Power System Toolbox 4

–User Manual–
Documentation Version 0.0.0-a.1

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Introduction

This is a PST user manual template. BONES!

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Glossary of Terms

1 Basic Formatting

This chapter will show basic formatting of text, figures, tables and equations. It will also be mostly filled with 'dummy' text so there is something to look at.

1.1 Body Text

Body text has a 1/2 inch indent on all paragraphs and double spaced lines. Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

1.2 Figures, In-Text Citations, and Footnotes

Figure 1.1 is an example of how images can be formatted. Additionally, citations to references will be shown such **latexcompanion**. Footnotes[1] will behave like this[2].

Figure 1.1: An Athletic logo?

A larger graphic example is shown on Page 2 as Figure 1.2. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. In-

[1] This is a footnote text message that doesn't offer much information.
[2] This is another footnote.

teger vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetuer at, consectetuer sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

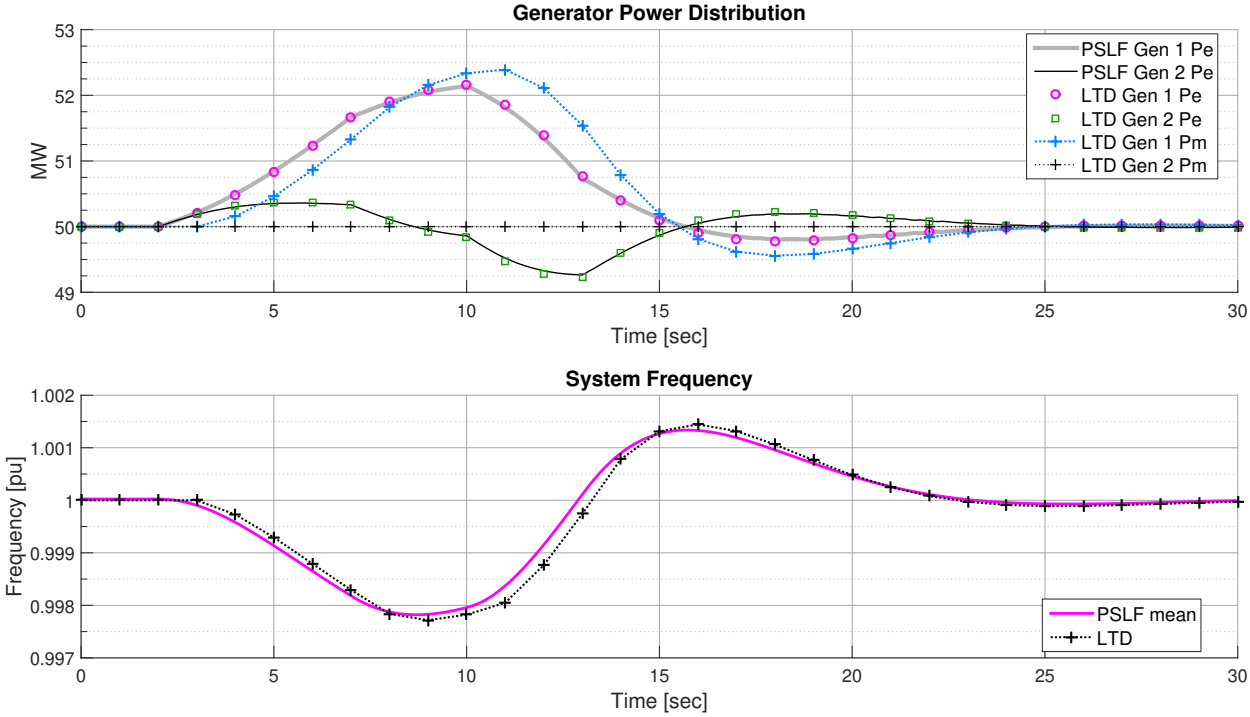

Figure 1.2: This is a fairly large graphic but can easily be set to any desired width. Additionally, this is a super long caption that would break the table of contents formatting if it weren't for an optional 'short title' parameter. There's even a citation in herestajcar.

Nulla in ipsum. Praesent eros nulla, congue vitae, euismod ut, commodo a, wisi. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Aenean nonummy magna non leo. Sed felis erat, ullamcorper in, dictum non, ultricies ut, lectus. Proin vel arcu a odio lobortis euismod. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Proin ut est. Aliquam odio. Pellentesque massa turpis, cursus eu, euismod nec, tempor congue, nulla. Duis viverra gravida mauris. Cras tincidunt. Curabitur eros ligula, varius ut, pulvinar in, cursus faucibus, augue.

1.3 Equations

A somewhat fancy equation involving symbols and an integral is pretty easy to put together. Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetuer.

$$x(t) = \Phi(t)x(0) + \int_0^t \Phi(t-\tau)Bu(\tau)\mathrm{d}\tau. \tag{1.1}$$

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio. Unlike Equation 1.1, Equation 1.2 is pretty basic.

$$a + b = c \tag{1.2}$$

Aligned rows of equations are also possible using the `align*` environment and a

custom `numberthis` command. The following math is very math.

$$
\begin{aligned}
G(\$) &= \frac{20}{\$(\$+5)(\$+10)} \\
\zeta = 0.59116, \Phi_M &= 58.59 \\
\therefore \omega_{\Phi_M} &= \omega\angle -121.41^\circ \\
\text{From Bode: } \omega_{\Phi_M} &= 1.9 \\
\left|\omega_{\Phi_M}\right| &= -14.3 \\
\therefore K &= 10^{\frac{14.3}{20}} = 5.188 \text{ abs}
\end{aligned} \tag{1.3}
$$

1.4 Tables

Tables can look like Table 1.1. Notice the slimming effect of no vertical lines…. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus.

Table 1.1: An example table with no vertical lines.

	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Old	29.631	17.333	222.999	11.222
Not Old	54.321	166.233	556.123	54.666
Almost New	118.791	54.289	445.321	88.122
New	222.897	10.000	777.000	90.100

Table style may be altered to a slightly different style if it seems appropriate. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Notice that chapters start on a new page.

Tables may also be input vai a single command incase it seems more logical...

Table 1.2: Trapezoidal integration results a of low pass filter using a t step of 0.5.

Method	Result	Absolute Error
Calculated	1.750083866	0.000000000
Exact	1.750082530	0.000001336
RK4	1.680138966	0.069944900
solve_ivp	1.719657220	0.030426646
lsim	1.671851297	0.078232568

2 Chapters and Sections

This chapter is used only to show nesting of sections and space around chapter and section headings.

2.1 First Section

This is the First Section. It will have two sub sections. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus.

2.1.1 First SubSection

This is the first... Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus.

2.1.1.1 A subsubsection

This is a fairly nested sentence. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus.

2.1.1.2 The second subsubsection

Seems like going any deeper than a subsubsection could be a bit much, but is possible to configure LaTeX to number paragraphs like sections if required.

2.1.2 Second Subsection

This is the second. This subsection will actually have another subsection in it.Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla.

2.2 Second Section

A second section. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc.

2.3 Third Section

A third Section. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc.

3 Bibliography

[1] .NET Foundation. (2018). Ironpython overview, [Online]. Available: https://ironpython.net/.

[2] P. M. Anderson and A. A. Fouad, *Power System Control and Stability*, Second Edition. Wiley-Interscience, 2003.

[3] J. Audenaert, K. Verbeeck, and G. V. Berghe. (2009). Mulit-agent based simulation for boarding, CODeS Research Group, [Online]. Available: https://www.semanticscholar.org/paper/Multi-Agent-Based-Simulation-for-Boarding-Audenaert-Verbeeck/24ba2c3190de5b7162c37e81581b062cda3e4d54.

[4] A. Aziz, A. Mto, and A. Stojsevski, "Automatic generation control of multigeneration power system," Journal of Power and Energy Engineering, 2014.

[5] W. E. Boyce and R. C. DiPrima, *Elementary Differential Equations and Boundary Value Problems*, 10th ed. Wiley Custom Learning Solutions, 2014.

[6] W. Briggs, L. Chochran, and B. Gillett, *Calculus Early Transcendentals*. Pearson Education, Inc., 2011.

[7] J. Carpentier, "'To be or not to be modern' that is the question for automatic generation control (point of view of a utility engineer)," International Journal of Electrical Power & Energy Systems, 1985.

[8] R. W. Cummings, W. Herbsleb, and S. Niemeyer. (2010). Generator governor and information settings webinar, North American Electric Reliability Corporation, [Online]. Available: https://www.nerc.com/files/gen-governor-info-093010.pdf.

[9] F. P. deMello and R. Mills, "Automatic generation control part II - digital control techniques," IEEE PES Summer Meeting, 1972.

[10] DEQ. (2004). Montana electric transmission grid: Operation, congestion, and issues, DEQ, [Online]. Available: https://leg.mt.gov/content/publications/Environmental/2004deq_energy_report/transmission.pdf.

[11] EIA. (2016). U.s. electric system is made up of interconnections and balancing authorities, [Online]. Available: https://www.eia.gov/todayinenergy/detail.php?id=27152.

[12] EIA. (2019). July2019map.png, U.S. Energy Information Administration, [Online]. Available: https://www.eia.gov/electricity/data/eia860m/.

[13] EIA. (2019). U.s. electric system operating data, U.S. Energy Information Administration, [Online]. Available: https://www.eia.gov/realtime_grid/.

[14] EIA. (2019). U.s. energy mapping system, U.S. Energy Information Administration, [Online]. Available: https://www.eia.gov/state/maps.php?v=Electricity.

[15] E. Ela and J. Kemper, "Wind plant ramping behavior," National Renewable Energy Laboratory, 2009.

[16] M. D. of Environmental Quality. (2020). Colstrip statistics, DEQ, [Online]. Available: http://deq.mt.gov/DEQAdmin/mfs/AllColstrip/DEQAdmin/mfs.

[17] ERCOT. (2017). Ercot-internconnection_branded.jpg, ERCOT, [Online]. Available: http://www.ercot.com/news/mediakit/maps.

[18] J. H. Eto, J. Undrill, C. Roberts, P. Mackin, and J. Ellis, "Frequency control requirements for reliable interconnection frequency response," Energy Analysis and environmental Impacts Division Lawrence Berkeley National Laboratory, 2018.

[19] D. Fabozzi and T. Van Cutsem, "Simplified time-domain simulation of detailed long-term dynamic models," IEEE Xplore, 2009.

[20] FERC, "Essential reliability services and the evolving bulk-power system–primary frequency response," Federal Energy Regulatory Commission, Docket No. RM16-6-000 Order No. 842, Feb. 2018.

[21] FERC. (2019). About ferc, [Online]. Available: https://www.ferc.gov/about/about.asp.

[22] T. Garnock-Jones and G. M. Roy. (2017). Introduction to pika, [Online]. Available: https://pika.readthedocs.io/en/stable/.

[23] GE Energy, *Mechanics of running pslf dynamics*, 2015.

[24] GeeksforGeeks. (2017). Thread in operating system, GeeksforGeeks, [Online]. Available: https://www.geeksforgeeks.org/thread-in-operating-system/.

[25] General Electric. (2020). Ge pslf main page, [Online]. Available: https://www.geenergyconsulting.com/practice-area/software-products/pslf.

[26] General Electric International, Inc, *PSLF User's Manual*, 2016.

[27] W. B. Gish, "Automatic generation control algorithm - general concepts and application to the watertown energy control center," Bureau of Reclamation Engineering and Research Center, 1980.

[28] J. D. Glover, M. S. Sarma, and T. J. Overbye, *Power System Analysis & Design*, 5e. Cengage Learning, 2012.

[29] R. Gonzales. (2019). Pg&e transmission lines caused california's deadliest wildfire, state officials say, NPR, [Online]. Available: https://www.npr.org/2019/05/15/723753237/pg-e-transmission-lines-caused-californias-deadliest-wildfire-state-officials-sa.

[30] M. Goossens, F. Mittelbach, and A. Samarin, *The LaTeX Companion*. Addison-Wesley, 1993.

[31] R. Hallett, "Improving a transient stability control scheme with wide-area synchrophasors and the microwecc, a reduced-order model of the western interconnect," Master's thesis, Montana Tech, 2018.

[32] E. Heredia, D. Kosterev, and M. Donnelly, "Wind hub reactive resource coordination and voltage control study by sequence power flow," IEEE, 2013.

[33] J. JMesserly. (2008). Electricity_grid_simple-_north_america.svg, United States Department of Energy, [Online]. Available: https://commons.wikimedia.org/wiki/File:Electricity_grid_simple-_North_America.svg.

[34] T. Kennedy, S. M. Hoyt, and C. F. Abell, "Variable, non-linear tie-line frequency bias for interconnected systems control," IEEE Transactions on Power Systems, 1988.

[35] Y. G. Kim, H. Song, and B. Lee, "Governor-response power flow (grpf) based long-term voltage stability simulation," IEEE T&D Asia, 2009.

[36] G. Kou, P. Markham, S. Hadley, T. King, and Y. Liu, "Impact of governor deadband on frequency response of u.s. eastern interconnection," IEEE Transactions on Smart Grid, 2016.

[37] D. Kuhlman, *A Python Book: Beginning Python, Advanced Python, and Python Exercises*. 2009.

[38] P. Kundur, *Power System Stability and Control*. McGraw-Hill, 1994.

[39] K. H. LaCommare and J. H. Eto, "Understanding the cost of power interruptions to u.s. electricity consumers," Ernest Orlando Lawrence Berkeley National Laboratory, 2004.

[40] M. Liedtke. (2020). Court approves pg&e's $23b bankruptcy financing package, AP News, [Online]. Available: https://apnews.com/b70582ee8d4bb7f781553215612da993.

[41] P. Maloney. (2018). What is the value of electric reliability for your operation? [Online]. Available: https://microgridknowledge.com/power-outage-costs-electric-reliability/.

[42] Y. Mobarak, "Effects of the droop speed governor and automatic generation control agc on generator load sharing of power system," International Journal of Applied Power Engineering, 2015.

[43] NERC, "Frequency response initiative report," North American Electric Reliability Corporation, 2012.

[44] NERC, "Procedure for ero support of frequency response and frequency bias setting standard," North American Electric Reliability Corporation, 2012.

[45] NERC, "Standard bal-003-1.1 — frequency response and frequency bias setting," North American Electric Reliability Corporation, 2015.

[46] NERC, "Standard bal-001-2 – real power balancing control performance," North American Electric Reliability Corporation, 2016.

[47] NERC. (2017). About nerc, [Online]. Available: https://www.nerc.com/AboutNERC/Pages/default.aspx.

[48] NERC. (2017). Nerc interconnections map, [Online]. Available: https://www.nerc.com/AboutNERC/keyplayers/PublishingImages/NERC%20Interconnections.pdf.

[49] NERC, "Bal-002-3 – disturbance control standard – contingency reserve for recovery from a balancing contingency event," North American Electric Reliability Corporation, 2018.

[50] NERC, "Frequency response annual analysis," North American Electric Reliability Corporation, 2018.

[51] NERC, "Reliability guideline application guide for modeling turbine-governor and active power-frequency controls in interconnection-wide stability studies," 2019.

[52] NERC, "Reliability guideline primary frequency control," 2019.

[53] NERC. (2020). Glossary of terms used in nerc reliability standards, NERC, [Online]. Available: https://www.nerc.com/files/glossary_of_terms.pdf.

[54] NERC Resources Subcommittee, "Balancing and frequency control," North American Electric Reliability Corporation, 2011.

[55] NERC Resources Subcommittee, "Bal-001-tre-1 — primary frequency response in the ercot region," North American Electric Reliability Corporation, 2016.

[56] J. W. Nilsson and S. A. Riedel, *Electric Circuits*, Ninth. Pearson Education, Inc., 2011.

[57] P. W. Parfomak, "Physical security of the u.s. power grid: High-voltage transformer substations," Congressional Research Service, 2014.

[58] PowerWorld Corporation. (2020). Powerworld main page, [Online]. Available: `https://www.powerworld.com/`.

[59] Python Software Foundataion. (2019). About python, [Online]. Available: `https://www.python.org/about/`.

[60] B. Rand. (2018). Agent-based modeling: What is agent-based modeling? Youtube, [Online]. Available: `https://www.youtube.com/watch?v=FVmQbfsOkGc`.

[61] C. W. Ross, "Error adaptive control computer for interconnected power systems," IEEE Transactions on Power Apparatus and Systems, 1966.

[62] G. van Rossum. (2009). A brief timeline of python, [Online]. Available: `https://python-history.blogspot.com/2009/01/brief-timeline-of-python.html`.

[63] RTDS Technologies. (2020). Rscad main page, [Online]. Available: `https://legacy.rtds.com/the-simulator/our-software/about-rscad/`.

[64] J. Sanchez-Gasca, M. Donnelly, R. Concepcion, A. Ellis, and R. Elliott, "Dynamic simulation over long time periods with 100% solar generation," Sandia National Laboratories, SAND2015-11084R, 2015.

[65] P. W. Sauer, M. A. Pai, and J. H. Chow, *Power System Dynamics and Stability With Synchrophasor Measurement and Power System Toolbox*, Second Edition. John Wiley & Sons Ltd, 2018.

[66] SciPy developers. (2019). About scipy, [Online]. Available: `https://www.scipy.org/about.html`.

[67] K. Siegel. (2012). The true cost of power outages, Yale Environment Review, [Online]. Available: `https://environment-review.yale.edu/true-cost-power-outages-0`.

[68] Siemens AG. (2018). Siemens main page, [Online]. Available: `https://pss-store.siemens.com/store/sipti/en_US/home`.

[69] M. Stajcar, "Power system simulation using an adaptive modeling framework," Master's thesis, Montana Tech, 2016.

[70] C. W. Taylor and R. L. Cresap, "Real-time power system simulation for automatic generation control," IEEE Transactions on Power Apparatus and Systems, 1976.

[71] The SciPy community. (2019). Scipy scipy.integrate.solve_ivp page, [Online]. Available: https://docs.scipy.org/doc/scipy/reference/generated/scipy.integrate.solve_ivp.html.

[72] The SciPy community. (2019). Scipy scipy.signal.lsim page, [Online]. Available: https://docs.scipy.org/doc/scipy-0.16.0/reference/generated/scipy.signal.lsim.html.

[73] D. Trudnowski, "Properties of the dominant inter-area modes in the wecc interconnect," Montana Tech, 2012.

[74] T. Van Cutsem and C. Vournas, *Voltage Stability of Electric Power Systems*, 1st ed. Springer US, 1998.

[75] WECC. (2015). About wecc, [Online]. Available: https://www.wecc.org/Pages/AboutWECC.aspx.

A Appendix A: Formatting Examples

This appendix is included to show how appendices work, blowing up of numbering, and to also serve as an easy LaTeX formatting template. Despite this being an appendix, it is still numbered like a chapter.

A.1 Numberings in Equations

Additionally, a reminder of Ohm's law

$$V = IR \tag{A.42}$$

shows that equation numbering has blown up. This is to show spacing on the table of contents.

A.2 Numberings in Tables

Table A.14 is full of nonsense data and is numbered artificially large.

Table A.14: Another Table.

One	Two	Three	Four	Five
2.35	45.87	9.00	1.00	0.33
5.88	48.01	7.85	2.35	0.45

A.3 Numberings in Figures

Finally, Figure A.67 shows how figure numbers look when double digit.

Figure A.67: A boxcat in its natural environment.

A.4 Code using Minted

Code can be added using the `minted` package. The example below is for a Python example, but can be configured other ways. Note that a `--shell-escape` command had to be added to the TeXStudio build command due to peculiarities with the package. Additionally, the `minted` LaTeX package requires python to be installed with the `pygments` package. This can be done via the '`py -m pip install -U pygments`' console command.

```
1  def sumPe(mirror):
2      """Returns sum of all electrical power from active machines"""
3      sysPe = 0.0
4
5      # for each area
6      for area in mirror.Area:
7          # reset current sum
8          area.cv['Pe'] = 0.0
9
10         # sum each active machine Pe to area agent
11         for mach in area.Machines:
12             if mach.cv['St'] == 1:
13                 area.cv['Pe'] += mach.cv['Pe']
14
15         # sum area agent totals to system
16         sysPe += area.cv['Pe']
17
18     return sysPe
```

Figure A.68: Code listing as a figure.

Other packages exist for code insertion, but they may or may not be as pretty. Remember, as with anything, this is totally optional and voluntary...