


Intelligent Systems Applications to Vulnerability Assessment and Control

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Background

- **Electric power grid is a national security matter**
- **The reliable operation of the system is of top priority to society.**
- **Reliability concerns are amplified by the utility's deregulation, which increases the system's openness while simultaneously decreasing the applied degree of control.**


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Vulnerability Assessment

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Vulnerability Assessment

- **Is the assessment of power system's ability to continue providing service in case of unforeseen catastrophic contingency.**


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Sources of Vulnerability

- **Natural calamities**
- **Component failures**
- **Breaks in communication links**
- **Faults**
- **Human errors**
- **Inadequate security margin**
- **Gaming in the market**
- **Sabotage or intrusion by external agents**
- **Missing or uncertain information**

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The system is vulnerable if any of these contingencies lead to a disruption of service to part (outages) or all (blackouts) of the system

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Challenges

- **Vulnerability assessment is computationally intensive process**
 - **Highly nonlinear problem**
 - **Closed form detailed models do not exist**
 - **Power network is large and extensive**
 - **Operating conditions are wide Range**
 - **Topology is continuously changing**
 - **The list of contingencies is long**
- **Assessments need to be continually repeated**

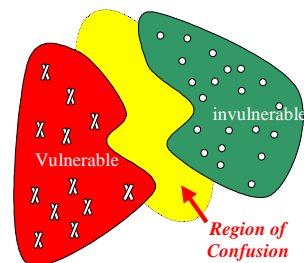
Challenges

- **Some of the failures are single events and some as a sequence of events.**
- **Measurements and operating conditions are noisy**
- **Available knowledge is in historical examples**

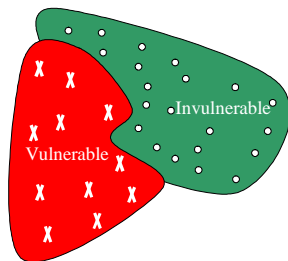
Why Computational Intelligence (CI)?

- **CI is capable of generating a complex nonlinear mapping through a set of input/output examples.**
- **CI does not require structured model.**
- **Variables can be easily include or excluded.**
- **CI has a superior noise rejection capability.**
- **CI is a fast execution process**

Vulnerability Assessment

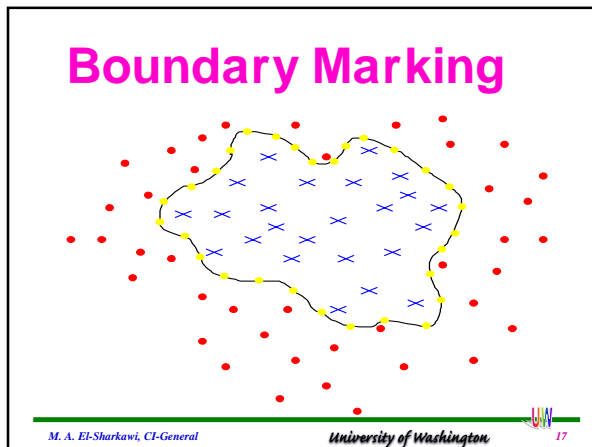
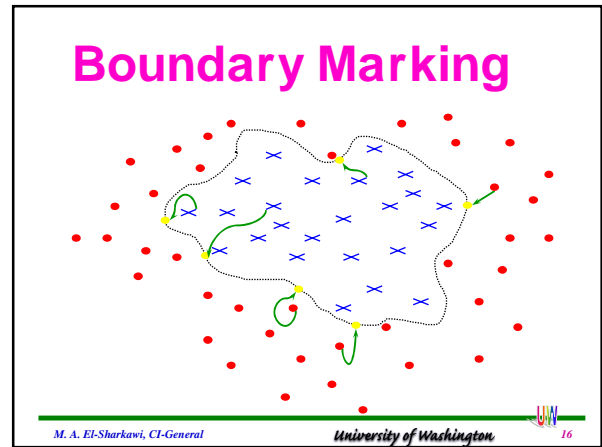
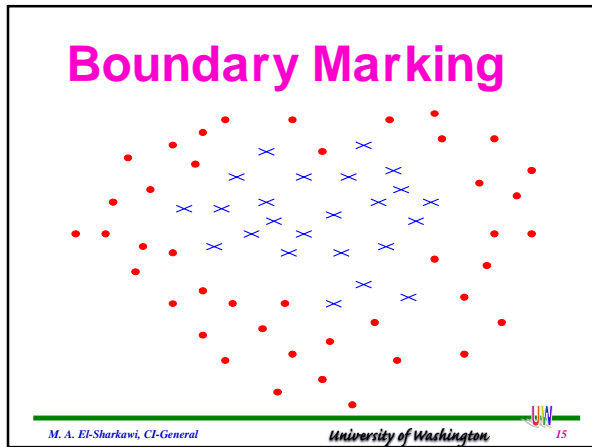
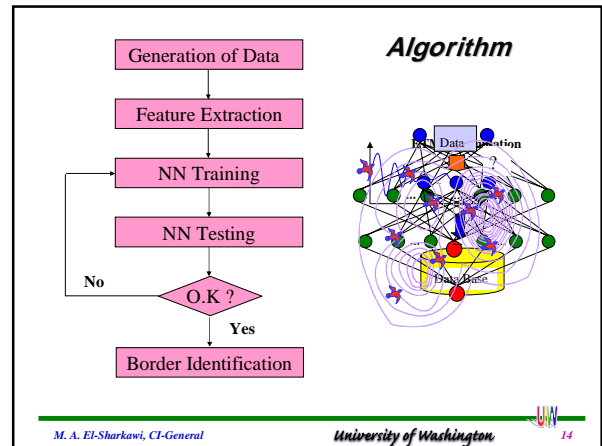
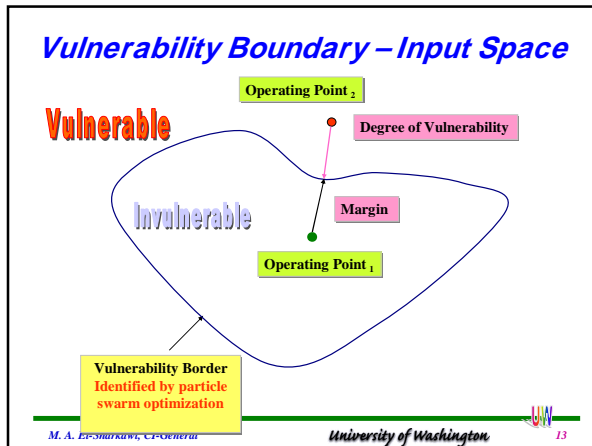


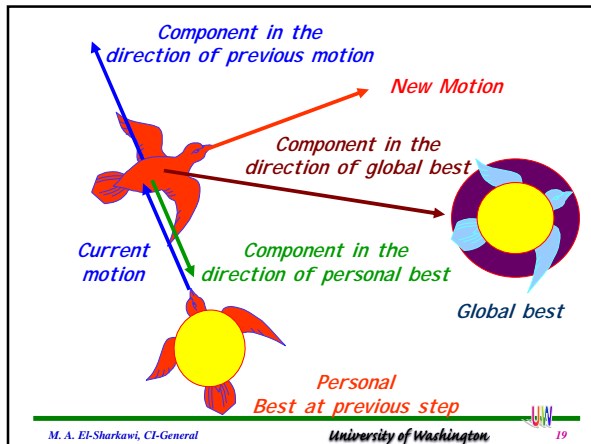
Vulnerability/Security Assessment



Objectives

- **Generate an index for vulnerability**
- **Provide the operator with the vulnerability index on-line**
- **The index is dynamically updated when the system operation is changed**
- **The index is used as one key factor while operator is steering the power systems**

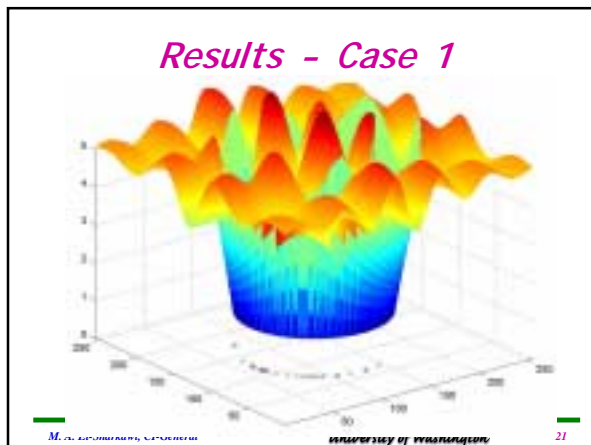




The Art of Fitness Function

- To find points anywhere on the boundary

Metric: $|f(x) - \text{boundary value}|$



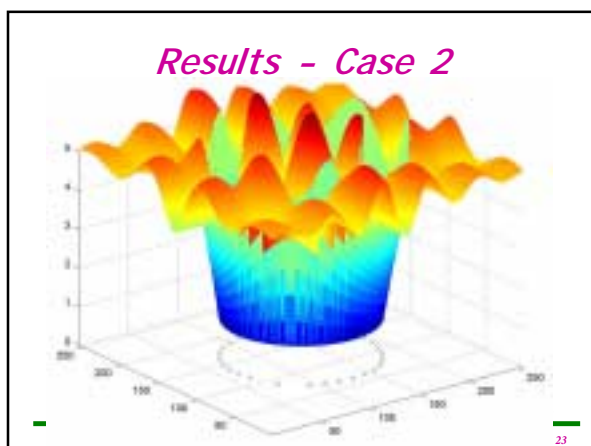
The Art of Fitness Function

- Distribute points uniformly on the boundary

Metric:

$|f(x) - \text{boundary value}| - \text{Distance to closest neighbor}$

(to penalize proximity to neighbors)



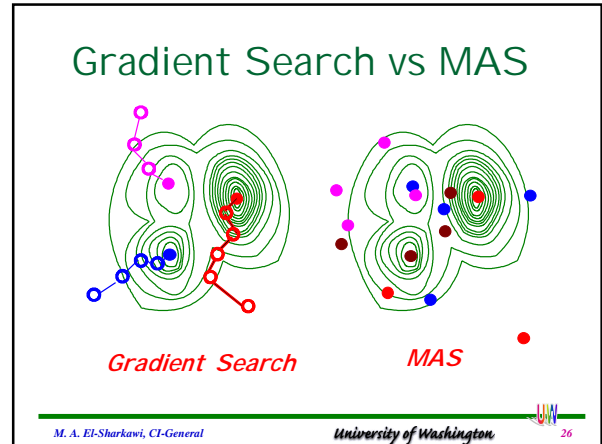
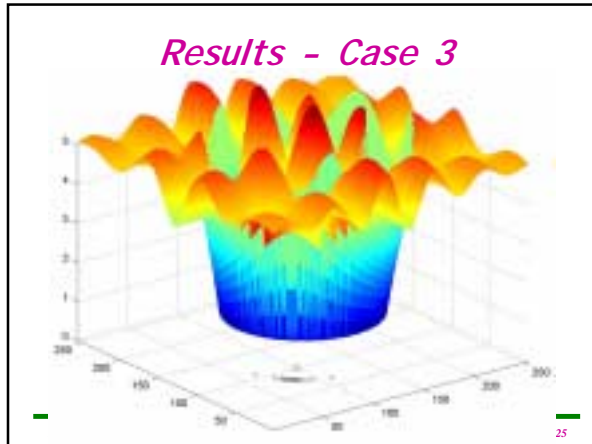
The Art of Fitness Function

- Distribute points uniformly on the boundary close to current state

Metric:

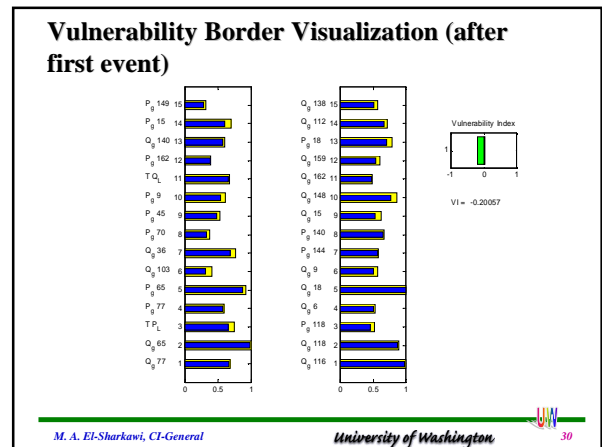
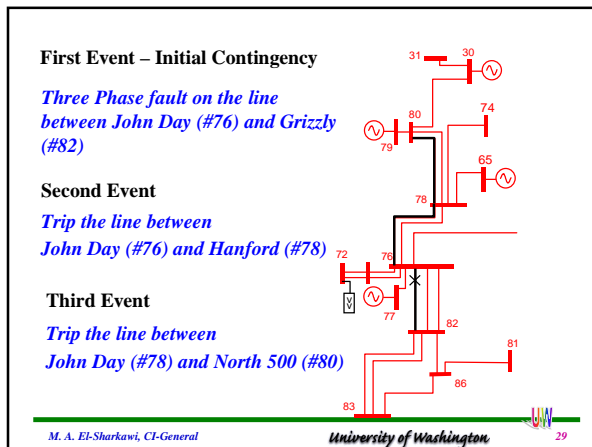
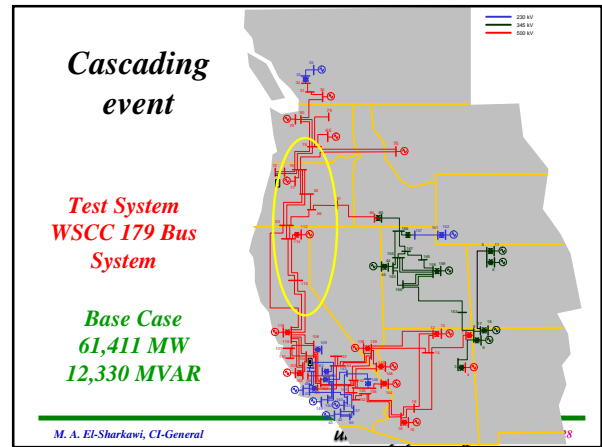
$|f(x) - \text{boundary value}| - \text{Distance to closest neighbor} + \text{Distance to current state}$

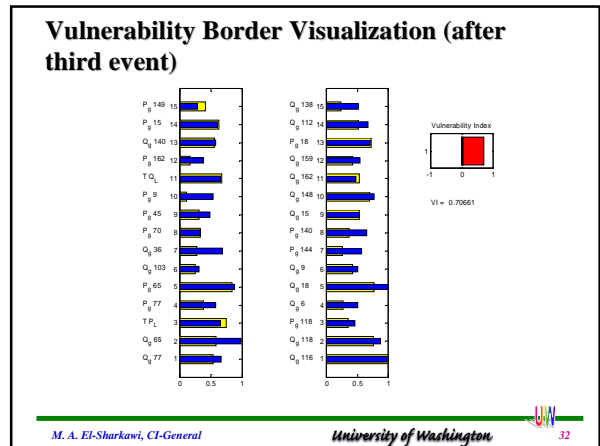
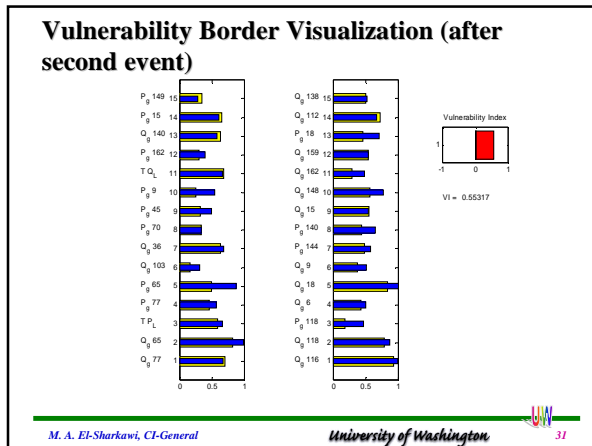
(penalize proximity to neighbors, penalize distance from current state)



Test Cases

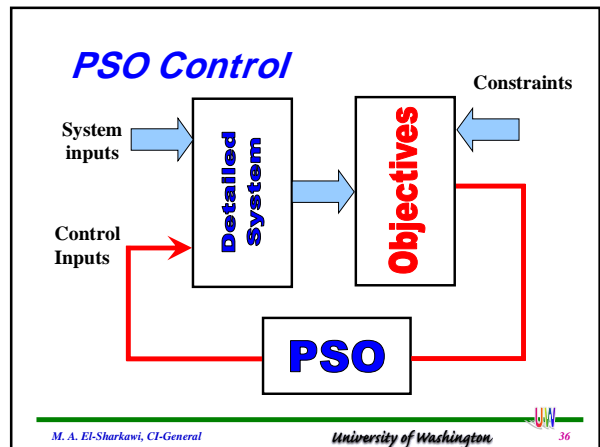
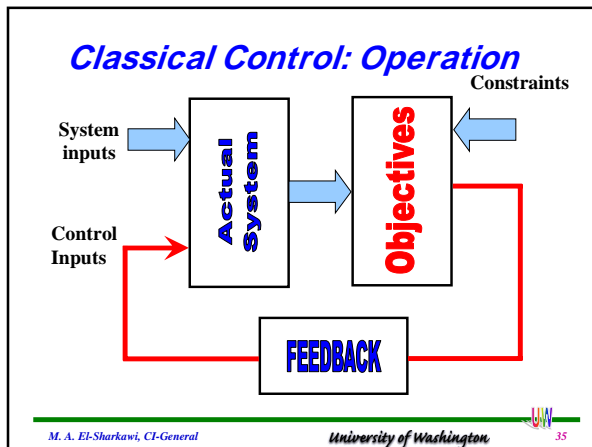
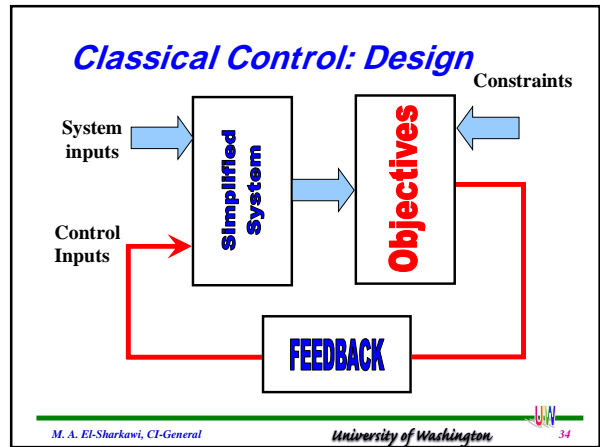
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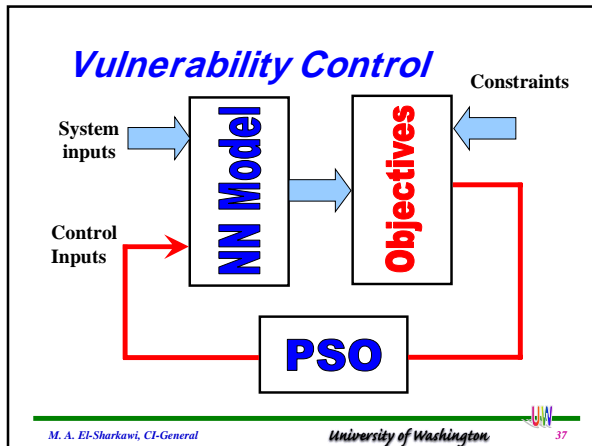




Vulnerability Control

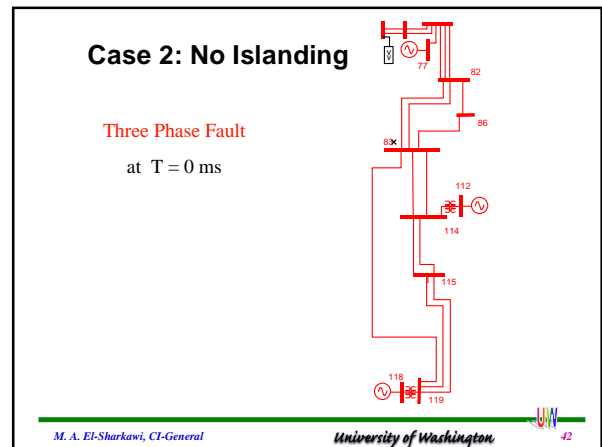
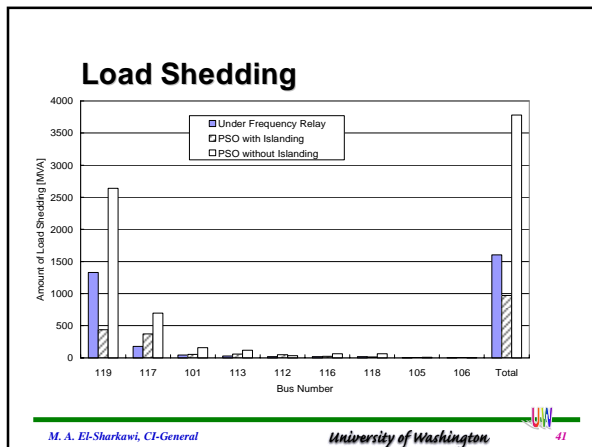
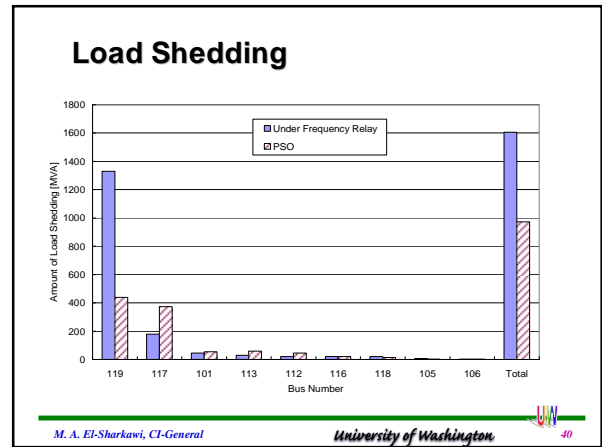
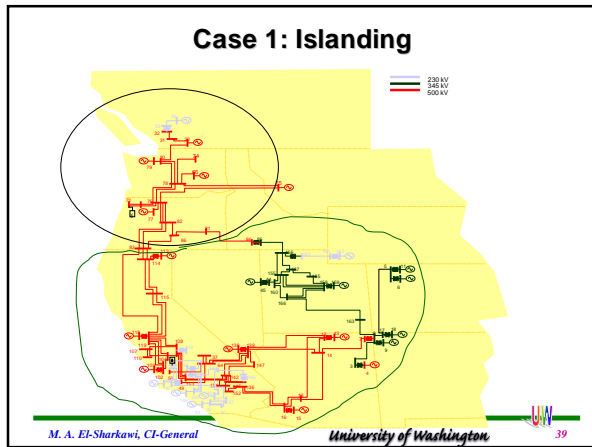
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Test Cases

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Case 2: No Islanding

Line Tripped
at T = 100 ms

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Case 2: No Islanding

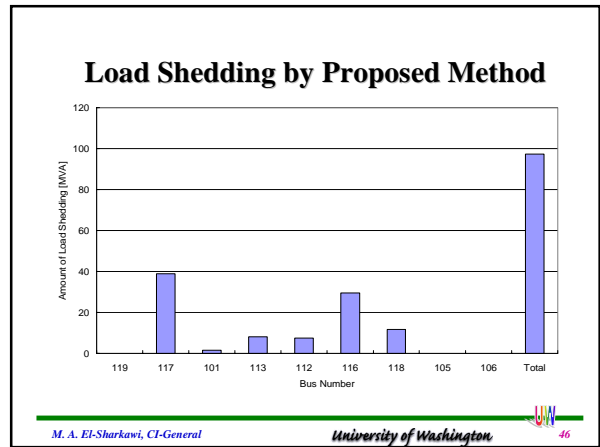
Additional Tripping due
to Hidden Failure
at T = 100 ms

Load Shedding Control
is Activated
at T = 400 ms

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Under Frequency Relay
– *Cannot stabilize this event*

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The Cranial Nerves

- Olfactory Nerve
- Optic Nerve
- Oculomotor Nerve
- Trochlear Nerve
- Abducent Nerve
- Vestibulocochlear Nerve
- Vestibular Nerve
- Auditory Nerve
- Glossopharyngeal Nerve
- Vagus Nerve
- Hypoglossal Nerve
- Accessory Nerve

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