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User Manual: Simulator for Power System Studies

System Configuration:

Before launching the simulator, configure the power system in the following CSV files:

- Buses.csv
- Generators.csv
- LineCodes.csv
- LineGeometries.csv
- Lines.csv
- Loads.csv
- Transformers.csv

These CSV files can be generalized to construct any power system in the simulator. See the file descriptions below for each CSV file to see how to configure the files. All sections will be structured like the example below:

Object.csv

For a power system with ***k*** objects, the CSV file will have the following format:

Object 1, Data Field 1	Object 1, Data Field 2	Object 1, Data Field 3	Object 1, Data Field 4
…			
Object ***k***, Data Field 1	Object ***k***, Data Field 2	Object ***k***, Data Field 3	Object ***k***, Data Field 4

Notes: This notes section may include information about excluding data or special options with a certain class.

Buses.csv

For a power system with ***k*** buses, the CSV file will have the following format:

Bus 1, Name	Bus 1, Voltage Magnitude (pu)	Bus 1, Voltage Angle (degrees)	Bus 1, Bus Type	Bus 1, Generator Voltage (kV)
…				

Bus ***k***, Name	Bus ***k***, Voltage Magnitude (pu)	Bus ***k***, Voltage Angle (degrees)	Bus ***k***, Bus Type	Bus ***k***, Generator Voltage (kV)

Notes:

- Bus Type can either be *S* for slack bus, *PQ* for PQ bus, or *PV* for PV bus.
- Generator Voltage is the kV rated voltage level for the generator at that bus.
- If a bus will not be connected directly to a source, put an *X* for the Generator Voltage data field.

Generators.csv

For a power system with ***k*** generators (gen), the CSV file will have the following format:

Gen 1, Name	Gen 1, Bus	Gen 1, Rated V (kV)	Gen 1, Set V (pu)	Gen 1, P Set point	Gen 1, Q Set point	Gen 1, Min Q Limit	Gen 1, Max Q Limit	Gen 1, Bus Type	Gen 1, X_{g1}	Gen 1, X_{g2}	Gen 1, X_{g0}	Gen 1, Gnd	Gen 1, Gnd Z
…													
Gen ***k***, Name	Gen ***k***, Bus	Gen ***k***, Rated V (kV)	Gen ***k***, Set V (pu)	Gen ***k***, P Set point	Gen ***k***, Q Set point	Gen ***k***, Min Q Limit	Gen ***k***, Max Q Limit	Gen ***k***, Bus Type	Gen ***k***, X_{g1}	Gen ***k***, X_{g2}	Gen ***k***, X_{g0}	Gen ***k***, Gnd	Gen ***k***, Gnd Z

Notes:

- Rated V is the rated voltage of the generator in kV
- Set V is the per unit voltage set point of the bus the generator will be connected to
- P Set point is the real power generated in MW
- Q Set point is the reactive power generated in Mvar. If this is a generator on a PV bus, leave this value as 0
- Min Q Limit and Max Q Limit define the reactive power limits in Mvar for the generator. Default values are -10,000 Mvar and 10,000 Mvar
- Bus Type is either *S* for slack or *PV* for PV bus
- X_{g1}, X_{g2}, and X_{g0} are the positive, negative, and zero sequence reactances of the generator in per unit on the generator's rated voltage and P setpoint
- Gnd is a boolean variable. If 1, the generator is grounded, if 0, the generator is ungrounded

- Gnd Z is the grounding impedance for the generator in ohms. If a generator is ungrounded this value is irrelevant. As a standard, put a -1 in this column if ungrounded. For complex value, enter the grounding impedance as R+Xj (ex: '1+2j')

LineCodes.csv

For a power system with ***k*** Line Codes (LC), the CSV file will have the following format:

LC 1, Name	LC 1, Diameter	LC 1, GMR	LC 1, Ampacity	LC 1, Resistance
…				
LC ***k***, Name	LC ***k***, Diameter	LC ***k***, GMR	LC ***k***, Ampacity	LC ***k***, Resistance

Notes:

- All of these values can directly be pulled from a transmission line datasheet
- Diameter of the line is in inches
- GMR is given in feet
- Resistance is the value for ohm per conductor per mile at 60 Hz and 50 degrees Celsius

LineGeometries.csv

For a power system with ***k*** Line Geometrics (LG), the CSV file will have the following format:

LG 1, Name	LG 1, Number of Conductors	LG 1, Bundle Spacing	LG 1, Dab	LG 1, Dbc	LG 1, Dca
…					
LG ***k***, Name	LG ***k***, Number of Conductors	LG ***k***, Bundle Spacing	LG ***k***, Dab	LG ***k***, Dbc	LG ***k***, Dca

Notes:

- Number of conductors is given as number per phase. Default value is 1.
- Bundle spacing is the subconductor bundle spacing in feet. Default value is 1.
- Dab, Dbc, and Dca are the spacings between each phase A, B, and C in feet. Based off of the datasheet, these values have been set to a default value of 1.

Lines.csv

For a power system with ***k*** Lines, the CSV file will have the following format:

Line 1, Name	Line 1, Length	Line 1, Bus 1	Line 1, Bus 2	Line 1, Line Code	Line 1, Line Geometry
…					
Line ***k***, Name	Line ***k***, Length	Line ***k***, Bus 1	Line ***k***, Bus 2	Line ***k***, Line Code	Line ***k***, Line Geometry

Notes:

- Line Length is in miles
- Bus 1 and Bus 2 are the names of the buses that the line connects
- Line Code and Line Geometry are the names of the codes and geometries as listed in their respective CSV files
- If a Line Geometry name is listed and not found in the Line Geometry file, then the default line geometry will be used

Loads.csv

For a power system with ***k*** Loads, the CSV file will have the following format:

Load 1, Name	Load 1, Bus	Load 1, Real Power Draw	Load 1, Reactive Power Draw
…			
Load ***k***, Name	Load ***k***, Bus	Load ***k***, Real Power Draw	Load ***k***, Reactive Power Draw

Notes:

- Bus is the name of the bus the load is connected to
- Real and Reactive Power draw values are listed in MW and Mvar
- For power draw values use positive values for resistive MW and inductive Mvar draw and negative values for capacitive Mvar draw.

Transformers.csv

For a power system with ***k*** Transformers (XFMR) , the CSV file will have the following format:

XFMR 1, Name	XFMR 1, Bus 1 Name	XFMR 1, Bus 2 Name	XFMR 1, Bus 1 V	XFMR 1, Bus 2 V	XFMR 1, Rated S	XFMR 1, %Z	XFMR 1, X/R Ratio	XFMR 1, Bus 1 Config	XFMR 1, Bus 2 Config	XFMR 1, Bus 1 Gnd	XFMR 1, Bus 2 Gnd

…											
XFMR ***k***, Name	XFMR ***k***, Bus 1 Name	XFMR ***k***, Bus 2 Name	XFMR ***k***, Bus 1 V	XFMR ***k***, Bus 2 V	XFMR ***k***, Rated S	XFMR ***k***, %Z	XFMR ***k***, X/R Ratio	XFMR ***k***, Bus 1 Config	XFMR ***k***, Bus 2 Config	XFMR ***k***, Bus 1 Gnd	XFMR ***k***, Bus 2 Gnd

Notes:

- Bus 1 V and Bus 2 V are the rated voltages of side 1 and side 2 of the transformer in kV. These determine the turns ratio of the transformer
- Rated S is the rated apparent power of the transformer
- %Z is the per unit impedance of the transformer
- Bus 1 and Bus 2 Config values can be *D* for Delta, *YG* for wye grounded, and *YU* for wye ungrounded
- Bus 1 and Bus 2 Gnd are the grounding impedance in ohms of the transformer for each connection side. If a connection is ungrounded, this can be any value, but the standard is to put a -1. For complex value, enter the grounding impedance as R+Xj (ex: '1+2j')

Program Operation:

Once the system is configured on the CSV files, launch the main.py file to run the simulator. Note that all class python files and all CSV files must be in the same folder as the main in order for the program to run.

Upon launch, you will see the options below. Select an option by entering the number corresponding to the desired choice in the terminal. Below are descriptions of all main menu options:

(1) Power Flow

Takes you to the power flow to select which method you would like to use

(2) Fault Study

Takes you to the fault study menu to select which type of fault study you would like to use

(3) System Options

Takes you to the system option menu

(0) Cancel

Exits the program

Power Flow Studies:

(1) Newton-Raphson Power Flow

Runs power flow analysis using the Newton-Raphson method and outputs voltage, current, power injection, and power losses

(2) Fast Decoupled Newton-Raphson Power Flow

Runs power flow analysis using the Fast Decoupled Newton-Raphson method and outputs voltage, current, power injection, and power losses

(3) DC Power Flow

Runs power flow analysis using the DC Power Flow method and outputs voltage, current, and real power injection for all lines and buses. Due to the assumptions and simplicity of the DC Power Flow solver and under instruction from our professor, the power losses and reactive power calculations were not included.

(4) Cancel

Returns to the main menu

Fault Studies:

(1) Three Phase Symmetrical Fault

Runs the fault analysis for a symmetric fault. This option will request the name of the faulted bus and the prefault voltage in per unit from the user

(2) Line to Line Fault

Runs the fault analysis for a line to line fault. This option will request the name of the faulted bus and the prefault voltage in per unit from the user, as well as the fault resistance and reactance in ohms

(3) Single Line to Ground Fault

Runs the fault analysis for a line to ground fault. This option will request the name of the faulted bus and the prefault voltage in per unit from the user, as well as the fault resistance and reactance in ohms

(4) Double Line to Ground Fault

Runs the fault analysis for double line to ground fault. This option will request the name of the faulted bus and the prefault voltage in per unit from the user, as well as the fault resistance and reactance in ohms

(0) Cancel

Returns to the main menu

Power Flow System Options:

These options allow a user to change elements of the power system

(1) Reset to Flat Start

Resets all buses to a voltage of 1 per unit at an angle of 0 degrees

(2) Change Bus Voltage (per unit)

Allows a user to enter a bus name, and if the bus exists, change the voltage magnitude and angle at that bus

(3) Change Slack Bus

Allows a user to change the system slack bus

(4) Change Load MW

Allows a user to enter the name of a load, and if a load exists under that name, change the MW value of the load

(5) Change Load Mvar

Allows a user to enter the name of a load, and if a load exists under that name, change the Mvar value of the load

(6) Change Generator Power Output

Allows a user to enter the name of a generator, and if a generator exists under that name, change the real power setpoint of that generator in MW

(7) Change Generator Mvar Limits

Allows a user to enter the name of a generator, and if a generator exists under that name, change the minimum and maximum Mvar limits of that generator

(8) Change System S Base

Allows a user to change the apparent power base of the system in MVA

(0) Cancel

Returns to the main menu