Design of Distributed Generation System for Islanding & Anti-Islanding Rural Application

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Presentation Overview

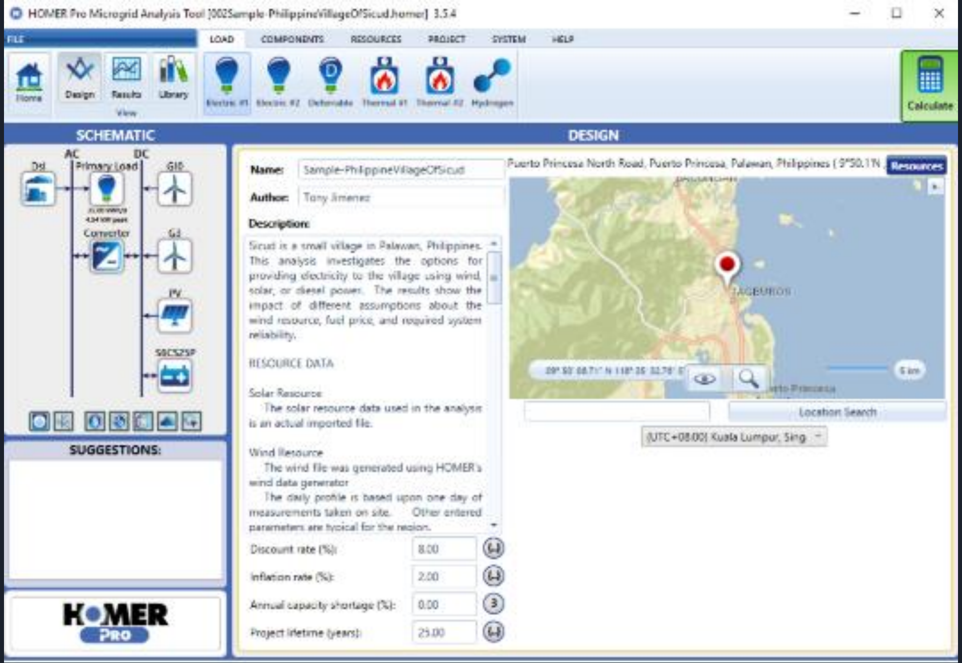
- Restate Project Objective
- Existing Solution Example
- How Our System Works
- Technical Design
    - Project Requirements
    - Standards Utilized in Design
    - Implementation of Concepts (IOC)
- Testing & Design Tradeoffs
- Demo
- Conclusion

Objective

- Microgrid Optimization
  - Distributed Generation (DG) - Placement, Resources (Solar & Wind)
  - Location based

- Constraints
  - Financial - Must see a return on investment
  - Stability
    - Varying climate conditions
    - Must satisfy load of the microgrid at any point in time
    - Smooth disconnection & reconnection to the main power grid

Existing Solution: Homer Pro



Applications of HOMER PRO

- Island Microgrids
- Energy Access/ Rural Electrification
- Unreliable Grids
- Grid Extension

How HOMER works

- Simulation
- Optimization
- Sensitivity Analysis

How Our System Works

Three main components to our system design

- Graphical User Interface (GUI)
- MATLAB/ Optimization Code
- Simulink Model

Key Features

- Selection of which Canadian province or territory the microgrid will be located in
- Optimization of distributed penetration
- Embedded Simulink plots in the GUI
- Access to Simulink design & backend

Benefits

- Tailored made for the country of Canada
- Simulink plots are embedded in the GUI

Technical Design Overview

- Project Requirements
- Design Standards
- Implementation of Concepts (IOC)

Project Requirements

As defined in Report 1:

1. Measure difference (error) in parameters between the IEEE Std. 1729-2014 and our Simulink model.
2. Satisfy the Power Balance Equation ($P_{Generated} = P_{Delivered} + P_{Loss}$).
3. Operate Connected to Grid
4. Operate in Islanding mode
5. Maintain Operation during disconnection from main grid
6. Maintain Operation during connection back to main grid

Standards Utilized in Design

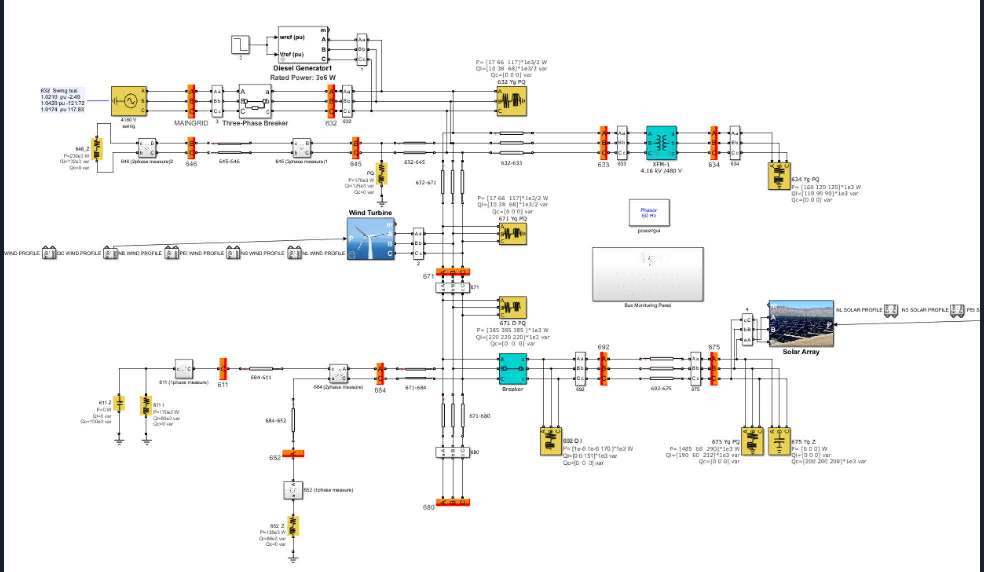
- IEEE Std. 1729-2014 *Recommended Practice for Electric Power Distribution* [i]
  - Definition of design challenges and conceptual systems
  - Testing of those systems
- ANSI C84.1 *Electric Power Systems and Equipment - Voltage Ranges* [ii]
  - Performance levels of the grid
  - Safe operating limits
- CSA C22.1-18 *Canadian Electrical Code Part I Safety Standard for Electrical Installations* [iii]
  - Fundamentals and safe practice of design and construction
    - Section 8 / page 104 — Circuit loading and demand factors
      - Page 116 — Calculated load for services and feeders

[i] IEEE Recommended Practice for Electric Power Distribution System Analysis," in *IEEE Std 1729-2014* , vol., no., pp.1-20, 5 Dec. 2014 doi: 10.1109/IEEESTD.2014.6974967

[ii] Power Quality World, "ANSI C84.1 Electric Power Systems and Equipment - Voltage Ranges," Power Quality World, Apr. 2, 2011. [Online]. Available: http://www.powerqualityworld.com/2011/04/ansi-c84-1-voltage-ratings-60-hertz.html?

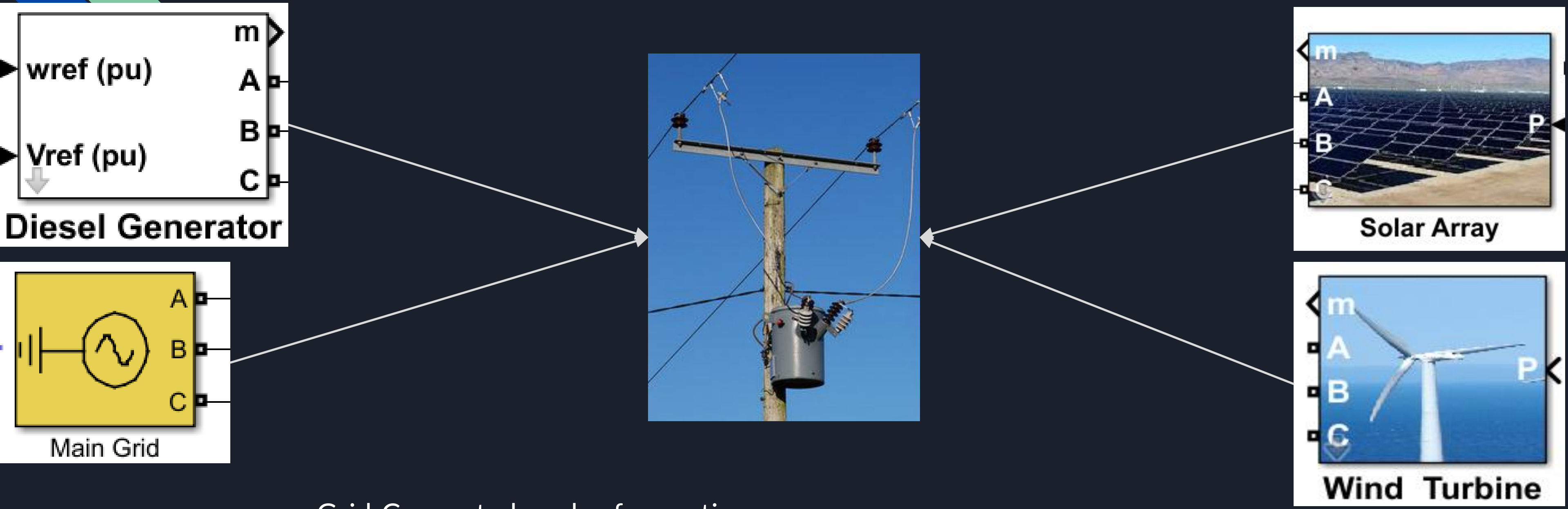
[iii] Canadian Standards Association, "C22.1-18 Canadian Electrical Code Part I Safety Standard for Electrical Installations" Canadian Standards Association. 24th Edition, Published by CSA Group 2018, 943 pages. SKU: 2425666.

IOC - Simulink Model



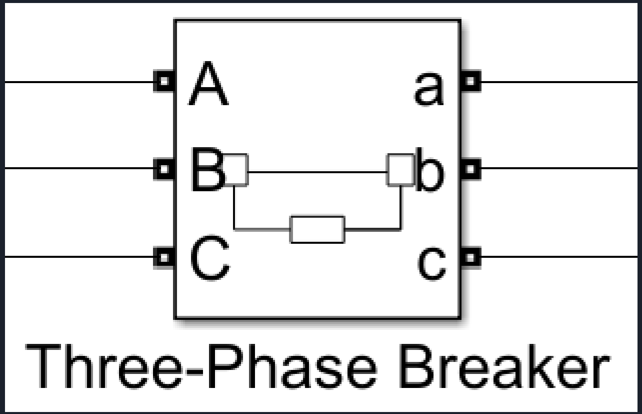
- Modified model of the IEEE 13 Node Test Feeder [2]

IOC - Simulink Model - Distributed Energy Resources (DERs)



- Grid-Connected mode of operation
- Islanded mode of operation

IOC - Simulink Model - Main Grid Disconnection and Reconnection



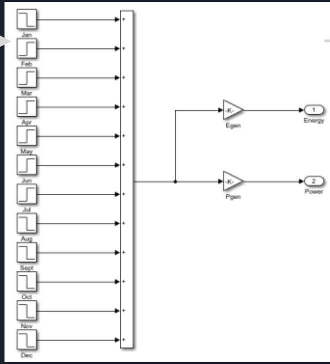
- Three-Phase Breaker is programmed to open/close at user-defined times of the year

IOC - Simulink Model - Realistic Climate Data

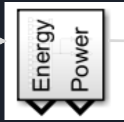
Ontario Solar Production [2]

Month	kWh/kW
January	66
February	92
March	109
April	115
May	119
June	124
July	125
August	118
September	104
October	86
November	56
December	52

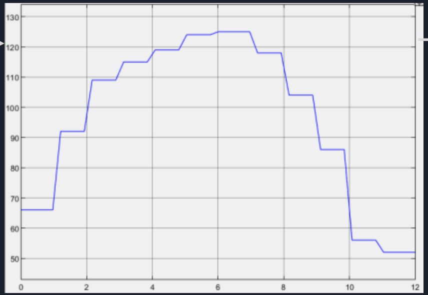
Scale by Installed Solar Capacity



Create Subsystem



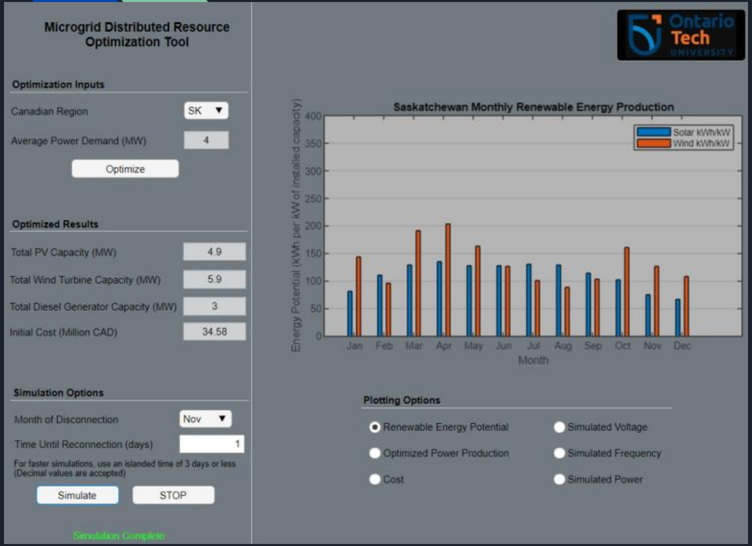
Generate Signal

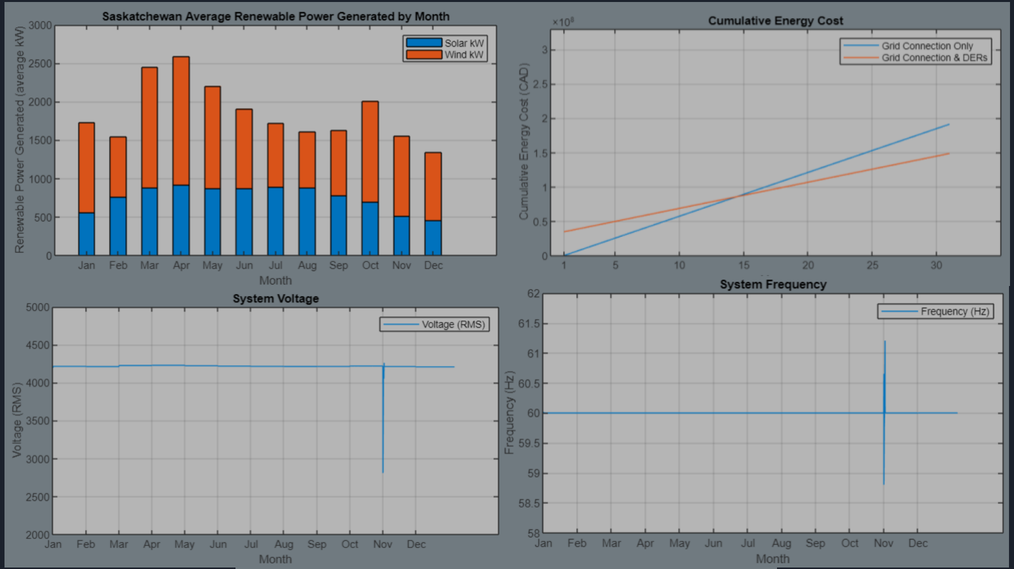


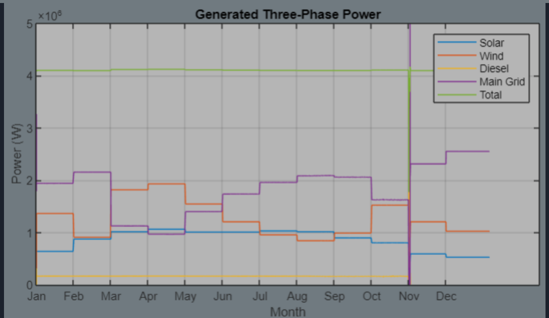
Solar Output

- Utilize factual climate data from each region of Canada
- Simulate power generated by renewables based upon optimized capacities of solar & wind

IOC - Graphical User Interface (GUI)







- Location selection
- Optimized capacities
- Simulation settings
- Variety of plots
- Seamless control of the Simulink model

Testing

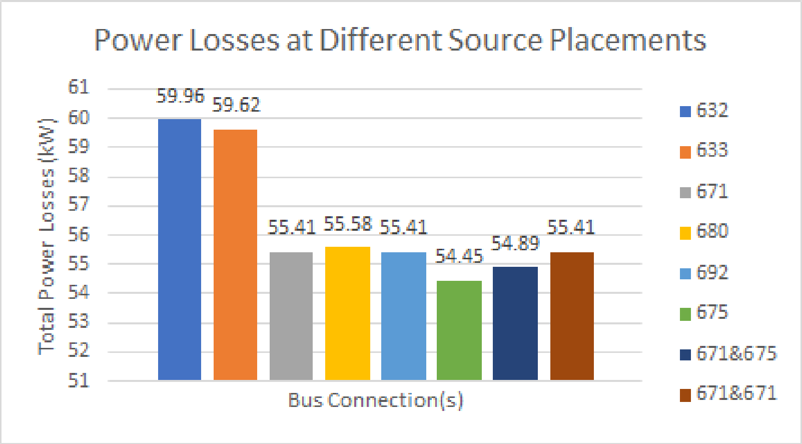
- Test several different ‘blocks’ available for wind, solar and diesel generation
  - Decision made based on integrability and simplicity

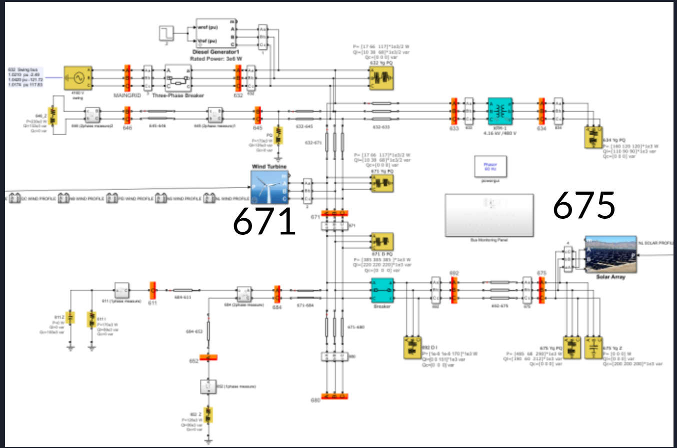
- Grid disconnection and reconnection
  - Three-Phase breaker
  - Diesel generator power control

- Optimization
  - Ratio based - amount of wind to solar energy over the course of the year
    - Areas experiencing very little wind yielded erroneous results

Power Loss Testing - Optimal Source Placement

- Connect a diesel generator to each bus of the model, one at a time
- Measure power losses and determine optimal source placement
- Connect DERs to low-loss buses





Design Tradeoffs

- Simulink solver issues
    - Some solvers require extensive time to simulate the system
    - Sacrifice accuracy for decreased simulation time
- Many available ‘block’ configurations for sources
    - Some are not compatible with each other, require different ‘powergui’ settings
    - Sacrifice customizability for integrability and simplicity
- Integration of the GUI & Simulink model
    - Significant amount of research required to develop a proper relationship
    - Sacrifice some features for decreased simulation time

Demo

- Walkthrough of the user experience

Conclusion

We are proud of our project, and a special thanks is owed to the following Ontario Tech University affiliates:

- Dr. Walid Morsi Ibrahim
- Daniel Mabuggwe
- Dr. Qusay H. Mahmoud

References

[1] HOMER Energy, “HOMER Pro,” *HOMER Energy*, n.d. [Online]. Available: https://www.homerenergy.com/products/pro/index.html [Accessed Mar. 28, 2020].

[2] G. Sybille (Hydro-Quebec), “IEEE 13 Node Test Feeder,” *MathWorks Documentation*, n.d. [Online]. Available: https://www.mathworks.com/help/physmod/sps/examples/ieee-13-node-test-feeder.html. [Accessed Oct. 15, 2019].

[3] Energy Hub, “Solar Energy Maps Canada (Every Province),” *Energy Hub*, Jun. 14, 2019. [Online]. Available: https://energyhub.org/solar-energy-maps-canada/ [Accessed Nov. 12, 2019].