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Optimal Decentralised Dispatch of Embedded Generation to Increase Efficiency of the Smart Grid

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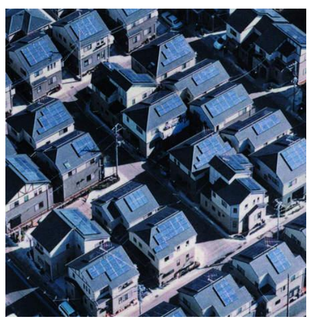
Aims

Coordinate generators in an electricity network in order to minimise the cost (i.e., CO_2 emissions) by using active network management (ANM)



Due to rising incentives for cleaner energy, renewable generators will increase in the distribution network. Brownouts or blackouts could occur if distribution network operators (DNOs) don't manage increased generation

Key Challenges

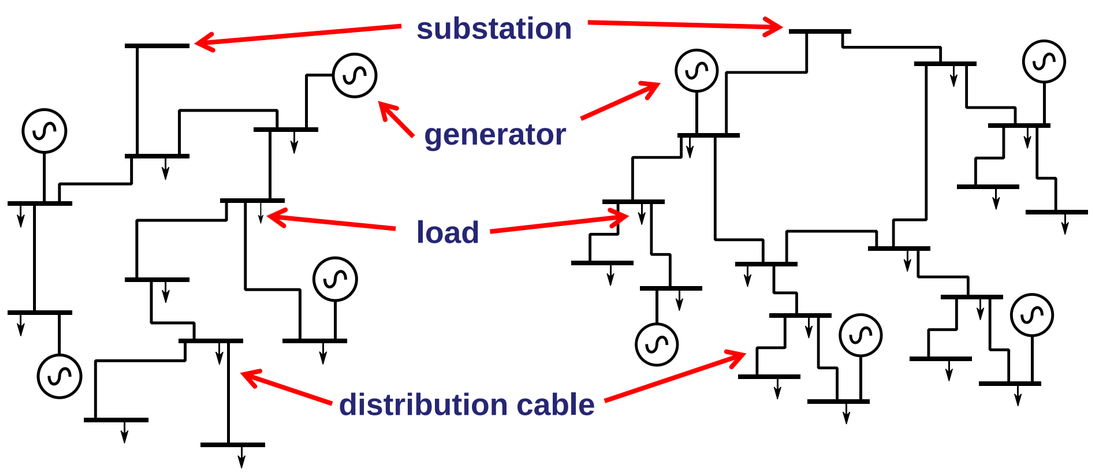
- Coordinate increased number of generators
- Reduce network cost
- Central control infeasible due to exponential computation
- Complexities of electricity

The Optimal Dispatch Problem

Use ANM and optimal dispatch in distribution network microgrids

Radial distribution networks

Ring main distribution networks



Minimise the cost of the generators

number of generators

carbon intensity

generator output

set of generator outputs

$$\arg\min_{\boldsymbol{\alpha}} \sum_{i=0}^{n} CI_i \alpha_i$$

Subject to local and global constraints

max capacity

flow

$$|f_{ij}| \leq t_{ij}^{c}$$

number of loads

$$\sum_{w \in adj(v_i)} f_{wi} + \sum_{l \in \mathbf{L}(v_i)} \beta_l + \sum_{g \in \mathbf{G}(v_i)} \alpha_g = 0$$

$$\sum_{i=0}^{n} \alpha_i = \sum_{j=0}^{m} \beta_j$$

adjacent nodes | set of loads | set of generators

Solving in a centralised manner is infeasible

- Computation grows exponentially with the size of the network
- Central point of failure
- Requires large amounts of centrally available information

Decentralised is better

- Decompose to scale
- Distribute for robustness and to maintain local dependencies
- Natural fit to agent framework

Model Optimal Dispatch as a DCOP

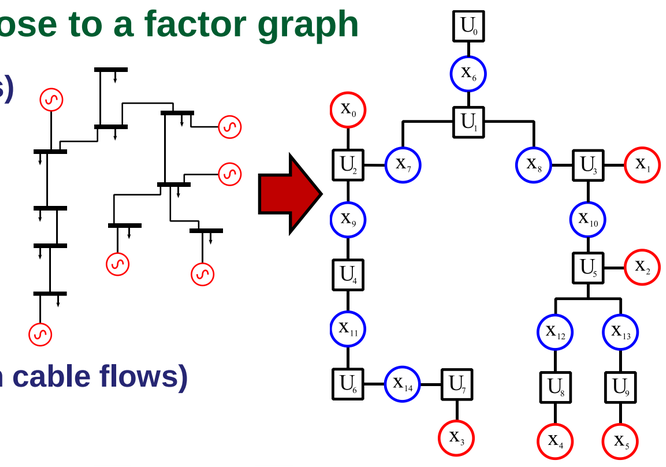
Decompose to a factor graph

variables (generators/distribution cables)

utilities

$\langle \mathbf{X}, \mathbf{D}, \mathbf{U} \rangle$

domains (generator outputs/distribution cable flows)

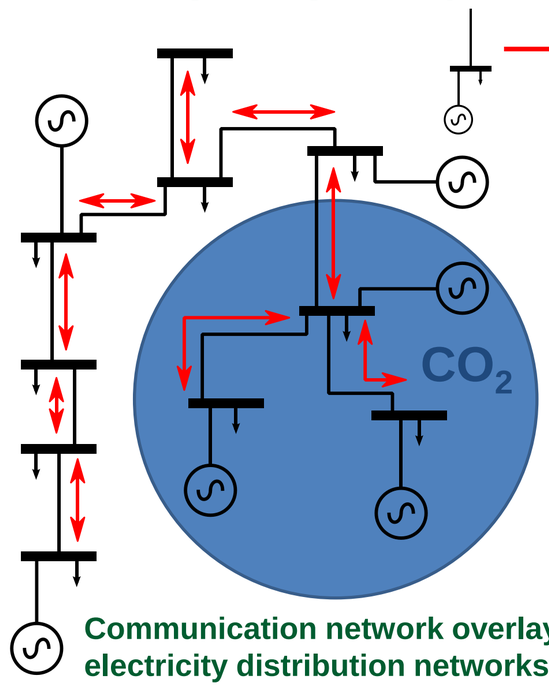


$$U_i = \begin{cases} \sum_{g \in \mathbf{G}(v_i)} CI_g \alpha_g & \sum_{w \in adj(v_i)} f_{wi} + \sum_{l \in \mathbf{L}(v_i)} \beta_l + \sum_{g \in \mathbf{G}(v_i)} \alpha_g = 0 \\ \infty & \text{otherwise.} \end{cases}$$

Solve Using Message Passing Techniques

Peer-to-peer interaction between substations controlled by agents

- Crucially, each agent makes local decisions, network converges to global optimum



Agent controlled "node"

In radial networks, propagate message from leaf nodes to root of the network

- Each node summarises its ability to produce power
- Sends summary to parent node
- Root node makes optimal generator output
- Each node uses parents optimal decision to determine own optimal generator output

Communication network overlays existing electricity distribution networks

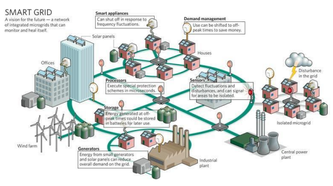
In ring main networks, harder to determine the amount of power in the cyclic part of the network due to coupled nature

- Use the Auxiliary Problem Principle (APP) to decompose the optimal dispatch problem into decoupled sub-problems
- Each sub-problem can be solved in parallel
- Agents share variables with their neighbours which they continually update until they converge to a solution

The Bigger Picture

Techniques discussed so far solve a one shot optimisation problem

In order to be applicable to the real smart grid, must incorporate time into the model



- Each generator has a certain latency time for changing output
- Must predict how the weather will affect generation from renewable resources
- Run algorithm at multiple points over the day, give generators a range of power which results in the optimum for the network

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