Load Following Flexibility of Small Modular Reactors Coupled with Wind Farms in the Presence of Extreme Wind Conditions

U.S.NRC — United States Nuclear Regulatory Commission — *Protecting People and the Environment*

Western Carolina UNIVERSITY — School of Engineering + Technology

Problem Statement

- The goal of this research is to determine the largest wind farm alongside which small modular reactors (SMRs) can load follow in the presence of extreme wind conditions while under restrictions imposed by industry standards.
- Induction generator (IG) and doubly fed induction generator (DFIG) style turbines will be analyzed to determine which system is most optimal for pairing.

Requirements

- *Research* wind power generation applications.
- *Research* nuclear power generation applications.
- Using IG and DFIG wind farm models, *calculate* output power from given wind speed profiles.
- *Determine* the largest wind farm size that SMRs can be paired with for each case study.
- *Publish* the team's research.

Concepts

- The initial approach was to carry out the project using wave power (variable generation) and hydroelectric power (base load) in addition to wind and nuclear.
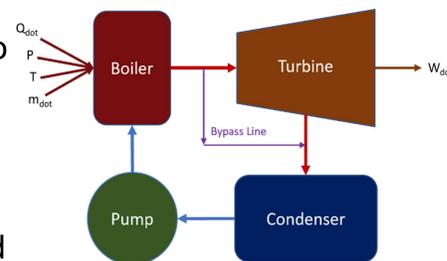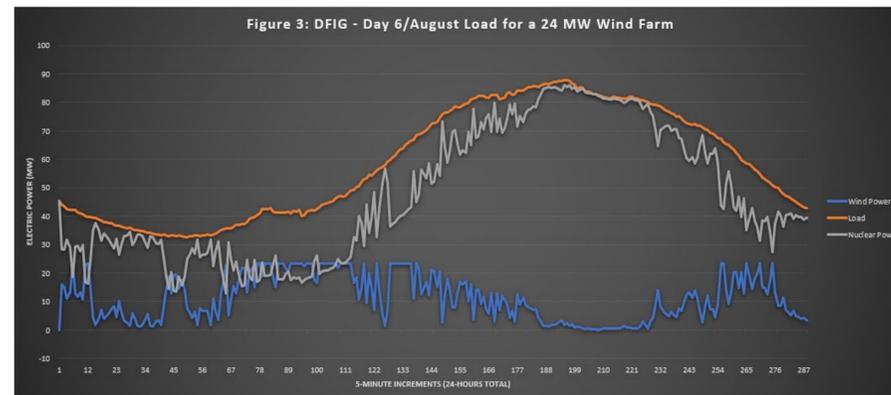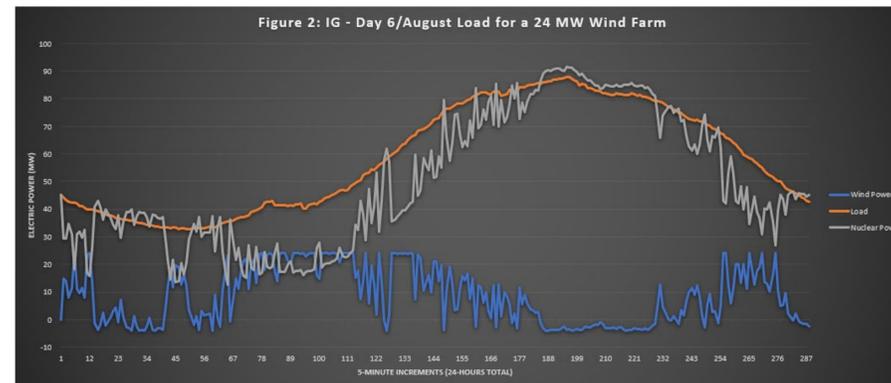

Figure 1: Nuclear Model Concept

  - This concept was abandoned because it became apparent the scope was too large.

- Additionally, a nuclear model (figure 1) was constructed to incorporate the limits on the SMRs and calculate nuclear power output using this method.
  - This concept was abandoned because the team could not gain access to the necessary constants and values needed to build a detailed enough model.

Final Design

- The final approach to this study was to calculate the required nuclear power output by subtracting wind farm power output from gathered load data. This is represented by equation 1 below.

SMR Output = Load Profile – Wind Turbine Output   Equation 1

- Using seven days' worth of wind speed data and four days of load data, 28 unique case studies were generated each for IG and DFIG systems.
- For illustration, the IG and DFIG power profiles for the August, Day 6 case are displayed in figures 2 and 3, respectively.

Figure 2: IG – Day 6/August Load for a 24 MW Wind Farm

Figure 3: DFIG – Day 6/August Load for a 24 MW Wind Farm

- Using SMR ramp rate standards provided by the Electric Power Research Institute's Utility Requirements Document (EPRI-URD), the maximum acceptable size wind farm is calculated.
- Each case study is tested with a script that starts with a 1.5 MW wind farm and tests it against the 3 ramp rate standards. If the current wind farm size meets the ramp rate standards, then the wind farm size is increased by 1.5 MW and ran through the script again. This process continues until failure.
- The last wind farm value prior to failure is the maximum wind farm size compatible with that case study. The process is repeated for each case study.
- See the flow chart in the summary section for further details.

Results

- The project goal was to find the maximum wind farm size still compatible with the SMR nuclear plant for the IG and DFIG systems using the unique 28 cases. The corresponding results are shown in figures 4 and 5 below.
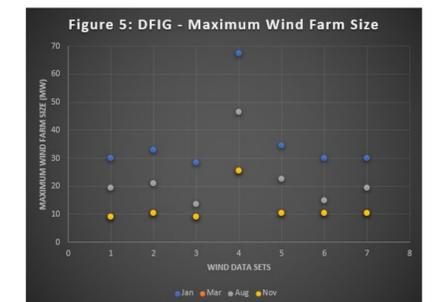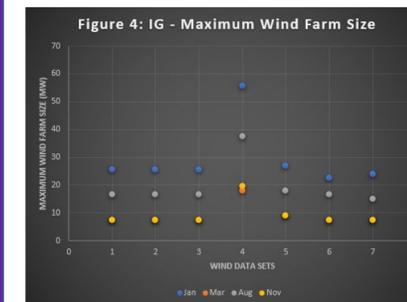
- *Note the March values are present but often covered by the November values.*

- The maximum allowable wind farm size for a given month's load data is determined by the lowest value in that wind data set. The results are listed in the table below.

| System | Load Data Set | | | | |
	January	March	August	November	All Cases
IG (MW)	22.5	7.5	15	7.5	7.5
DFIG (MW)	28.5	9	13.5	9	9

Summary
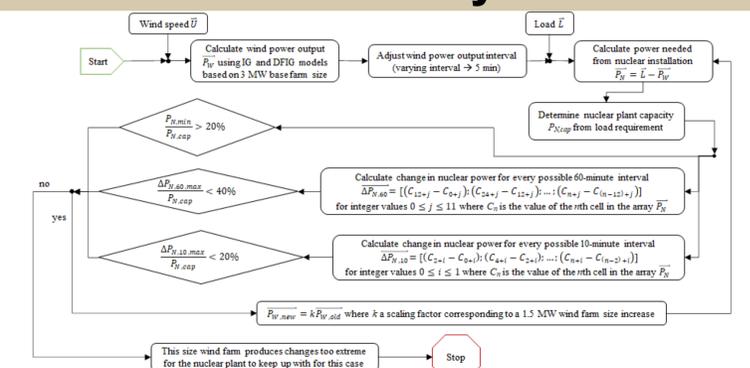
Team & Acknowledgements

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