

CHALLENGES TO A SECURE ELECTRIC POWER GRID

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- Declining Reliability
- Absence of Need Models, Data, Analyses, Design and Operational Rules
- Immaturity of NERC Equipment Configuration Requirements
- Need for Study Before Restructuring Proceeds Further

RELIABILITY AND AVAILABILITY TRENDS

- Reliability*: The Probability of Successful Mission Completion.
- Availability*: The Probability of Success at Time, t , in the Future.
- Regional Scale Grid System Collapses are Becoming More Frequent (e.g., August 14, 2003, northeast U.S and lower Canada; midwest, 1998; west, 1996; Italy, 2003; London, 2003)
- Deregulation is Resulting in Much Larger Flow of Power Over Long Distances, as “Merchant” Power Plants Contract to Serve Distance (usually industrial loads)
- Grid Components and States are Operating Over Much Broader Ranges and for Longer Times Than Designed For
- Other Power Delivery Aspects (e.g., reactive power) are Excluded From Markets, and are Provided More Poorly

CATEGORIES OF FAILURES – MOST ARE DEPENDENT

- Independent Failures – The Component Failure Frequency is Independent of the States of Other Components
- Dependent Failures – The Component Failure Frequency Changes as the States of Other Components Change
 - A change in the state of another component causes a change in the state of a component
 - A shared cause affects the states of several components simultaneously
 - When components become heavily loaded, failure frequencies increase
 - State-dependent failure frequencies are poorly quantified

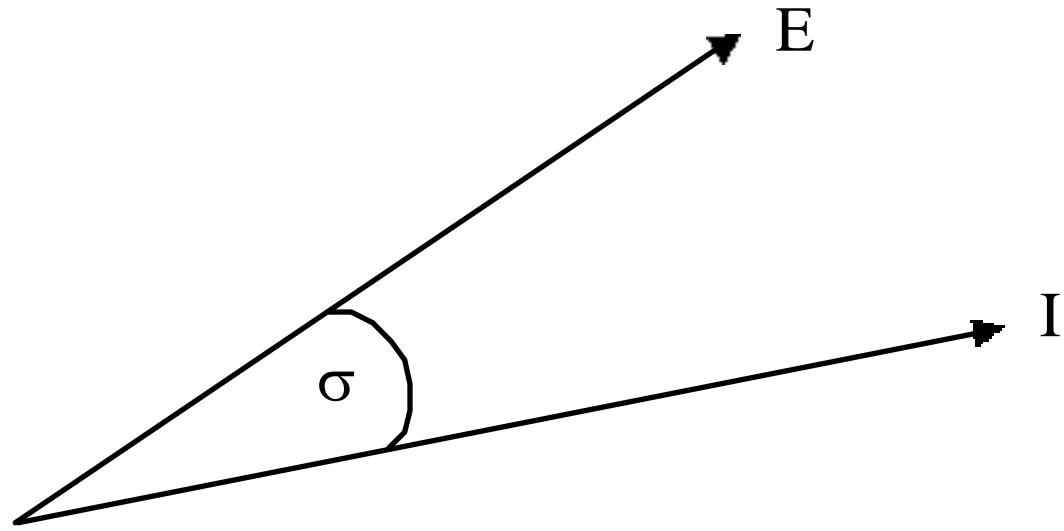
CONTROL OF RELIABILITY AND AVAILABILITY

- Models for Forecasting Reliability and Availability for Large, Complex, Heavily-Loaded Grids Have Not Been Developed
- Consequently, the Operational Constraints Needed to Maintain Such Systems Within Reliable Domains Have Not Been Developed
- The Natural Scale Limits of Such Grids Remain Unformulated
 - Is it necessary to utilize a weakly-connected cellular grid architecture?
 - Can continental-scale interactive architectures be formulated?
 - What are the requirements for reactive power generation for such grids?

FUTURE NEEDS

- Replace NERC's Configuration-Based Rules by Availability and Reliability Standards
- Develop the Tools Needed to Permit this Replacement
- Use These Tools to Formulate
 - Stable architectures
 - Risk-based constraints
 - Design rules
 - Operational rules
- Put Restructuring On-Hold Until Progress Has Been Achieved

REAL AND REACTIVE POWER



$$\text{Real Power} = |E| \cdot |I| \underbrace{\cos \sigma}_{\text{power factor}}$$

$$\text{Reactive Power} = |E| \cdot |I| \sin \sigma$$

- Grid Stability Requires Spatially Uniform E
- Change σ Permits E to Stay Constant While Changing I