

Motivation

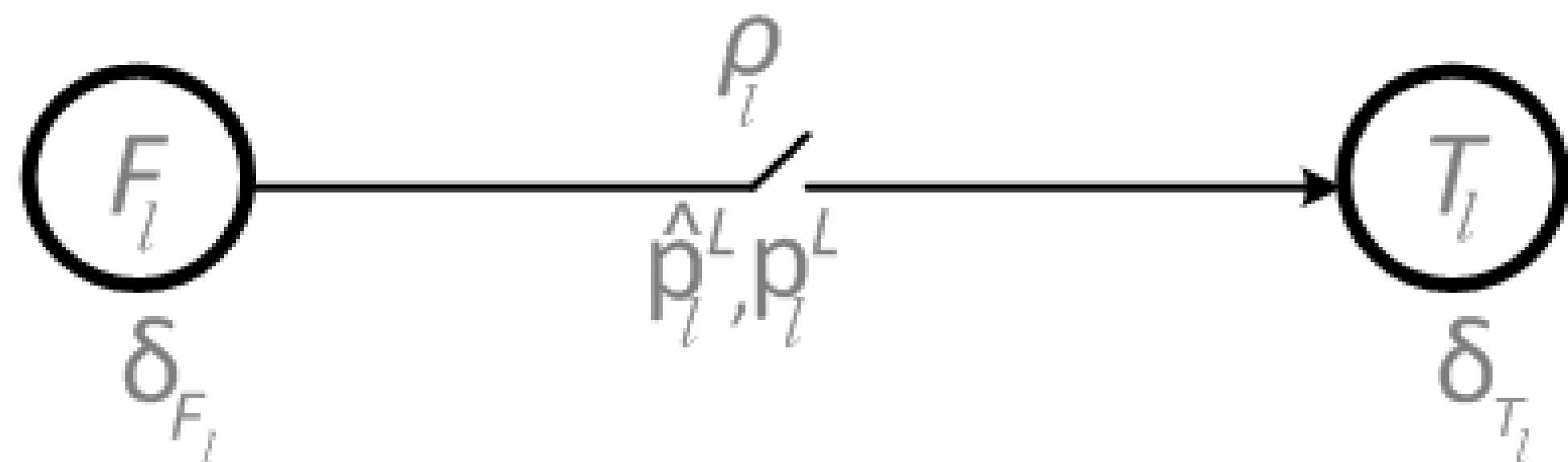
Modern power systems are designed to handle *single* outage at a time. But sometimes unpredictable events like wind storms or natural disasters happen and they cause two or more outages at a time. Since power system is not designed to handle such a situation, cascading outages occur and lead to large area blackout.

In the last decade we have witnessed numerous wide area blackouts. These blackouts initially were triggered by a disturbance in a small part of network. Disturbance was not curtailed to the affected area and eventually it spread across the network causing blackout.

Here we propose mixed integer linear programming (MILP) model for preventative islanding of power systems. Given an area of disturbance, this model will curtail the disturbance to some optimal subset of network, so that the system can operate normally outside that region.

Islanding Model

Let B , D and L denotes set of buses, demands and lines in the network. We define B^0 and L^0 as set of affected buses and lines. We wish to confine the disturbance to some optimal region. We call this region *section 0*. *Section 1* is rest of the network. Our optimization model will determine the regions and there boundaries.



We define $p_d^D = \alpha_d P_d^D$, where P_d^D is the real demand and α_d is the proportion of load delivered at demand d . We define β_d as the load satisfaction probability in section 0. Probability of load satisfaction in section 1 is unity. This is achieved by following set of equations:

$$\begin{aligned} \alpha_d &= \alpha_{0d} + \alpha_{1d} \quad \forall d \in D \\ 0 &\leq \alpha_{0d} \leq 1, \\ 0 &\leq \alpha_{1d} \leq \gamma_b, \quad \forall d \in D, b \in B \end{aligned}$$

Objective Function

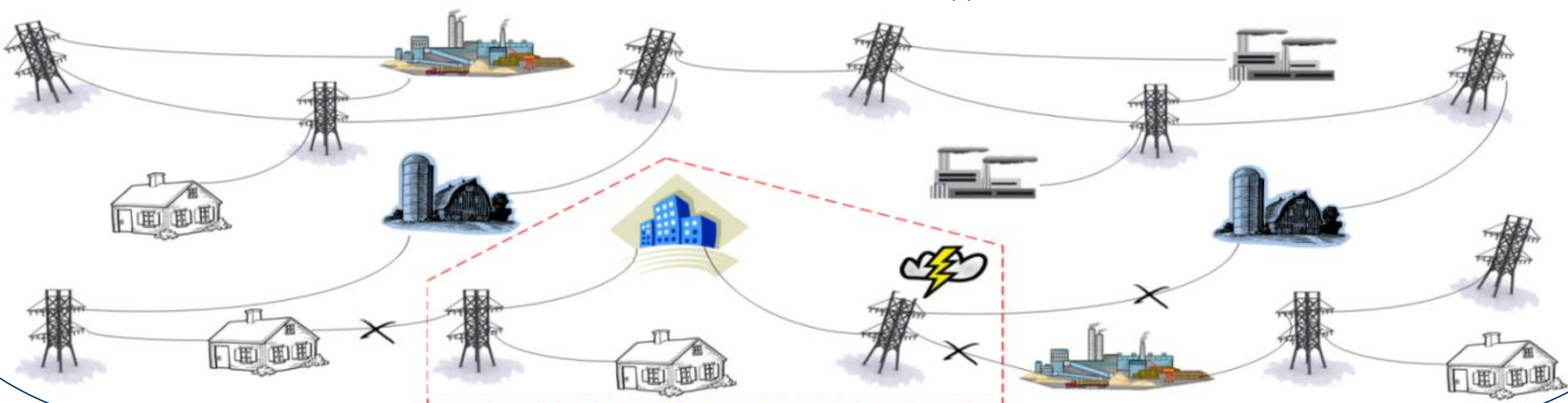
The objective of our optimization model is to maximize the amount of load delivered to customers. The objective function is given as follows:

$$\max \sum_{d \in D} P_d (\beta_d \alpha_{0d} + \alpha_{1d})$$

DC Line flow equations

We use small angle approximation of Kirchhoff's voltage laws (KVL). The implementation of KVL is given by following equations:

$$\begin{aligned} \hat{p}_l^L &= -B_l^L (\delta_{F_l} - \delta_{T_l}) \\ -(1 - \rho) \hat{p}_l^{L-} &\leq p - \hat{p}_l^L \leq (1 - \rho) \hat{p}_l^{L+} \\ \rho \hat{p}_l^{L-} &\leq p \leq \rho \hat{p}_l^{L+} \end{aligned}$$



Sectioning Constraints

We define binary variables γ_b for each bus b and ρ_l for each line l in the network respectively. γ_b is zero if bus b is in section 0 and 1 otherwise, ρ_l is switch on lines. The constraints to partition the network into two sections are as follows:

$$\begin{aligned} \rho_l &\leq 1 + \gamma_{F_l} - \gamma_{T_l} & \forall l \in L \setminus L^0 \\ \rho_l &\leq 1 - \gamma_{F_l} + \gamma_{T_l} & \forall l \in L \setminus L^0 \end{aligned}$$

$$\begin{aligned} \rho_l &\leq 1 - \gamma_{F_l} & \forall l \in L^0 \\ \rho_l &\leq 1 - \gamma_{T_l} & \forall l \in L^0 \end{aligned}$$

$$\begin{aligned} \gamma_b &= 0 & \forall b \in B^0 \\ \gamma_b &= 1 & \forall b \in B^1 \end{aligned}$$

Other Constraints

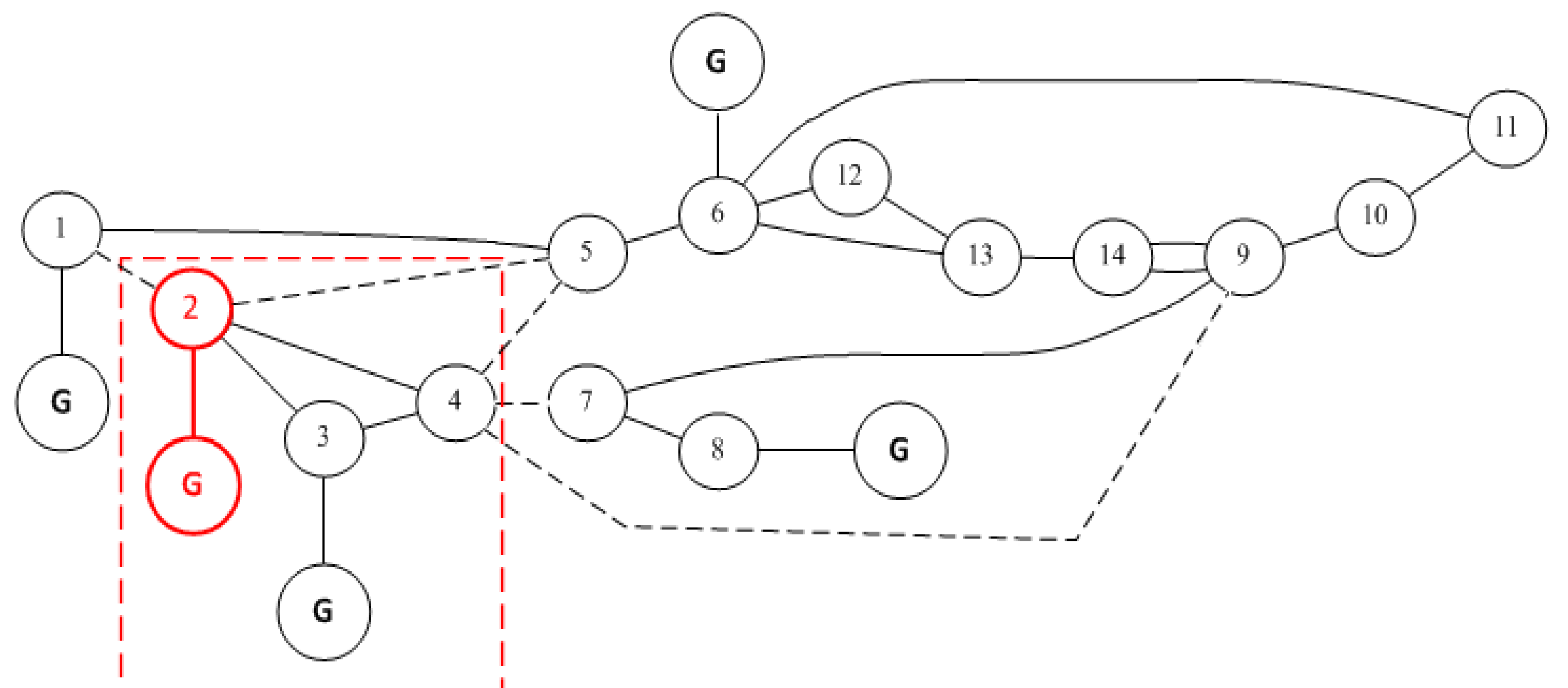
Following are the other constraints which we implement in our optimization model:

- Kirchhoff's current law
- Line flow limits
- Power generation limits

Numerical Result

This model has been tested on test cases ranging from 14 nodes to 2746 nodes.

Here we present islanding solution for IEEE 14 bus test case. In this system we assume that bus 2 is uncertain. Red dotted line shows the boundary of section 0 determined by our islanding model.



Challenges

Some of the problems we are working on:

- Including power system dynamics in optimization framework
- Nonlinear power system islanding model
- Improving computational times
- MILP approximation of nonlinear KVLs