Blackouts: Revival Call for Power Systems Engineering Education

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Content

- Blackout of August 14 ,2003
- Barriers in training Power Engineers
- Integration of newer topics and ideas in teaching Power Systems Engineering
- Systems approach solution in removing the Barriers
- Concluding Remarks

August 14, 2003 Blackouts: 9/12/03 US/Canada Power Outage Task Force

- Events Leading to the Blackout
  - [1] 12:05:44 Conesville 375 MW Unit 5 trips
  - [2] 1:14:04 Greenwood 785 MW Unit 1 trips
  - [3] 1:31:34 Eastlake 597 MW Unit 5 trips
  - [4] 2:02 Stuart-Atlanta 345 kv Line disconnects
- Transmission Lines Disconnect (E-N Ohio)
  - [5] 3:05:41 Harding-Chamberlain 345 kv
  - [6] 3:32:03 Hanna-Juniper 345 kv
  - [7] 3:41:33 Star-South Canton 345 kv

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Sequence of Events Leading to Blackouts

- The three E-N Ohio Trans Lines reduced the MW flow Capacity to North from East Ohio. (All Lines are 345 kv)
- The MW flow over 138 kv lines Increased, the Voltage dropped, and 600 MW disconnected in Northern Ohio

- 3:45:33 – 4:08:58 PM Line Disconnects
- [8] 3:45:33 Canton Central-Tidd 345 kv (345/138 kv Xformer didn't return to service)
- [9] 4:06:03 Sammis-Star 345 kv
- 138 kv lines in Northern Ohio disconnected themeself

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Generation tripping in Michigan

- 4:08:58 to 4:10:27 PM
  - [10] 4:08:58 Galion-Ohio Central-Muskingum 345 kv
  - [11] 4:09:06 East Lima-Fostoria Central 345 kv
  - [12] 4:09:23-4:10:27 Kinder Morgan Rating 500 MW (at 200 MW)
- 4:10:00 to 4:10:38 PM
  - [13-18] More transmission lines disconnect
  - Twenty Generators loaded to 2174 MW tripped off line along Lake Erie
  - Loss of generation increased power flows into Northern Ohio and Eastern Michigan

Possible Causes and Effects of the Blackout

- Apparent Voltage Collapse in Northern Ohio and Eastern Michigan
- Lack of sufficient Reactive Power
- Possible lack of appropriate Balance between Static and Dynamic Reactive Power
- Lack of Remedial Operating Actions: Load shedding, capacitor switching, and dynamic reactive dispatch
- Insufficient Operator Training for dealing with V Collapse
- Installation of insufficient On-line assessment tools
- Transmission of Power close to line Thermal Limits

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Designing and Operating a Complex System

- Design of large scale systems with high levels of nonlinearities, time-scale properties, and interconnection
- There are uncertainties in input (loads and weather)
- For near-future power systems, there will be uncertainty for MW-output Price. (Locational Marginal Pricing)
- Real-time Operation (PJM example)
- Inclusion of Financial Transmission Rights (FTRs) that credits the FTR Holder based on Differences in Day-Ahead Congestion of LMPs
- Need for new tools for Modeling, Simulation, Analysis, Design, and Control (Engineering and Management)

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Barriers in Training Power Engineers

- Does Engineering Education Have Anything to do With Either One? (Richard M. Felder, October 1982)
  - The decline of American Technology
  - Hiring neither engineers nor educators to educate engineers
  - We discourage good teaching and dedicated teachers
  - We are not meeting the needs of our most gifted students
  - We are not fostering the creativity needed to solve society's most pressing technological problems

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Barriers in Training Power Engineers

- “Review of electric power engineering education worldwide” (IEEE, PES Con in Edmonton, 1999)
- “How much does the U.S. rely on immigrant engineers?” (L. Burton and J. Wang, NSF, NSF 99-327, Feb 1999)
- Electric Power Engineering Resources, IEEE PES Educational Resources Subcommittee, IEEE Transactions, 1996, 1994, and 1992
- Shortage of trained engineering personnel: “For decades things have gone downhill” (IEEE Spectrum).
- “The salaries paid to Power Engineers is lower than those of virtually all other electrical engineers”

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Barriers in Training Power Engineers

- Prestige: Student enrollments in PE have steadily declined
- Resources: University programs in PE have been closing
- Electric power industry has been radically reorganizing
- PE employment abroad has enjoyed more prestige and competitive salaries, causing migration and return of PE from US
- The shortage of PE will worsen in the next five years (Mycoff & Associates, Placement firm. IEEE Spectrum)
- Utilities will face a large wave of retirements (retiring baby boomers during the next 10-20 yrs). Public Utilities Forthnightly, June 1, 2003

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Integration of Newer Topics in Training PE

- Application of Fuzzy Logic in Equipment Maintenance
- Application of Artificial Neural Nets in Forecasting
- Application of Genetic Algorithms in Game Theory
- Application of New Technologies (FACTS) in Power Management
- Application of Optimization Techniques in Locational Marginal Pricing
- Management of Large Scale Transmission System Real-Time Transactions
- Application of Parallel Computing in modeling, simulation, analysis, and control of Power Systems
- Alternative Energy Sources

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Applications of Fuzzy Logic in Power Systems

- Contingency Analysis
- Diagnosis/monitoring
- Distribution planning
- Load frequency control
- Generator maintenance
- Generation dispatch
- Load flow computations

- Load forecasting
- Load management
- Reactive power-V. control
- Security assessment
- PS Stabilizers
- Unit commitment

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PS Example 1: Load Tap Changer Diagnosis

- Identify a Methodology for LTC Predictive Maintenance
- Apply the Methodology on a most widely used LTC
- Apply Pattern Recognition Methods to discriminate (distinguish) between different data corresponding to different characteristics of the LTC
- Use the discriminated data to alarm an Operator via SCADA system
- Automatically Dispatch maintenance crew to Preventively repair the LTC

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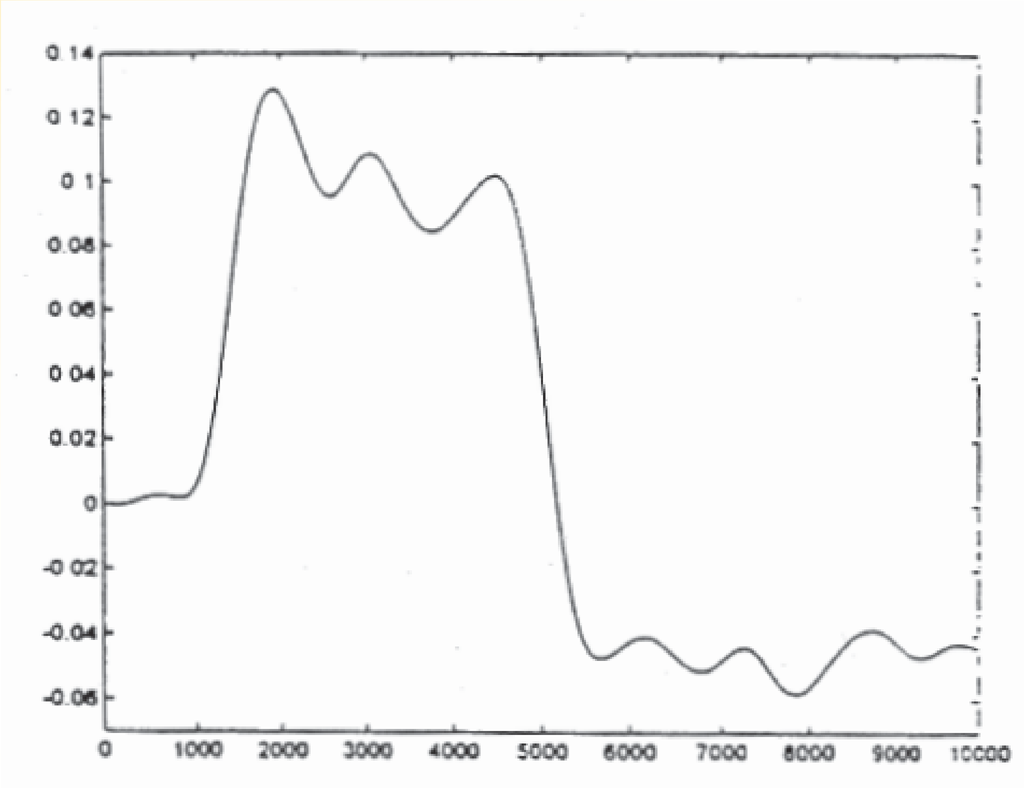
Pattern of Good Contacts



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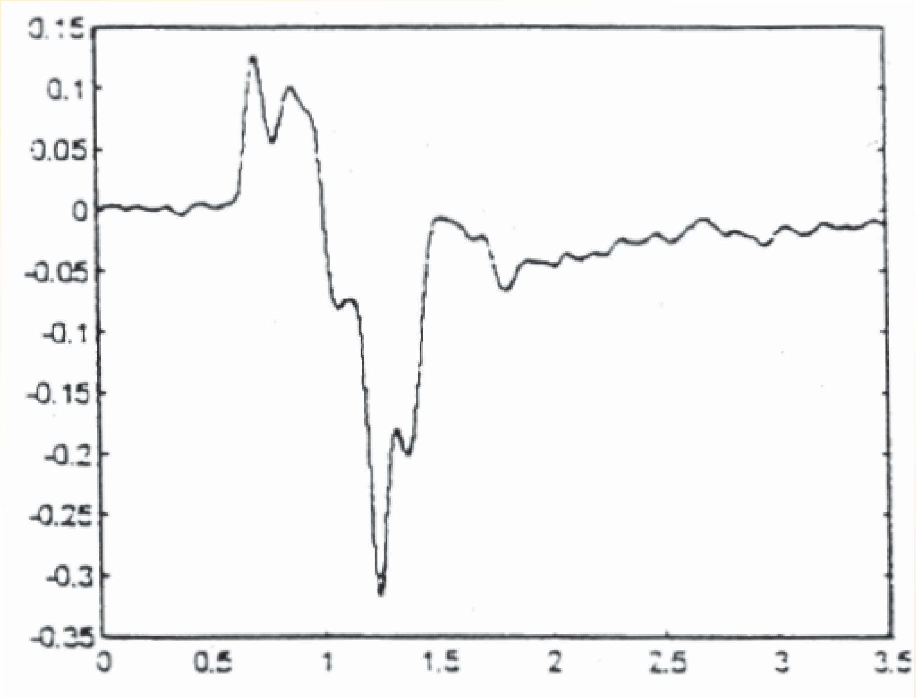
Pattern of Deteriorated Contacts



Pattern of Burned Contact Test [5]
Vertical Axis is voltages in volts
Horizontal axis (x10,000) is samples at 100,000 samples / sec

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LTC Pattern Analysis by HCM and FCM

- Take the LTC data and apply:
  - Hard C-Means for two, three, and four clusters
  - Fuzzy C-Means for two, three, and four clusters
  - Fuzzy C-means for two, three, and four clusters when the data can be clustered in ellipsoids
  - Address the above when the number of clusters is not known a priori
  - Check the Validity of Clusters for all methods applied above.

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Cluster Validity

- Find an objective function for determining "how good" a partition generated by a clustering algorithm is.
- Validity measures:
  - Membership-based validity measures: Measures the Degree of Fuzziness of each Cluster
  - Geometric-based validity measures (extension of the fuzzy C-Means): Measures Compactness and Separation
  - Performance-based validity measures: Measures the Distance between Data and the the Centers

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Artificial Neural Networks

- The conventional forecasting methods are not sufficiently Robust in response to rapid change in weather
- Artificial Neural Nets seem to be promising for Short-Term Load Forecasting (STLF)
- ANN learn from historical data by ADJUSTING the STRENGHTS between input, hidden layer neurons, and the outputs

Practical EXAMPLE 2: Voltage Instability

- 1. Select the Optimum Locations for SCB to improve Voltage Stability margin
- 2. Select the proper size of SCB
- 3. Apply Artificial Intelligence to identify the Optimum Location and Size of SCB

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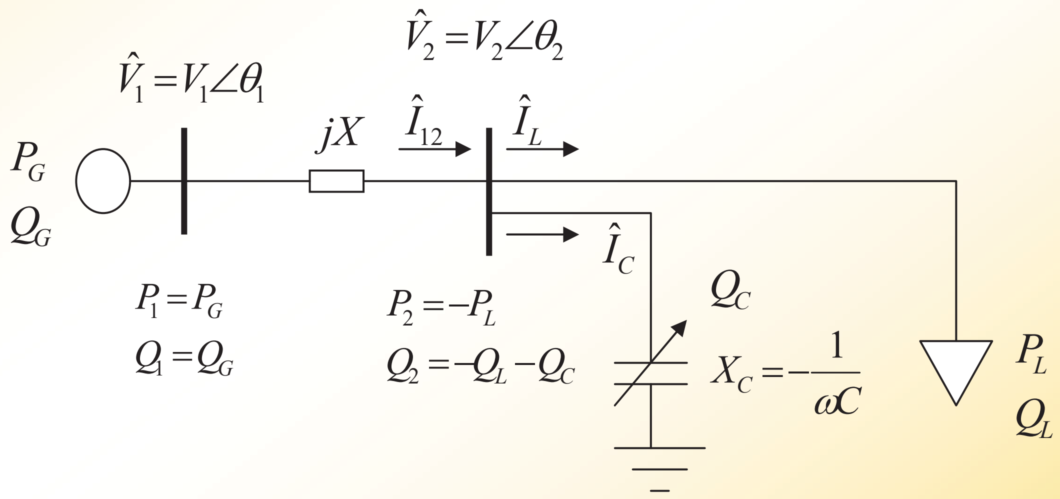
Two-Bus System Voltage Variation VS Load Change



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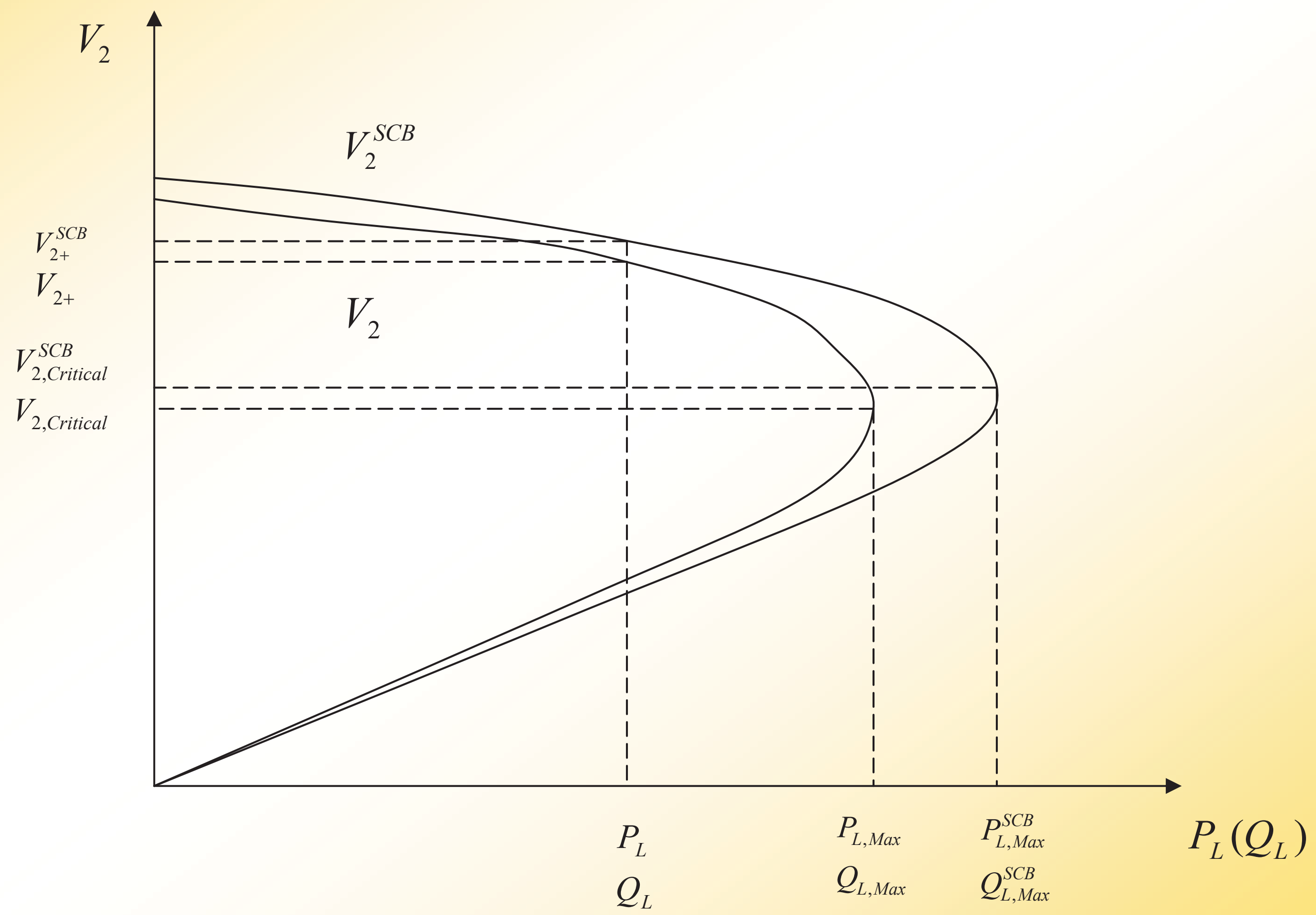
P V Curves as a Function of SCB



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7 Applied ANN Methods

- Multi-Layer Perceptron MLP
- Generalized FeedForward GFF
- Modular Neural Nets MNN
- Jordan/Elman Neural Net JENN
- Principal Component Analysis PCA
- Radial Basis Function RBF
- Self-Organizing Feature Map SOFM

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An investigation of Transient Stability of Power Systems Equipped with FACTS

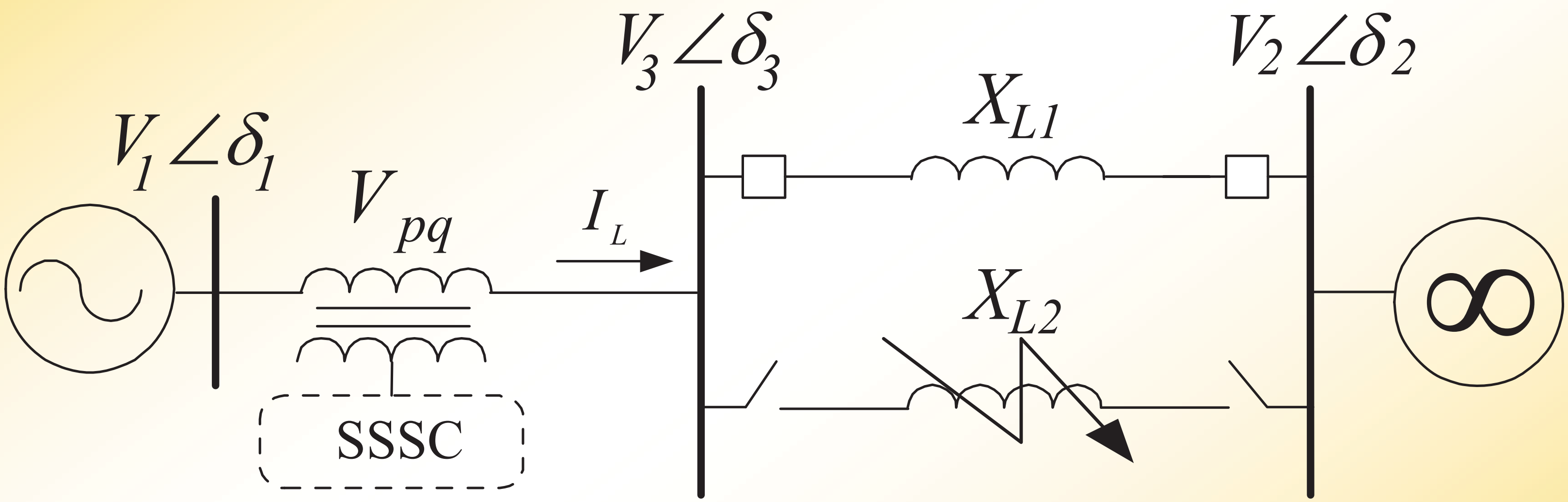

Figure 1

Single line diagram of test power system equipped with SSSC

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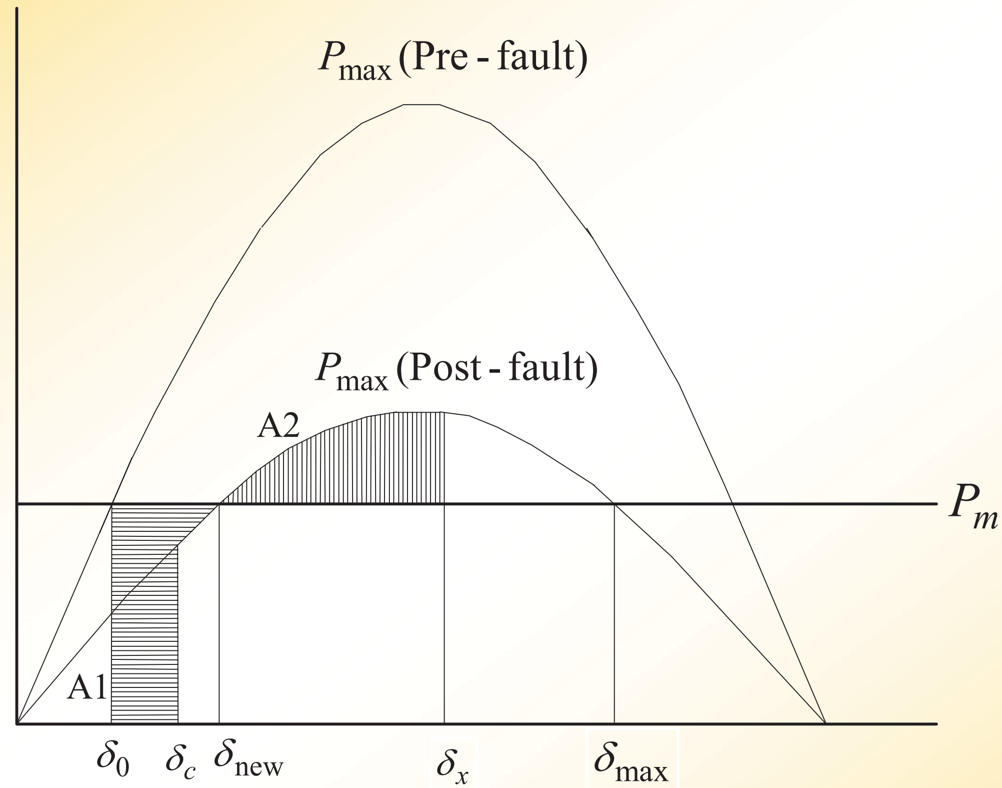

Figure 3

Power-angle characteristics of Test Power System

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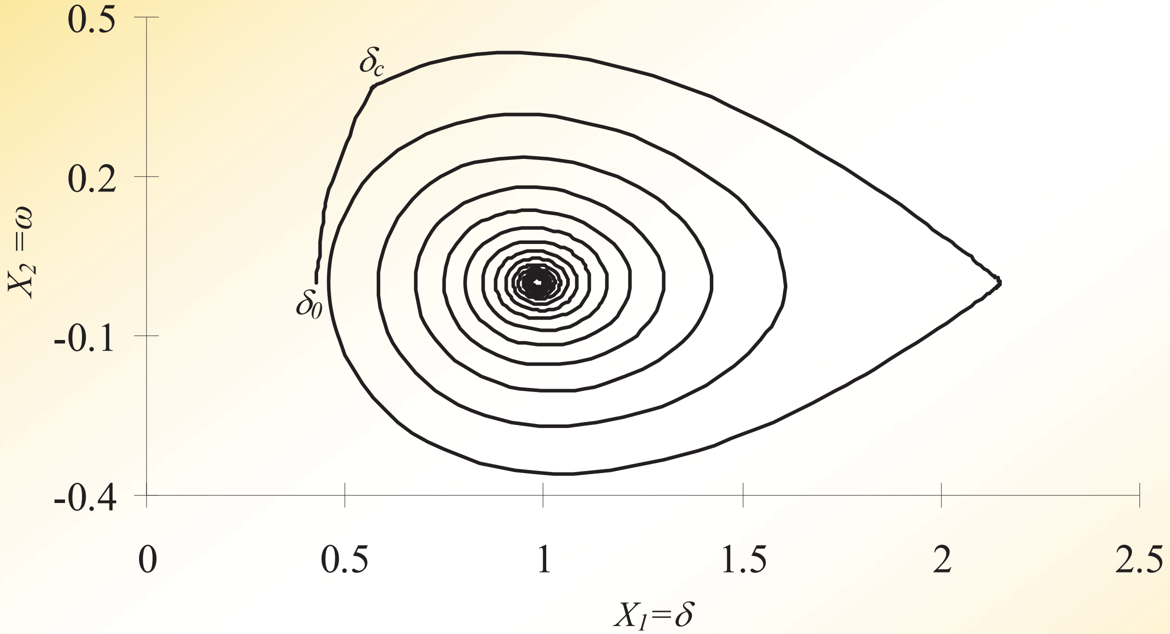

Figure 11

Post-fault variations of δ and ω for Test Power System without SSSC depicting oscillation for *tc* = *tcc*

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Toward Systems Approach Solution to Training Power Engineers Problem

- The “electric system” could no longer be understood by investigating only the properties of its Components
- In addition to “physical components”, the Electric System consists of several non-physical components such as:
  - Government,
  - Academia,
  - Industry,
  - Accreditation Agencies
  - Professional Organizations, and
  - Local and International Communities,
- Interactions between the System’s Components and the System and its surrounding including the experimenters need to be studied

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Toward Systems Approach Solution

- Closer collaboration between Government, University, and Industry needs to be practiced. Research and Educational Centers and Institutes need to be established
- Universities need to value Teaching, Research, and Engineering Practice of the faculty and recognize the faculty's achievement in each of the categories.
- Universities need to hire some faculty who have industrial experience and do not expect these faculty to conduct extensive research.
- Universities need to hire some faculty who are purely Researchers or mainly Teachers

Toward Systems Approach Solution

- Team-Teaching courses that go beyond the traditional departmental and school boundaries
- Establishing Electrical Engineering Program Board of Advisors who have industry experience and are interested in producing Power Engineers
- Integrating year-long undergraduate research in curriculum in general and Power Systems Engineering projects in particular
- Responding to Accreditation Agencies by designing curriculum that has clear Objectives and Outcomes
- Training students who are Flexible, Independent, Creative, and Competent

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Toward Systems Approach Solution

- Using the European model in integrating Academic programs with Industry goals (Norway, Sweden, UK)
- Establishing internship and co-op programs and involving industry representatives in Ph.D. dissertation committees
- Providing options for pursuing entrepreneurship, management, medicine, and/or law in EE undergraduate curriculum
- Increasing industry and government dollar investment in power system engineering Research, Development, and Application

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Concluding Remarks

- Power Systems Blackouts, Energy, Environment, and Economic Crises are ***positive EXTERNAL events*** that can be used to REVIVE Power System Engineering Education
- Although External Events are necessary conditions, they are not Sufficient for the Change. The Sufficient conditions are ***Internal.***
- ***Academia, Industry, and Government need to work together towards achieving the Objective of the WHOLE***