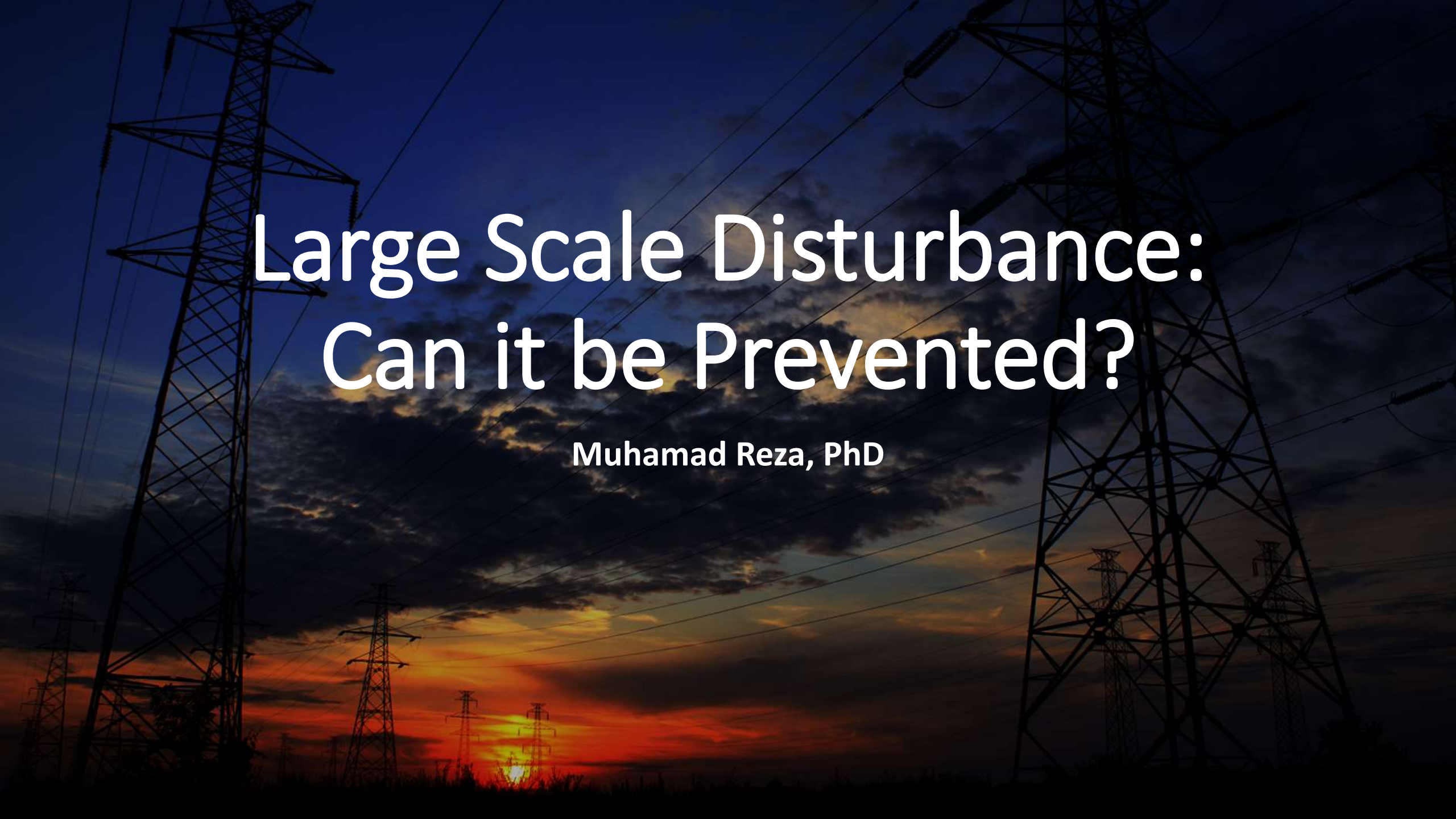


Large Scale Disturbance: Can it be Prevented?

Muhamad Reza, PhD

THE CURRENT WAR

THE TALE OF AN EARLY TECH RIVALRY

DC

DIRECT CURRENT

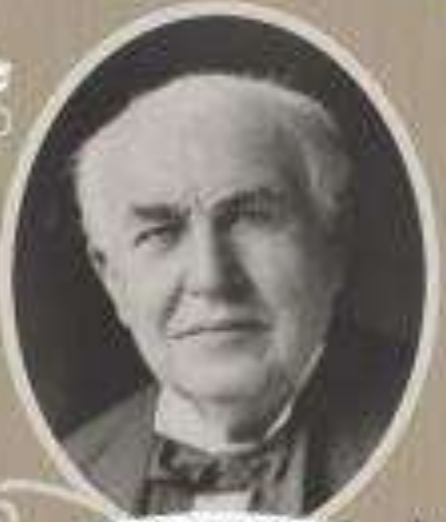
The flow of electricity is in one direction only. The system operates at the same voltage level throughout, and is not as efficient for high voltage, long distance transmission.

Direct current runs through:

Battery-Powered Devices | Fuel and Solar Cells | Light Emitting Diodes

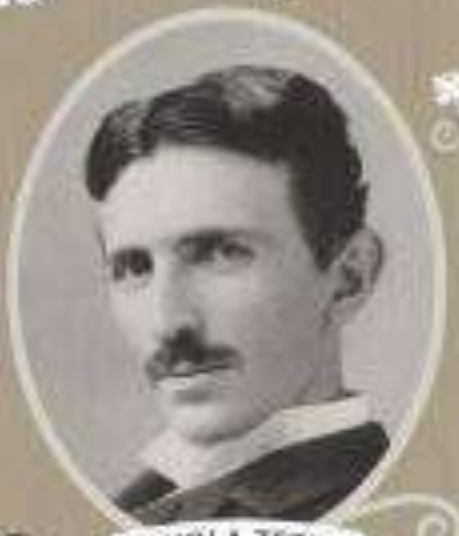
"[TESLA'S] IDEAS ARE SPLENDID, BUT THEY ARE UTTERLY IMPRACTICAL."

–THOMAS EDISON



THOMAS EDISON

VS.



NIKOLA TESLA

The world has never found two geniuses so spiteful of each other beyond turn-of-the-century inventors Nikola Tesla and Thomas Edison. They worked together—and hated each other. Let's compare their life, achievements, and embittered battles.

AC

ALTERNATING CURRENT

Electric charge periodically reverses direction and is transmitted to customers by a transformer that could transfer much higher voltages.

Alternating current runs through:

Car Motors | Radio Signals | Appliances

"IF EDISON HAD A NEEDLE TO FIND IN A HAYSTACK, HE WOULD PROCEED AT ONCE... UNTIL HE FOUND THE OBJECT OF HIS SEARCH. I WAS A SORRY WITNESS OF SUCH DOINGS, KNOWING THAT A LITTLE THEORY AND CALCULATION WOULD HAVE SAVED HIM 90 PERCENT OF HIS LABOR."

–NIKOLA TESLA

LATE BLOOMER

Thomas Edison, the youngest in his family, didn't learn to talk until he was almost 4 years old.

1847	BORN
Milan, Ohio	BIRTHPLACE
Wizard of Menlo Park	NICKNAME
Home-schooled and self-taught	EDUCATION
Mass communication and business	FORTE
Trial and error	METHOD
DC (Direct Current)	WAR OF CURRENTS: ELECTRICAL TRANSMISSION IDEA
Incandescent light bulb, phonograph, motion-picture camera, early alkaline storage battery, DC motors and electric lamps	NOTABLE INVENTIONS
1,093	NUMBER OF U.S. PATENTS
0	NUMBER OF NOBEL PRIZES WON
1	NUMBER OF ELEPHANTS ELECTROCUTED

1931—Passed away peacefully in his sleep at his estate in West Orange, New Jersey, surrounded by friends and family.

1856 BORN 1943

Smiljan, Croatia BIRTHPLACE

The Lightning Rod Man NICKNAME

Graduate studies, physics, and mechanics at The Polytechnic Institute of Graz EDUCATION

Electrical engineering and mechanical engineering FORTE

Visualizing inventions in his mind, a detail before fully constructing it METHOD

AC (Alternating Current) WAR OF CURRENTS: ELECTRICAL TRANSMISSION IDEA DC (Direct Current)

Induction motor, rotating magnetic field, radio transmitter, fluorescent light, AC motors and electric power generation system NOTABLE INVENTIONS

Over 300 NUMBER OF U.S. PATENTS

1 NUMBER OF NOBEL PRIZES WON

0 NUMBER OF ELEPHANTS ELECTROCUTED

1943—Passed away penniless in his room at the New Yorker Hotel.

WAR OF CURRENTS OFFICIALLY SETTLED

In 1887, Con Edison ended 125 years of direct current electricity service that began when Thomas Edison opened his power station in Manhattan to only private electricity consumers.

NOBEL PRIZE CONTROVERSY

FALLING OUT

Edison promised Tesla a generous reward if he could execute all the direct current system. The proud engineer took on the assignment and stated on seeing Edison was true. $100,000 dollars in current-to-today's-standards. When Tesla asked for his rightful compensation, Edison declined to pay him. Tesla resigned shortly after and the elder inventor spent the rest of his life campaigning to discredit his counterpart.

EDISON FRIES AN ELEPHANT

In order to prove the dangers of Tesla's alternating current, Thomas Edison staged a highly publicized electrocution of the Bronx zoo elephant known as "Topsy." She died instantly after being electrified with 6,600 volts of AC current.

Source: https://blurppy.files.wordpress.com/2012/03/transparency.jpg

The power grid

Below is a simplified example of how electricity is distributed throughout the grid.

1

Generating station

Electricity is typically generated by a steam or hydro-driven turbine at the power plant.

2

Step-up transformer

The power is then ramped up to high voltage for long-distance transmission.

3

Transmission

Next, a series of high-voltage lines transmit the electricity throughout the power grid.

4

Step-down transformer

Power is then reduced to a lower voltage for use in homes and businesses.

5

Subtransmission customer

The electricity then passes through a series of switches to distribution lines.

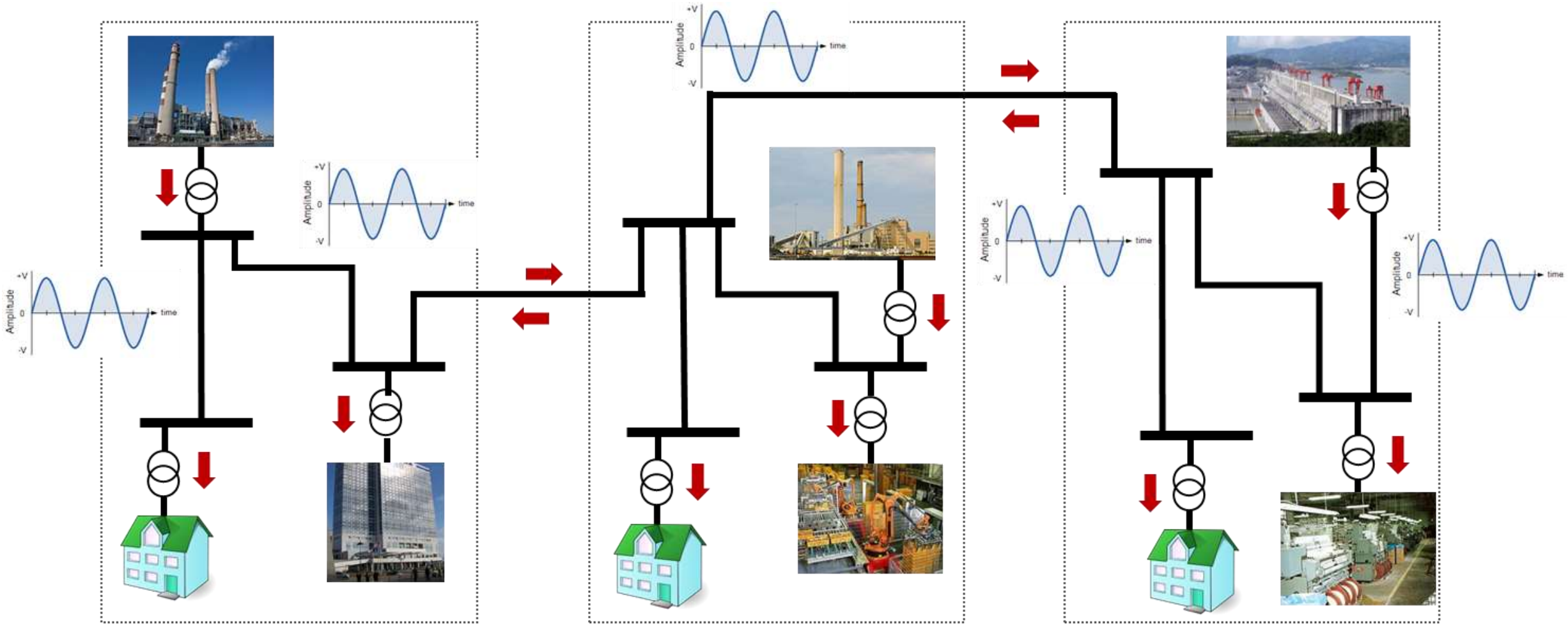
6

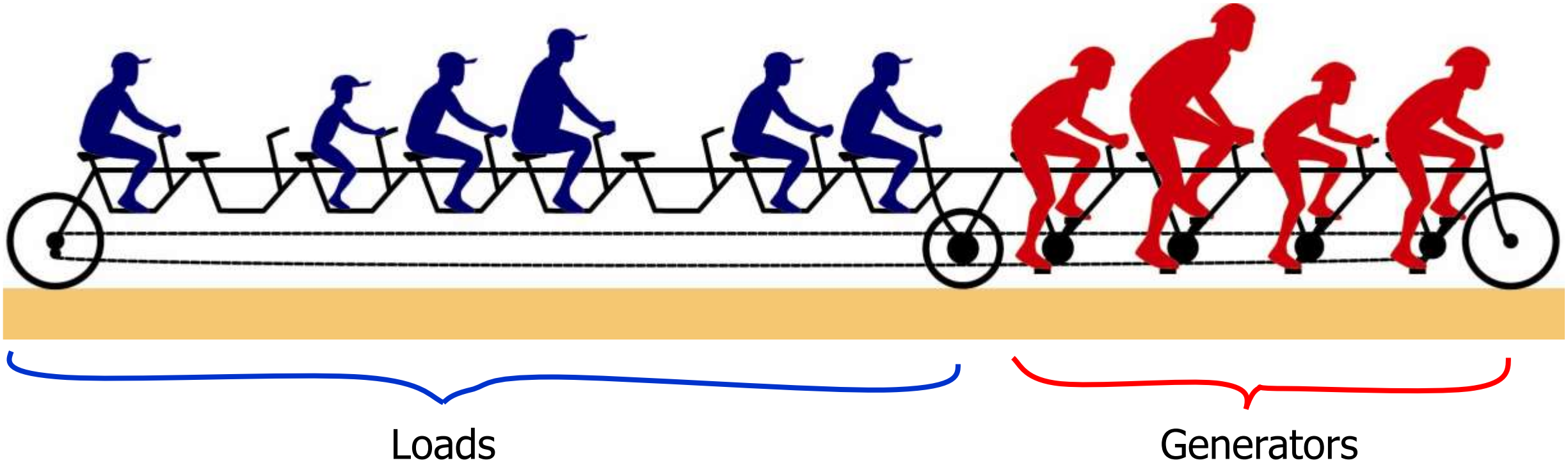
Customers

Power is then delivered to customers via local lines.

Source: http://www.greenbearsolar.com/howthegridworks.html

Flexible Power Sharing Reference Frequency





- Constant frequency for electric equipment design
- Generator adjust power follows changing load
- Load sharing generators based on its capability
- Unsynchronization results in broken chain & collaps

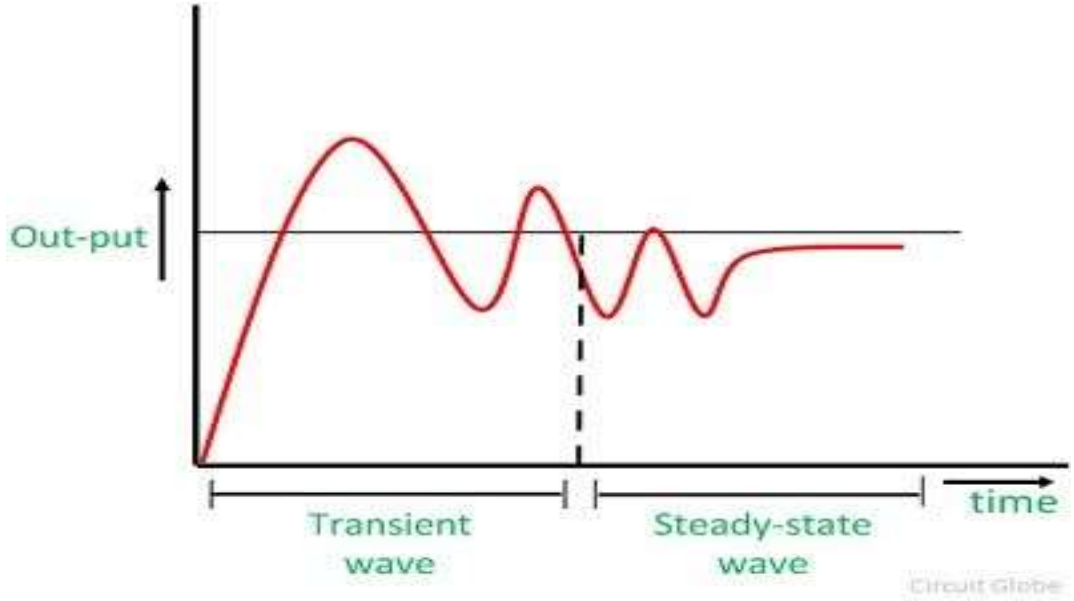
Power System Stability

Property of a power system that enables it to :

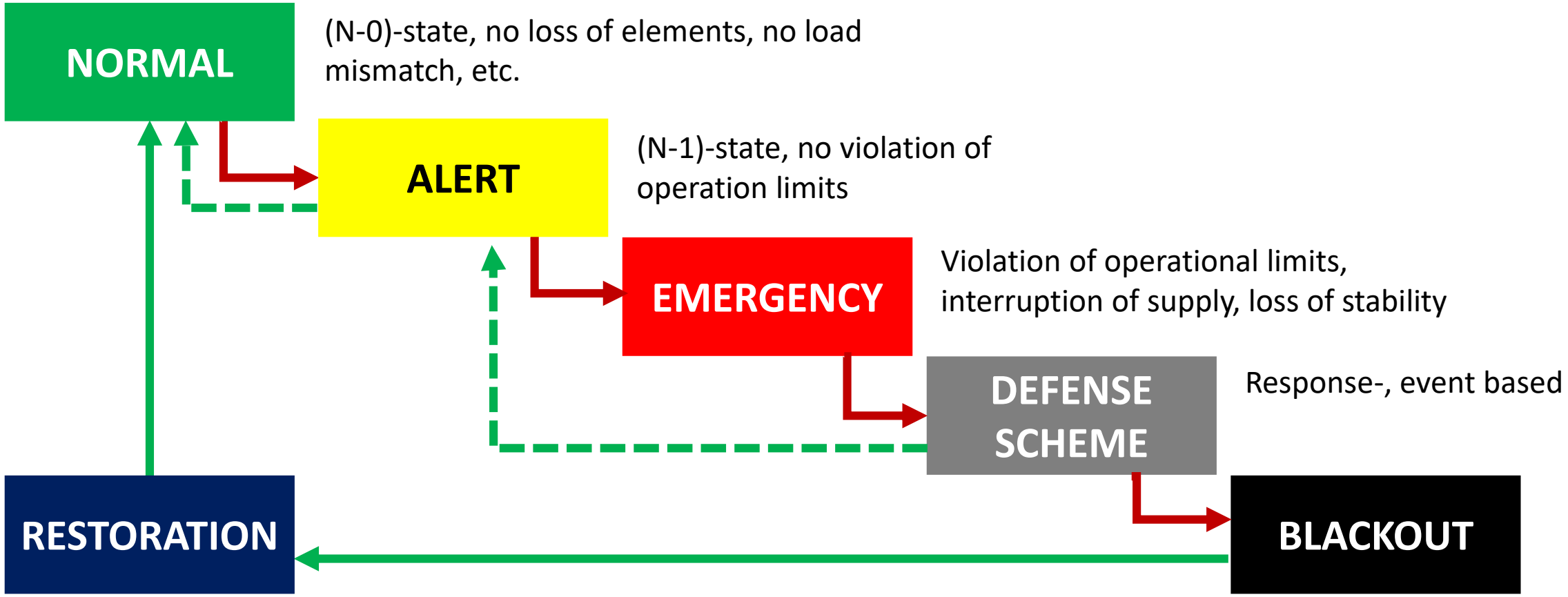
- Remain in state of operating equilibrium under normal operating condition
- Regain acceptable state of equilibrium after being subjected to disturbance
- System quantities become constant again after fault is removed

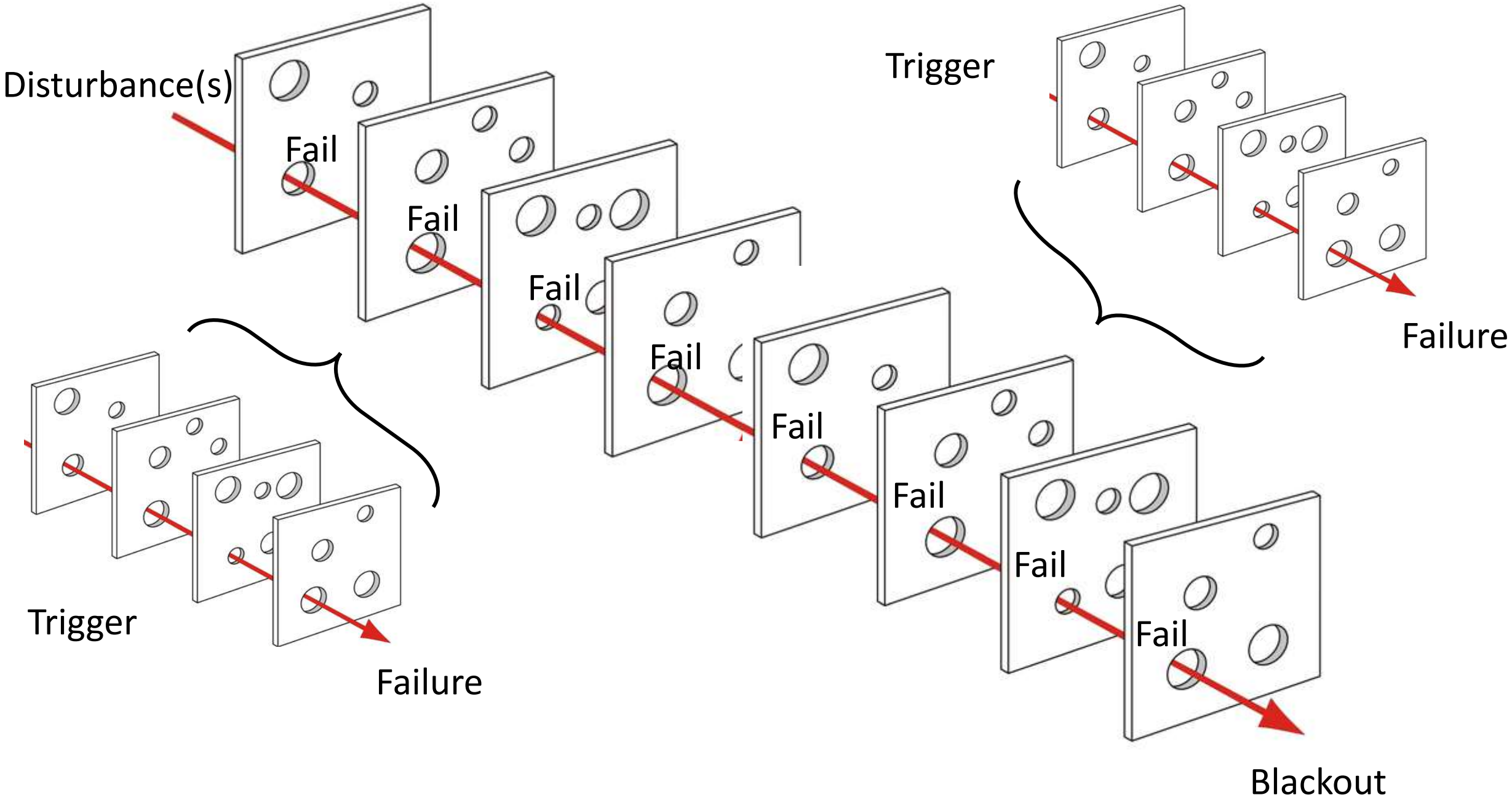
Stability depends on:

- Nature of disturbance
- Initial operating condition

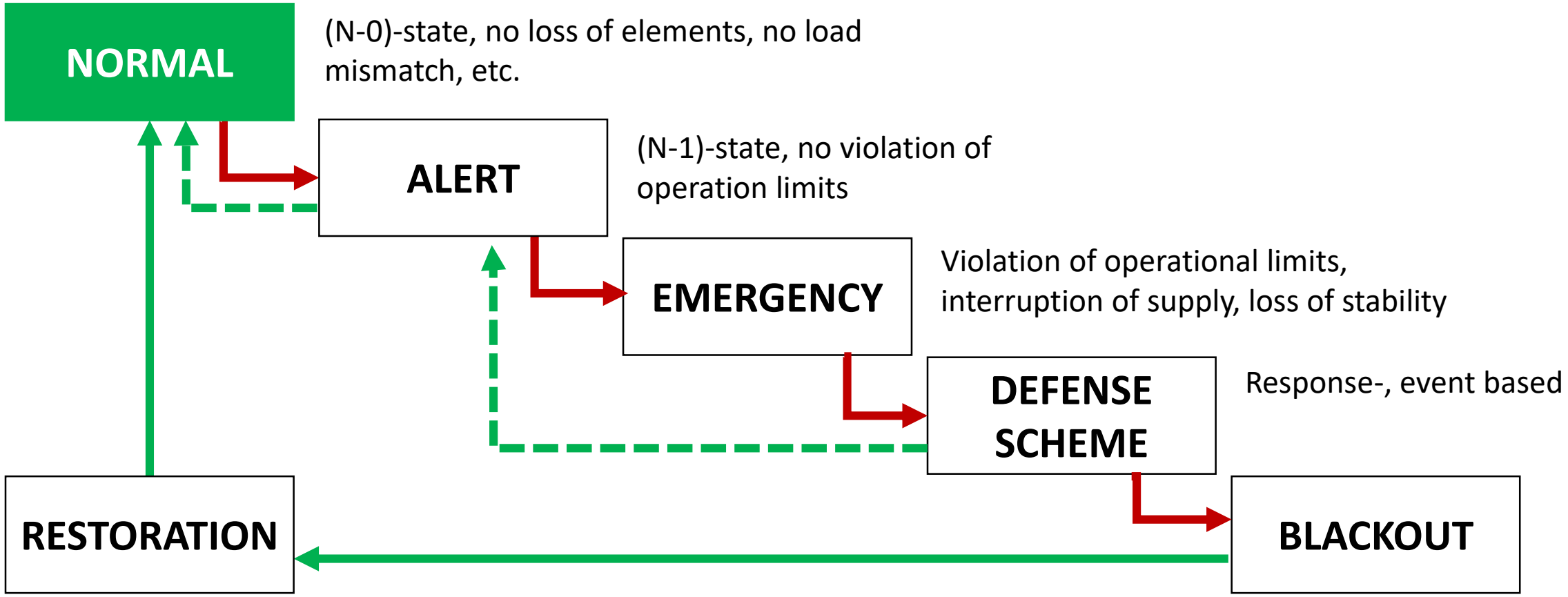


Power System Operation Paradigm




Disturbance(s)
Fail
Fail
Fail
Fail
Fail
Fail
Fail
Trigger
Failure
Trigger
Failure
Blackout

Power System Operation Paradigm



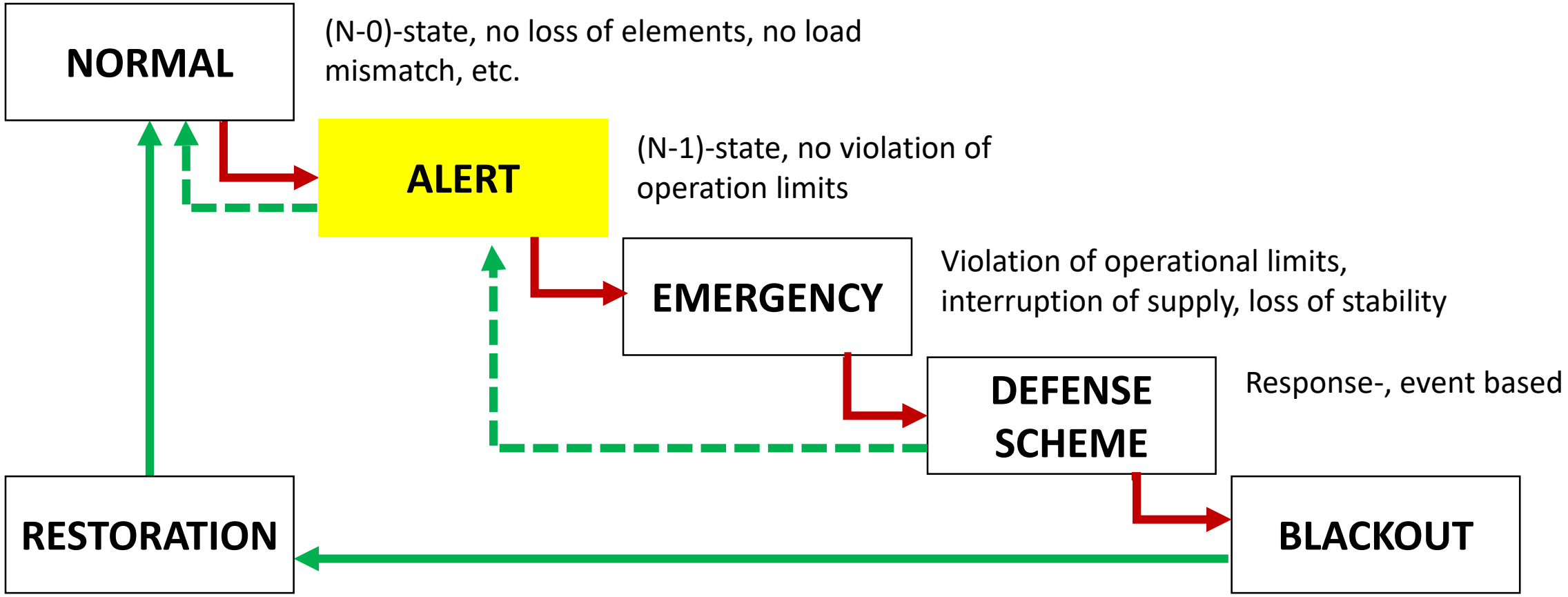
Normal - Power System Requirements

- Voltages must be kept near rated values
  - Typically ±5%
- Synchronous machines must operate stable
  - Disturbance stability: large, small disturbance
  - Voltage and frequency stability
- Minimize transfer of reactive power
- Low losses
- Economic

Normal

- Components: Generation, Transmission, Distribution, Protection, …
- Systems: Planning, Studies, Redundancy, …
- SOPs: Compliance, Operation, Maintenance, …
- Competence: Placement, Training, Knowledge Management, …
- Culture: Organization, H&S, …
- …

Power System Operation Paradigm



Alert

- Reliability – Quality – Economy
- Technology: Hardware & Software
- Importance of Studies/Modeling/Risk Mitigation
- Competence: …
- …

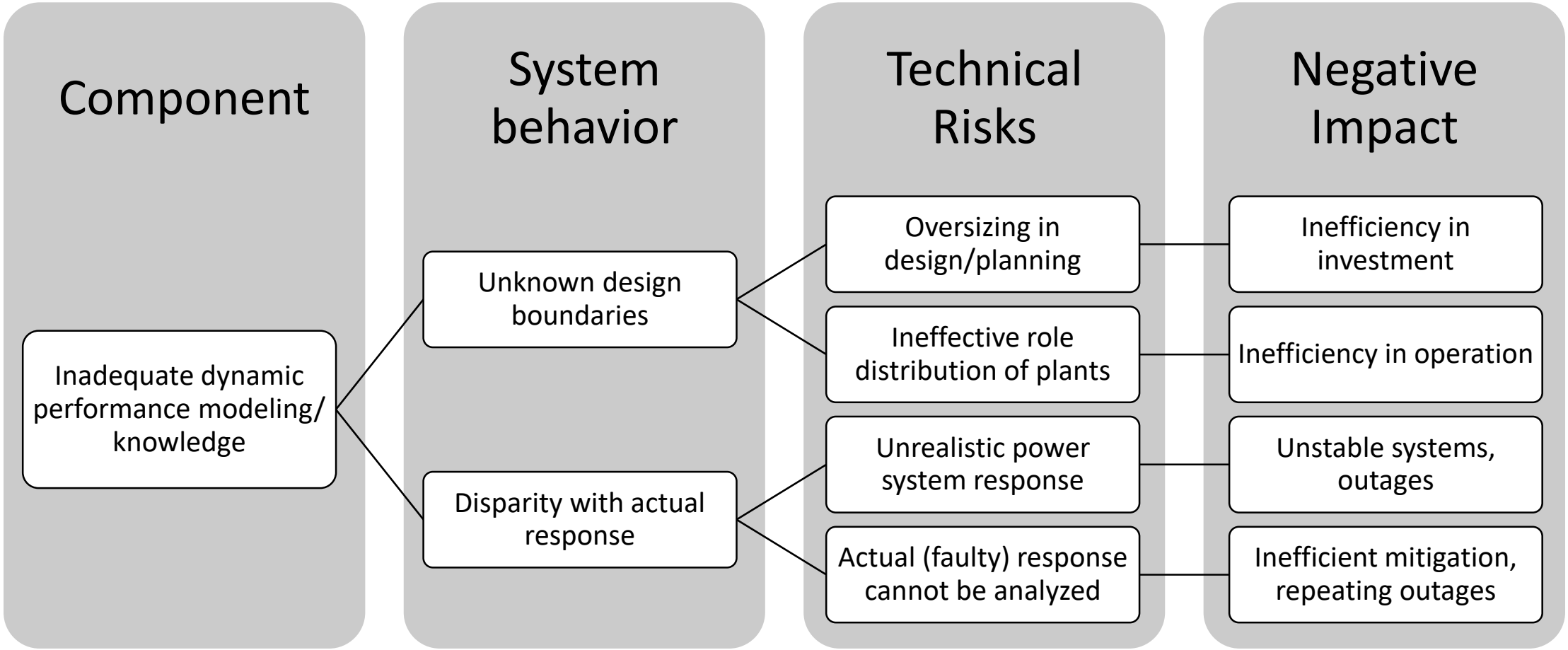
Reliable Electrical Power Grid

- To be reliable it needs to be secure
- To be secure it needs to be stable
- Grid Codes are there to ensure that generators are sufficiently stable for the grid to be reliable

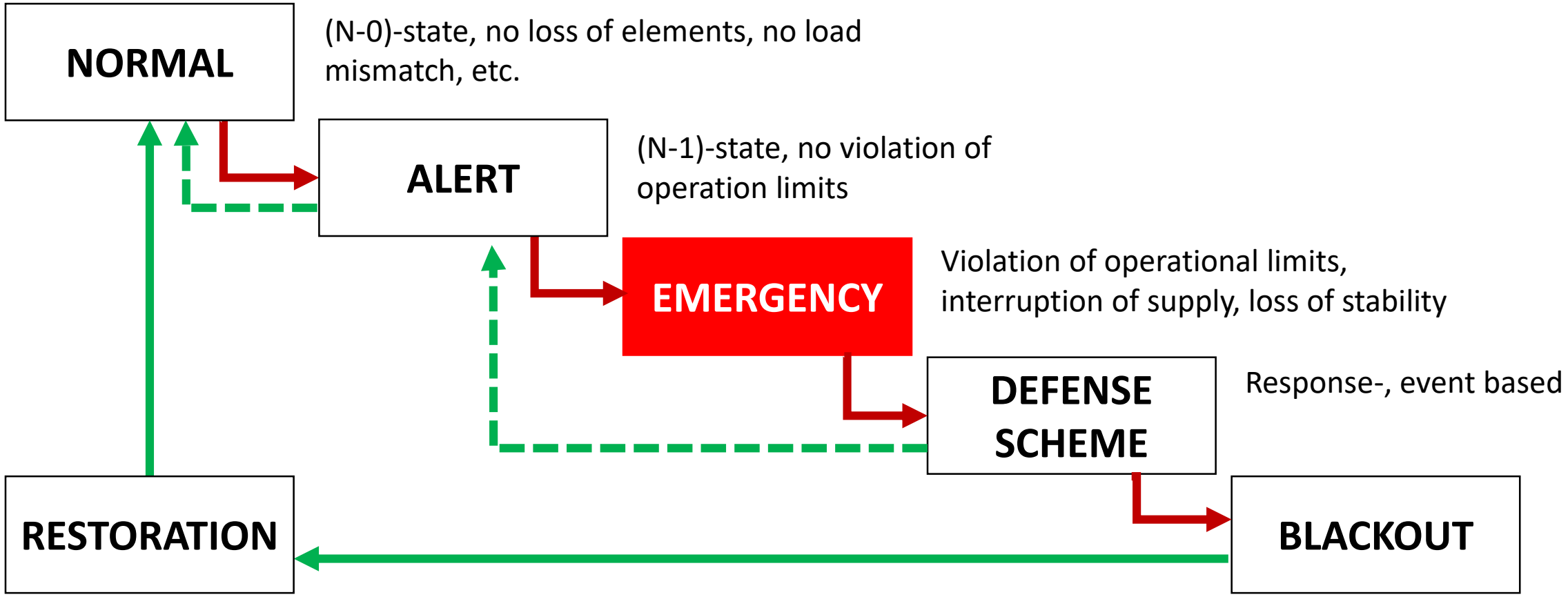
Importance of Modelling

- How to perform power system tests to validate correct operation?
- Defense actions deals with behavior of power system under large disturbances
  - Modelling to reproduce a realistic response of power system
  - Achieve reliable conclusions on the ability of the defense plan to secure the integrity of the power system
- Simulation should reflect usual/conservative grid operator practices to adequately reproduce the level of stress upon which the defense action would be activated
- Replicate recent past incident, validate defense actions

System dynamic modeling issues



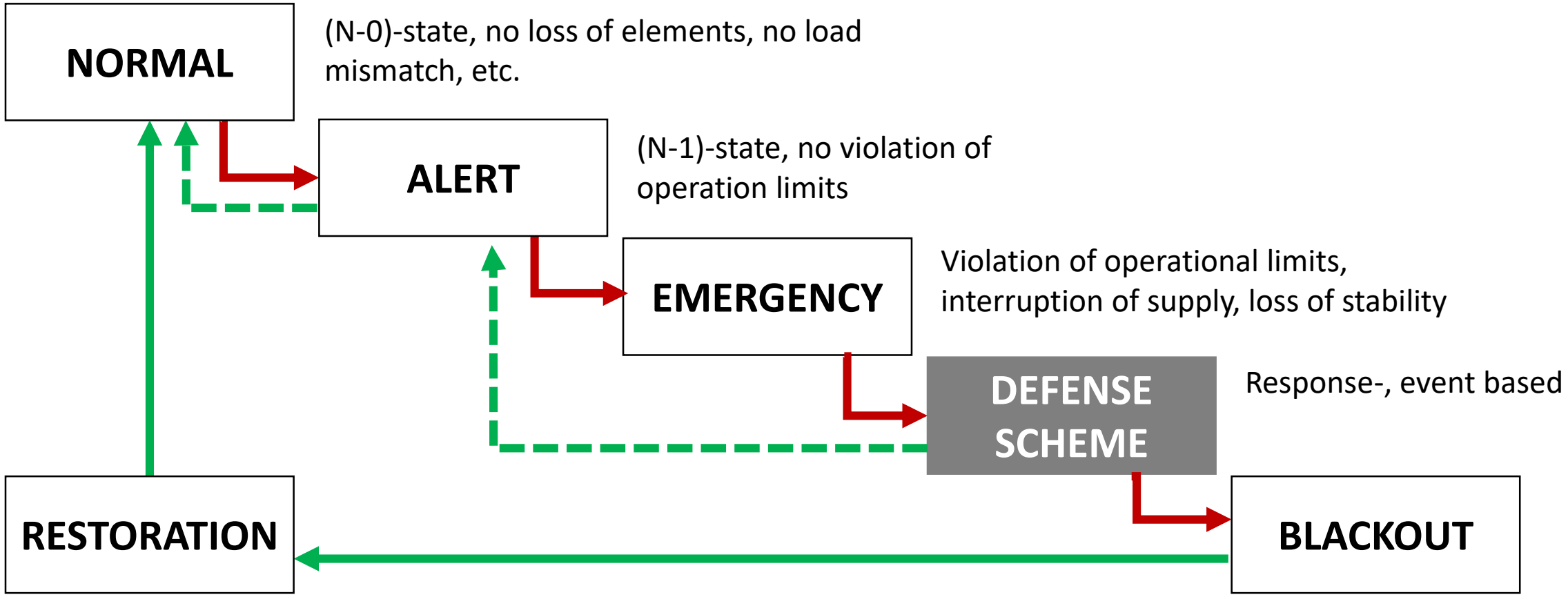
Power System Operation Paradigm



Crisis Simulation, Training

- Nation wide restoration plans
- Blackstart & island operation strategy
- Confirm & optimize power plant capability
- Power availability in emergency
- Operation & emergency instruction
- Psychological aspects
- …

Power System Operation Paradigm

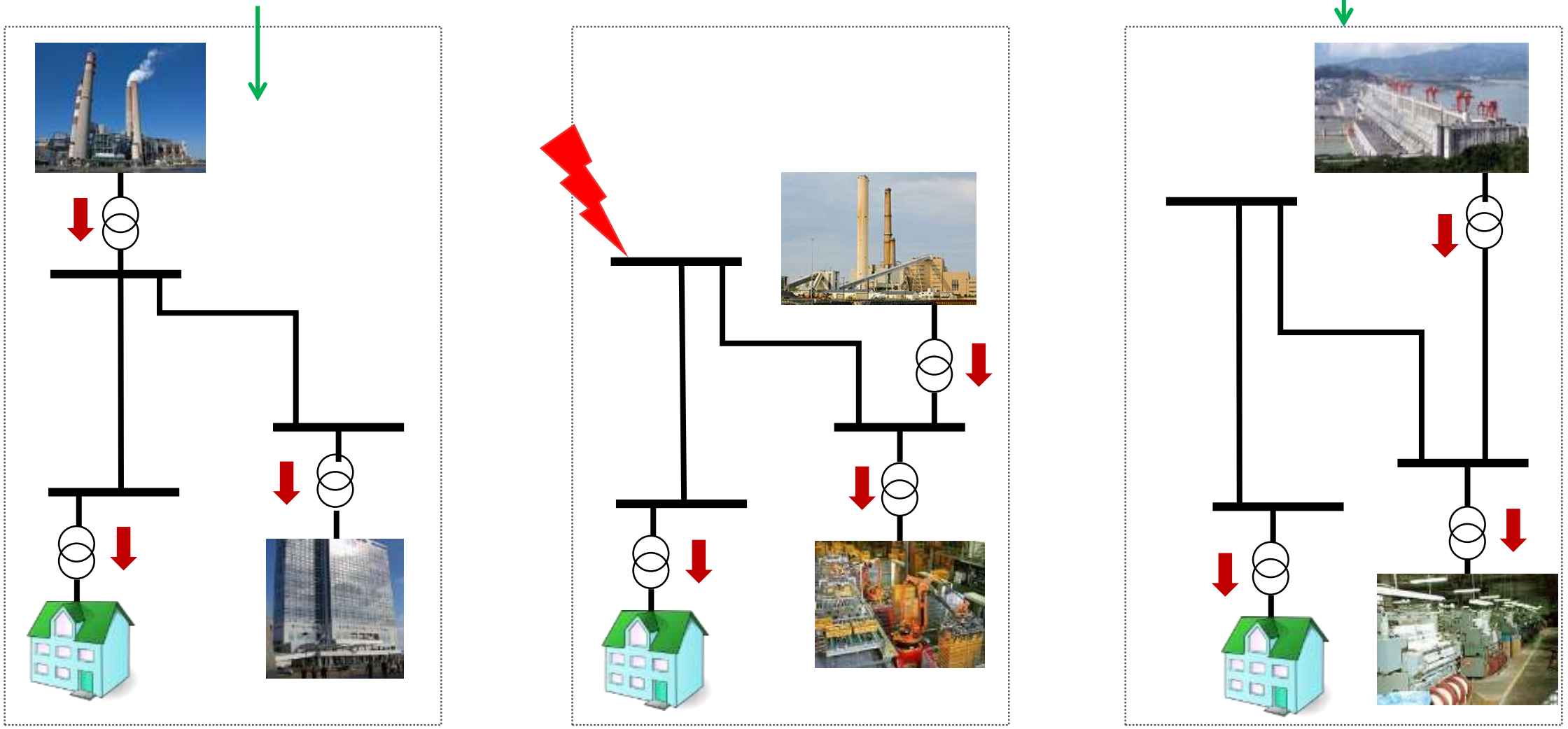


Defense Scheme

- Generator Shedding Scheme
- Rapid Load Shedding Scheme
- Under-frequency Load Shedding Scheme
- Undervoltage Load Shedding Scheme
- Island operations
- …

- Frequency stability and governor tuning and validation
- Load shedding scheme validation
- PSS settings tuning and validation
- Power system stability and system oscillation studies
- Island operation tests ...

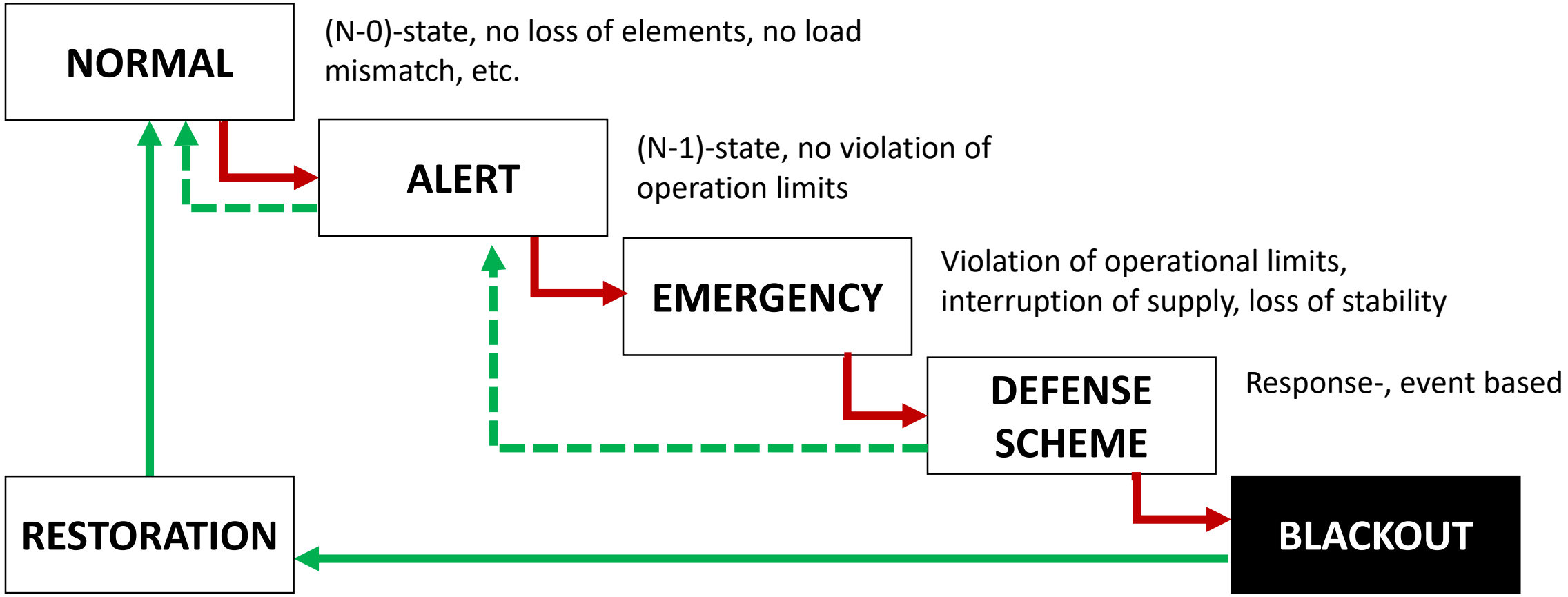
Islands Operation



Island Operation

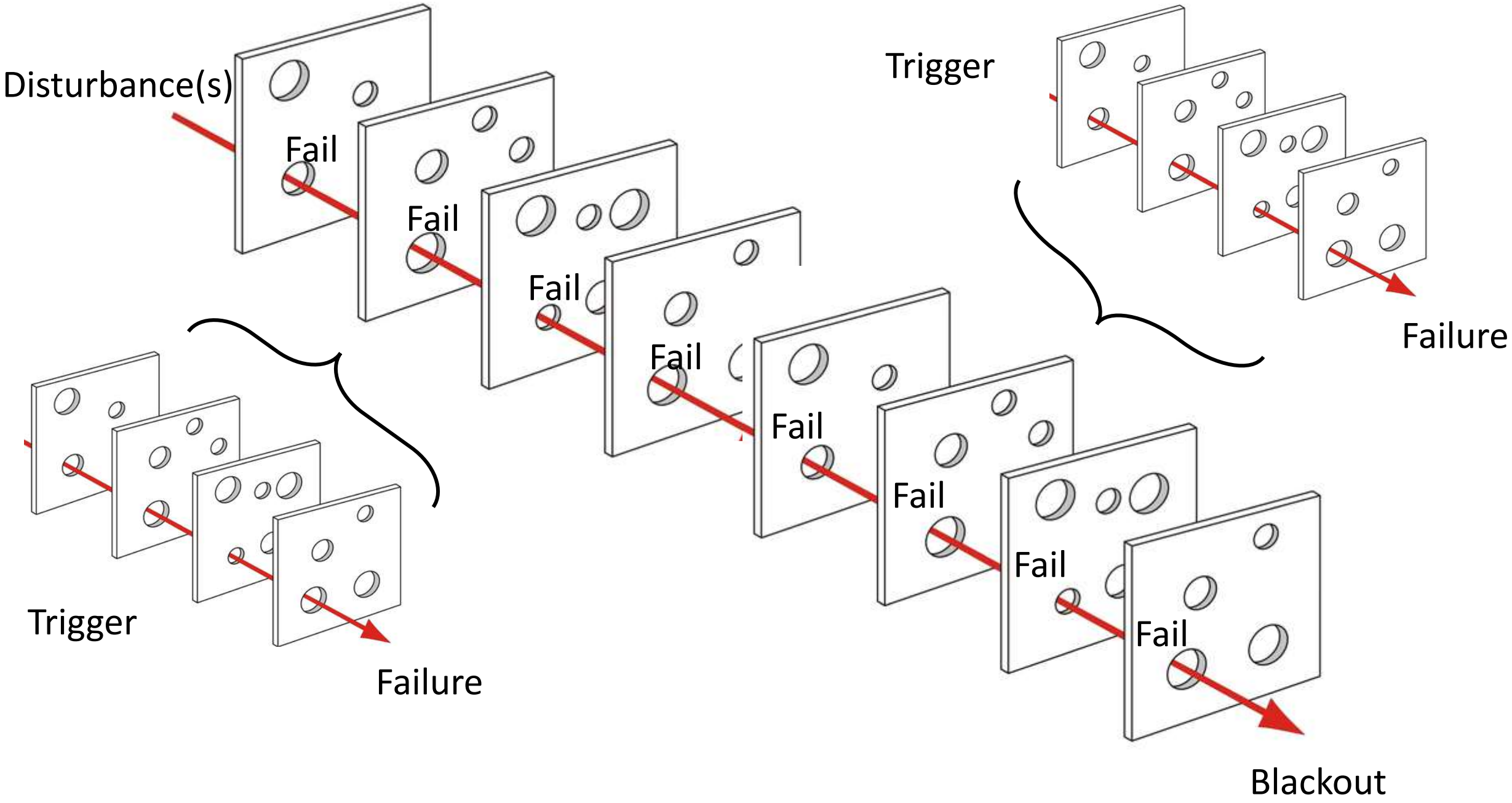
- Crucial for reliability
- Load supply secured
- Restoration of blacked out power grids
- A major concern is to control frequency
- Units to be equipped with proper controllers and tested
- Capability is tested, tuned and validated

Power System Operation Paradigm



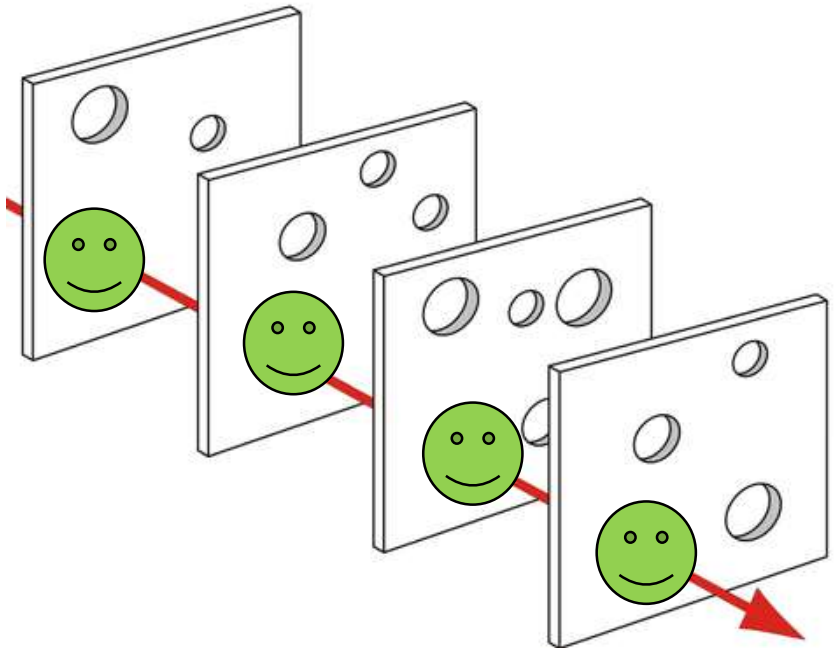
Blackout

- Understand the root cause of the incident:
  - What (tripped, failed, …)?
  - Why did it trip?
  - What was violated?
  - Was it normal operation or was it a malfunction?
  - Could have it been avoided or mitigated?
  - …
- Provide recommendations to avoid repetition
  - Replicate & simulate cases
  - Validate prevention control, defence mechanism, restoration action


Disturbance(s)
Fail
Fail
Fail
Fail
Fail
Fail
Fail
Trigger
Failure
Trigger
Failure
Blackout

Preventing Major Blackouts

- Well-functioning components & protection elements as individual & system
- System understanding on interaction of different components within power systems
- Proper plant & system control taking into account power plant & power system dynamic interaction
- Personnel competence
- Safery culture




Thank you!