EENG 573: Electric Power Quality
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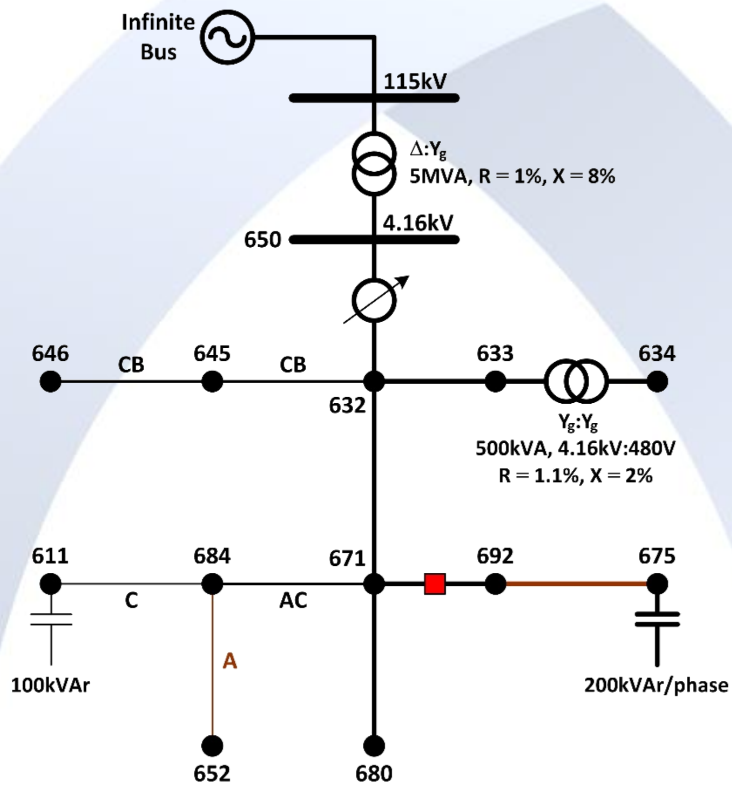
Course Project, Spring 2024

Overview

This is a simulation project in which you will be modeling, testing, and mitigating various power quality issues that we have studied in this course. You are free to choose any software package you feel more comfortable with, including but not limited to MATLAB/Simulink and PSCAD[1].

Problem Statement

An electric utility owns and operates a small-scale 4.16 kV distribution system shown below [1]. The system consists of a combination of overhead lines and underground cables, unbalanced loading, a voltage regulator at the distribution substation, an in-line transformer, and two capacitor banks. In your analysis, consider node 650 as the PCC.



Your project report should closely follow the structure outlined below. Deliverables for each section are highlighted in blue. No additional deliverables or discussions are required.

A. Base Case

As the first step, you need to simulate the system in your software of choice. Note that Simulink model of the above system is publicly available through the MathWorks website and can be used for the purpose of this project.

If on the other hand you choose to model the system yourselves or decide to use a different software package, follow the assumptions below:

- Model all loads as spot loads, with the data provided below.
- Model all lines as short lines (i.e., series R and X), with the data provided below.

[1] If you choose to use PSCAD, a temporary license will be provided to all team members to be used throughout the semester.

- The voltage regulator can be modeled as an ideal three-phase transformer with ±10% tap range (consider 16 tap positions in each direction, which is the common industry practice). Assume that the regulator is located at the quarter length of the line connecting node 650 to node 632 and is controlled in such a way that it regulates the voltage at node 632 to be at rated value, i.e., 1.0 per unit.
- Capacitor banks are fixed, i.e., not switchable.

Node	Load Connection/Type	A		B		C	
		P (kW)	Q (kVAr)	P (kW)	Q (kVAr)	P (kW)	Q (kVAr)
632	Y-PQ	17	10	66	38	117	68
634	Y-PQ	160	110	120	90	120	90
645	Y-PQ	0	0	170	125	0	0
646	D-Z	0	0	230	132	0	0
652	Y-Z	128	86	0	0	0	0
671	D-PQ	385	220	385	220	385	220
675	Y-PQ	485	190	68	60	290	212
692	D-PQ	0	0	0	0	170	151
611	Y-PQ	0	0	0	0	170	80

Line Segment	Line Length (feet)	Type	R (Ω/mile)	X (Ω/mile)
650 – 632	2,000	OH, Three Phase	0.3465	1.0179
632 – 633	500	OH, Three Phase	0.7526	1.1814
632 – 645	500	OH, Two Phase (B, C)	1.3294	1.3471
645 – 646	300	OH, Two Phase (B, C)	1.3294	1.3471
632 – 671	2,000	OH, Three Phase	0.3465	1.0179
671 – 680	1,000	OH, Three Phase	0.3465	1.0179
671 – 684	300	OH, Two Phase (A, C)	1.3238	1.3569
684 – 652	800	UG, Single Phase (A)	1.3425	0.5124
684 – 611	300	OH, Single Phase (C)	1.3292	1.3475
692 – 675	500	UG, Three Phase	0.7982	0.4463

Deliverables:

- A single graph of node voltage magnitudes (all in per-unit) in the form of a bar plot, one bar for each node[2]. Clearly label nodes and indicate thresholds of 0.95 and 1.05 per-unit.
- Values of the total active and reactive powers (in kW and kvar) supplied through the PCC.

B. Electric Vehicle Charging Station (EVCS)

There is a proposal to the utility to install a large-scale commercial EVCS with multiple level 2 chargers at node 680. For the purpose of this project, model the station as a 6-pulse AC/DC rectifier rated at 400 kW DC. Consider stepwise variations in charging load at 10%, 40%, 70%, 100%, and 50% of the rated value every hour (corresponding to 10 seconds of simulation time).

Deliverables:

- Plot of rms voltage/current at node 680 (all in per-unit).

[2] If a node consists of multiple phases with voltage imbalance, show those separately.

C. Solar Park

A second proposal is to install a 1 MVA solar park at node 671. Assume that the park operates under MPPT conditions. Model and simulate the solar resource in software[3]. Your model should allow for changing the solar irradiance, as the input to the solar park, due to cloud movements. Consider a windy and cloudy day[4], so that solar resource may affect system voltages and powers in a non-negligible way. For this analysis, consider 10 seconds of simulation time to equate one hour in real-life.

Deliverables:

- Screenshot of the solar park model and its controller, with proper annotations.
- Discussion on how variations in solar irradiance due to cloud coverage are modeled.
- Plot of rms voltage/current at node 671 (all in per-unit).

D. Power Quality Analysis

Our goal in this step is to assess the impact of the above proposals on the overall power and voltage quality of the system. Assume that both proposals have been implemented in the system and operate as described in the previous steps. Run the model and closely monitor the electrical quantities in order to identify the worst-case scenario from a power quality perspective.

Deliverables:

- Identify the worst-case scenario and discuss its characteristics, i.e., what makes it problematic.
- Bar graph indicating node voltages (all in per-unit) under the worst-case scenario. Clearly label nodes and indicate thresholds of 0.95 and 1.05 per-unit.
- Plot of voltage harmonics at the PCC (all in per-unit) under the worst-case scenario. Include as many harmonics as necessary. Clearly indicate the threshold of 1.0 per-unit.
- Plot of current harmonics at the distribution transformer (all in per-unit) under the worst-case scenario. Include as many harmonics as necessary. Clearly indicate the threshold of 1.0 per-unit.
- Table listing the calculated voltage THD at the PCC and the current TDD at the distribution transformer, under the worst-case scenario.

E. Mitigation

The utility wishes the system to be compliant with IEEE 519 and IEEE 18 and that voltages remain within the ANSI limits. As a power quality consulting firm, you have been asked to study the system (when all proposals are approved), propose mitigation solutions to ensure that the utility's goals are met, and verify the effectiveness of your solutions. Consider the worst-case scenario identified above.

Deliverables:

- Discussion of the solution proposed and the justification behind it.
- Bar graph indicating node voltages (all in per-unit) under the worst-case scenario with the implemented solution. Clearly label nodes and indicate thresholds 0.95 and 1.05 per-unit.
- Table listing the calculated voltage THD at the PCC and the current TDD at the distribution transformer, under the worst-case scenario with the solution implemented.

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[3] Many software packages have embedded blocks to model solar resources. Feel free to use those, i.e., you do not need to start from scratch.

[4] You can use historical data for any location of interest to support your choice of cloud coverage and wind speed variations.

Rubric

Section	Description	Points
Base Case	Voltage bar graph is provided and is accurate	2
	Total active and reactive powers through the PCC are provided and the values are close to the total load	2
EVCS	Plots of rms voltage/current at node 680 are provided	2
	Voltage and current plots clearly show changes based on the operation schedule of the EVCS	2
Solar Park	Solar resource is modeled with reasonable detail, including irradiance variations due to cloud movements in the sky	3
	Plots of rms voltage/current at node 671 are provided	2
	Voltage and current plots clearly show changes based on the variations in solar irradiance	2
Power Quality Analysis	Worst-case scenario is identified and discussed	2
	Voltage bar graph is presented and is accurate	2
	Plot of voltage harmonics at PCC is presented and is accurate	2
	Plot of current harmonics at the distribution transformer is presented and is accurate	2
	THD and TDD values are calculated properly	2
Mitigation	A solution is proposed to address the main power quality issues	2
	Justification behind the chosen solution is provided and is well-thought-out	2
	The solution proposed by the team is innovative and demonstrates outside-the-box thinking. The novelty of your solution may be compared to those proposed by other groups	2
	Voltage bar graph with the implemented solution is presented and shows improvement compared to the non-mitigated system	2
	THD and TDD values are provided and show improvement compared to the non-mitigated system	2
Report	Reports is well-written, professional, and clear and follows the required format	2
	All graphs are legible and properly labeled	2
	Report is limited to 5 pages[5] (excluding references and the appendix)	1
	Total	**40**

References:

[1] IEEE PES Test Feeders, [Online]. Available at: https://cmte.ieee.org/pes-testfeeders/resources/.

[5] All essential diagrams listed under the deliverables must be included in the body of the report. Appendix must be reserved for non-essential information.