Advanced Nuclear Reactor Digital Twin

Senior Design II – Spring 2022

Team Members: Alex French (afrench8@uncc.edu) , Abrar Altaay (aaltaay1@uncc.edu)
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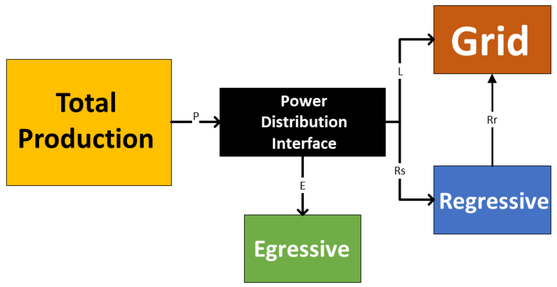
Industry Supporters:
Dr.Sven Bader, Brad Crotts, Michael Murray

Faculty Mentor:
Dr. Mohamed-Ali Hasan

Objective

- Models total energy load to satisfy demand then determine the most efficient allocation of surplus energy.
- Models the reactor's total energy contribution to the grid
- Allocates Egressive and Regressive energy to maximize profits within the restraints of the outlets energy capacity.

Performance Specifications



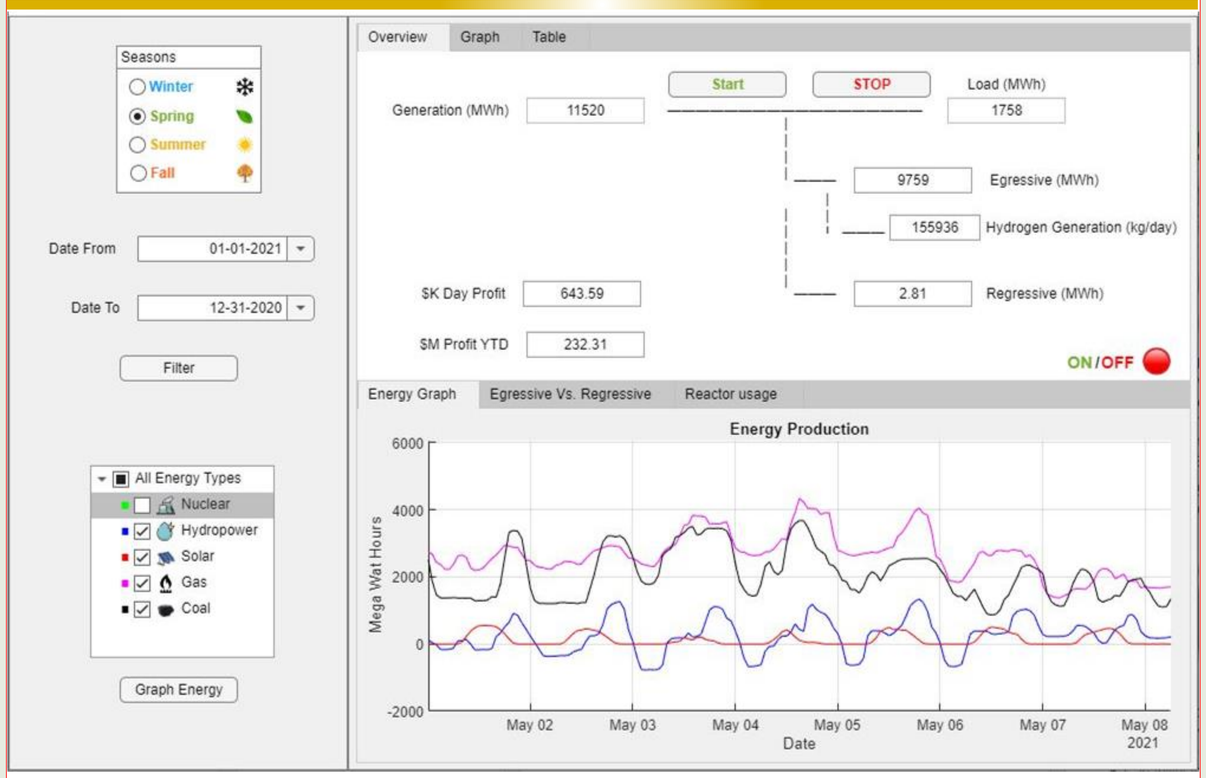
Model the replacement of the Mayo Steam station with 6 XE-100 SMRs

- Reactors run at full power with all excess energy committed to hydrogen production
- The energy storage capacity is maximized to ease the load following behavior of the energy distribution configuration
- Revenues for each energy type, fixed costs and variable costs are used to perform real time financial analysis of the plant

System Overview

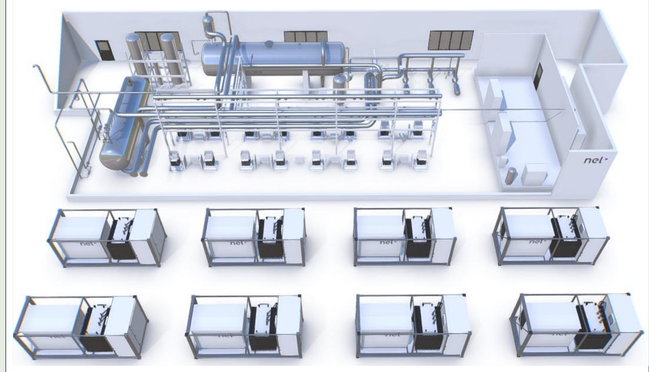
MATLAB Application Features

- Ingests historical data from the Energy Information Analysis database
- Outputs the total energy apportioned to Hydrogen Generation, Grid demand and Battery Storage
- Graph energy grid demand and total generation in MWh by yearly seasons (Winter, Spring, Summer, and Fall)
- Ability to graph & select from multiple energy sources to graph on a Megawatt Hours vs Date graph for any day of the year.
- View Total MWh generation and grid load by day and analyze where energy is being distributed.
- Formulated key features such as "Egressive" and "Regressive" energy types and view values by day in real time.
- Ability to analyze the day by day and year to date profit generated from Egressive and Regressive energy types.



Matlab Application

Egressive Energy



- Hydrogen production via electrolysis
  - Nel Hydrogen M-5000 Electrolyser
    - Average power consumption
      - 50 kWh/kg
    - Daily Hydrogen Production
      - 10,618 kg

Regressive Energy

- Battery Energy Storage System
  - Honeywell Flow Battery
    - 31 MW Capacity
    - Capability to store energy for up to 12 hours

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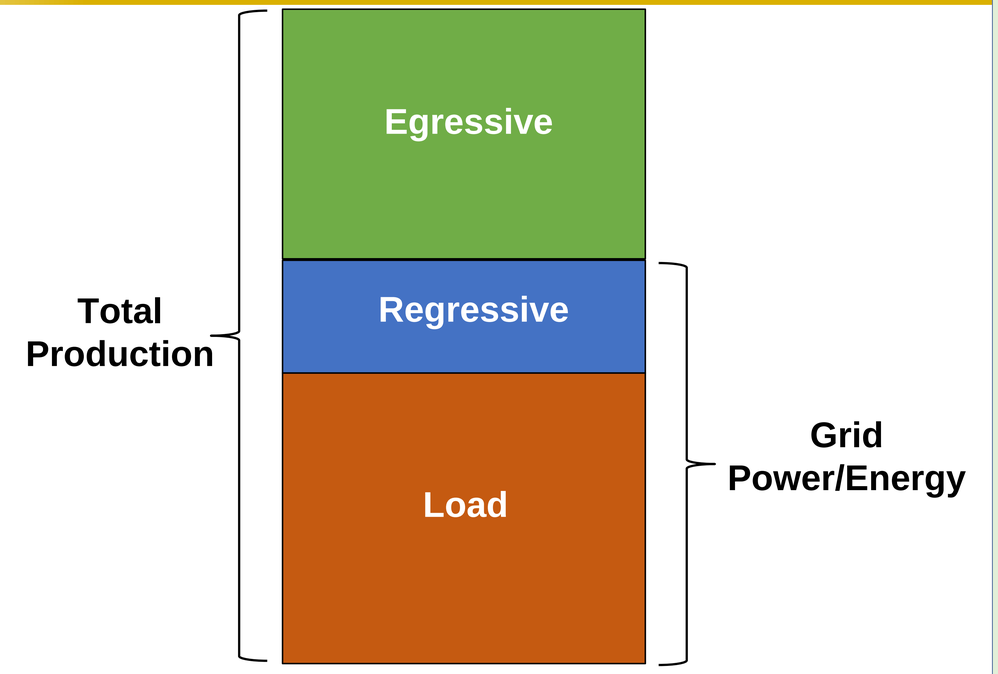
Objective

- Models total energy load to satisfy demand then determine the most efficient allocation of surplus energy.
- Models the reactor's total energy contribution to the grid.
- Allocates Egressive and Regressive energy to maximize profits within the restraints of the outlet's energy capacity.
- Take into consideration the maximum capacity of hydrogen storage to determine the most profitable allocation of excess energy.



Performance Specifications

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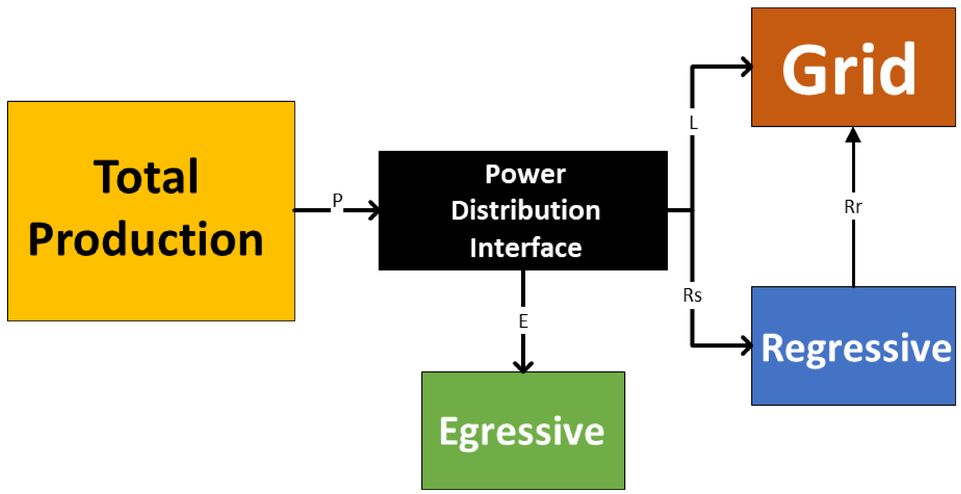
- Revenues for each energy type, fixed costs and variable costs are used to perform real time financial analysis of the plant



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System Overview

Respective Energy Production Methods The Model Digests

- Nuclear
- Coal
- Hydropower
- Solar
- Pumped Storage
- Gas

Objective of Algorithm

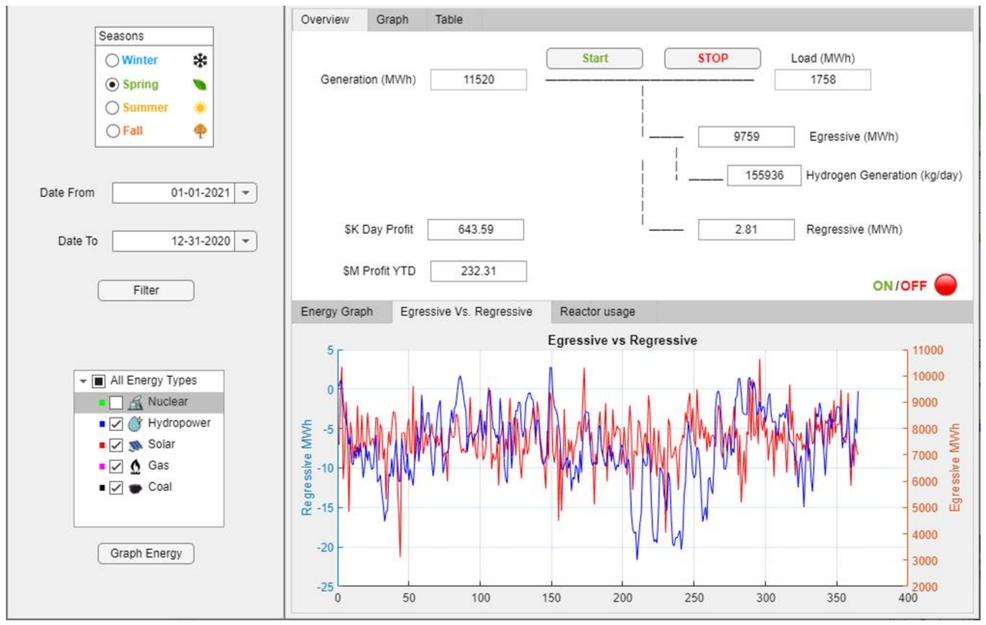
- Decrease energy produced by coal by replacing it with state-of-the-art Advanced Nuclear Reactors
- Produce hydrogen using excess energy to increase profitability of the overall system

Egressive Energy

- Type of alternative energy produced from the excess energy for the purpose of an application outside of the grid
- Hydrogen production via electrolysis for fuel

Regressive Energy

- Type of alternative energy produced from excess energy for the purpose of an application toward the grid
- Battery storage



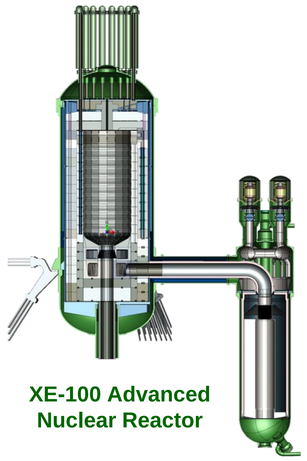
Matlab Application

The Digital Model via MatLab

- Ingests historical data from the Energy Information Analysis database
- Outputs the total energy apportioned to Hydrogen Generation, Grid demand and Battery Storage

The Goal of the Model

- Calculate the excess energy
- Calculate the profit of energy production to include the generation of Hydrogen
- Ensure the most profitable allocation method without affecting the grid
- Display the amount of generation capacity going to each system outlet



XE-100 Advanced Nuclear Reactor

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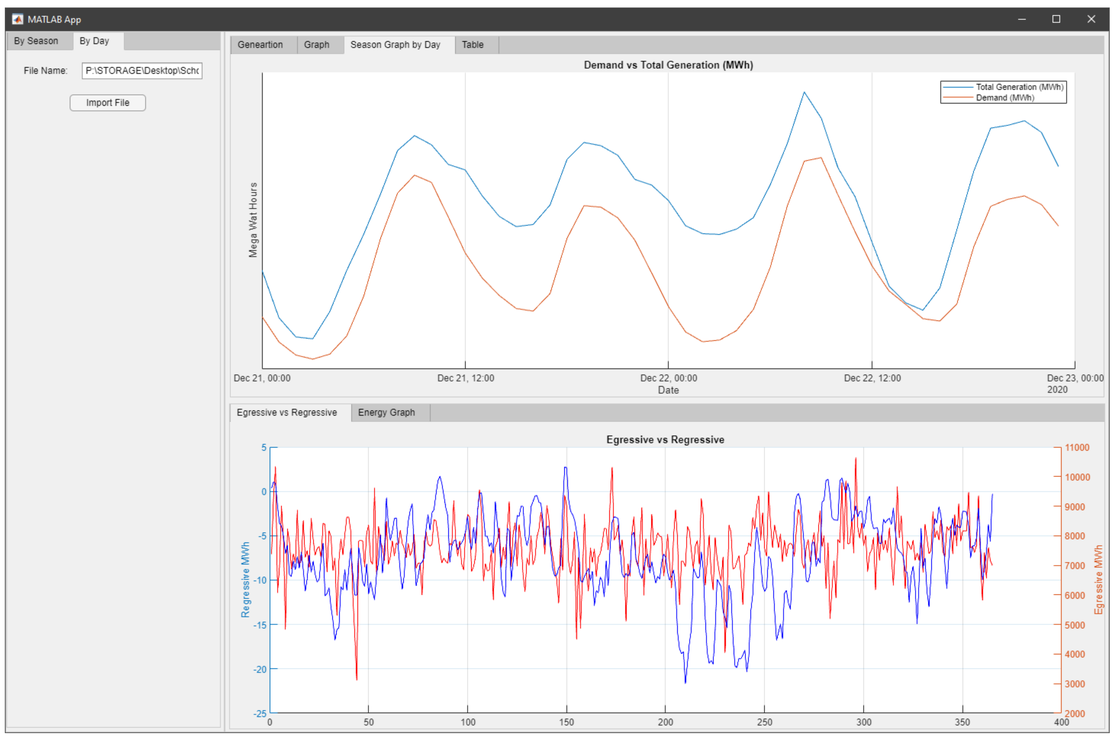
Project Status

- Developed MATLAB model to demonstrate energy generation and apportioning of energy at any given time
- Graphing historical data to aid end users to understand power consumption trends
- User is able to select specific dates to display only necessary data
- Model capabilities include graphing:
  - The 6 generation sources that make up grid power
  - Reactor usage for each avenue it supplies
  - Egressive Vs. Regressive for each day selected
  - Custom input data

Duke Energy Mayo Steam Station

Future Work



- To allow the user more interactivity with the data, such as manipulating Egressive and Regressive numbers using a number slider. This will allow for rapid analysis of the total profitability of the system.
- Implement a feature where a user is able to upload a multi-year data set using the “Import File” button instead of having to change directories in the code.
- Packaging the application using MATLAB Packaging to allow the use of a single executable file instead of a compressed file.
- Implement other Egressive and Regressive generation methods other than hydrogen production and battery storage.
- Improve overall GUI design to a more modern look.

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