EDGIE: Electrification Distribution Grid Impacts Emulator

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Version 1

This document lists the information about the modeling strategy. The code simulates the homes with heat pump, heat-pump water heater and electric vehicles in a neighborhood and later these loads are optimized and investigates the impact on the grid. The simulation code can be found on the github repository EDGIE.

1 Required Software

Below are the list of software that needs to be installed:

1.1 MATLAB

The code is developed in MATLAB. It is a powerful programming language and environment that is widely used in various fields such as mathematics, engineering, and scientific research. Developed by MathWorks, MATLAB provides a comprehensive set of tools and functions that allow users to perform numerical computations, data analysis, visualization, and algorithm development. It is known for its ease of use, making it accessible to both beginners and experts alike. It is available for both windows and macOS.

1.2 MATPOWER

MATPOWER is a package of free, open-source Matlab-language M-files for solving steady-state power system simulation and optimization problems, such as:

- power flow (PF),
- continuation power flow (CPF),
- extensible optimal power flow (OPF),
- unit commitment (UC)
- stochastic, secure multi-interval OPF/UC.

It is intended as a simulation tool for researchers and educators that is easy to use and modify. MATPOWER is designed to give the best performance possible while keeping the code simple to understand and modify. It can be downloaded from here. Further, installation instruction can be found on: YouTube.

1.3 CVX

CVX is a popular optimization software package designed for solving convex optimization problems. Developed by Michael Grant and Stephen Boyd, CVX provides a user-friendly interface that allows users to express optimization problems in a natural and intuitive mathematical form. It eliminates the need for dealing with low-level optimization details and focuses on the high-level problem formulation. The installation instruction can be found here.

2 Input Files & Functions

2.1 Input Files

- **Weather Data**: The simulation requires weather data which can be obtained from Oikolab.
- **Baseload Data**: A non-electrified household is created using the Multifamily Residential Electricity Dataset (MFRED). The csv file is provided in the repository with the name *MFRED-2019-NYC-Apartments-Electricity-Data.csv*
- **Water Withdrawal Data**: The csv file name *DHWEventGeneratorOutput.csv* contains the domestic household water withdrawal schedule.

2.2 Functions

- **baselinePlots**: creates plots of aggregate power with different appliances.
- **btu2wh**: converts from BTU to Wh unit.
- **evSimulation**: performs simulation for electric vehicles as it commutes and returns back home.
- **f2c**: converts temperature in °F to °C.
- **fullStairs**: draws a stair step plot.
- **gauss**: creates gaussian distribution with 95% confidence interval.
- **generateBuildingModels**: creates input parameters for heat pump.
- **generateEVmodels**: creates input parameters for electric vehicle.
- **generateWaterHeaterModels**: creates input parameters for heat-pump water heater.
- **heatPumpSimulation**: performs simulation for heat pump.
- **heatPumpWaterHeaterSimulation**: performs simulation for heat-pump water heater.
- **importBaselineElectricity**: imports non-electrified load data.
- **importBaseElectricityfromWorkPlace**: imports electrical load profile for workplace.
- **importweather**: imports the outdoor temperature data from the csv file downloaded from Oikolab. It requires two inputs (i) weather file (ii) time period during which user wants to analyze.
- **losslife**: computes loss of life of a transformer.
- **matpowerSimulation**: performs matpower simulation for voltage profile behaviour.
- **optimizationCVX**: performs optimization using the cvx.
- **optimizedPlots**: creates optimized plots of aggregate power with different appliances.
- **transformerTempPlot**: creates plot of top-oil temperature and hot-spot temperature.
- **transformer_git**: performs the calculation for top-oil temperature and hot-spot temperature.
- **trirnd**: creates triangular distribution

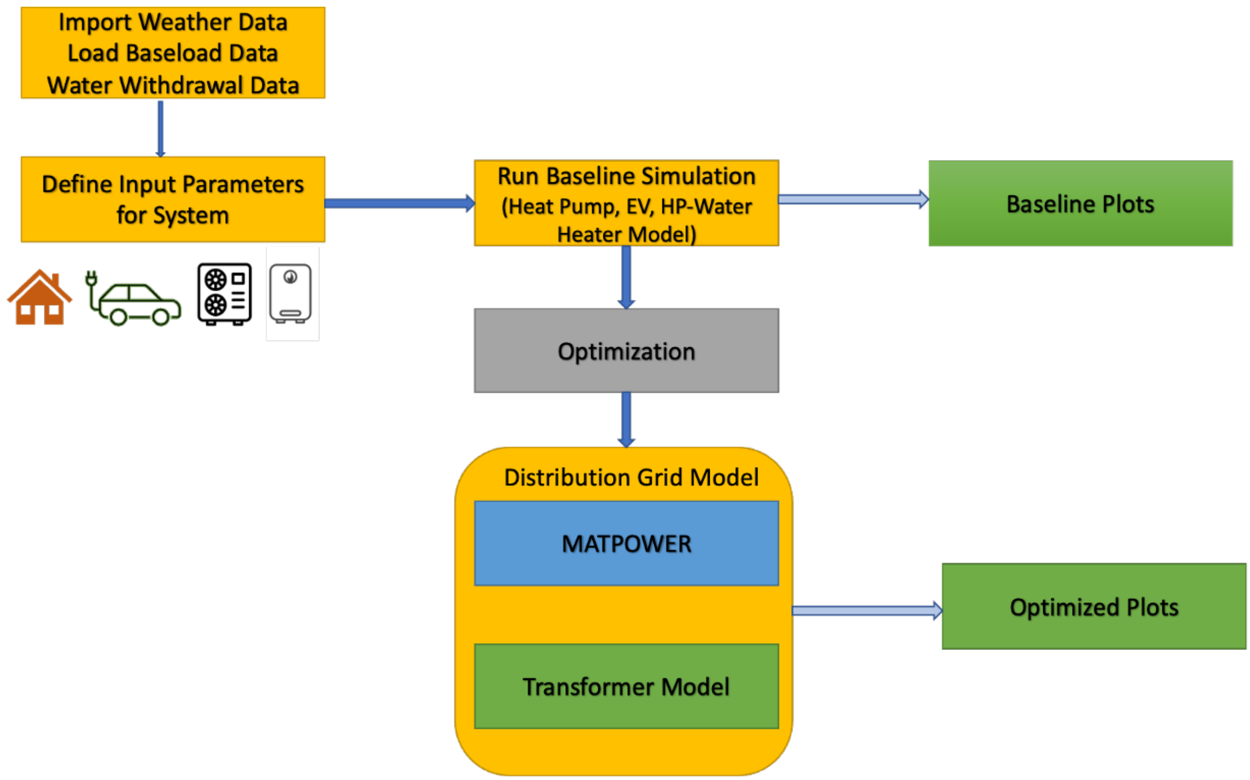


Figure 1: Model Wokflow

3 Information Flow

Fig. 1 describe the overview of information flow in the code. Firstly, the input files and parameters are provided. These mainly include the weather file, non-electrified load profile and water withdrawal schedule. After that inputs for different appliances like heat pump, heat-pump water heater and electric vehicles are given. This will enable the user to run the baseline simulation.

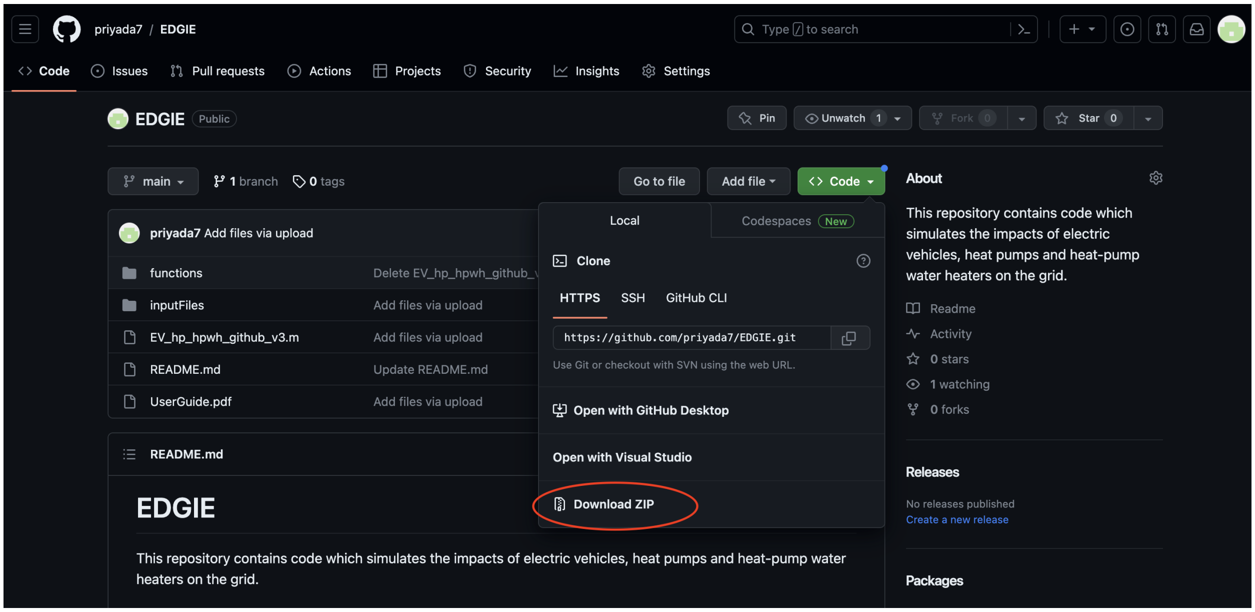
Once the baseline simulation is setup, optimization model can be run using the CVX software. In the present code, vehicle-to-grid strategy is used to optimize the peak. Once the baseline and optimization is done, user can visualize these results with the help of plots.

Distribution grid models calls for MATPOWER and transformer model to study the voltage regulations and temperature characteristics.

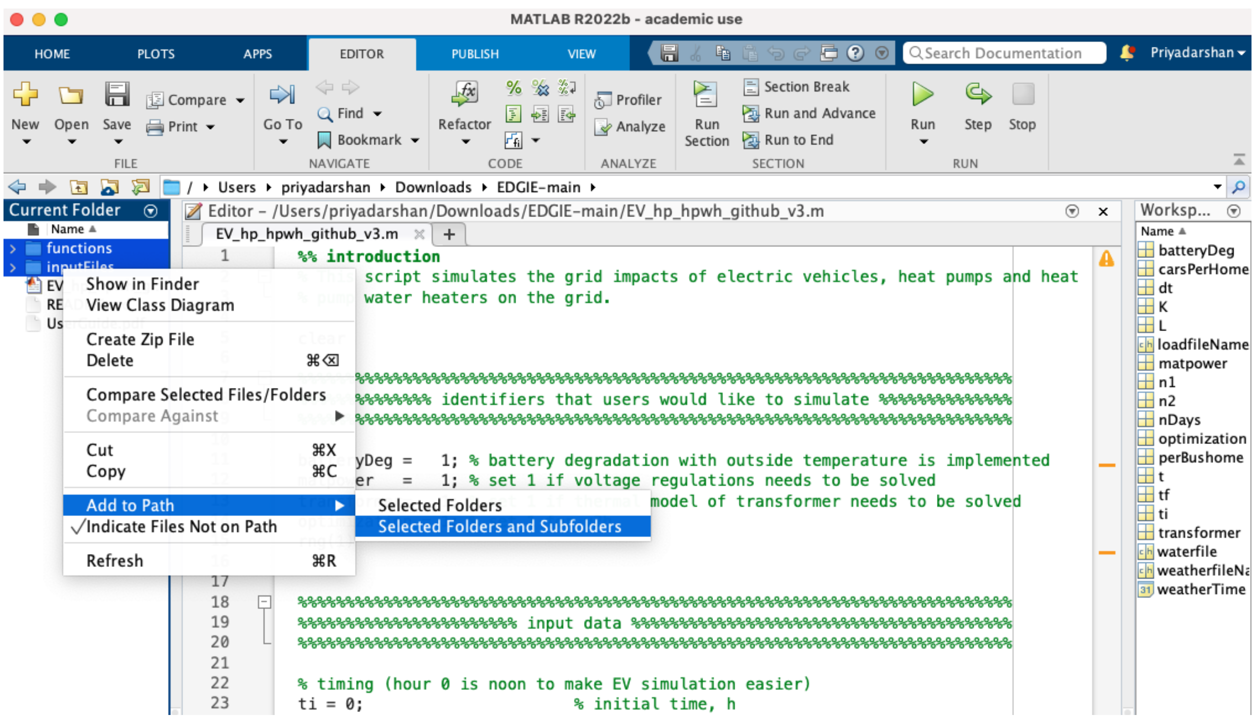
4 EDGIE Installation

After installation of the required software packages follow these steps to run EDGIE:

- Download the files from github repository, EDGIE.



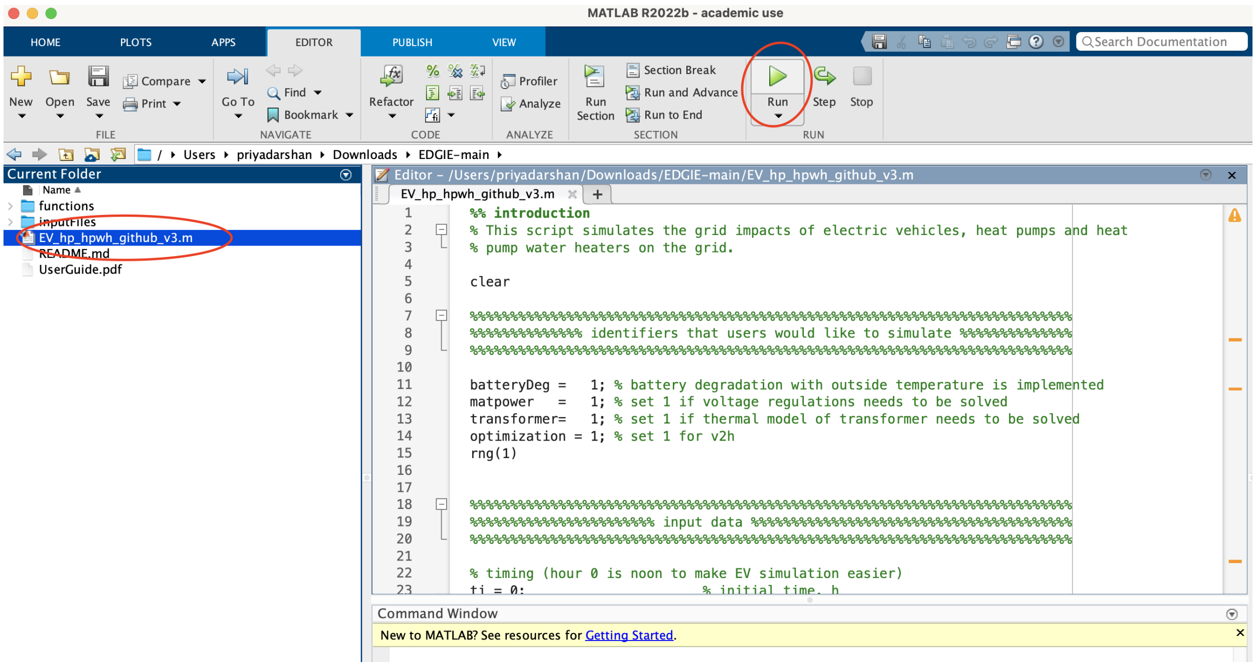
- Extract the files in a location of your choice and add the *functions* and *inputFiles* to the path.



- Open the *EV_hp_hpwh_github_v3.m* and one can find the parameters are already defined to run a test case:

```
%% introduction
% This script simulates the grid impacts of electric vehicles, heat
    pumps and heat pump water heaters on the grid.

clear

%% identifiers that users would like to simulate %%

batteryDeg =   1; % battery degradation with outside temperature is
    implemented
matpower   =   1; % set 1 if voltage regulations needs to be solved
transformer=   1; % set 1 if thermal model of transformer needs to be
    solved
optimization = 1; % set 1 for v2h
rng(1)



%% input data %%


% timing (hour 0 is noon to make EV simulation easier)
ti = 0;                          % initial time, h
nDays = 5;                       % no. of days
tf = nDays*24;                   % final time, h
dt = 1;                          % time step, h
K = tf/dt;                       % number of time steps
t = (0:dt:tf)';                  % time span, h
n1 = 66;                         % number of homes (= number of HPs)
carsPerHome = 2;                 % number of cars per home
n2 = carsPerHome*n1;             % number of EVs
perBushome = 2;                  % factor which decides how many house
    loads will be on each bus of 33 bus network (normally 990 homes
    gives 30 homes on each bus in a 33 bus network)
L = n1;                          % number of water heater

weatherfileName = 'cambridge-weather-2019.csv';                 %
    load weather file
loadfileName = 'MFRED-2019-NYC-Apartments-Electricity-Data.csv';  %
    load base load file
waterfile    = 'DHWEventGeneratorOutput.csv';                   %
    load water schduler file
```

- Click 'Run' on MATLAB editor section. The code will run and plot the results.



5 Which solver to use for optimization?

CVX can solve the optimization problem using different solvers namely, SDPT3, SeDuMi, Gurobi and MOSEK. While SDPT3 and SeDuMi can be used by default in cvx but Gurobi and MOSEK requries academic license. Refer to Using Gurobi with cvx and Using MOSEK with cvx for obtaining the license.

6 Support

This document is intended as the first line of support for users. We are happy to provide email support: priyada@purdue.edu. We are particularly interested in finding and fixing bugs, but we'd also love to hear about functionality that you'd like to see added, or concepts or tools that have not been clearly explained.