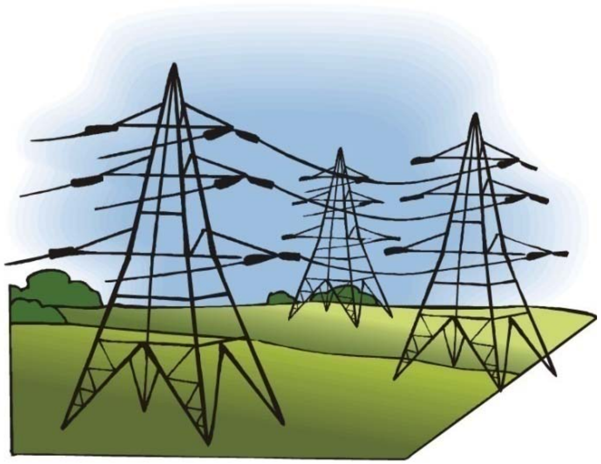

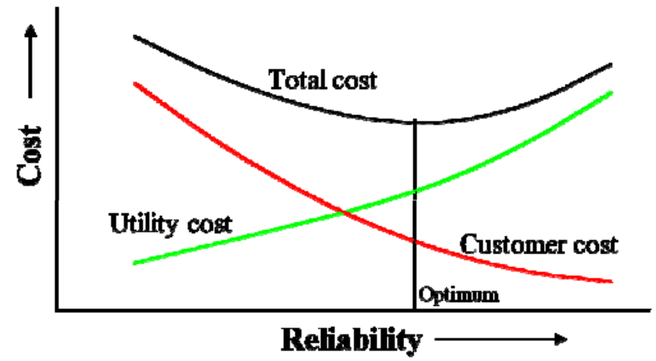

Bulk Electric System Reliability Simulation and Application

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Outline

- Introduction
- Planning and Operating Criteria
- Power System Functional Zones
- Power System Reliability
- System Well-Being Analysis
- System Planning Applications
- Concluding Remarks

Introduction

Definition of "<u>Bulk Electric System</u>"

"The bulk electric system is a term commonly applied to that portion of an electric utility system, which encompasses the electrical generation resources, transmission lines, interconnections with neighboring systems, and associated equipment, generally operated at voltages of 100 kV or higher."

(defined by North American Electricity Reliability Corporation, NERC)

Introduction

- Maintaining the reliability of the bulk electric system relies on the complicated and technically sophisticated activities.
- In addition, the bulk electric system has recently been facing with even more challenges in coping with "<u>greater uncertainties</u>" while maintaining the bulk electric system reliability at a high level to satisfy customers' expectation.

Introduction

Bulk electric system in a restructured and open access environment introduces "**greater uncertainties**" caused by:

- Unbundled Electric System: *many entities with diverse objectives and less coordination*
- Market Conditions & Transmission Congestions
- Asset Management: *aging, end-of-life, maintenance, etc.*
- Government Policies: *clean energy target, feed-in tariff, etc.*
- Intermittent Renewable Energies: *wind, solar, wave, etc.*
- Distributed generation
- Load Behaviors: *load forecast, DSM, electric vehicles (charge & discharge), etc.*

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Planning and Operating Criteria

- The uncertainty in future system conditions is a problem for the long-term planning processes, "planning uncertainty", as well as for short-term operational decision making, "operational uncertainty".
- The planning process should result in a system that is adequate and safe under various operational conditions.
- Bulk electric system planning and operating criteria have been designed and used to cope with uncertainties. These criteria can be generally defined as "Deterministic" and "Probabilistic" criteria.

Planning and Operating Criteria

Deterministic Criteria

- Straightforward, easy to implement, no new computing tool
- Consequence analysis only, no probability
- The “worst case” study but the worst case may be missed.
- Not dealing with multiple outages
- Hard Criteria

Probabilistic Criteria

- Need of more knowledge, more efforts in studies, and new computing tools
- Both consequence and probability
- All possible system states and load levels which can occur.
- Dealing with multiple outages
- Soft Criteria

Planning and Operating Criteria

Deterministic Criteria

- N-1 (loss of one equipment)
- % reserve or margin

Probabilistic Criteria

- Total Cost = Investment Cost + Operation Cost + Unreliability Cost
- Specified system risk index target (e.g. SAIDI, SAIFI, SI, etc.)

Objective: to satisfy the customer load requirement as economically as possible with a reasonable assurance of continuity and quality.

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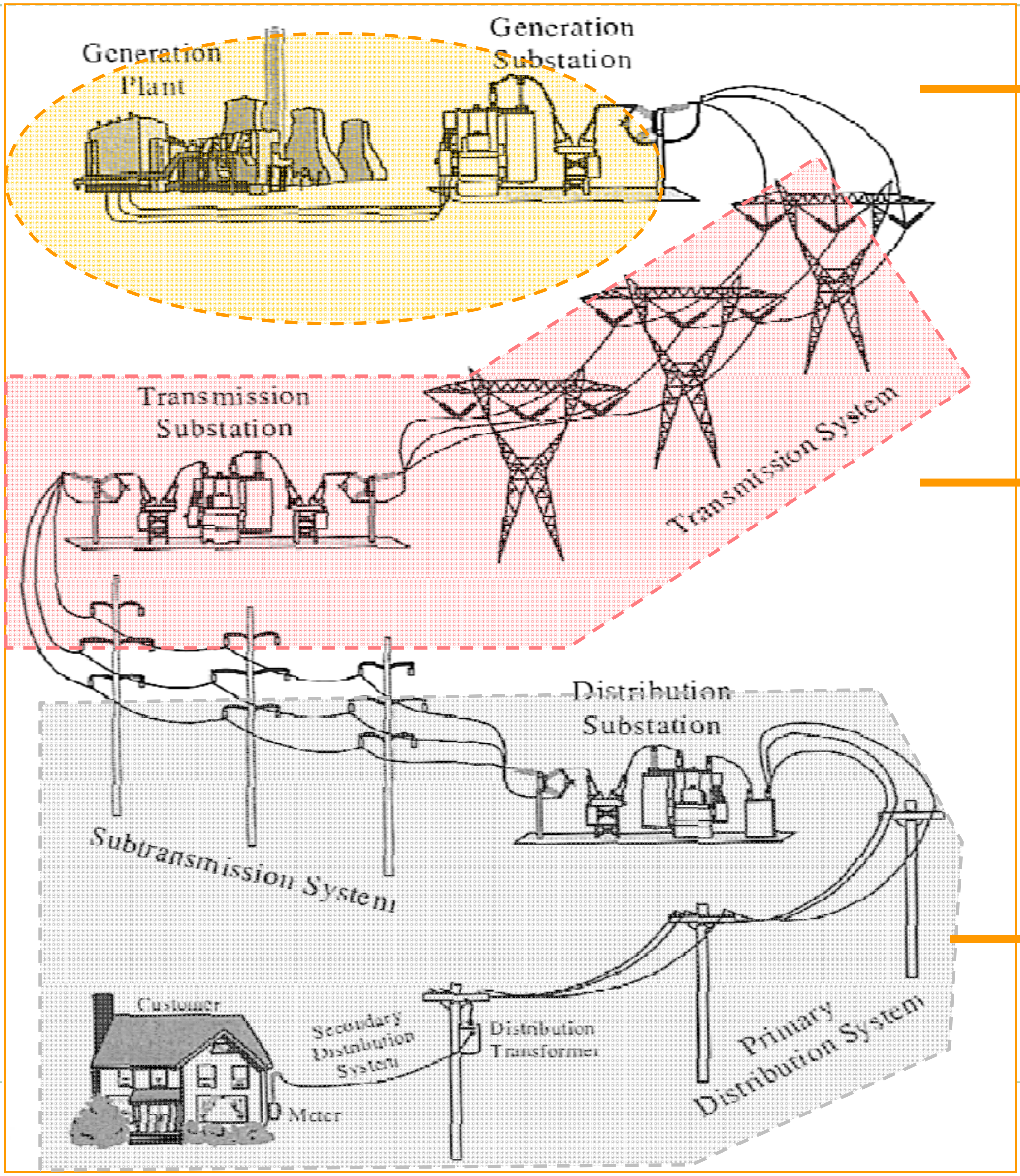
Power System Functional Zones

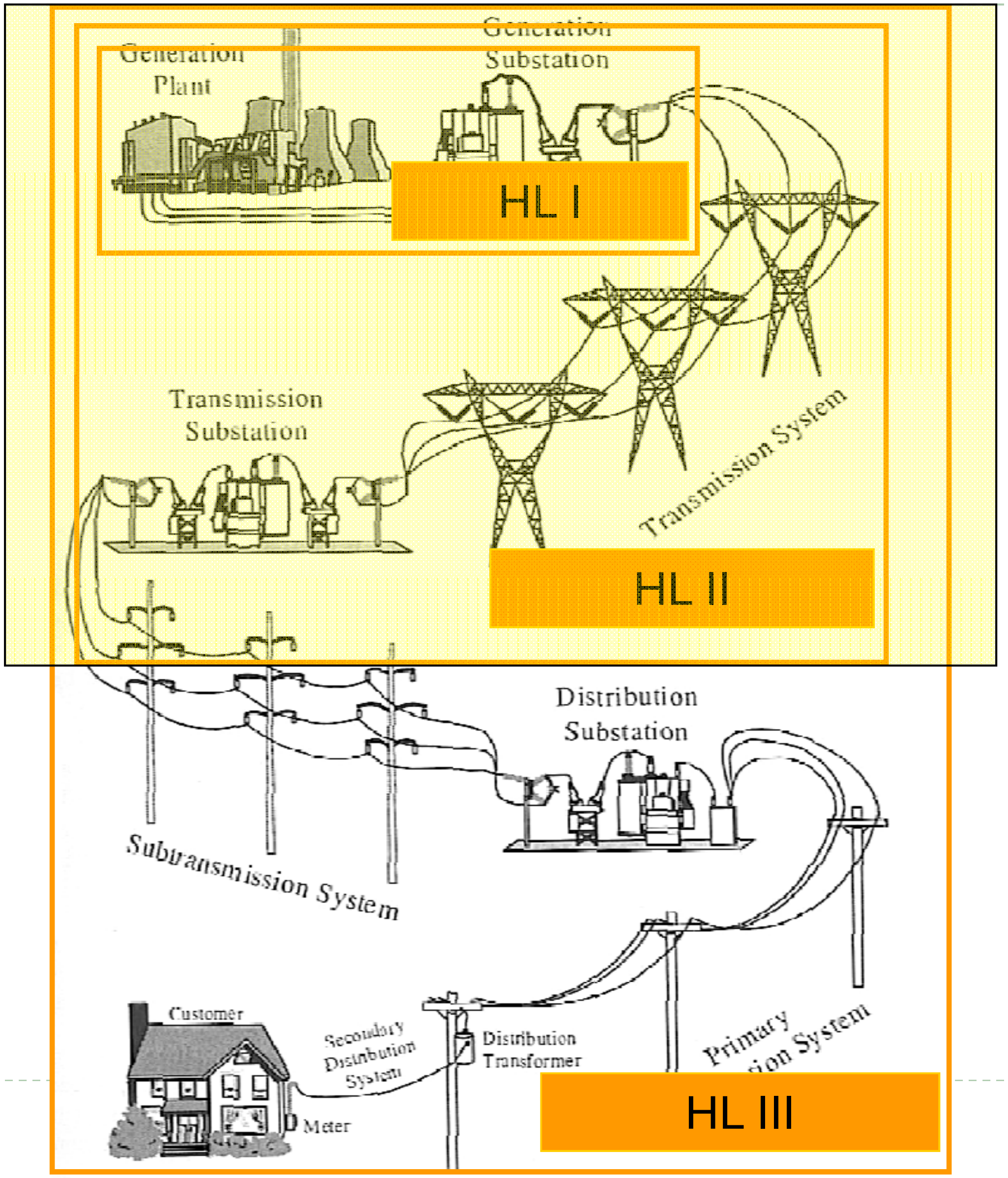


Generation system

Transmission system

Distribution system

Power System Functional Zones



“<u>Hierarchical Levels</u>”
from power system reliability evaluation context

HL-II Reliability Evaluation can be alternatively called:

- Bulk Electric System
- Bulk Power System
- Composite Generation and Transmission System
- Composite System

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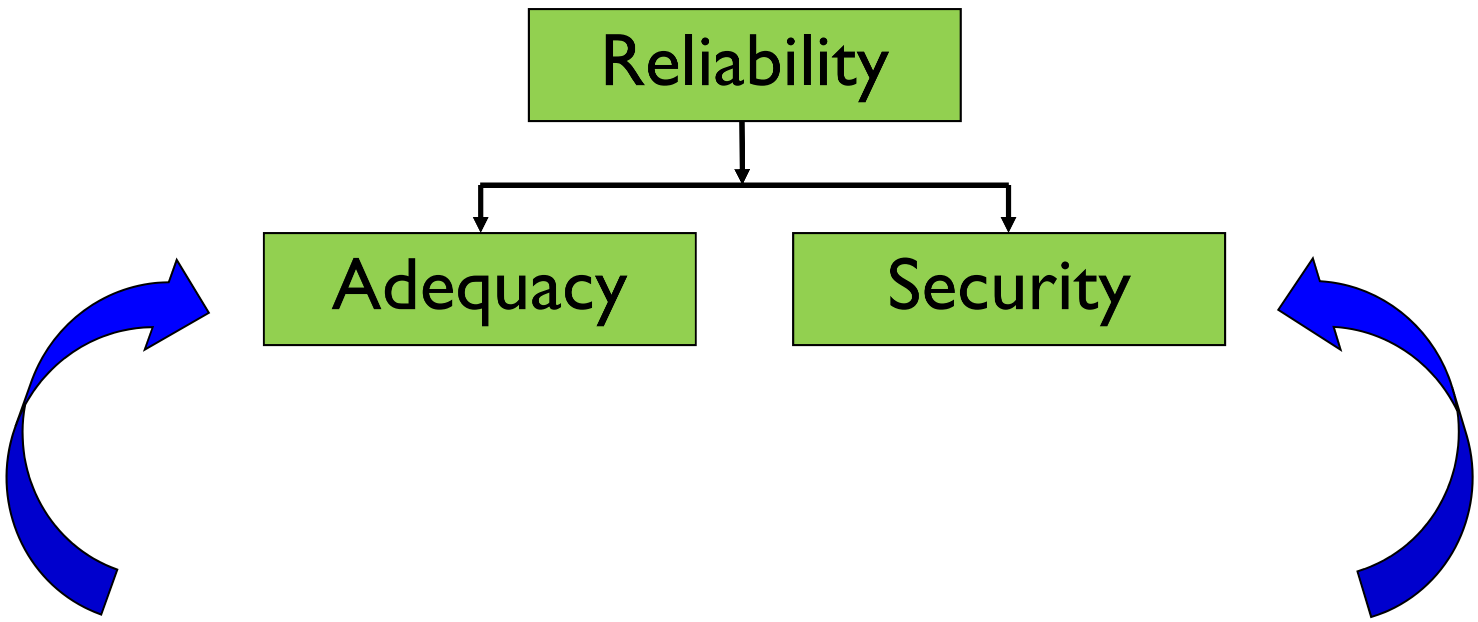
Power System Reliability

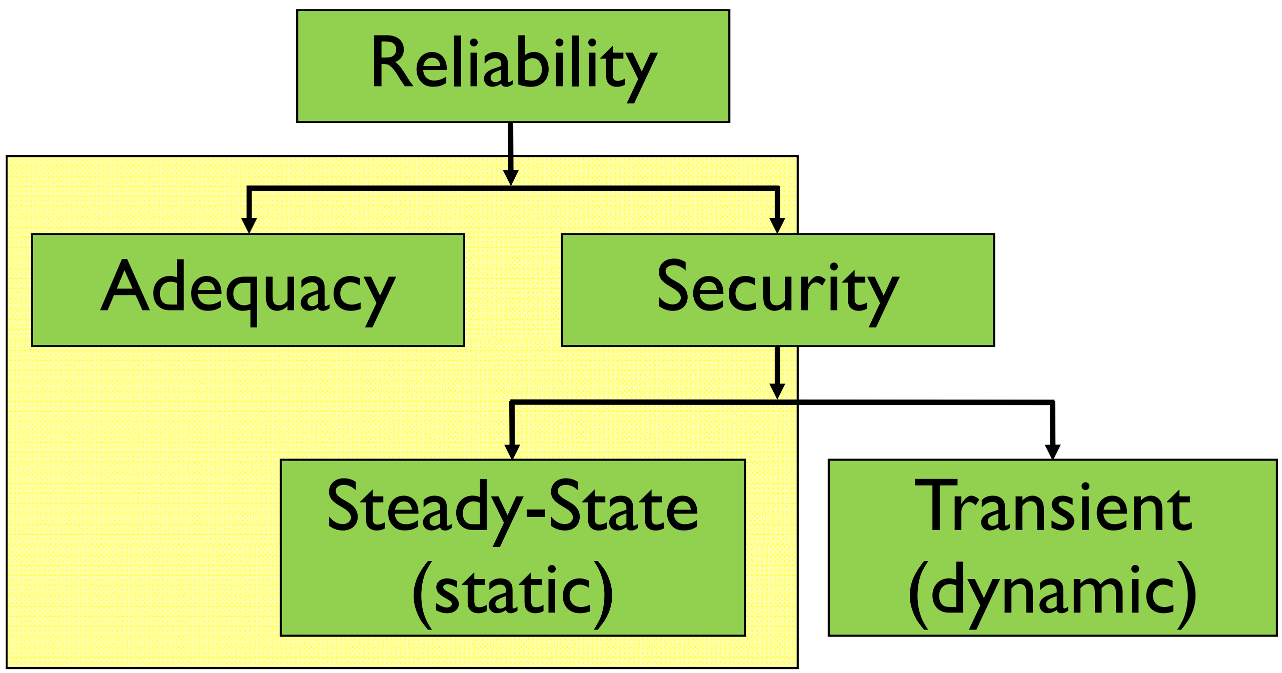


Existence of sufficient generation and transmission facilities.

Ability to respond to system disturbances.

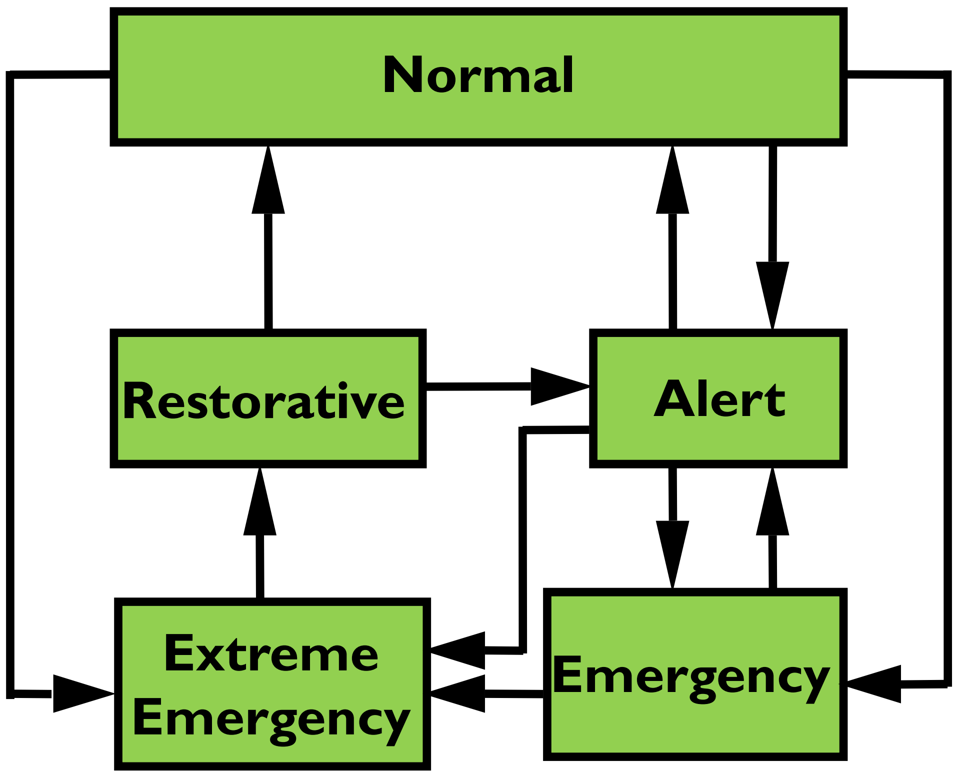
Power System Reliability

Security Constrained Adequacy Evaluation



Power System Reliability

Security Constrained Adequacy Evaluation



Traditional Operating States

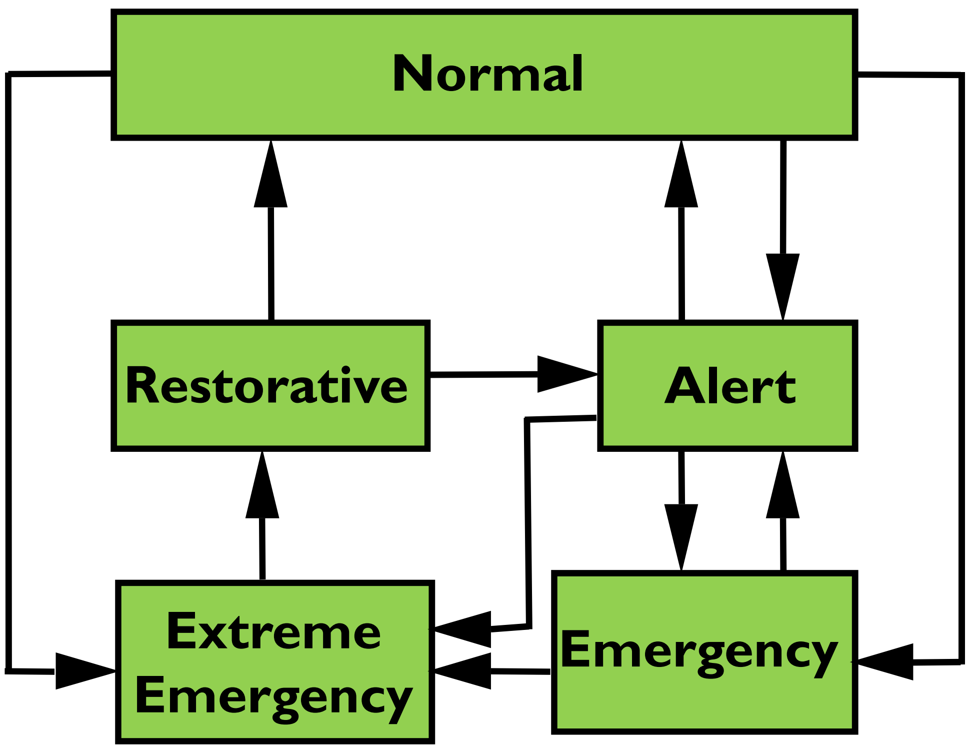
Normal:
- Adequacy is satisfied.
- Security is satisfied.

Alert:
- Adequacy is satisfied.
- Security is ***not*** satisfied.

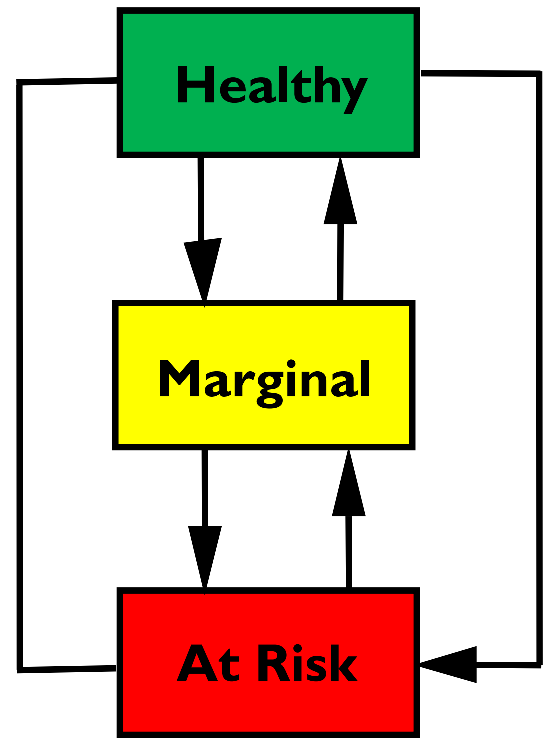
Emergency & Extreme Emergency:
- Adequacy is ***not*** satisfied.
- Security is ***not*** satisfied.

Security Constrained Adequacy Evaluation

a). Traditional Operating States



b). Well-Being Framework



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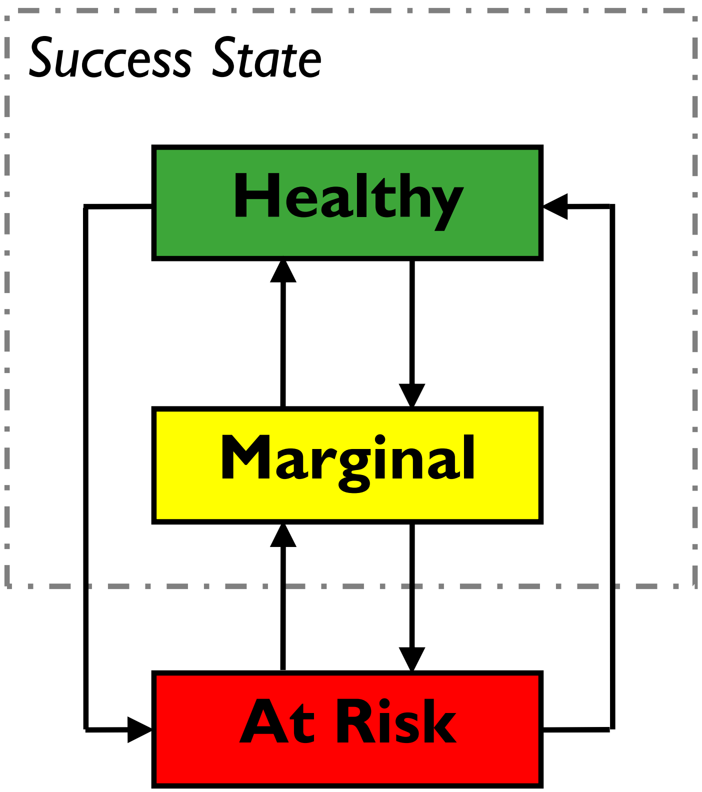
System Well-Being Analysis



Well-Being Framework

Healthy: ⇨ **Degree of Security**

All equipment and operating constraints are within limits and ***there is sufficient margin*** to serve the total load demand even with the loss of any element (deterministic N-1 criterion).

Marginal: ⇨ **Degree of Insecurity**

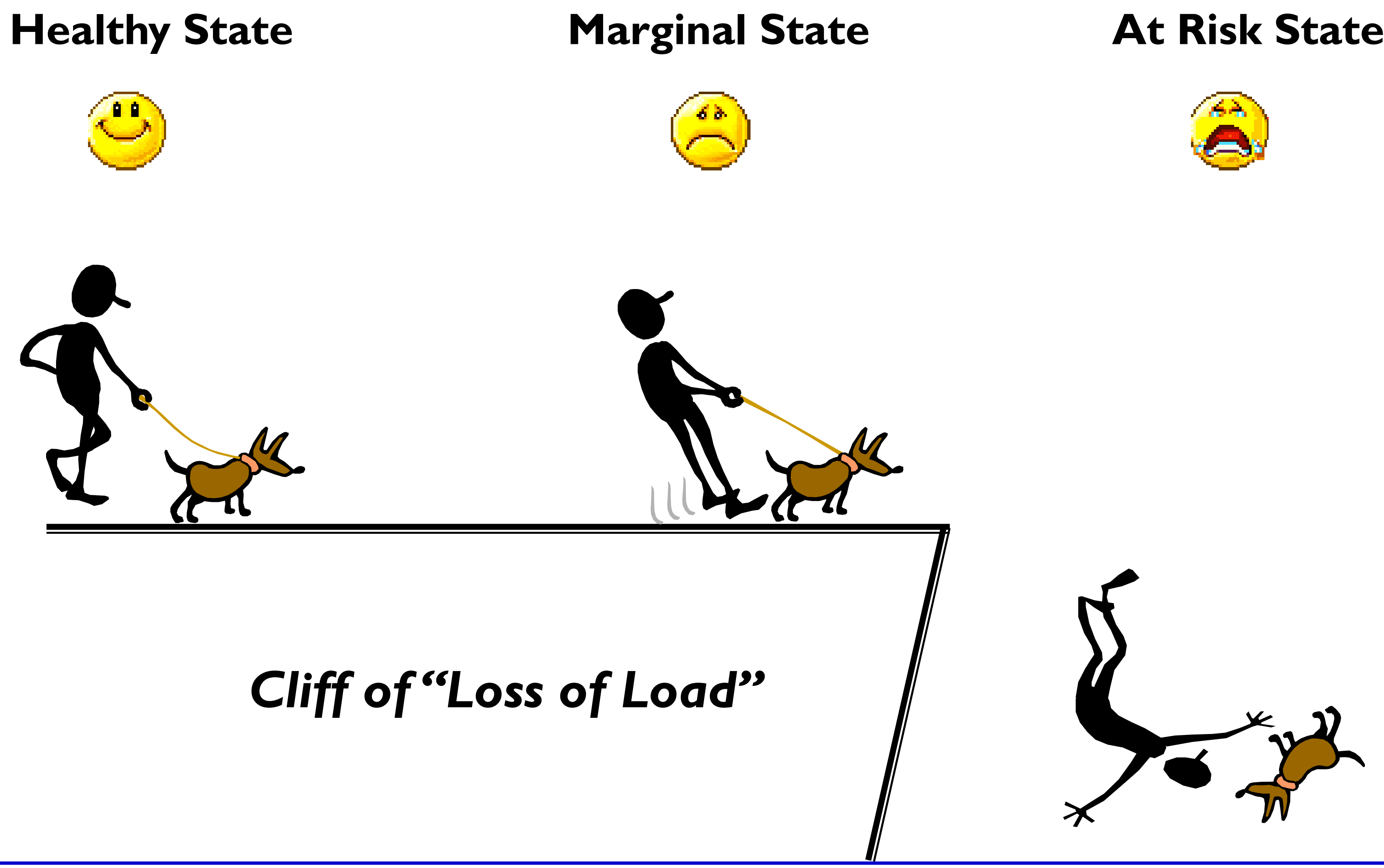
The system is still operating within limits, but ***there is no longer sufficient margin*** to satisfy the accepted deterministic criterion.

At Risk: ⇨ **Degree of Inadequacy**

Equipment or system constraints are violated and some load is curtailed.

The most common security criterion is the deterministic N-1 criterion

System Well-Being Analysis



"It is difficult if not impossible to determine where you want to go if you do not know where you have been." – Dr. Roy Billinton, Canada

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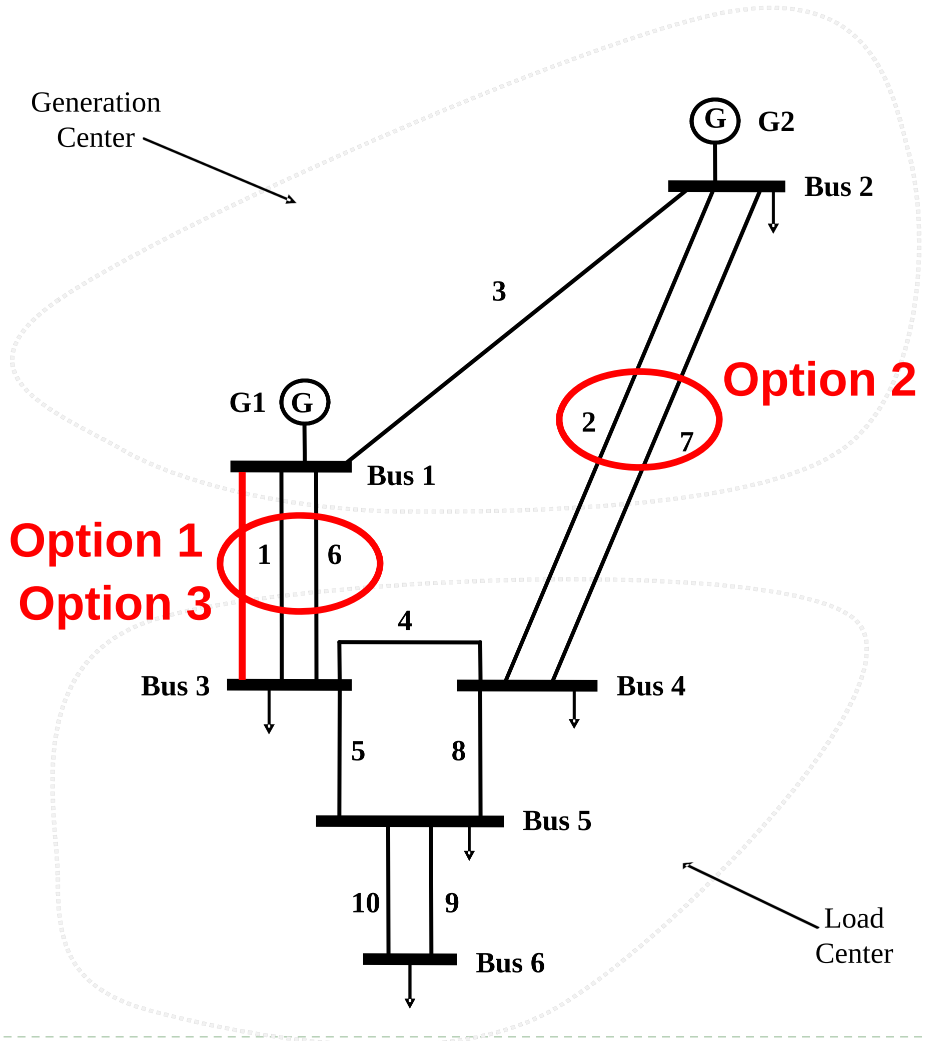
System Planning Application – No.1



Study System:

Bus 1 Generation = 170 MW

Bus 2 Generation = 130 MW

System Load = 215 MW

Reinforcement Options:

1. Add FACTS devices to 1 & 6
2. Add FACTS devices to 2 & 7
3. Build a new line (// to 1 & 6)

System Planning Application – No.1

System Indices	Base Case	Option 1	Option 2	Option 3
P_H	0.86200	0.86703	0.87727	0.99343
P_M	0.13721	0.13256	0.12257	0.00653
P_R	0.00079	0.00041	0.00016	0.00004
SI	19.97	10.39	3.95	1.33
ECOST	201.99	121.88	48.17	16.99

Where:

P_H = Healthy State Probability (per year)
P_M = Marginal State Probability (per year)
P_R = At-risk State Probability (per year)
SI = Severity Index (system.minutes)
ECOST = Expected Customer Interruption Cost (k$/year)

System Planning Application – No.2

- **Adequacy Cost**:

  Expected Customer Interruption Cost (ECOST)

- **Security Cost**:

  Expected Potential Insecurity Cost (EPIC)

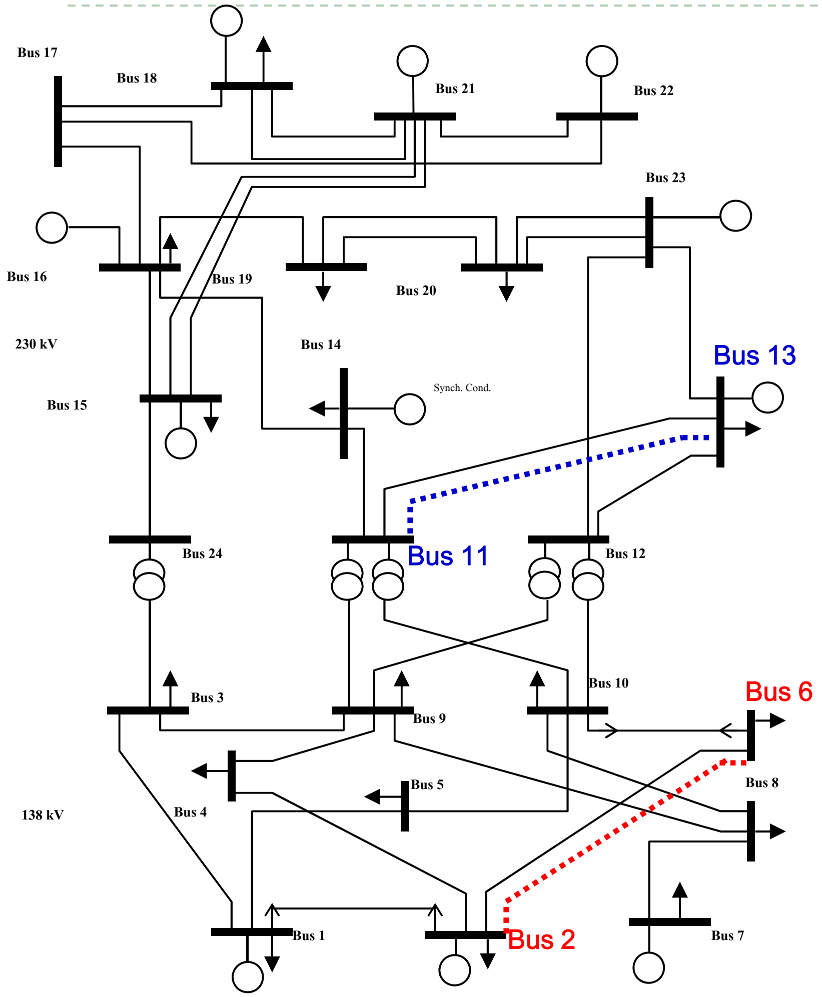
  where: $EPIC = P_M \times \{\text{Insecurity Cost}\}$

- **Overall Adequacy and Security Costs**:

  Expected Overall Reliability Cost (EORC)

  where: $EORC = ECOST + EPIC$

System Planning Application – No.2



IEEE-Modified RTS
(Doubled generation & load in order to stress transmission)

System Indices	Base Case	Option 1 (B2-B6)	Option 2 (B11-B13)
P_H (/yr)	0.72783	0.97898	0.73479
P_M (/yr)	0.27010	**0.01956**	**0.26341**
P_R (/yr)	0.00207	0.00146	0.00180
SI (sys.mins)	71.3	**55.9**	**53.1**
ECOST (M$/yr)	19.4	15.0	14.6
EPIC (M$/yr)	5.2	0.3	3.9

adequacy

security

Exp. Overall Reliability Cost (EORC) = ECOST+EPIC

EORC for Base Case = 24.6 (M$/yr)

EORC for Option 1 = 15.3 (M$/yr) ..Saving 9.3 M$/yr

EORC for Option 2 = 18.5 (M$/yr) ..Saving 6.1 M$/yr

Concluding Remarks

- Bulk electric systems are facing with greater uncertainties. Deterministic rules currently used cannot adequately address various planning and operating uncertainties.
- There is a need to re-design and apply deterministic techniques that include probabilistic considerations in order to assess the increased system stress due to the restructured electricity environment. The desired technique should be capable of maintaining an acceptable balance between system utilization and the required system reliability. The overall reliability framework should address both adequacy and security concerns.

Concluding Remarks

- The system well-being analysis concept is a complementary way of incorporating deterministic engineering judgments together with probabilistic variables and uncertainties.
- The system well-being analysis framework can provide comprehensive knowledge on what the degree of system vulnerability might be under a particular system condition. It gives system engineers and risk managers with a quantitative interpretation of the degree of system security (healthy) and insecurity (marginal) in addition to the traditional risk (inadequacy) measure.

Thank you very much for your attention.

Questions ?

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