EENG 480: Power System Analysis
ENGY 503: Energy Systems Integration and Efficiency
Course Project
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Project Description

In this project, we will continue to work on the IEEE 34-bus test distribution system that you modeled in homework assignment 4. The map of the system is now modified by overlaying it on hypothetical census tracts. Census tracts are the smallest geographical units used by the US Census Bureau for conducting the American Community Survey. Tracts can contain anywhere from 1,000 to 8,000 residents, with 4,000 a typical number across the country. As you can imagine, the geographical area spanned by a tract in rural regions is significantly larger than urban areas.

For the purpose of this exercise, we assume that we have a total of 6 tracts, identified with hypothetical IDs 101–106. Some hypothetical demographic and socioeconomic data is provided in Table 1 for each tract.

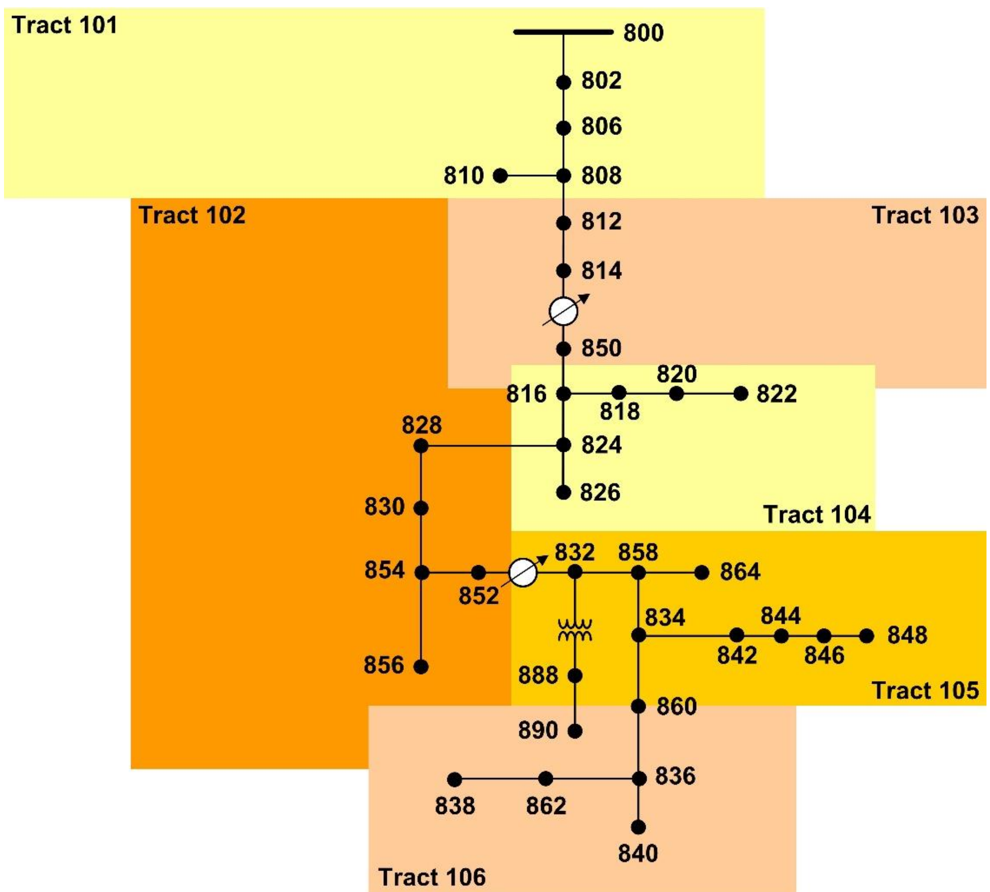

Fig. 1. Overlay of the system under study with hypothetical census tracts.

Table 1. Census tract data.

Tract ID	Population above the age of 65 (%)	Population below the age of 5 (%)	Homeownership Ratio (%)	Percentage of People of Color (%)	Household Median Income ($)	Median Age of Homes (yrs.)	Average House Size (sq. ft)	Average Size of Household
101	12	21	28	48	46,000	52	1,000	6
102	25	10	92	5	178,000	10	4,500	4

103	21	14	56	12	72,000	25	2,500	3.2
104	15	7	44	21	61,000	29	2,100	3
105	5	4	21	63	57,000	66	1,200	2.5
106	20	16	78	8	134,000	28	3,800	4

A. Variable PV Generation

In homework assignment 4, we assumed that PV resources generate their rated power at all times. We know that this is not true, and that PV power changes with time of day as well as the level of cloud coverage. Here, we will model different scenarios based on various times of day:

- 20% PV penetration level, 10:00 am,
- 20% PV penetration level, 4:00 pm,
- 20% PV penetration level, 8:00 pm,
- 50% PV penetration level, 10:00 am,
- 50% PV penetration level, 4:00 pm,
- 50% PV penetration level, 8:00 pm.

Naturally, PV power depends on solar irradiance, which itself is a function of location (latitude, longitude), time of day, day of the year, and cloud coverage. Consider the city of Denver, on June 21, under clear sky conditions. Determine solar irradiance data for the above times of day, compare it with solar irradiance under the Standard Test Conditions (STC), and adjust the PV generation as a function of its rated power accordingly.

B. EV Demand

Next, we add EV demand to the network. First, pick 10 nodes to represent aggregate EV load in the system (justify your selection). Consider 20%, 50%, and 100% penetration levels for each node. In this study, consider the penetration level as the ratio of 'EV power at the node' to the 'base case active power of the node.' Naturally, EV demand changes during the day, but we will ignore that here.

C. Impact of EV and PV on Grid Performance

Assess the performance of the power system for different combinations of PV and EV profiles (we have a total of 18 scenarios). Tabulate your results as follows:

Table 2. Power grid performance summary.

Scenario ID	PV Penetration (%)	Time of Day	EV Penetration (%)	Active Power from Distribution Substation (kW)	Reactive Power from Distribution Substation (kvar)	Total Power Losses (kW)	Highest Node Voltage (in p.u)	Lowest Node Voltage (in p.u)	No. of Nodes with Voltages outside ±5% range

Power losses need to be calculated as the sum of generation (distribution substation and PV) minus the sum of demand (general demand and EV).

D. Mitigation

Pick the worst-case scenario from Table 2. Address the following questions:

- What are the main operational problems? High voltages? Low voltages? High power losses?
- What is the root cause of the problem(s) experienced by the grid in this scenario?
- What solutions can you think of? Some example solutions can be demand response, load shifting, load shedding, PV power curtailment, EV power curtailment, etc.

Pick two solutions and implement them in the system. Clearly indicate where in the system (e.g., what nodes) you will apply your proposed solutions. Discuss the results and pick the best solution accordingly. Justify your choice using metrics, including but not necessarily limited to those listed in Table 2.

E. Equity and Justice

At the high level, energy justice in power systems can be viewed in terms of distributional justice, procedural justice, and recognition justice:

- Distributional Justice: the potential harms and benefits that arise from adopting a dispatch solution must be equally distributed among all users.
- Procedural Justice: all community members should be informed of the pros and cons of various dispatch solutions and have a say in decision making.
- Recognition Justice: the special needs of socially vulnerable users (or user groups) must be identified and incorporated into the proposed dispatch solution.

In this project, we are more concerned about distributional and recognition aspects of energy justice. Develop one metric for each (you can brainstorm within your group or choose a metric from the literature) and rate the energy justice aspects of your final proposed solution. If you are not completely happy with those ratings, what recommendations would you have? What can be done to improve the energy justice aspect of your solution?

Rubric:

Item	Points
All 18 possible scenarios are properly created	3
Information in Table 2 is provided for all scenarios	5
The worst-case scenario is identified and discussed in detail	2
Two solutions are proposed and implemented for the worst-case scenario	4
The solutions proposed are innovative and demonstrate outside-the-box thinking	2
The team has identified the best solution and has used appropriate metrics to do so	2
The team has selected (or developed) two metrics to assess distributional justice and recognition justice aspects of their solution	3
Discussion of energy justice is well-thought-out and informative. Recommendations demonstrate outside-the-box thinking	2
Report is less than 4 pages (excluding references and the appendix, if any)	1
Report is clear, professional, and well-written	1
Total	25