Investigation of Time Impact of Power Flow Solver Algorithms on Transmission Outage Scheduling

By: Ariel Colón Rodríguez, Brandon Blankenship, Nathan Winebarger

Western Carolina University
School of Engineering + Technology

Problem Statement

Power grid operators and engineers must coordinate transmission, distribution, and generation system modifications amid growing challenges. The rise of intermittent energy sources, electric vehicle expansion, increasing demand, and extreme weather events strain traditional utility planning. Maintenance, upgrades, and new infrastructure must uphold bulk electric system safety and reliability (including N-1 contingency compliance) while navigating supply chain constraints, regulations, land use, system conditions, and competing priorities.

Objective

Develop a flexible tool for optimizing outage scheduling that allows adjustable priority weighting and dynamic updates based on project status while ensuring the reliability of the electric system.

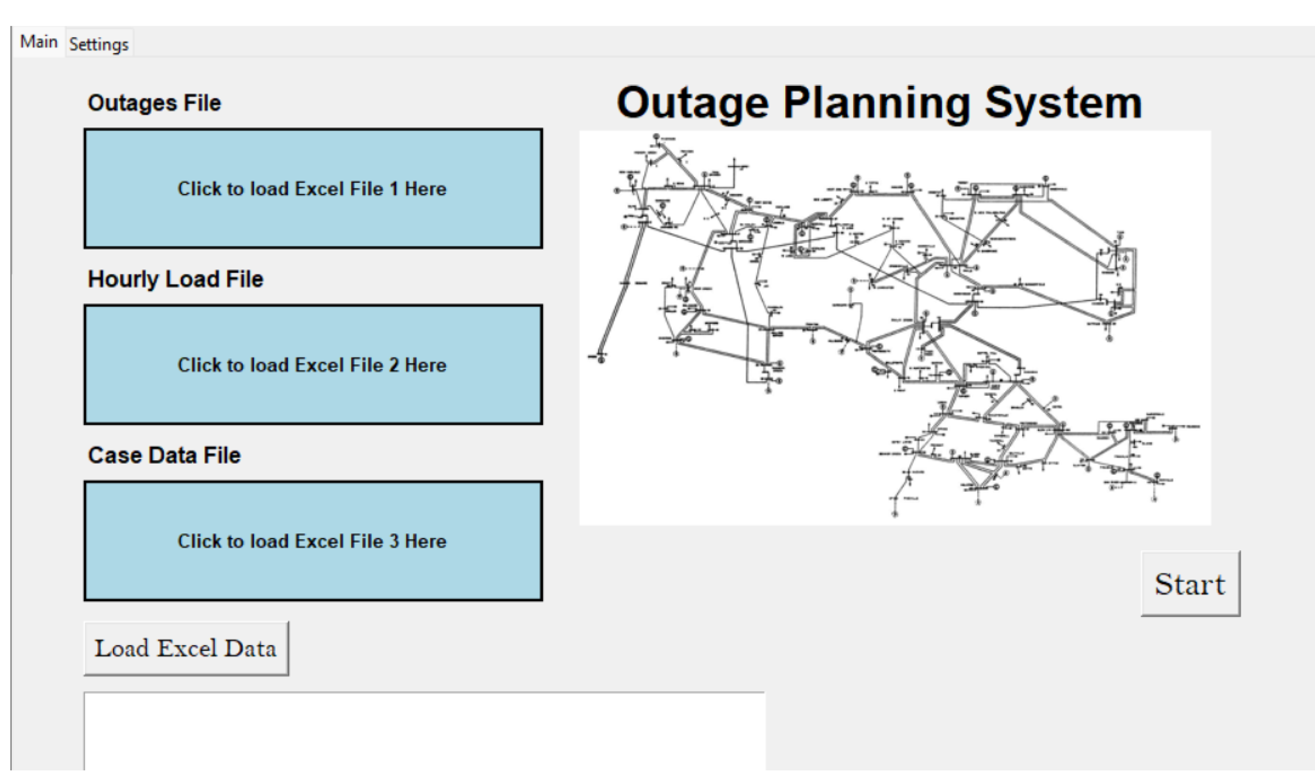

Figure 1: Graphic User Interface Main Window

Importance

The power grid faces increasingly complex regulatory requirements, unprecedented energy demand, and reduced online generation availability. Growing operational challenges and accelerated transmission expansion further strain the system. To address these issues, grid modernization is essential to enhance resiliency and support climate goals.

Methodology

The code will initially sequentially traverse all load cases in a year and determine passing/failing cases to meet the outage criteria. An optimization algorithm will later be implemented to reduce search time for the optimum schedule such as by starting in spring and fall time frames

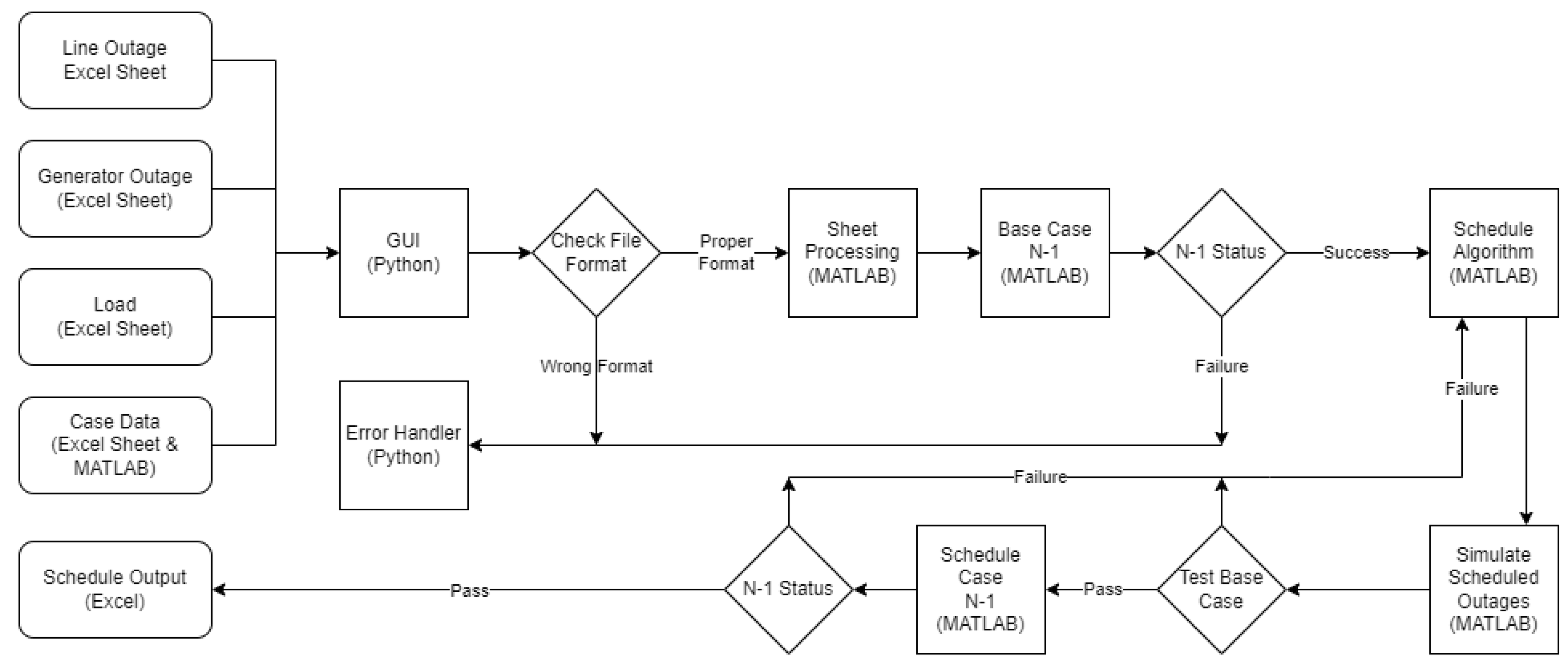

Figure 2: Transmission Outage Scheduling Flowchart

The tool provides an interactive interface for outage scheduling, supporting multiple Excel sheets with real-time validation. It prioritizes outages based on system impact, dependencies, duration, and constraints while incorporating hourly load data to assess stability. After forming an initial schedule, it performs N-1 to N-3 contingency analyses to evaluate concurrent outages and adjusts scheduling to minimize disruptions. Additionally, it identifies critical contingencies, ensures grid reliability, and integrates seamlessly with the simulation system.

Figure 3: Monthly Output Calendar

Optimization

Designed for optimal performance, the system enhances transmission outage scheduling with a base case contingency analysis (entire year of simulation takes 35 minutes), streamlined data ingestion, error handling, and parallel processing for resilient and efficient power system planning.

Time Impact

Newton-Raphson Sparse Hybrid (NR-SH) solver significantly improves power flow processing time, reducing simulation time by an order of magnitude compared to the standard Newton-Raphson method. As shown in the table, NR-SH consistently achieves lower processing times across multiple test cases, demonstrating its potential to enhance outage scheduling efficiency and grid resiliency in the face of increasing operational challenges. The Newton-Raphson Inner Coupled (NR-IC) solver follows as the next best performer, providing a notable improvement over traditional methods while maintaining computational stability.

Table 1: Impact of Power Flow Solver Algorithms for a 5-Hour Segment

	Duration (seconds)						
Power Flow Algorithm Type	Run 1	Run 2	Run 3	Run 4	Run 5		Average
NR	44.957	35.235	32.010	28.785	31.503		34.498
NR-SP	34.013	33.017	28.835	28.501	28.234		30.520
NR-SC	33.482	31.235	28.827	29.380	28.107		30.206
NR-IP	31.689	30.282	27.525	28.573	30.875		29.789
NR-SH	3.879	3.108	2.653	2.463	2.745		2.970
NR-IC	24.047	31.700	29.007	31.083	32.253		29.618
NR-IC	3.957	3.114	2.854	2.850	2.949		3.145
NR-IH	45.030	49.185	48.915	37.319	39.424		43.974
FDXB	42.612	47.438	47.450	47.155	45.685		46.068
FDBX	34.048	31.724	21.547	28.285	30.847		29.290

Conclusion

The problem statement was effectively addressed by the proposed method of outage scheduling. The approach effectively optimized the scheduling process, minimizing disruptions while ensuring system resiliency. The results from the proposed method meets all the objectives.

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