Incremental Cost Consensus Algorithm in a Smart Grid Environment

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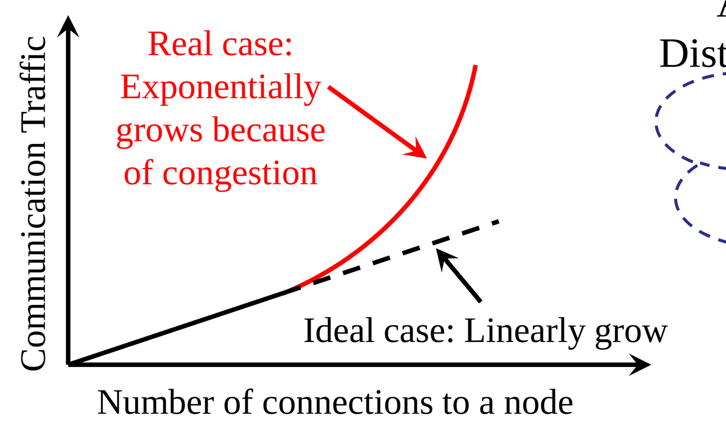
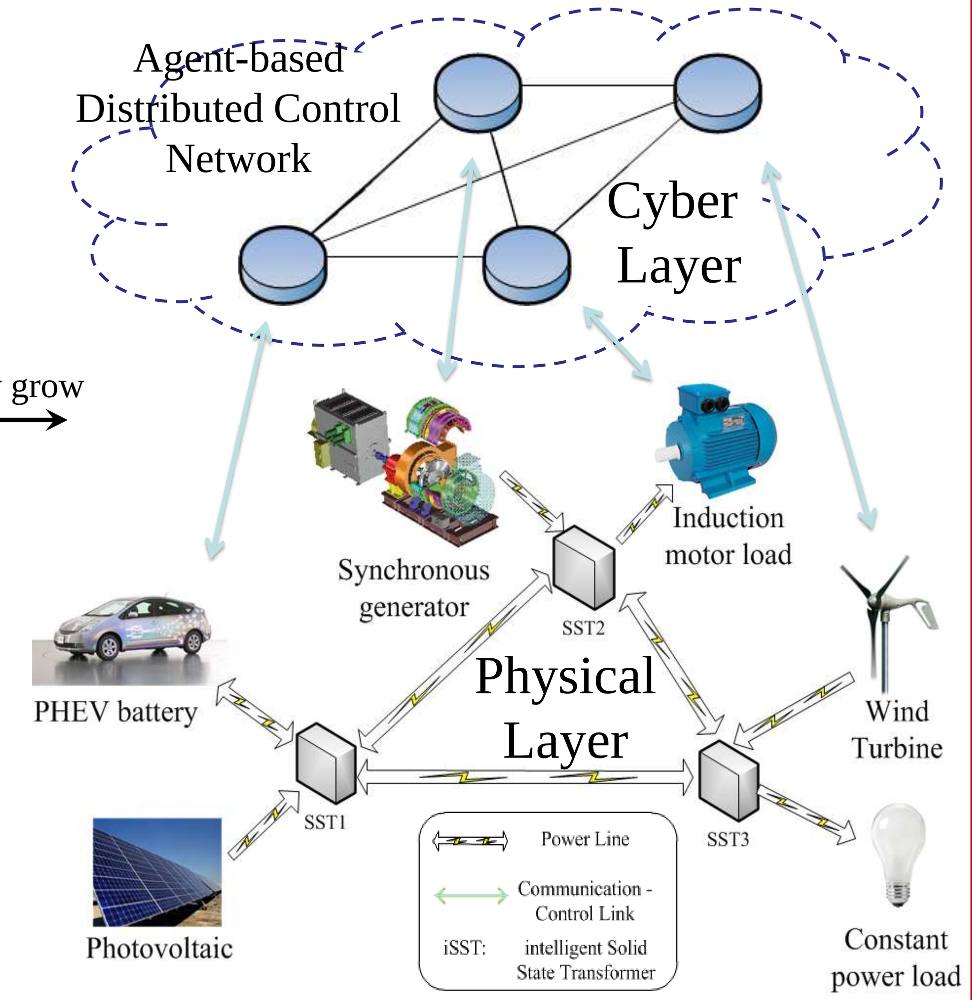
Challenges of the Smart Grid

- The number of Distributed Generators connected to the grid will be increased tremendously.
- The communication topologies are time-varying in smart grids so the more robust control algorithms are desired.
- The communicational and computational limitation of central controller will become the bottleneck of centralized control power system.





A Prototype of Smart Grid

Objective

The objective of this project is to design and implement high performance distributed controls to achieve real-time intelligent power allocation in Smart Grids.

Incremental Cost Consensus (ICC) Algorithm Formulation

Assume the fuel-cost curve of each generating unit is known and expressed in terms of the output power:

$$C_i(P_{Gi}) = \alpha_i + \beta_i P_{Gi} + \gamma_i P_{Gi}^2, \quad i = 1,2,\ldots m$$

where $C_i(P_{Gi})$ is the cost of generation for unit *i*.

P_{Gi} is the output power of unit *i*

The objective is to minimize total cost of operation:

$$\textbf{Min: } C_T = \Sigma C_i(P_{Gi}).$$
$$\text{St: } \Sigma P_{Di} - \Sigma P_{Gi} = 0;$$

From the conventional economic dispatch we know:

$$IC_i = \partial C_i(P_{Gi}) / \partial P_{Gi} = \lambda_i$$

Pick λ as the information state, use the first order discrete consensus algorithm :

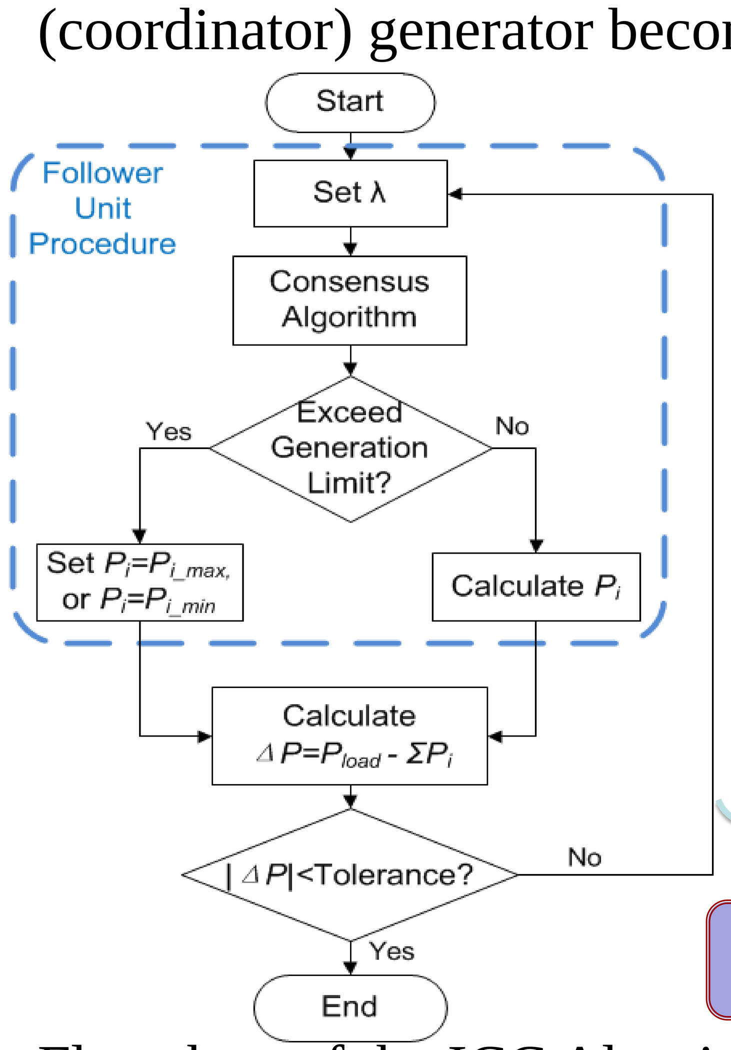
$$\lambda_i[k+1] = \Sigma d_{ij} \lambda_j[k],$$

where d_{ij} is the (i,j) entry of row-stochastic matrix D_n.

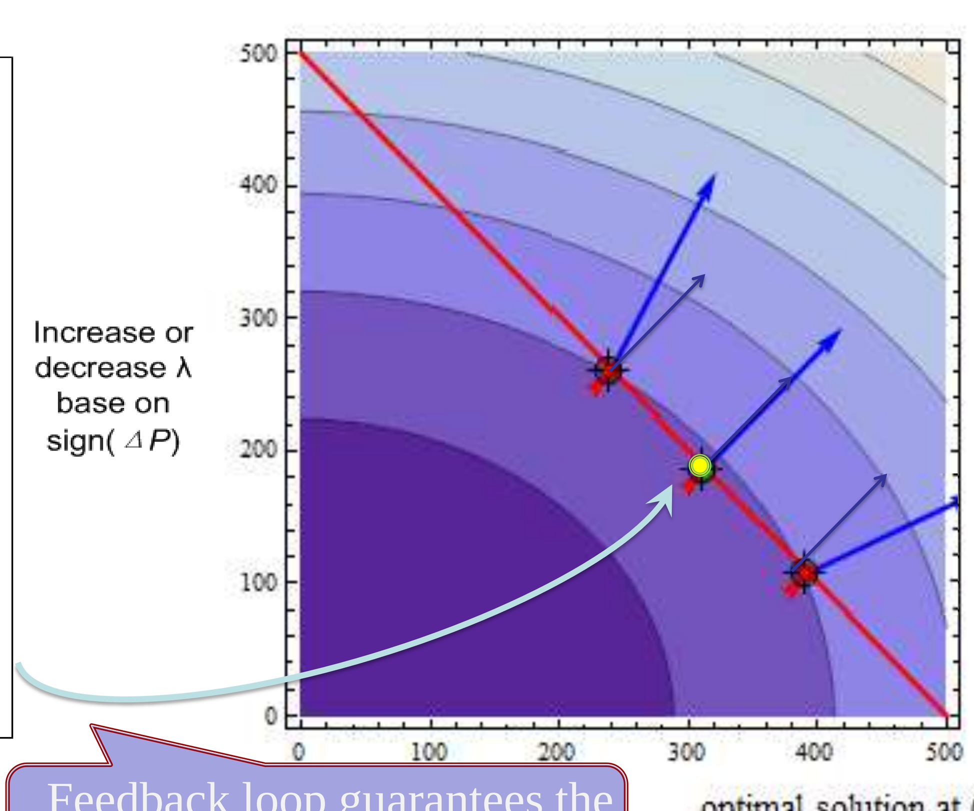
The consensus algorithm for the leader (coordinator) generator becomes:

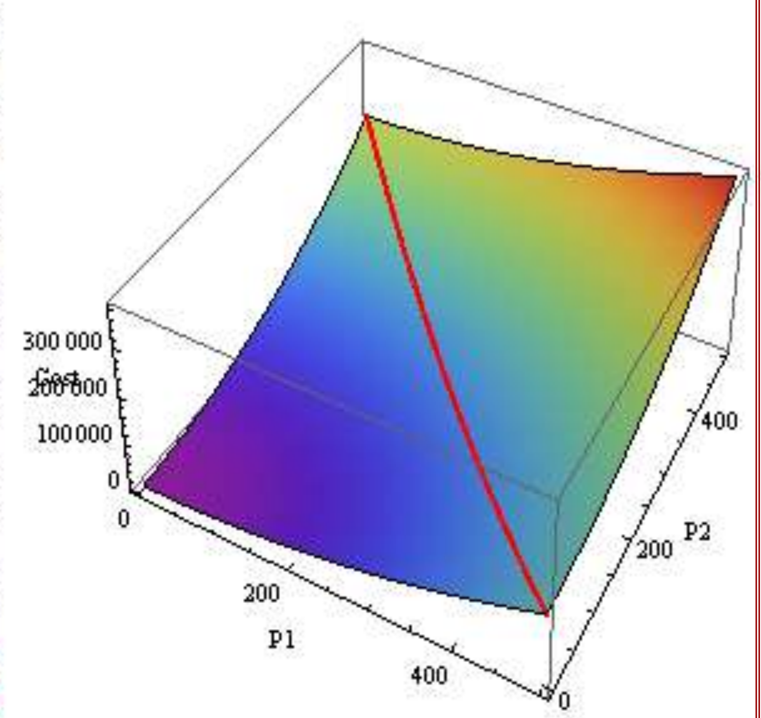
$$\lambda_i[k+1] = \Sigma d_{ij} \lambda_j[k] + \varepsilon \Delta P,$$

where ε is a scalar which controls the convergence speed. $\Delta P = \Sigma P_{Di} - \Sigma P_{Gi}$.



Flowchart of the ICC Algorithm



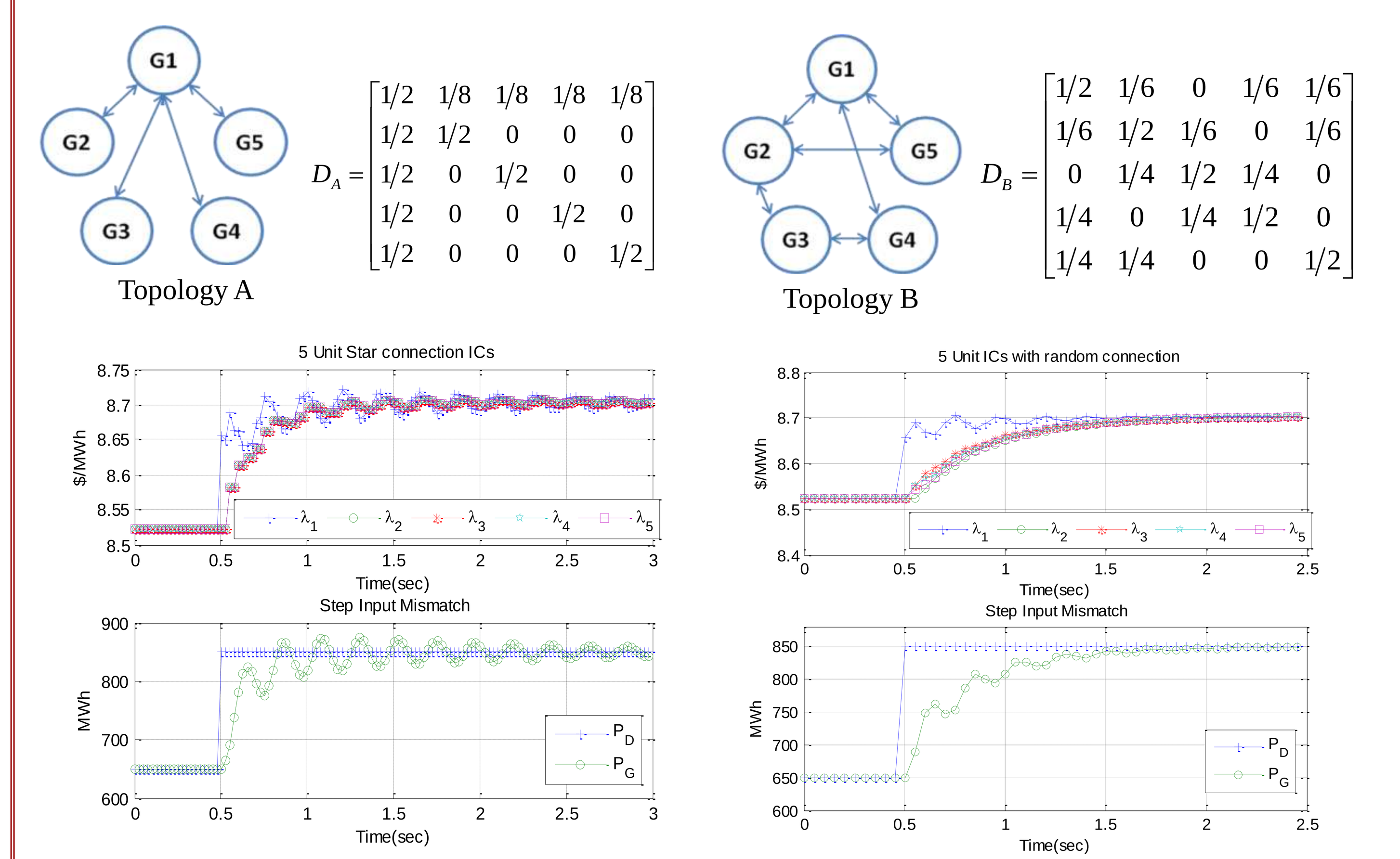


At the optimal point: $\nabla f(x, y) = \lambda \nabla g(x, y)$

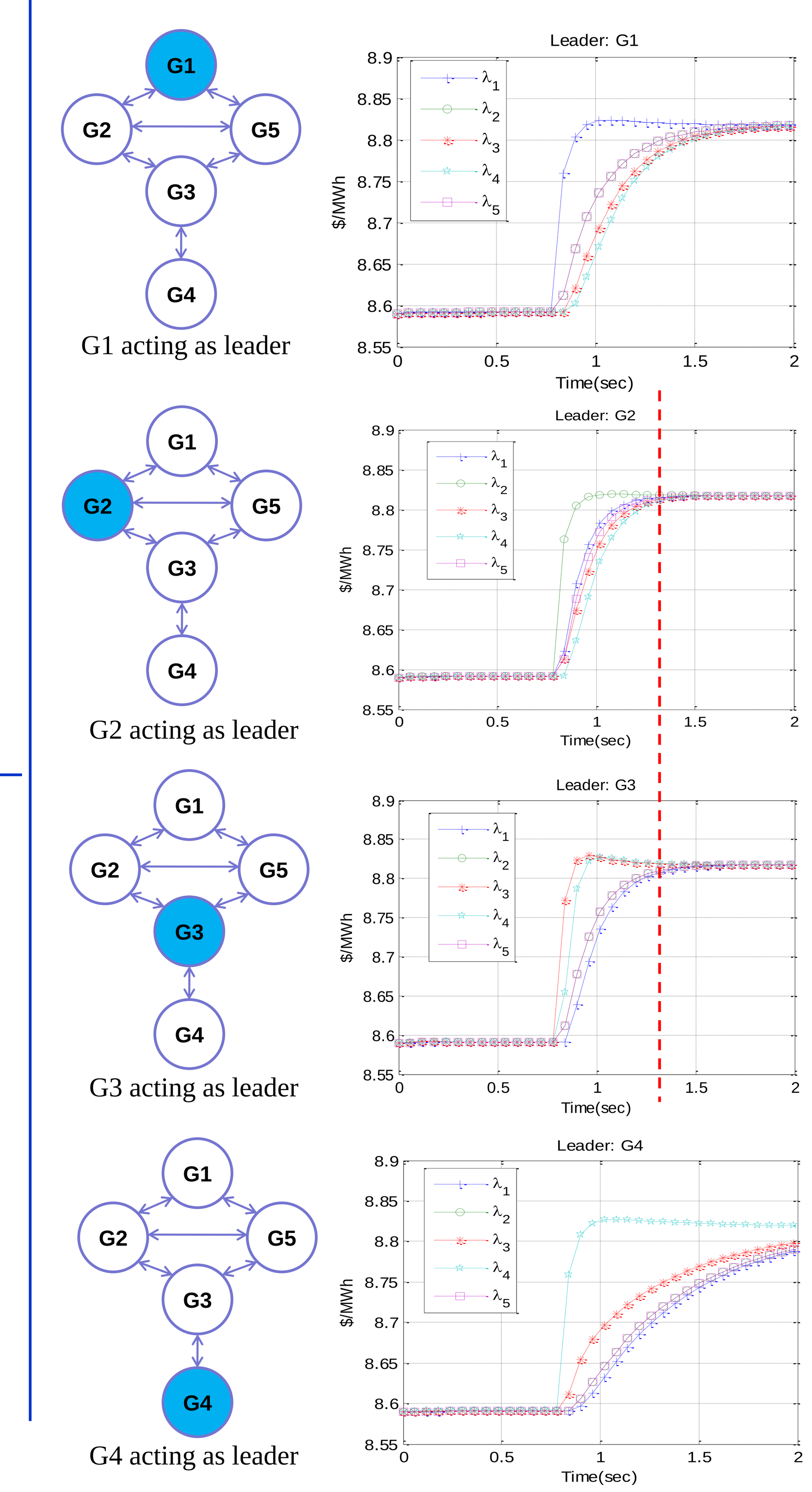
Convergence Analysis

- When IC Consensus algorithm reaches the steady state, the final IC we obtained is equal to the λ which calculated by using the Lagrange multiplier method.
- However, similarly as most of the distribute algorithms, the ICC algorithm takes time to converge to the finial solution.
- The convergence rate could be affect by many parameters such as:

Under the different communication topologies



Under the different of locations of the leader unit



Conclusions

- The ICC algorithm is able to solve the conventional Economic Dispatch problem in a distributed fashion.
- The ICC algorithm guarantees that all of the generation units can converge to optimal IC asymptotically, as long as there exists a common optimal IC.
- The convergence is also guaranteed under different communication topologies as long as a minimal spanning tree exists in the communication topology.

Work in Progress

- Detailed power system distributed control modeling and simulation
  - –Include both communication network and power grid and their interactions
  - –Use dynamic topology to simulate "Plug-and-Play" scenario
- Analyze the robustness of algorithms under package loss, link failure and node failure
- Investigate network delay effects on the ICC algorithm
  - –Develop corresponding network delay compensation algorithms

Acknowledgment

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