Identifying Critical Elements to Enhance the Power Grid Resilience

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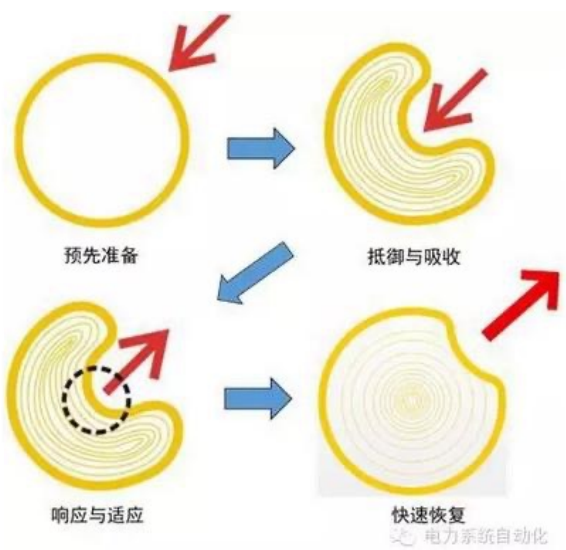
Outline



1 Concept of Power Grid Resilience

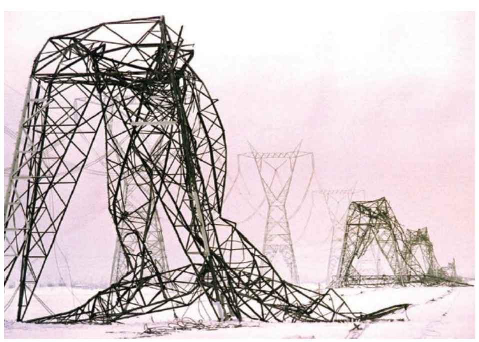
2 Model Description

3 Critical Link Detection Methods

4 Conclusions

1 Resilience-Background

Today's power system has been constructed strong enough to high frequency low-impact disturbances. But it is still vulnerable to extremes: like man-made attacks and natural disasters.



1 Resilience-Definition

The resilience of the power grid refers to its ability to effectively resist and quickly recover from the extremes.

Two U.S. Presidential Policy Directives, PPD-8 and PPD-21, emphasized the power grid resilience [1].

National Resilience Program of Japan totaled $210 billion investment in year 2013 [2].

UK set up the Resilience Electricity Networks for Great Britain (RESNET) project in year 2015 [3].

[1] Presidential Policy Directive (PPD) 21, The White House, Washington, DC, USA, 2013.
[2] The Resilience of the Electricity System, Science and Technology Committee—House of Lords, London, U.K., 2015.
[3] A. Dewit, "Japan's 'National Resilience' and the legacy of 3–11," Asia–Pacific J., vol. 14, no. 6, pp. 1–7, 2016.

1 Resilience-Viewpoints

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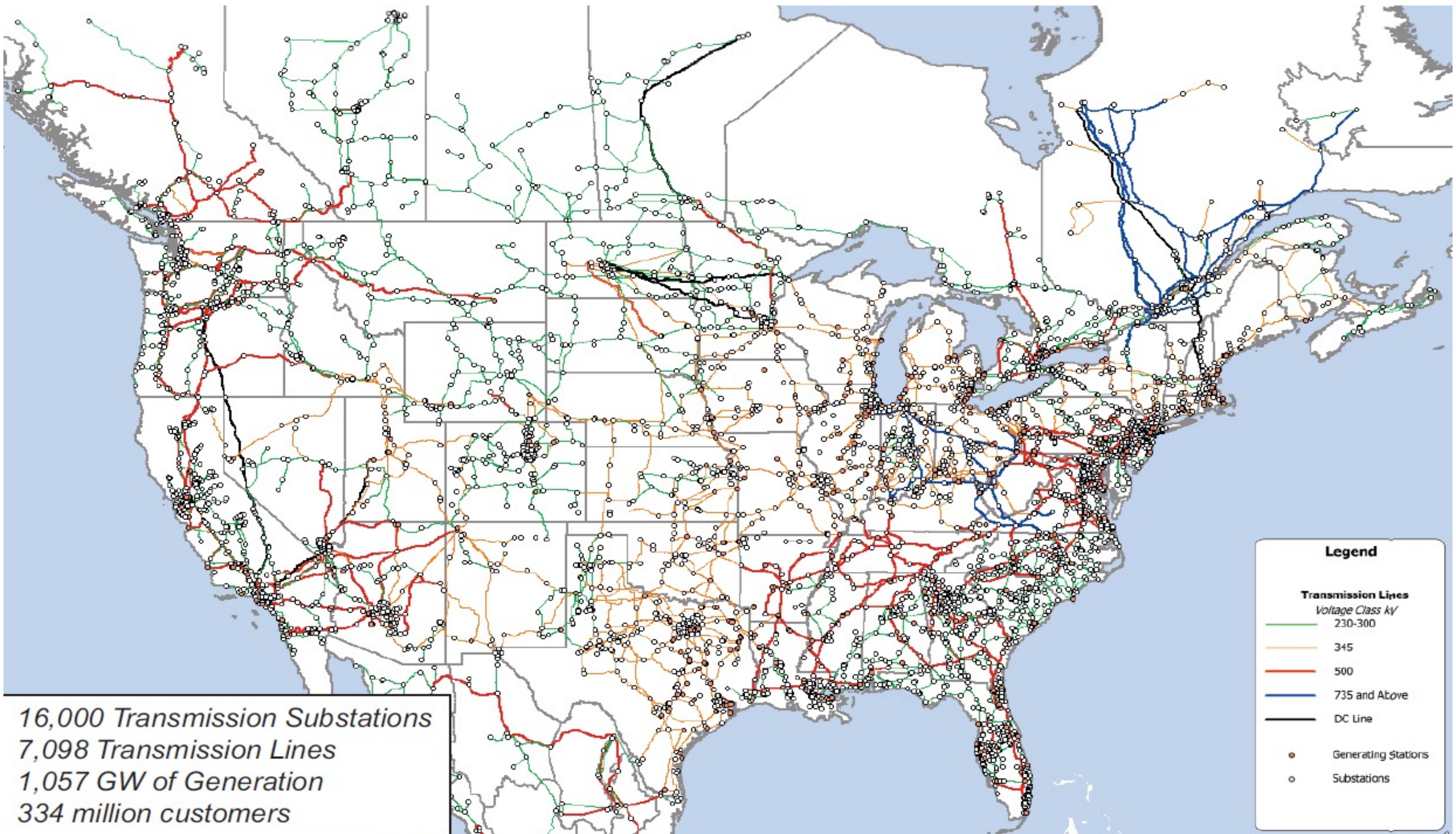

Figure 1 Transmission Network in North America

1 Resilience-Viewpoints

Viewpoint 1：The power grid is a typical complex adaptive system.

Viewpoint 2：There are a variety of recovery methods with different time scales.

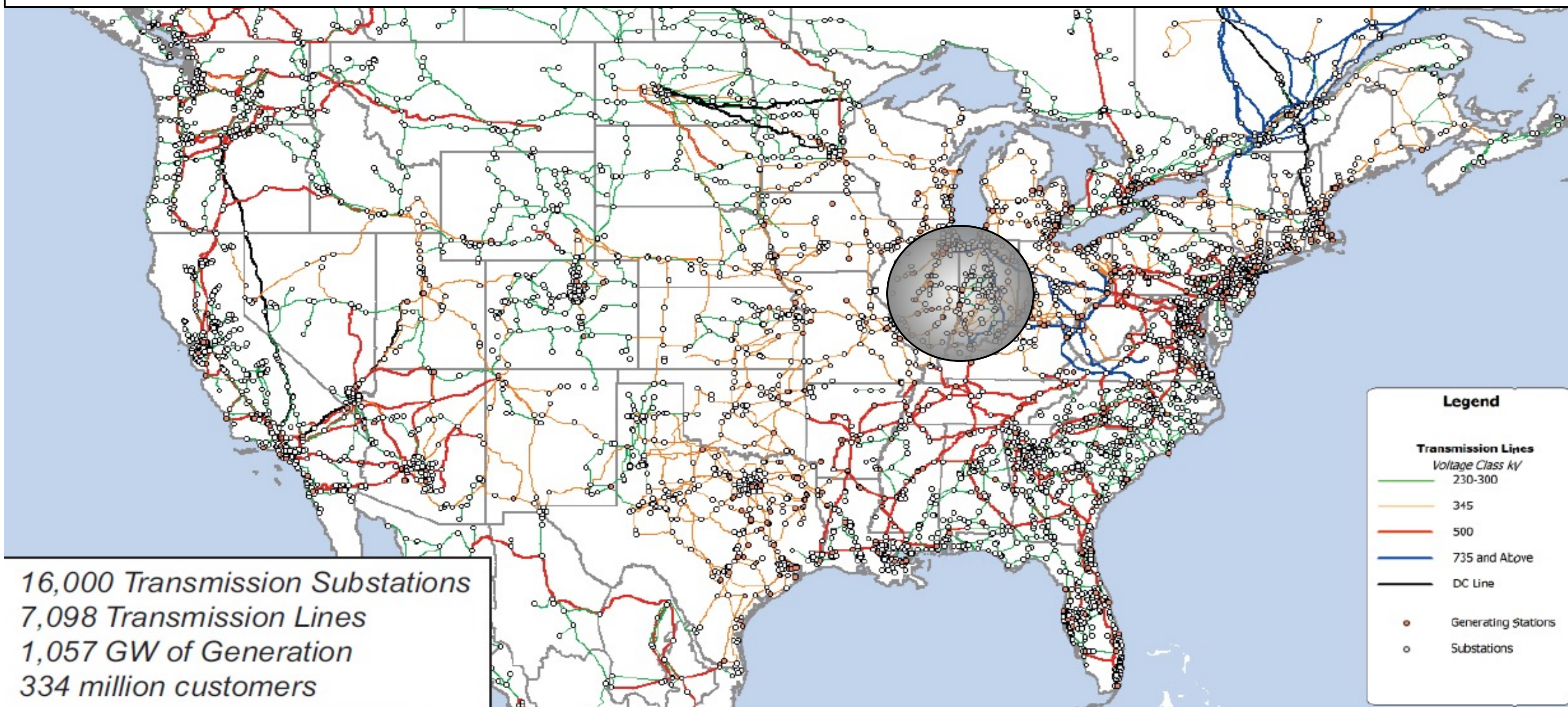

Figure 1 Transmission Network in North America

Resilience Metric-Maximum Power Supply

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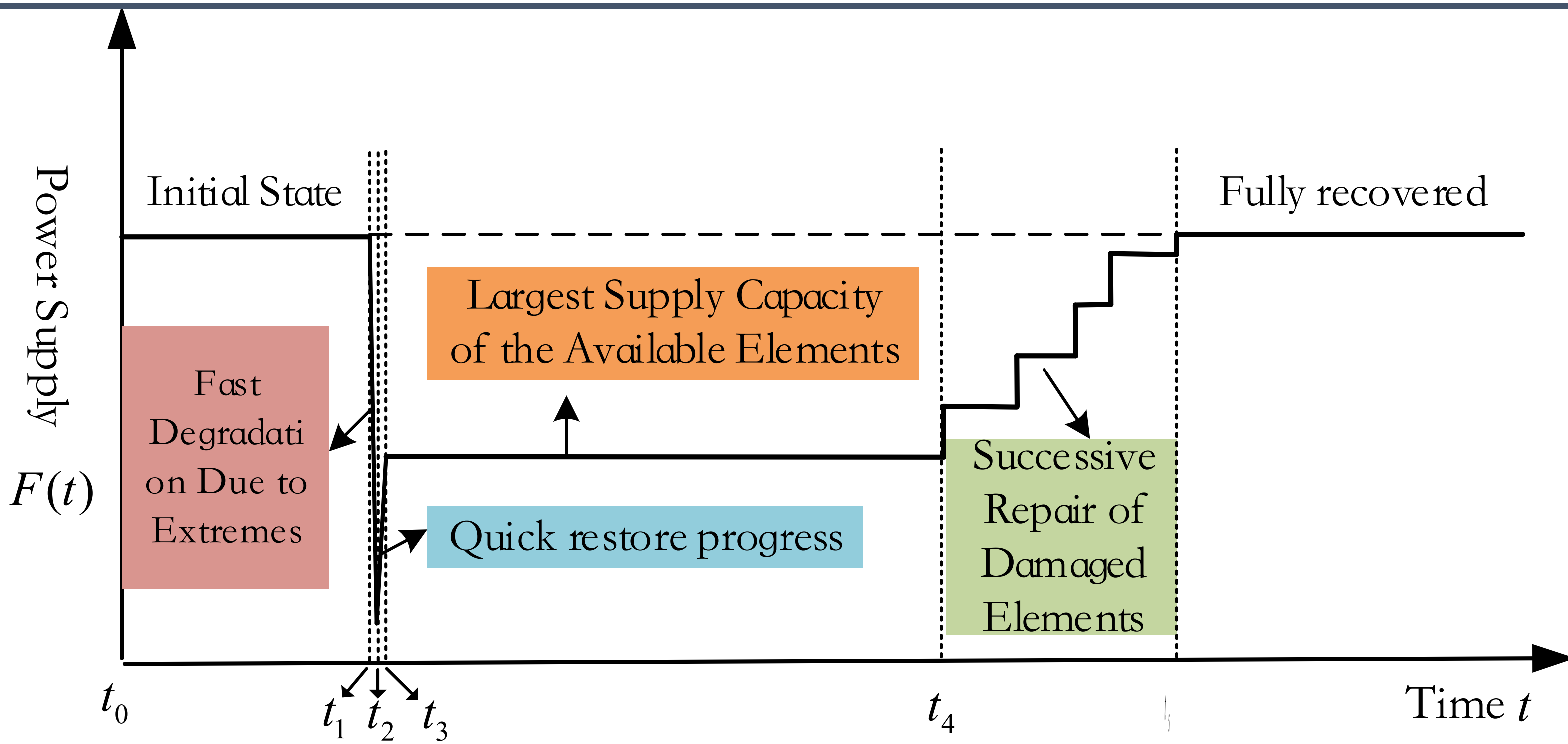
Multi-dimensional characteristic

Considering different time scales of the events, we consider the following three critical stages:

Stage 1: Cascading failure: a sequence of switching off actions of protective relays

Stage 2: Quick recovery: to adjust the operation modes of the remaining elements

Stage 3: Slow recovery: to repair/reconstruct the damaged elements



2 Model Description

How to coordinate the remaining available resources to get the maximum power supply in the post-disaster network.

Objective Function：

$$F_{max}(G, t_3) = -\min \sum \boldsymbol{L_i}$$

Where $i \in N_L$ **and** $\boldsymbol{L_i}$ is the power consumed of the loads

Variables: the output power of generators and consumed power of loads

Constraints:

$$p_{ij} = a_{ij} * (\theta_i - \theta_j)$$

$$A\theta = P$$

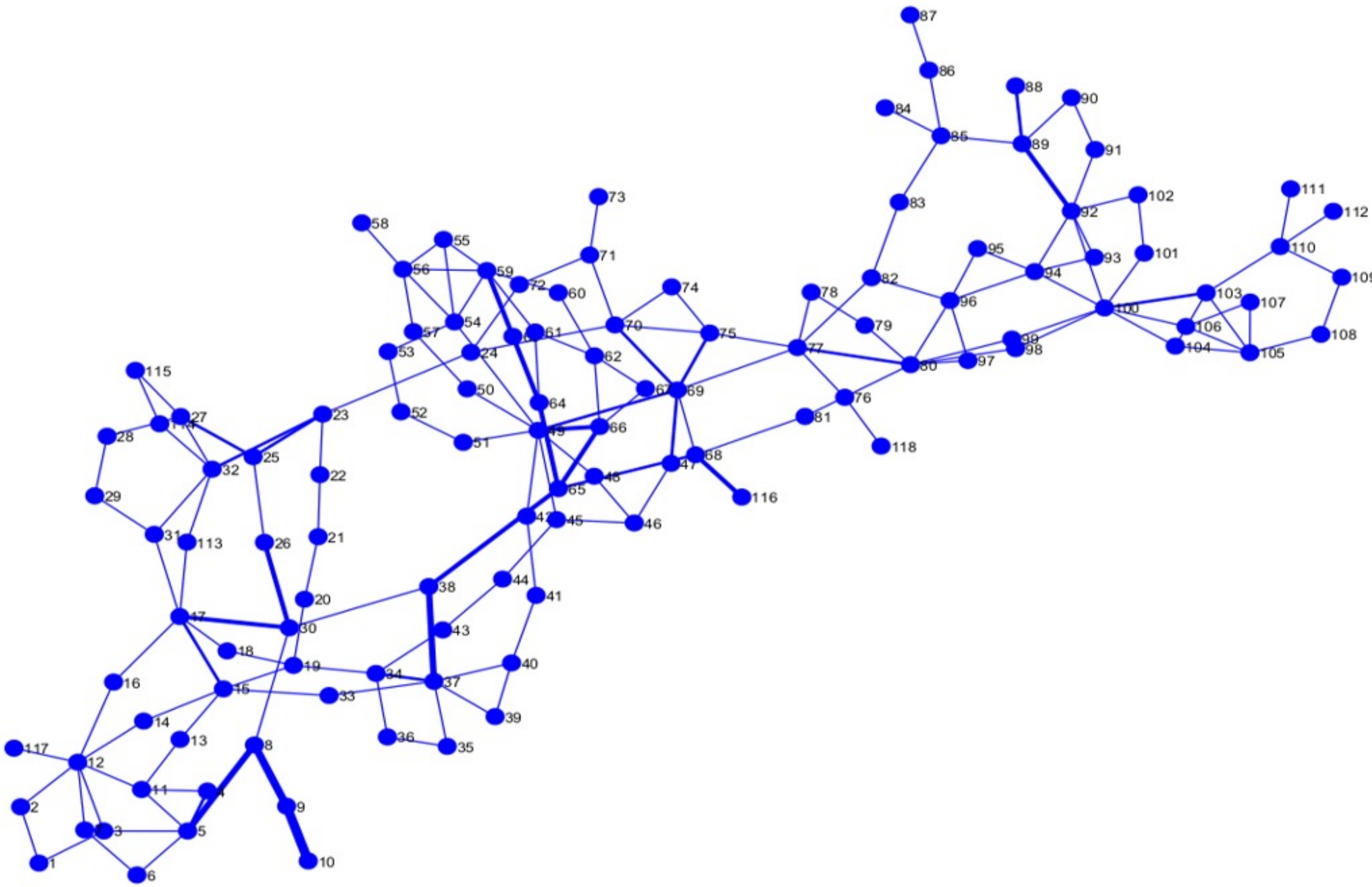
$$-C_{ij} \le p_{ij} \le C_{ij}$$

$$0 \le p_i \le C_i, i \in N_g$$

$$-C_i \le p_i \le 0, i \in N_L$$

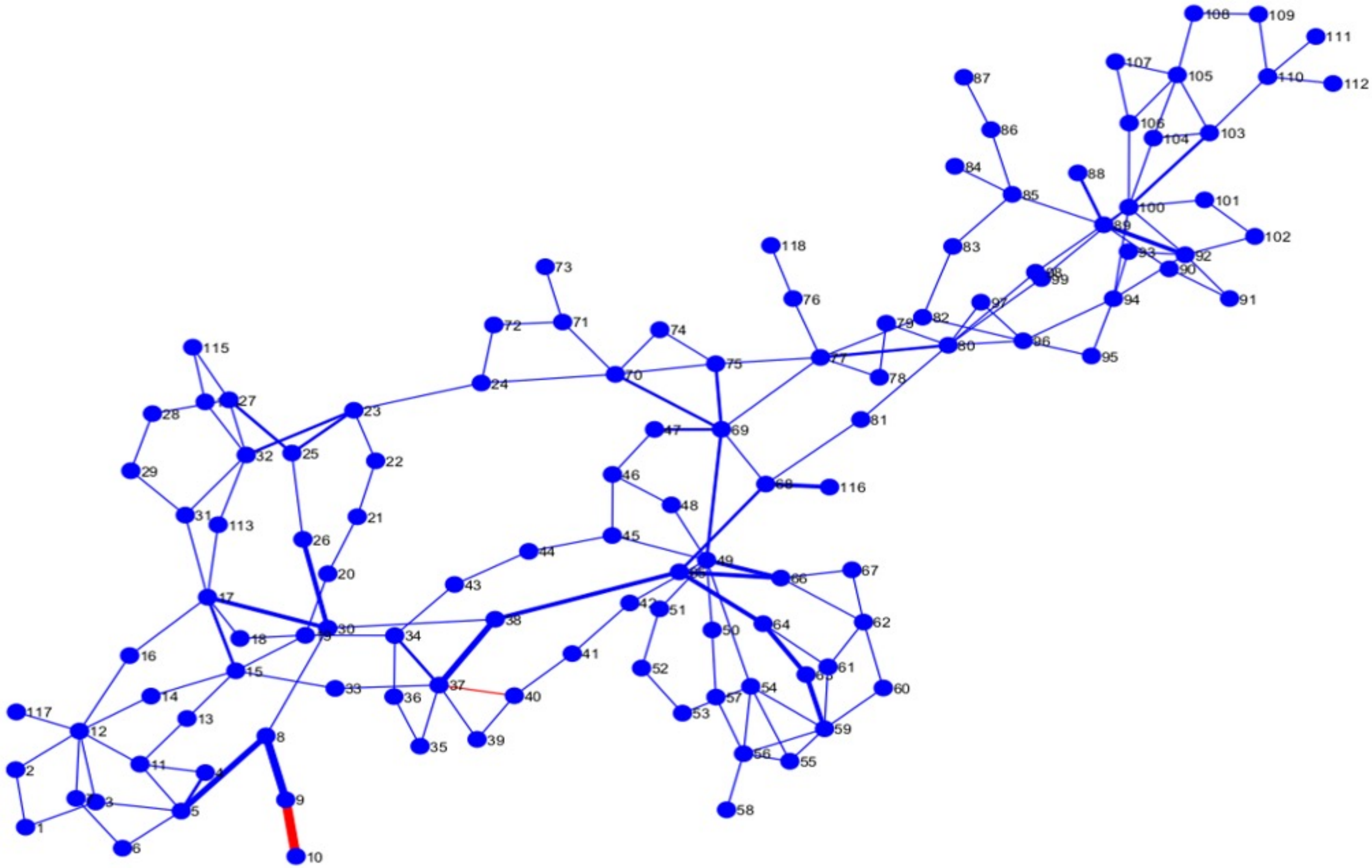
where N_L is the set of undamaged loads, N_g is the set of undamaged generators. θ_i , p_i and c_i are the phase angle the power and upper limit of node i. a_{ij}, p_{ij}, and C_{ij} are the admittance, power flow and power limit of transmission line ij .

Model Description



The initial power supply to the loads in the IEEE 118 Bus System is 36.7 MW.

Model Description



The maximum power supply to the loads has dropped to 32.2 MW.

3 Critical Link Detection

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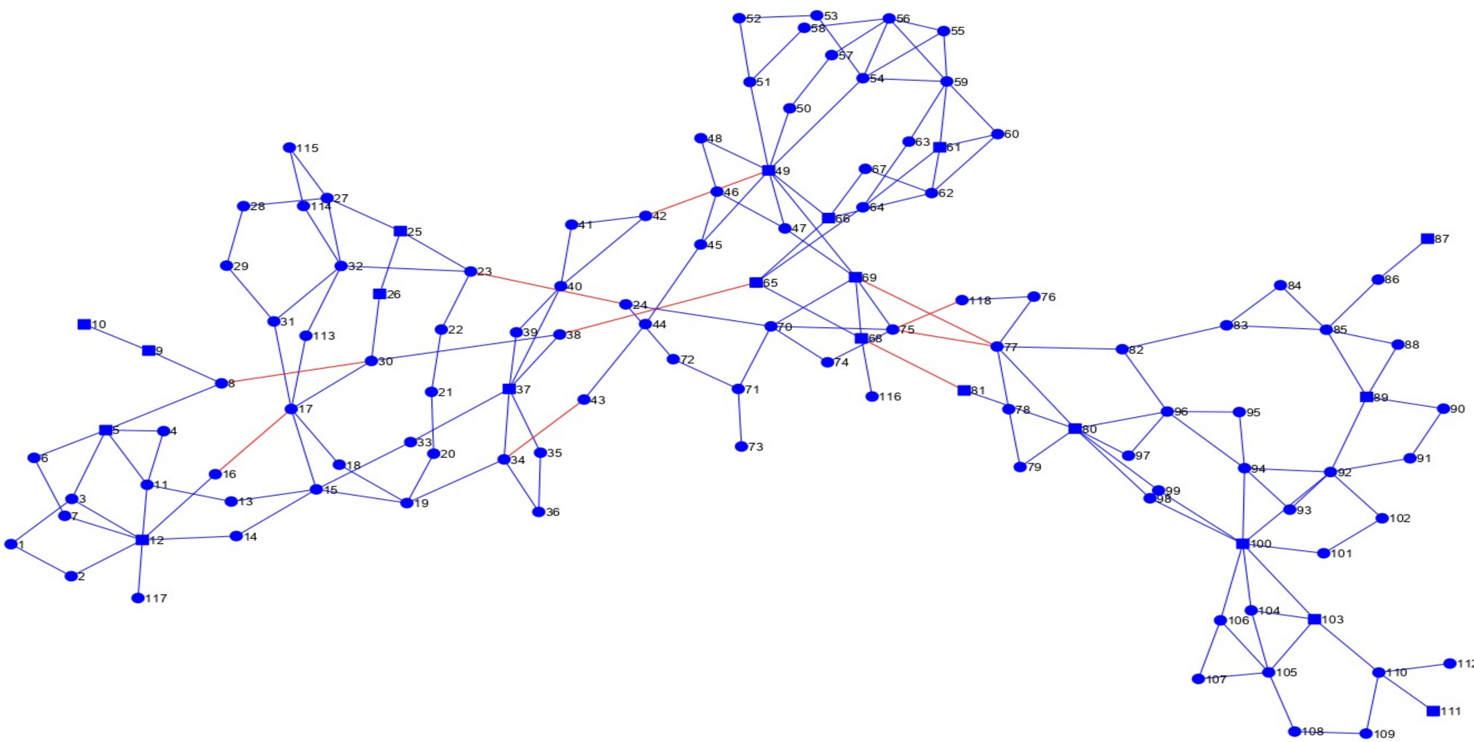
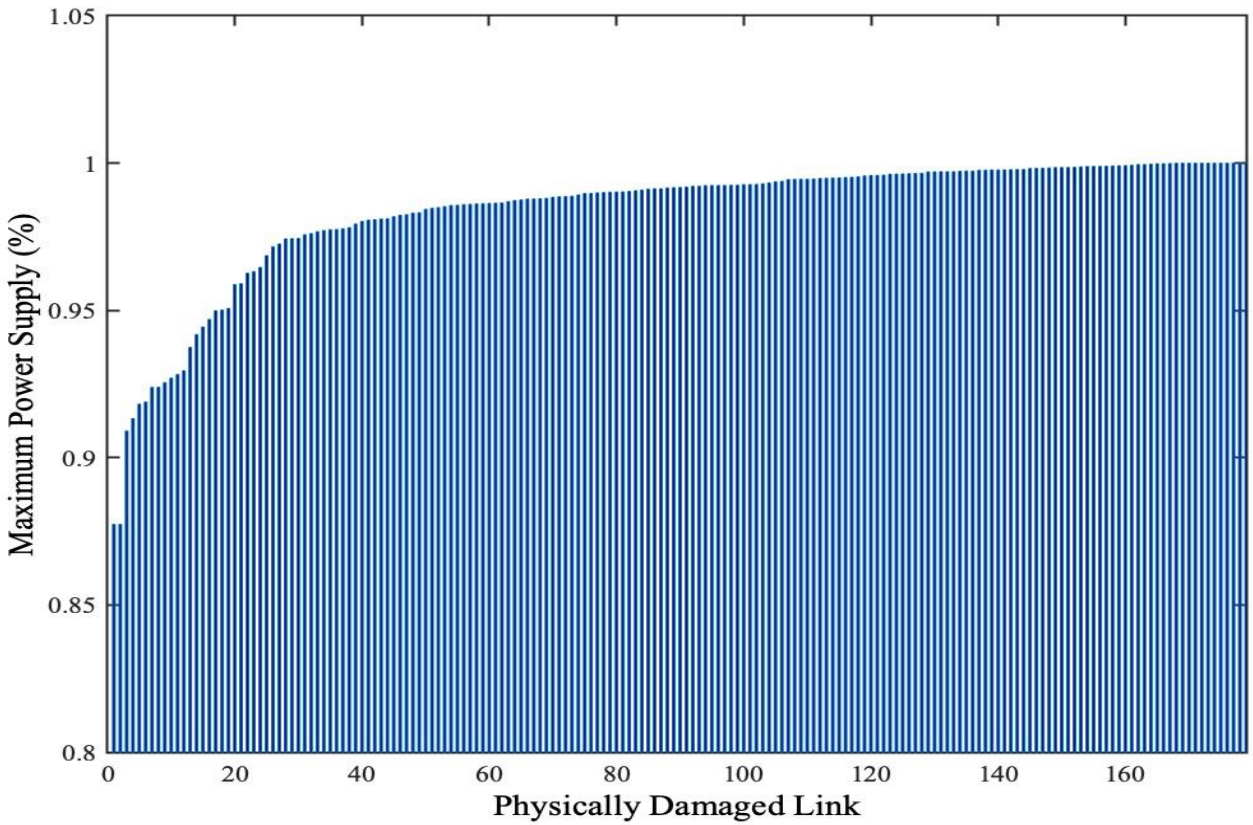
1. Do the components in the power network play the same role in determining its resilience? Is the power network homogeneous or heterogeneous?

2. How to identify the critical components, whose combinatorial removal will significantly decrease the maximum power supply of the power system?



Critical Link Detection

The following figure shows the maximum power supply of the remaining network after the individual removal of the links in the IEEE 118 Bus Case. The roles of different links in the power grid are distinct with each other. The power grid is heterogeneous.



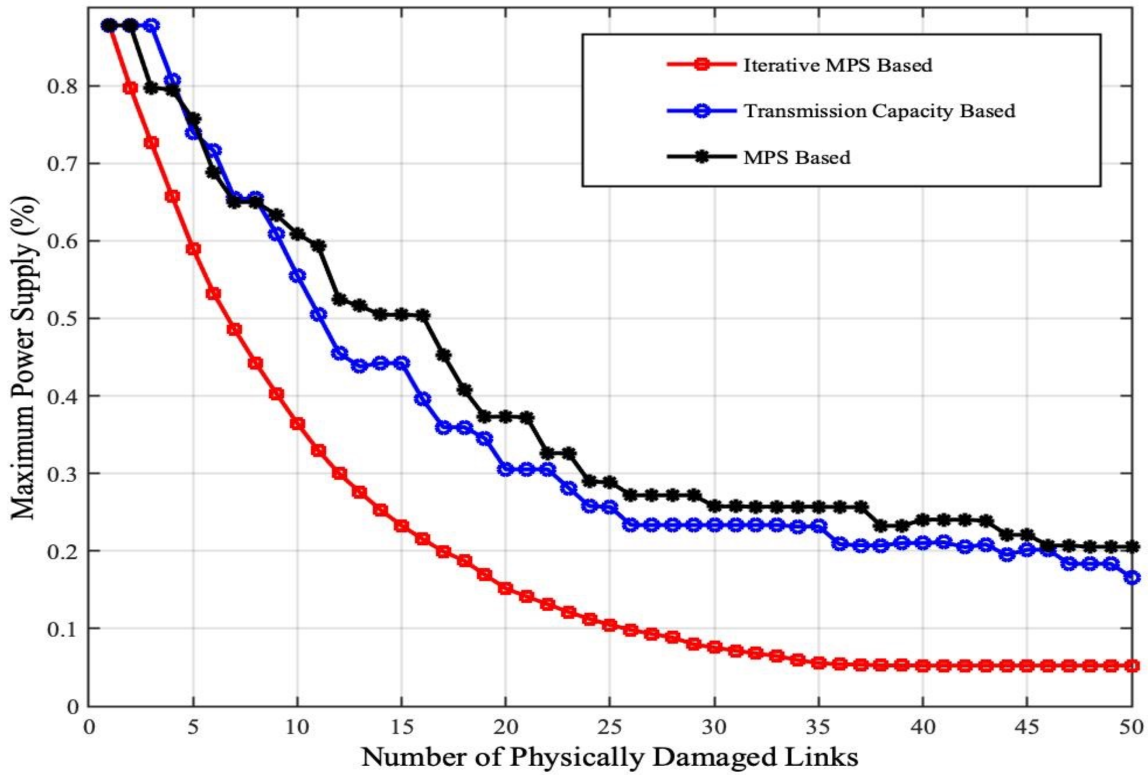
Critical Link Detection

Three different strategies:

(1) To iteratively remove one element that can most decrease the MPS;

(2) To select the links with largest power flows;

(3) To select the links based on MPS.



Conclusion and Future Work

Conclusions:

（1） We revisited the power grid resilience by taking into consideration different time scales. The maximum power supply that can be achieved through quick recovery strategies is identified as an important indicator for the power grid resilience.

（2） An optimization model is proposed to generate the maximum power supply of the post-disaster network.

（3） Three different methods are proposed and compared in identifying the set of critical elements.

Future work:

(1) More effective methods for identifying the critical components.

(2) Strategies for enhancing the power grid resilience.

谢谢各位老师
敬请批评指正

Thanks for your listening

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