Electric Power and Energy Systems

Smart Grid Surveillance With Unmanned Aerial Vehicle
Using K-Resiliency Modeling

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Motivation

- Power line inspection provides a means for the smart grid surveillance to ensure the usual operational flow.
- Cyber/physical attacks by adversaries on the control system or natural calamities causing physical damage to the power line will hamper the functional integrity of the grid.
- Any damage to the power network can be occurred in hard-to-reach remote areas.
- Understanding the amount of impairment will be time consuming whereas control center needs to take immediate steps in case of any disturbance.

Problem Scenario

- Smart grid being a widely distributed engineering system, may run through deep forests to long rivers, coastal areas, and over the cities.
- Breakage of any line or outage in generation on the bus network can not be acknowledged in short duration by occurrence based inspection process.
- Continuous monitoring for the critical transmission lines costs high maintenance expenses.
- Emergency circumstances (natural disasters/intruder attacks) threaten safety for human patrol.
- k-resiliency: If k number of UAVs fails (due to attacks/technical difficulties), the rest of the UAVs still conduct the minimum required surveillance.

K-Resiliency Solution

- Bus contingency analysis with SP[2] provides selection of critical lines from PI calculation.
- Transmission lines get critical weights (descending) applying k-means clustering over PI values.
- UAVs are placed over lines and formal model assigns route[3] to provide surveillance satisfying the threshold time and fuel constraints for UAV routing paths.
- Inspected lines by the fleet of UAVs add critical weights to the surveillance score for analyzing costs.
- Resiliency score is calculated from k failed UAVs in the surveillance based on the % of critical line coverages.

Research Challenges

- Transmission lines in a grid possess critical overload situation due to line flow and generation outages.
- Event based surveillance delays the immediate decision making process and response time during hazardous situations.
- Appropriate deployment of UAVs depends on satisfying the constraints of surveillance time interval, lines to be covered, communication with control, cost effective fuel usage, and data record, making the scenario a NP-hard problem.
- In case of k failure from the fleet of UAVs, re-routing needs to be done ensuring k-resilient surveillance system.

Future Directions

- Apply solution model over real bus dataset if available to solve the surveillance resiliency.
- Optimize cost of UAV deployment and maximize resiliency surveillance coverage.
- Introduce collaborative UAVs for faster data collection and delivery.
- Strengthen encryption methods to ensure security against cyber intrusion.

References: