Emerging Technologies in Transmission Networks

Miroslav Begovic
Georgia Institute of Technology

Nature of Transmission Network Disruptions

- Natural Events
- Human errors, hidden failures
- Failure of equipment (aging or neglect)
- Accidental failure (or deliberate destruction) of the monitoring and control infrastructure
- Malicious actions which deliberately seek and exploit system vulnerabilities (not likely, but quite possible)

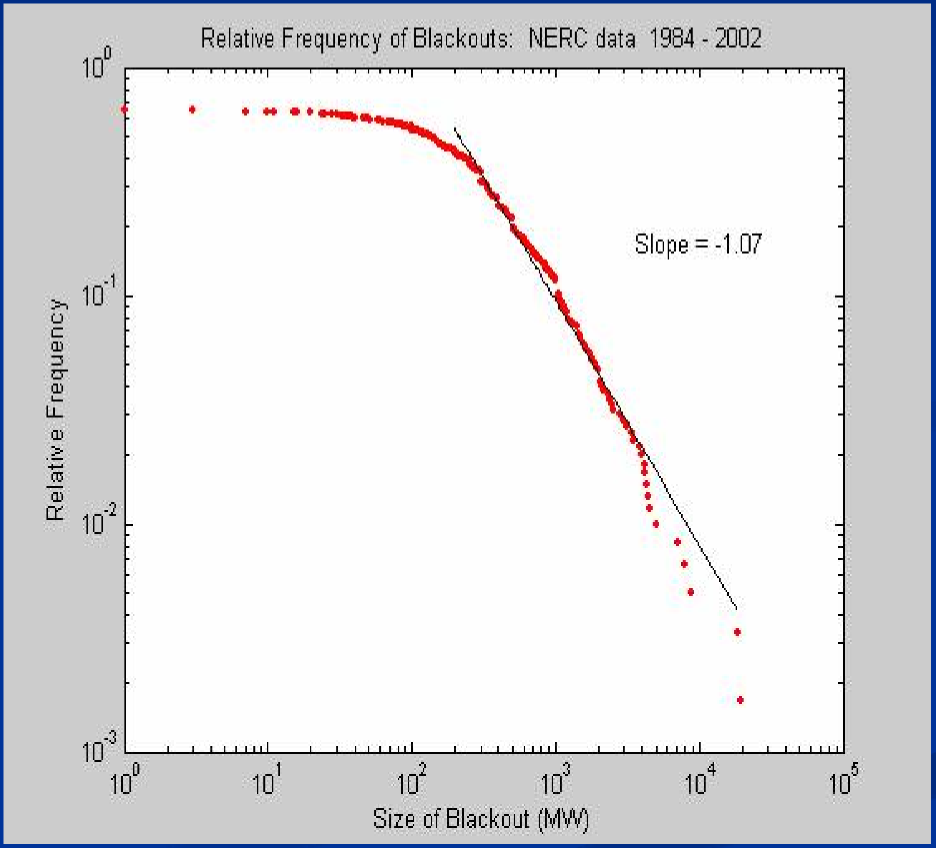
Cost of Failures

- Large amount of data on past failures: about 60 major disturbances per year, averaging 250 MW each
- Estimation of the cost to society is more than statistical analysis of size, frequency, duration and location
- No theoretical basis for estimating the cost of delivery (or non-delivery) of unit of energy
- Circumstances play a significant role; interpretations are highly subjective
- Metric: how much are customers willing to pay for emergency power supply? (According to surveys, 5-40 times the commercial cost of electricity is not uncommon)

Source: "Brittle Power: Energy Strategy for National Security", Amory and Hunter Lovins, 1982

Cost of Failures (cont.)

- Social costs: lost income, life, health, comfort, downstream economic consequences…
- New York 1977 Blackout cost estimates:
  - Riot damage (37 percent)
  - National economic costs (24 percent)
  - Various social and economic costs (39 percent)
  - Total: $310M (7 percent of then national GNP-day)
  - Higher estimates: $100/affected person ($1 Billion)
  - Today's blackouts cost much more



Source: "Brittle Power : Energy Strategy for National Security", Amory and Hunter Lovins, 1982

Assessment of Emerging Technologies for Energy Systems

- Market Infrastructure Analysis
- Performance Indices of the Candidate Technology
- Regulatory Barriers or Obstacles to Introduction
- Stage of Market Introduction

Market Infrastructure

- Potential for Large Scale Production
- Supply Chain Assessment
- Infrastructure Support for Design and Construction
- Ease of Use/Quality Control/Experience
- Support/Training Infrastructure
- Availability of Turnkey Solutions

Source: www.leonardo-energy.org

Performance Indices

- Integration in the Overall System
- Reliability (Dependability) of the Solutions
    - Operational Accuracy
    - MTBF / MTTR
- Economic Indicators (Cost Benefit Analysis)
- Complexity of Use

Source: www.leonardo-energy.org

Example: Industry Experience with SIPS

- Motivation: "*Industry Experience with Special Protection Schemes*" *IEEE/CIGRE Special Report*, P. Anderson, B.K. LeReverend, *IEEE Transactions on Power Systems*, Vol. 11, No. 3, Aug. 1996, pp. 1166-1179

- 2004: System Protection SC of the IEEE PSRC started an initiative to update the industry experience on SPS and SIPS

- Medium: a survey, which would attempt to attract a wide response from the industry worldwide

System Studies Done Prior to Deploying the SIPS

- Planning criteria
- Types of planning studies
- Real-time operational studies
- Protection and control coordination studies
- Coordination with other Protection and Control systems
- Types of protective relaying technology used
- Existence of standards for SIPS applications

Architecture Issues

- **Hardware Description and Outage Detection**
  - Outage detection Method
  - Questions on use of programmable logic controllers
- **Scheme Architecture**
  - Objective: decision making
  - Redundancy needs/implementation - Both telecommunication and hardware
  - Redundancy philosophy
  - Questions on use of the voting schemes
  - Questions about control: event based, or response based
  - Questions on Breaker Failure
  - Performance requirements:
    - Throughput timing: entire scheme
    - Throughput timing of the controller

Measurements and Communication

- **Data acquisition and related tools**
  - Measured Quantities
  - Time synchronization requirements
  - Use of SMART SIPS / Intelligent SIPS
  - Blocking (by the scheme) of any automatic reclosing
  - Restoration Issues and Planned Mechanisms

- **Communication, Networking, and Data Exchange**
  - Architecture of the communication
  - Communication medium and protocols
  - Information about shared communication (with other applications)
  - Impact of communication failure on reliability index and availability
  - Cyber security implementation and protection features
  - Operability of the scheme with a communication channel failure
  - Control Area Visibility

SIPS: Implementation

- **Arming methodology**

- **Implementation issues**
  - Multi-functionality of the scheme
  - Design: Centralized or Distributed Architecture
  - Availability of event reconstruction or system playback capability
  - Description of event records and their availability within the organization

SIPS: Testing, Reliability and Cost

- **Testing Considerations**
  - Testing procedures
  - Periodicity of testing
  - Maintenance issues
- **Cost Considerations**
  - Approximate cost
  - System information (infrastructure)

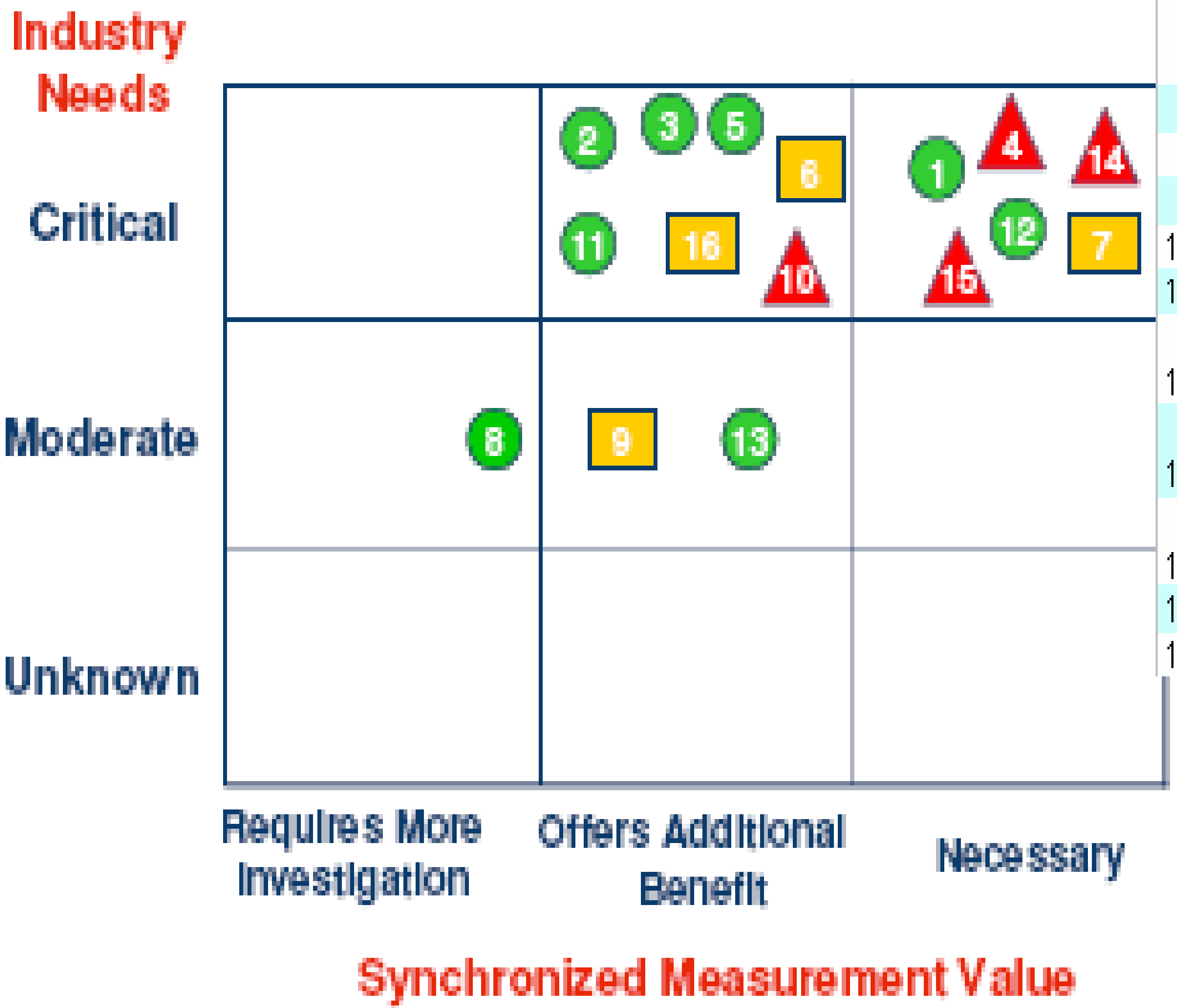
SIPS: Summary

- Advanced analytical techniques are becoming available for various types of SIPS applications
- Traditional scheme requirements evolve towards SIPS
- Fast changing operating conditions in power systems and quickly changing enabling technologies for power system control and protection
- Industry is changing quickly and adapting to the conditions imposed by new business practices
- Survey: should provide valuable information to industry practitioners and researchers alike about the trends and experiences in system protection

Sample of ET in TD

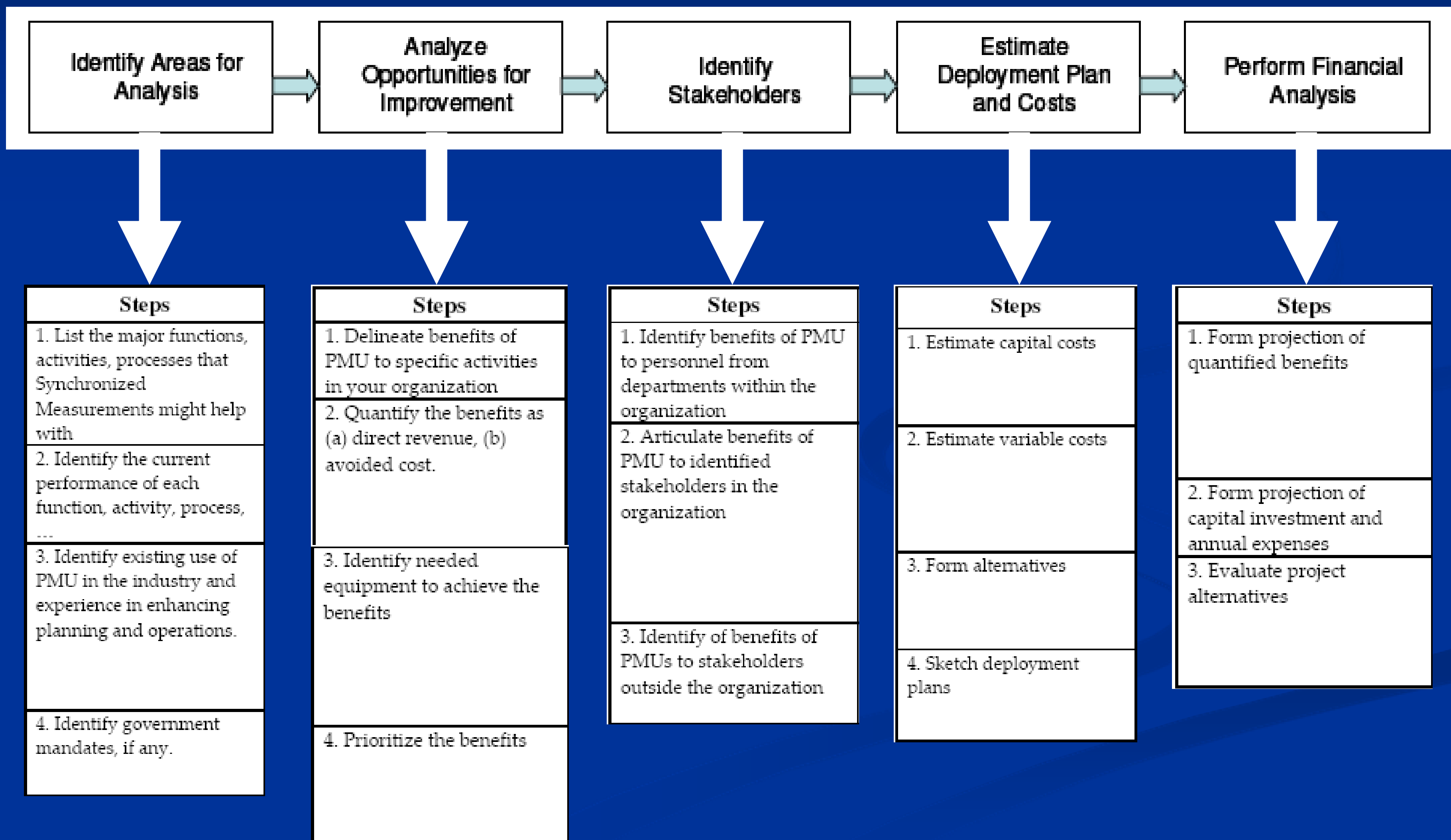
- High-Speed Monitoring and Systemwide Communication and Control
- System Integrity Protection Schemes (SIPS)
- Advanced Algorithms and IED for Control
- Power Electronics (FACTS, smart sensors)
- Custom Power Systems/Devices
- Sensor Networks for Diagnostics
- High Temperature Superconductivity (HTS)

Industry Needs vs. Synchronized Measurement Values



1	Angle/Freq. Monitoring
2	Voltage Stability Monitoring
3	Thermal Overload Monitoring
4	Real-Time Control
5	State Estimation (Improvement)
6	State Estimation (boundary conditions)
7	State Measurement (linear)
8	WA stabilization (WA-PSS)
9	Adaptive Protection
10	Congestion Management
11	Power-system Restoration
12	Post-mortem Analysis (incl. Compliance Monitoring)
13	Model Benchmarking; Parameter Estimation (Steady-State)
14	Model Benchmarking; Parameter Estimation (Dynamic)
15	Planned Power-System Separation
16	DG/IPP applications

Economic Analysis Process



Control Technologies

- Statistical Learning Theory
- Data Mining for Dynamical Systems
- Biologically Inspired Control Architectures
- Integration of Control and System Health Mgt.
- Nonlinear Control Theory
- Modeling of Economic (Sub)systems
- Complex Adaptive Systems

Problem Environment

- High dimensionality, abundance of data
- Issues: modeling accuracy, measurement errors, sensing and actuation delays
- Problem solutions may be intractable in terms of their scaling properties (multi-scale decompositions are a logical option)
- Objective measures of success (accuracy, speed, stability) require substantial computational complexity

Conclusions

- Activities of ETCC and PES Technical Committees in identifying and assessing emerging technologies are important
- IEEE can greatly support/facilitate/provide feedback/enable standards introduction in support of emerging technologies
- Operational reality of transmission networks requires (or will soon require) support of a number of emerging (or soon to be emerging) technologies