\max_{\lambda} \quad \min_{P_1,P_2} \quad C_1(P_1) + C_2(P_2) + \lambda(D_1 - P_1 + D_2 - P_2)$$

Consensus + subgradient --- not that frequency deviation is used to represent power imbalance.

$$\begin{bmatrix} \lambda_1 \\ \lambda_2 \end{bmatrix}^{k+1} = A \begin{bmatrix} \lambda_1 \\ \lambda_2 \end{bmatrix}^{k} - K \begin{bmatrix} \Delta f_1 \\ \Delta f_2 \end{bmatrix}$$

$$\lambda_1 = 2a_1 P_1 + b_1$$
$$\lambda_2 = 2a_2 P_2 + b_2$$

$$\begin{bmatrix} P_1 \\ P_2 \end{bmatrix}^{k+1} + \begin{bmatrix} \frac{b_1}{2a_1} \\ \frac{b_2}{2a_2} \end{bmatrix} = A \left(\begin{bmatrix} P_1 \\ P_2 \end{bmatrix}^{k} + \begin{bmatrix} \frac{b_1}{2a_1} \\ \frac{b_2}{2a_2} \end{bmatrix} \right) - K \begin{bmatrix} \frac{\Delta f_1}{2a_1} \\ \frac{\Delta f_2}{2a_2} \end{bmatrix}$$

$$\begin{bmatrix} \Delta P_1 \\ \Delta P_2 \end{bmatrix} = \underbrace{-(\tau s - A + I)^{-1} \begin{bmatrix} \frac{K}{2a_1} & 0 \\ 0 & \frac{K}{2a_2} \end{bmatrix}}_{G_1(s)} \begin{bmatrix} \Delta f_1 \\ \Delta f_2 \end{bmatrix}$$

Analysis & simulation results

Case 1: Every 2 seconds, an iteration

Case 2: Every 5 seconds, an iteration