ELEG 587V
Electric Power Regulation

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Credit Hours 3

Prerequisite Graduate Standing

Text Books

Books

- Andrews, C. J. (1995). *Regulating regional power systems*. Westport, Conn: Quorum. (Chapter 7, 25 and 26)
- Kahn, A. E. (1970). The economics of regulation: principles and institutions. New York: Wiley. (Chapter 1. Part I)
- Hughes, T. P. (1983). Networks of power: Electrification in Western society, 1880-1930. Baltimore, Maryland: Johns Hopkins University Press. (Chapter XIII)

EBooks

1. Li, W. (2005). *Risk assessment of power systems: Models, methods, and applications*. Piscataway, NJ: IEEE Press. (Chapters 1 and 13)
2. Jayaweera, D. (Ed.). (2016). *Studies in Systems, Decision and Control : Smart Power Systems and Renewable Energy System Integration*. Cham, CH: Springer (Chapters 1 and 9)
3. Li, Y., Yang, D., & Liu, F. (2015). *Power Systems : Interconnected Power Systems : Wide-Area Dynamic Monitoring and Control Applications*. Berlin, Heidelberg, DE: Springer. (Chapter 1)
4. Messina, A. R. (2015). *Wide area monitoring of interconnected power systems*. London, England: The Institution of Engineering and Technology. (Chapters 1, 2 and 8)
5. Funabashi, T. (Ed.). (2016). *Integration of Distributed Energy Resources in Power Systems : Implementation, Operation and Control*. US: Academic Press. (Chapter 13)
6. Ceraolo, M., & Poli, D. (2014). *Fundamentals of electric power engineering: From electromagnetics to power systems* (First ed.). Hoboken, New Jersey;Piscataway, NJ;: IEEE Press. (Chapter 15)
7. Meier, A. v., & John Wiley & Sons. (2006). *Electric power systems: A conceptual introduction*. Hoboken, N.J: IEEE Press. (Chapters 6, 8 and 9)
8. Casazza, J., & Delea, F. (2010). *Understanding electric power systems: An overview of the technology, the marketplace, and government regulation* (2nd ed.). Piscataway, NJ;Hoboken, N.J;: IEEE Press. (Entire Book)

9. Bevrani, H., Watanabe, M. (. e., & Mitani, Y. (2014). *Power system monitoring and control*. Hoboken, New Jersey: Wiley. (Optional)
10. Thomas, M. S., Mcdonald, J. D., & EBSCOhost. (2015). *Power system SCADA and smart grids*. Boca Raton, FL: CRC Press. (Optional)
11. Masters, G. M. (2004). *Renewable and efficient electric power systems*

Papers, webpages and other books not available at the library

12. McLean, I. (2002), "*The origin and strange history regulation in the UK: three case studies in search of a theory*", workshop paper.
13. Littlechild, S. (2001). Electricity: Regulatory developments around the world. *Verfügbar unter: www.econ.cam.ac.uk/electricity/publications/index. htm*.
14. Prosser, T. (2010). *The regulatory enterprise: government, regulation, and legitimacy*. Oxford University Press, USA.
15. Littlechild, S. (2001). *Electricity: Regulatory developments around the world*. Verfügbar unter: www.econ.cam.ac.uk/electricity/publications/index.htm.
16. Perrin, L. M. (2013). *Mapping power and utilities regulation in Europe*. Technical report, Assurance Power and Utilities Sector Resident, EY.
17. http://uk.practicallaw.com/1-523-9996?source=relatedcontent
18. Baldwin, R., Cave, M., & Lodge, M. (2012). *Understanding regulation: theory, strategy, and practice*. Oxford University Press on Demand.
19. Knight, M. & Brownell, N. (2010) "*How Does Smart Grid Impact the Natural Monopoly Paradigm of Electricity Supply?*" Part I. Grid-Interop Forum 2010
20. Borenstein, S., & Bushnell, J. (2000). *Electricity restructuring: deregulation or reregulation*. Regulation, 23, 46.
21. Warwick, W. M. (2002). *A primer on electric utilities, deregulation, and restructuring of US electricity markets* (No. PNNL-13906). Pacific Northwest National Laboratory (PNNL), Richland, WA (US).
22. Abhyankar, A. R., & Khaparde, S. A. (2013). *Introduction to deregulation in power industry*. Report by Indian Institute of Technology, Mumbai.
23. Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations https://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/BlackoutFinal-Web.pdf
24. Sun, W., Liu, C. C., & Liu, S. (2011, July). *Black start capability assessment in power system restoration*. In 2011 IEEE Power and Energy Society General Meeting (pp. 1-7). IEEE.
25. Wei, M., & Chen, Z. (2012, July*). Reliability analysis of cyber*

security in an electrical power system associated WAN. In 2012 IEEE Power and Energy Society General Meeting (pp. 1-6). IEEE.
26. Zhang, Y., Wang, L., Xiang, Y., & Ten, C. W. (2015). *Power system reliability evaluation with SCADA cybersecurity considerations*. IEEE Transactions on Smart Grid, 6(4), 1707-1721.
27. Kaster, P., & Sen, P. K. (2015, April). *Cyber Security and Rural Electric Power Systems.* In Rural Electric Power Conference (REPC), 2015 IEEE (pp. 49-54). IEEE.
28. Künneke, R. W. (1999). Electricity networks: how 'natural' is the monopoly? *Utilities Policy*, *8*(2), 99-108.
29. Pechman, C. (2012). *Regulating Power: The Economics of Electricity in the Information Age: The Economics of Electricity in the Information Age* (Vol. 15). Springer Science & Business Media.
30. Federal Power Commission. (1967). Prevention of Power Failures: An Analysis and Recommendations Pertaining to the Northeast Failure and the Reliability of US Power Systems; a Report to the President. *Volume I, Federal Power Commission*.
31. Federal Power Commission. (1967). Prevention of Power Failure Volume II: Advisory Committee Report, Reliability of Electric Bulk Power Supply. *Washington DC, June*.
32. Lazar, J. (2016). *Electricity Regulation in the US: A Guide. Second Edition.* Montpelier, VT: The Regulatory Assistance Project. Retrieved from http://www.raponline.org/knowledge-center/electricityregulation-in-the-us-a-guide-2
33. North American Electric Reliability Corporation – NERC (2014). Bulk Electric System Definition Reference Document Version 2.
34. North American Electric Reliability Corporation – NERC (2013). Standard Processes Manuel. Version 3.
35. North American Electric Reliability Corporation – NERC (2014). Improving Coordinated Operations Across The Electric Reliability Organization (ERO) Enterprise.
36. North American Electric Reliability Corporation – NERC. Reliability and Market Interface Principles.
37. North American Electric Reliability Corporation – NERC (2016). Glossary of Terms Used in NERC Reliability Standards.
38. Preventing Blackouts: Building a Smarter Power Grid. (2008, August. 13). Retrieved from: https://www.scientificamerican.com/article/preventing-blackouts-power-grid/#
39. Is the U.S. Grid Better Prepared to Prevent a Repeat of the 2003 Blackout? (2013, August 13). Retrieved from:
40. North American Electric Reliability Corporation – NERC. Integrated Bulk Power System Risk Assessment Concepts.
41. Kundur, P., Paserba, J., Ajjarapu, V., Andersson, G., Bose, A., Canizares, C., & Van Cutsem, T. (2004). Definition and classification of power system stability IEEE/CIGRE joint task force

on stability terms and definitions. *IEEE transactions on Power Systems*, *19*(3), 1387-1401.
42. Peak Reliability (2016). System Operating Limits Methodology for the Operations Horizon Rev. 7.1
43. California ISO (2015). System Operating Limits (SOL) Methodology for the Planning Horizon Version 3.1
44. WEQ Business Practice Standards. WEQ-004 Coordinate Interchange.
45. Muller, N., Irisarri, G., Medina, J., Gonzalez-Perez, C., Yassin, M., Latimer, J., & Mokhtari, S. (2009, March). NERC IDC: Managing congestion in the North American Eastern Interconnection. In *Power Systems Conference and Exposition, 2009. PSCE'09. IEEE/PES* (pp. 1-8). IEEE.
46. Xia, F., & Meliopoulos, A. S. (1996). A methodology for probabilistic simultaneous transfer capability analysis. *IEEE Transactions on Power systems*, *11*(3), 1269-1278.
47. Ou, Y., & Singh, C. (2002). Assessment of available transfer capability and margins. *IEEE Transactions on Power Systems*, *17*(2), 463-468.
48. dos Santos, M. J., Pereira, J. L. R., De Oliveira, E. J., & da Silva, I. C. (2004). A new approach for area interchange control modeling. *IEEE Transactions on Power Systems*, *19*(3), 1271-1276.
49. Pan, X., & Xu, G. (2005). Available transfer capability calculation considering voltage stability margin. *Electric power systems research*, *76*(1), 52-57.
50. Historic Nuclear Disasters. (2016, August. 13). Retrieved from: https://sites.suffolk.edu/cvasquez/2016/03/23/historic-nuclear-disasters/
51. Mapping the Post-Fukushima World. (2011). Retrieved from: http://spectrum.ieee.org/static/fukushima-and-the-future-of-nuclear-power
52. North American Electric Reliability Corporation – NERC (2010). Security Guideline for the Electricity Sector: Identifying Critical Cyber Assets.
53. McMillin, B. (2009, March). Complexities of information security in cyber-physical power systems. In *Power Systems Conference and Exposition, 2009. PSCE'09. IEEE/PES* (pp. 1-2). IEEE.
54. Wei, M., & Chen, Z. (2012, July). Reliability analysis of cyber security in an electrical power system associated WAN. In Power and Energy Society General Meeting, 2012 IEEE (pp. 1-6). IEEE.
55. Kaster, P., & Sen, P. K. (2015, April). Cyber Security and Rural Electric Power Systems. In Rural Electric Power Conference (REPC), 2015 IEEE (pp. 49-54). IEEE.
56. McMillin, B. (2009, March). Complexities of information security in cyber-physical power systems. In Power Systems Conference and Exposition, 2009. PSCE'09. IEEE/PES (pp. 1-2). IEEE.

57. Pietre-Cambacédes, L., Tritschler, M., & Ericsson, G. N. (2011). Cybersecurity myths on power control systems: 21 misconceptions and false beliefs. *IEEE Transactions on Power Delivery*, *26*(1), 161-172.
58. Tatar, U., Bahsi, H., & Gheorghe, A. (2016, June). Impact assessment of cyberattacks: A quantification study on power generation systems. In *System of Systems Engineering Conference (SoSE), 2016 11th* (pp. 1-6). IEEE.
59. Fernandez, J. D., & Fernandez, A. E. (2005). SCADA systems: vulnerabilities and remediation. *Journal of Computing Sciences in Colleges*, *20*(4), 160-168.
60. Chalamasetty, G. K., Mandal, P., & Tseng, T. L. (2016, March). Secure SCADA communication network for detecting and preventing cyber-attacks on power systems. In *Power Systems Conference (PSC), 2016 Clemson University* (pp. 1-7). IEEE.
61. NORDEL (2007). Grid Disturbance and Fault Statistics.
62. Kjolle, G. H., Gjerde, O., Hjartsjo, B. T., Engen, H., Haarla, L., Koivisto, L., & Lindblad, P. (2006, June). Protection System Faults--a Comparative Review of Fault Statistics. In *Probabilistic Methods Applied to Power Systems, 2006. PMAPS 2006. International Conference on* (pp. 1-7). IEEE.
63. Bian, J. J., Slone, A. D., & Tatro, P. J. (2014, July). Protection System Misoperation Analysis. In *PES General Meeting| Conference & Exposition, 2014 IEEE* (pp. 1-5). IEEE.
64. North American Electric Reliability Corporation – NERC (2010). Reliability Fundamentals of System Protection.
65. North American Electric Reliability Corporation – NERC (2013). Misoperations Report. Prepared by: Protection System Misoperations Task Force
66. North American Electric Reliability Corporation – NERC (2012). Special Protection Systems (SPS) / Remedial Action Schemes (RAS): Assessment of Definition, Regional Practices, and Application of Related Standards.
67. Transpower (2010). Automatic Under-Frequency Load Shedding (AUFLS) Technical Report.
68.

Grading

Modules 1 to 7 Assessments each 10%
Final Exam 30%
(A scale will be applied to total grades at the end of the semester as opposed to scaling each individual assignment or grade.)

Grading scale:

A: 100 to 85
B: Below 85 and greater or equal than 75
C: Below 75 and greater or equal than 55

D Below 55 and greater or equal than 50

Exams Each Module will be evaluated with a specific assessment that will be described in the Calendar sheet (See Excel file attached).
A final evaluation will be done during the last day of the course (24 hours) in relation with an analysis of a hypothetic case of penalty. The case will be send via email and it must be returned before a 24 hours' period.

Catalog Description This course will introduce students to the development of regulations of the electric power system. The ultimate goal of electricity regulation is to ensure the reliability of the Bulk Electric System (BES) by means of implementing laws with a socioeconomic outlook. This course will address questions of historical context and economics, general electric power regulations, key players and authorities involved in regulation as well as key current events especially related to some specific NERC standards such as the ones related to Critical Infrastructure Protection (Cybersecurity) and Protection and Control (System misoperation). Real-world scenarios and problem-solving will constitute and major component of the learning activities in the course. By the end of the course, the student will be able to discuss and plan for new electricity regulation development based on historical, economic, and governmental precedents.

Specific Goals To provide students with a basic knowledge of electric power regulation that allow them to face and understand properly how to interpret a regulatory standard and analyze different scenarios in order to take decisions. From this course both graduate and undergraduate students are expected to:

- Identify stakeholders, regulatory agencies, and other entities and their roles in the regulatory process
- Describe the role of industry experts in the development of regulations
- Defend the importance of electrical power regulation
- Properly interpret standards and regulations
- Apply existing standards and regulations to real-world scenarios
- Identify the relationship between basic principles of economics to the development of regulation.

List of Topics (Main Outline)

- Module 1 – Introduction
  - General aspects and framework.
  - Electric Power Systems Review.
  - History of Regulation
  - What does regulation do?
  - Examples of power regulation in the world

- Module 2 – Economics of Regulation
  - Principles of Economics I.
  - Principles of Economics II.
  - Principles of Economics III.
  - Natural monopolies: Electric Power Case

- Module 3 – Legal and Social Issues
  - Legal aspects
  - Regulation and deregulation.
  - Electric power regulation.

- Module 4 – Authorities, Agents and Stakeholders
  - Federal Energy Regulatory Commission - FERC
  - North American Electric Reliability Corporation - NERC
  - Electric Reliability Organizations (ERO)
  - Bulk Electric System (BES) and other Definitions

- Module 5 – What does NERC regulate?
  - Resource and Demand Balancing
  - Communications
  - Emergency Preparedness and Operations
  - Facility Design, Connections and Maintenance
  - Interchange Scheduling and Coordination
  - Interconnection Reliability Operations and Coordination
  - Modeling, Data and Analysis
  - Nuclear
  - Personnel Performance, Training and Qualifications.
  - Transmission Operations
  - Transmission Planning
  - Voltage and Reactive

- Module 6 – Critical Infrastructure Protection - Cybersecurity
  - Supervisory Control and Data Acquisition System (SCADA)
  - Power System Cybersecurity Vulnerabilities
  - NERC Standards

- Module 7 – Protection and Control, Power System Misoperation and Correction
  - Fundamentals of Power System Protection and Control
  - Power System Misoperation and Correction
  - NERC Standards

- Module 8 – Application of Course Materials

Assessment Tentative Dates

The assessment must be send via email before midnight of the following dates

- Module 1 – October 20
- Module 2 – October 27
- Module 3 – November 3
- Module 4 – November 10
- Module 5 and 6 – November 24
- Module 7 – December 1
- Module 8 – December 8
- Final assessment – December 12