GridEd - Basic Power System Course

1. General Information:

This course is provided as introductory course in electric power systems via The Center for Grid Engineering Education (GridEd) as a part of curriculum development under its U.S. DOE award from the Solar Energy Technology Office known as Grid Engineering for Accelerated Renewable Energy Deployment (GEARED) as well as conceptualized and funded in part by Electric Utilities comprising participants in an EPRI supplemental project "Educating Power Engineers for a Future Distribution Grid." (PID: 3002002386)

2. Course Description:

Course Title: Basic Power Systems I and II
Course Materials: Video recording of class lectures, instructor's notes (power point presentations), and problem sets and examples.

3. Purpose:

The creation of a two semester course series with the purpose of providing the fundamentals of electric power systems analysis. The materials present the primary components of an electric power system (generation, transmission, electricity demand) and their interaction. Models are developed and presented that allow analysis of single phase and three phase power systems under steady state operation. The power flow problem and its solution for three phase power systems is presented. Electric power systems are analyzed under faulted conditions using the principles of symmetrical components and fundamental power system dynamics and stability analysis is introduced.

4. Course Goals:

After completing the course sequence, the student should have the tools and practice to analyze and understand balanced single and three-phase power systems under normal and faulted conditions. This college-grade course will prepare engineering students and practicing engineers in the fundamentals of electric power system analysis.

5. Prerequisites:

In following this self-study of electric power systems, it is anticipated that a student will have an engineering background including college calculus II, differential equations, an electromagnetics course, a circuit analysis (Laplace, Fourier transforms, and network equations).

6. Instructional Strategy:

There are two instructional pathways:

A) Free Open-Access Instructional Materials: A sequence of recorded modular lectures, by multiple lecturers, following the syllabus of this course that is outlined below. Lecture videos, power point presentations, appropriate problems and solutions are available on EPRI|U. Reference textbook materials will be identified and are to be purchased separately by the student. The material is intended as a self-taught effort and students are expected to invest, studying on their own, at least the same amount of time invested listening to the recorded classes. The materials are created under Creative Commons Copyright and any person or organization may use these materials for their own purposes.

B) Fee based guidance through instructional material: Organizations seeking qualified instructional support to help guide participants through the material may approach GridEd to schedule appropriate instructional support. *(This does not limit any organization from providing their own instructional support for students working through this material.)*

7. Earning Professional Development Hours:

A letter certification to the student upon completion of the sequence and an exam administered by GridEd will result in 80 professional development hours (PDHs).

8. Textbook and other references:

1. Textbook: Glover, J.D., Overbye T.J and Sarma, M.S. (2016) Power System Analysis and Design. Sixth Edition. Cengage Learning, Stamford, CT, USA.
2. Saadat, H. (2010) Power System Analysis. Third Edition. PSA Publishing.
3. Grainger and Stevenson, Jr. (1994) Power System Analysis. Boston, Maryland: McGraw Hill.

The syllabus outline below tracks the recorded lectures and PowerPoints from professors that participated in GridEd program. The sequence number is the sequential order of following these materials from start to finish. The Record of Track is the reference number on the recorded materials. Each track has a narrative describing basic content and slide count is noted.

University/Professor Legend

- Georgia Institute of Technology – Georgia Tech
  - Prof. Sakis Meliopoulos
- University of North Carolina, Charlotte – UNCC
  - Prof. Badrul Chowdhury
- Clarkson University – Clarkson
  - Prof. Jie Li
  - Prof. Lei Wu
  - Prof. Thomas Ortmeyer
- University of Puerto Rico, Mayaguez – UPRM
  - Prof. Agustin Irizarry Rivera

GridEd - Basic Power System Course Syllabus						
Sequence #	**Record of Track**	**Description**	**Length (mins)**	**Slide Numbers**	**University**	**Professor**
		Fundamentals of Steady State AC Single Phase Circuit Analysis				
1	A1.1	Steady State AC - Time Domain & Phasor Representation	29	1-10	Georgia Tech	S. Meliopoulos
2	A1.2	Development of Impedance & Admittance and Ohm's & Kirchhoff's Law	28	10-20	Georgia Tech	S. Meliopoulos
3	A1.3	Applying Kirchhoff's Law	27	21-30	Georgia Tech	S. Meliopoulos
4	A1.4	Series Circuit Analysis	8	31-34	Georgia Tech	S. Meliopoulos
5	A1.4B	Parallel and Node Voltage Circuit Analysis	27	34-45	Georgia Tech	S. Meliopoulos
6	A1.5	Mesh Current Circuit Analysis, Thevenin Equivalents, & Superposition	30	46-56	Georgia Tech	S. Meliopoulos
7	A1.6	Applications of Thevenin Equivalents, & Superposition Principles	28	56-70	Georgia Tech	S. Meliopoulos
8	A1.7	Thevenin & Norton – Complex Circuits; Real Time Power – Purely Resistive & Inductive Load	31	71-82	Georgia Tech	S. Meliopoulos
9	A1.8	Real Time Power – Purely Capacitive Load, RLC Load, Real & Reactive Power, and Complex Power	41	83-96	Georgia Tech	S. Meliopoulos
10	A1.9	Complex Power, Apparent Power, Power Factor, and Non-Sinusoidal Analysis	35	97-109	Georgia Tech	S. Meliopoulos
		Fundamentals of Steady State Three Phase Power				
11	B1.1	Three Phase Power: Introduction to Principles	27	1-12	UNCC	B. Chowdhury
12	B1.2	Three Phase Power: Solving Basic Problems; Introduction of Complex Power	22	1-13	UNCC	B. Chowdhury
13	B1.3	Three Phase Power: One-line Diagram Equivalents	20	1-10	UNCC	B. Chowdhury
14	B1.4	Three Phase Power: Solving Complicated Problems	22	1-11	UNCC	B. Chowdhury
15	B2.9	Per Unit Representation: Single Phase and Three Phase Systems	23	1-17	UNCC	B. Chowdhury
16	B2.10	Per Unit Representation: Example Problem Solutions	26	1-17	UNCC	B. Chowdhury
		The Power Transformer				
17	B2.1	Introduction to Single Phase Transformers	29	1-20	UNCC	B. Chowdhury
18	B2.11	Single Phase Transformer: Open and Short Circuit Tests	19	1-12	UNCC	B. Chowdhury
19	B2.12	Single Phase Transformers: Other Types as Three Winding, Autotransformers, & Load Tap Changing (LTC)	17	1-16	UNCC	B. Chowdhury
20	B2.2	Single Phase Transformer: Construction, Equivalent Circuit, and the Ideal	28	1-10	UNCC	B. Chowdhury
21	B2.3	Single Phase Transformer: Non-Ideal, Reflecting Impedances, Voltage Regulation, and Typical Problem Statements	27	1-13	UNCC	B. Chowdhury
22	B2.4	Single Phase Transformer: Solving Problems	16	1-10	UNCC	B. Chowdhury
23	B2.5	Three Phase Transformers: Construction, WYE & DELTA Connections	23	1-19	UNCC	B. Chowdhury
24	B2.6	Three Phase Transformers: Key Items to Remember in Solving Problems	10	1-9	UNCC	B. Chowdhury
25	B2.7	Three Phase Transformers: Sample Problem Solutions	19	1-12	UNCC	B. Chowdhury
26	B2.8	Three Phase Transformers: Sample Problems on a Single Core Configuration	14	1-12	UNCC	B. Chowdhury

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#	Record of Track	Description	Length (mins)	Slide Numbers	University	Professor
		The Transmission Line				
27	A3.1	Introduction, Construction, and Basic Magnetics for AC Lines	28	1-11	Georgia Tech	S. Meliopoulos
28	A3.2	Line Inductance, Skin Effect, and Uniform & Non-Uniform Current Distribution	41	12-21	Georgia Tech	S. Meliopoulos
29	A3.3	Two Conductors in Parallel, Multi-Conductor Configurations	31	22-29	Georgia Tech	S. Meliopoulos
30	A3.4	Practical Line Configurations and Sample Problems	30	29-39	Georgia Tech	S. Meliopoulos
31	A3.5	Bundled Conductors, Typical Line Configurations, and Transposition	32	39-49	Georgia Tech	S. Meliopoulos
32	A3.6	Line Parameters (Inductance & Capacitance) for Various Configurations	36	50-64	Georgia Tech	S. Meliopoulos
33	A3.7	Sample Problems and Transmission Line Scenario Analysis	42	64-73	Georgia Tech	S. Meliopoulos
34	A3.8	Single & Three Phase Lines, Using A B C D Parameters	42	74-84	Georgia Tech	S. Meliopoulos
35	A3.9	Examples Analyses of Lines, Sequence Line Models, Pi-Models, and Complex Power for Lines	36	85-99	Georgia Tech	S. Meliopoulos
36	A3.10	Power Transfer: Series Compensation, Increasing Voltage, & Phase Shifters	45	100-110	Georgia Tech	S. Meliopoulos
		Power Flow Analysis and Solutions				
37	C2.1	The Power Flow Problem and the Admittance Formulation	40	1-17	Clarkson	J. Li
38	C2.2	Direct Solution to the Linear Power Flow Equations	32	1-14	Clarkson	J. Li
39	C2.3	Iterative Solution to the Linear Power Flow Equations—Jacobi & Gauss-Seidel	43	1-15	Clarkson	J. Li
40	C2.4	Iterative Solution to the Non-Linear Power Flow Equations	23	1-9	Clarkson	J. Li
41	C2.5	Newton-Raphson Method to Non-Linear Algebraic Equations	37	1-11	Clarkson	J. Li
42	C3.1	Power Flow Solution by Newton Raphson Model – Bus Branch	14	1-9	Clarkson	L. Wu
43	C3.2	Power Flow Solution by Newton Raphson Algorithm – Jacobian Matrix	15	1-18	Clarkson	L. Wu
44	C3.3	Power Flow Solution by Newton Raphson -- Example	27	1-14	Clarkson	L. Wu
45	C3.4	Control of Power Flow	19	1-8	Clarkson	L. Wu
46	C3.5	Sparsity Techniques	19	1-9	Clarkson	L. Wu
47	C3.6	Fast Decoupled Power Flow -- Algorithm	14	1-11	Clarkson	L. Wu
48	C3.7	Fast Decoupled Power Flow - Example	15	1-12	Clarkson	L. Wu
49	C3.8	Fast Decoupled Power Flow – A Further Simplification	13	1-13	Clarkson	L. Wu
50	C3.9	DC Power Flow	13	1-8	Clarkson	L. Wu
51	C4.1	*PowerWorld* Simulator Chapter 6 Exercises – Power Flow Analyses	36	1-4	Clarkson	T. Ortmeyer
		Fault Analysis				
52	C5.1	Series R-L Circuit Fault	33	1-14	Clarkson	T. Ortmeyer
53	C5.2	Synchronous Generator Fault Performance	33	1-12	Clarkson	T. Ortmeyer
54	C5.3	Power System Three Phase Faults	35	1-12	Clarkson	T. Ortmeyer
55	C5.4	Power System Three Phase Fault Calculations	43	1-12	Clarkson	T. Ortmeyer
56	C5.5	Using Zbus for Balanced Fault Calculations	28	1-10	Clarkson	T. Ortmeyer
57	C5.6	Fault Models – *PowerWorld* Fault Analysis	31	1-11	Clarkson	T. Ortmeyer
58	C5.7	Fault Clearing with Circuit Breakers and Fuses	32	1-29	Clarkson	T. Ortmeyer

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Sequence #	**Record of Track**	**Description**	**Length (mins)**	**Slide Numbers**	**University**	**Professor**
		Using Symmetrical Components in Fault Analysis				
59	D01	Definition of Symmetrical Components	15	1-34	UPRM	A. Irizarry
60	D02	Sequence Networks of Impedance Loads	11	1-24	UPRM	A. Irizarry
61	D03	Sequence Network of Series Impedances	12	1-24	UPRM	A. Irizarry
62	D04	Sequence Network of Rotating Machines	14	1-21	UPRM	A. Irizarry
63	D05	Per unit Sequence Models Three Phase Transformers – 2 & 3 Windings	12	1-21	UPRM	A. Irizarry
64	D06	Unsymmetrical Faults – System Representation	13	1-19	UPRM	A. Irizarry
65	D07	Unsymmetrical Faults – Single Line to Ground	8	1-13	UPRM	A. Irizarry
66	D08	Unsymmetrical Faults – Line to Line	9	1-14	UPRM	A. Irizarry
67	D09	Unsymmetrical Faults – Two Lines to Ground	10	1-16	UPRM	A. Irizarry
68	D10	Unsymmetrical Faults – Sequence Bus Impedance Matrices	20	1-30	UPRM	A. Irizarry
		Stability Analysis				
69	D11	Transient Stability – Definition and Stability for What?	23	1-25	UPRM	A. Irizarry
70	D12	Transient Stability – The Swing Equation	14	1-22	UPRM	A. Irizarry
71	D13	Simplified Synchronous Machine Model	19	1-37	UPRM	A. Irizarry
72	D14	Equal Area Criteria	10	1-19	UPRM	A. Irizarry
73	D15	Numerical Solution to the Swing Equation	12	1-34	UPRM	A. Irizarry
74	D16	Stability Analysis of a Multi-Machine using the Classical Model	15	1-25	UPRM	A. Irizarry
75	D17	Real Time Dynamic Security Assessment	7	1-13	UPRM	A. Irizarry