Hierarchical Coordinated Protection with High Penetration of Smart Grid Renewable Resources (2.3)

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Outline

- Current Needs and Study Goals
- Study Focus and Proposed Solutions
- Proposed Approach
- Example: Cascading Events Detection and Mitigation
- Example: Anti-islanding Protection

Needs and Goals

NEEDS:

- Define protection issues and network conditions that current solutions cannot handle well
- Specify new protection requirements associated with high penetration of renewable sources
- Outline criteria for the design of new protection solution that can improve efficiency and reliability

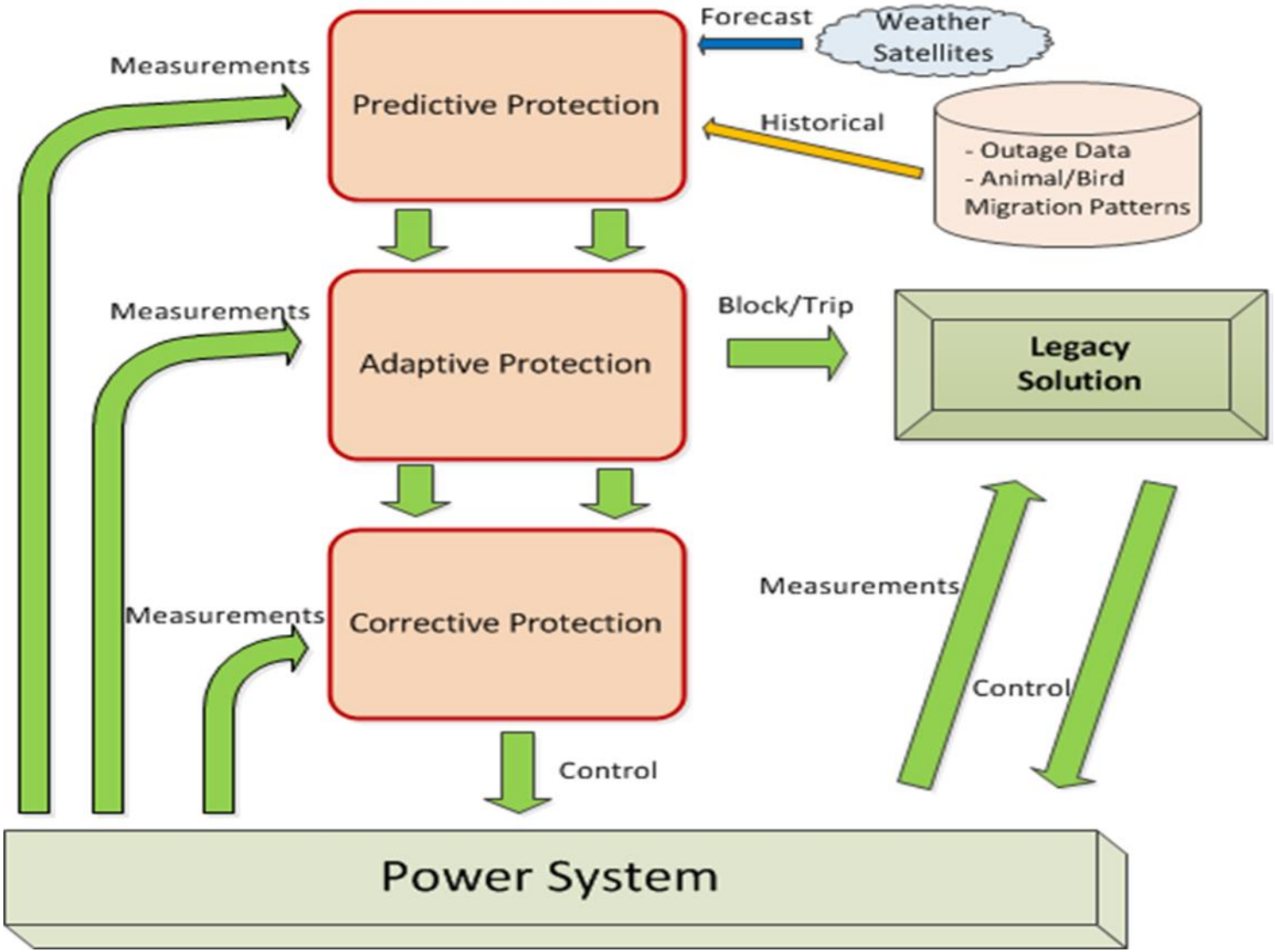
GOALS

- Propose conceptual solution for the hierarchically coordinated protection scheme
- Describe each of the three protection layers and explain how they may be implemented
- Present overall solution using some modeling and simulation, as well as real-life examples
- Assess major benefits of the new solution when compared to the legacy solution

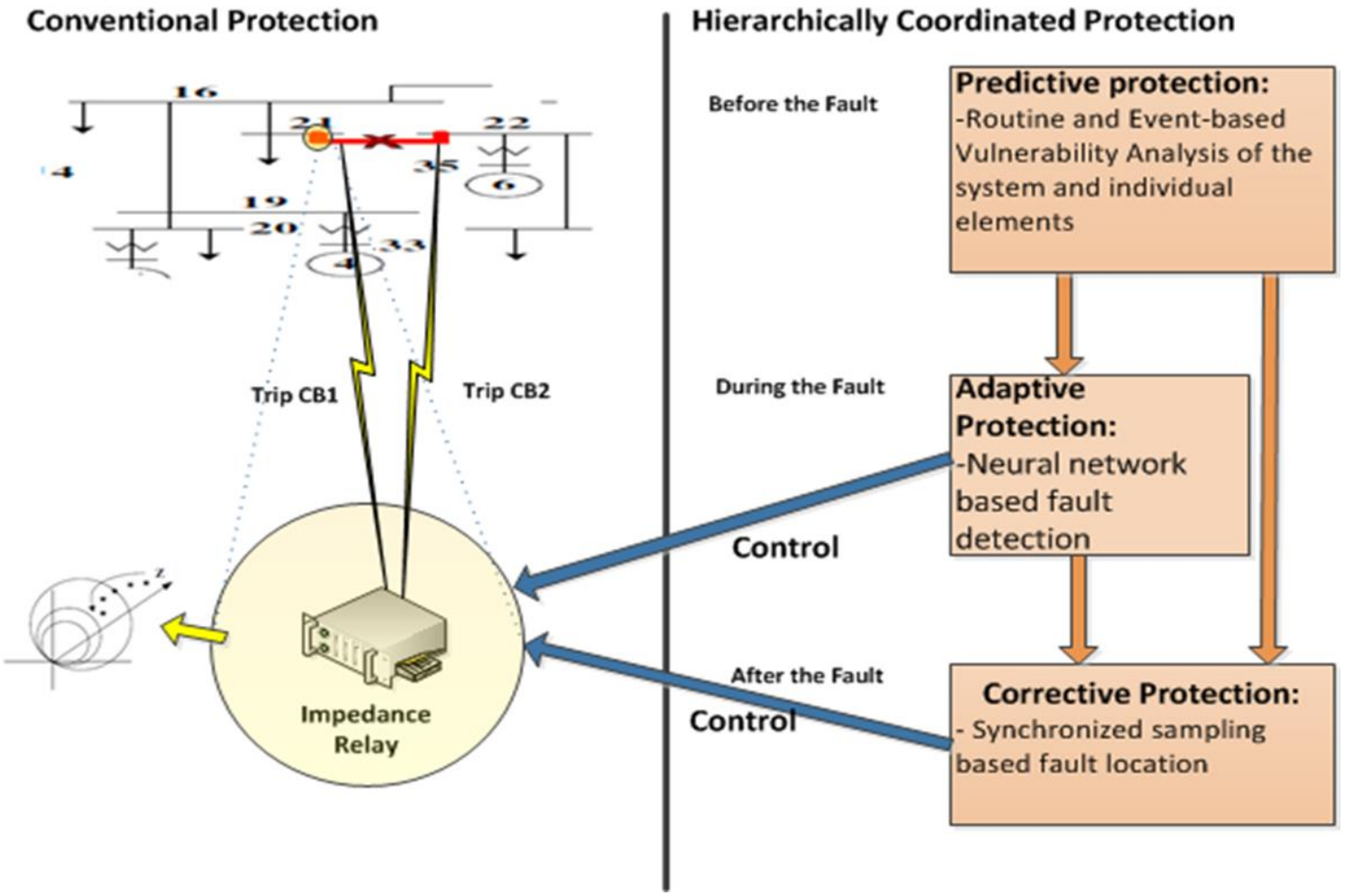
• Focus and Proposed Solutions

- **New Requirements:**
  - flexibility in the protection principle
  - robustness to the system behavior that has not been experienced before
  - self correction and verification
- **Proposed Layout:**
  - Predictive Protection:
    - provides “breathing time” for protection system to achieve flexibility (adjust bias between dependability and security)
    - conditions leading to major disturbances are anticipated well ahead of the time
    - triggers high computational methods
  - Adaptive Protection:
    - Adapts itself to prevailing operating conditions, but NOT through setting changes
    - It implements settingless protection
    - learning from data to recognize prevailing disturbances
  - Corrective Protection:
    - Uses distrubance verification tool and modifies the relay action as needed
- **New Applications:**
  - Anti-islanding protection
  - Cascading event detection and mitigation

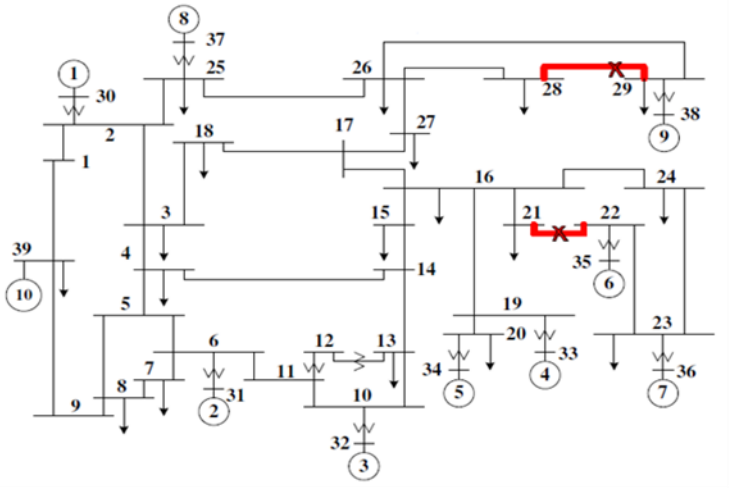
Proposed Solution

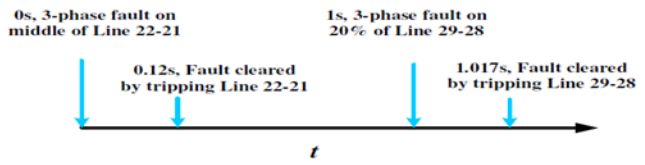


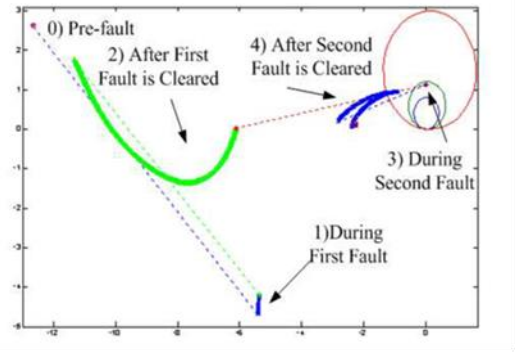
Cascading Event Detection and Mitigation



Cascading Event Detection and Mitigation





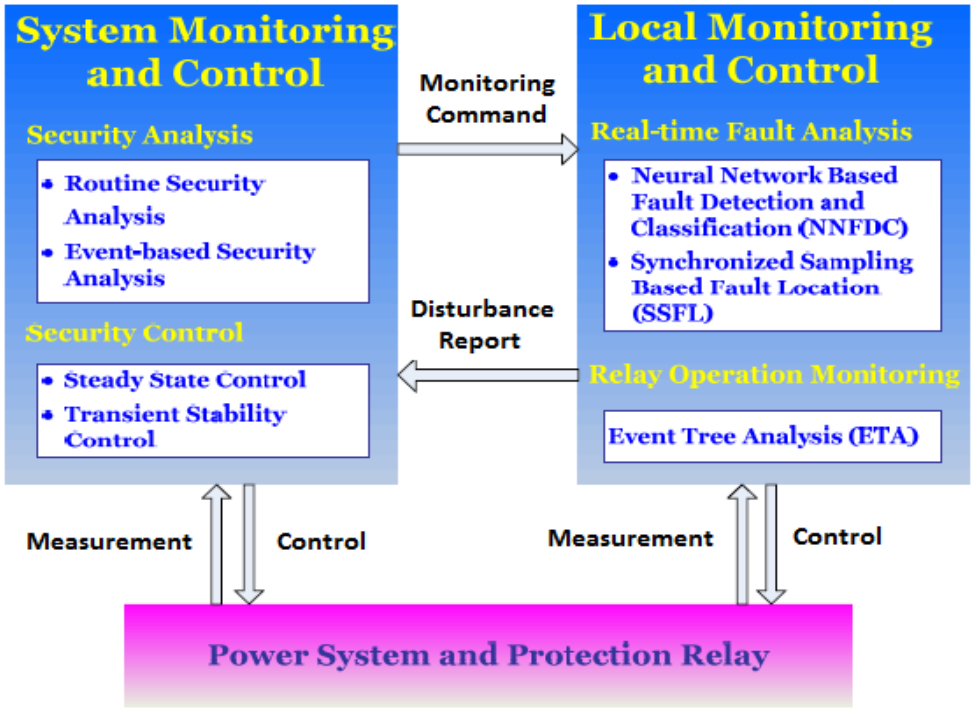


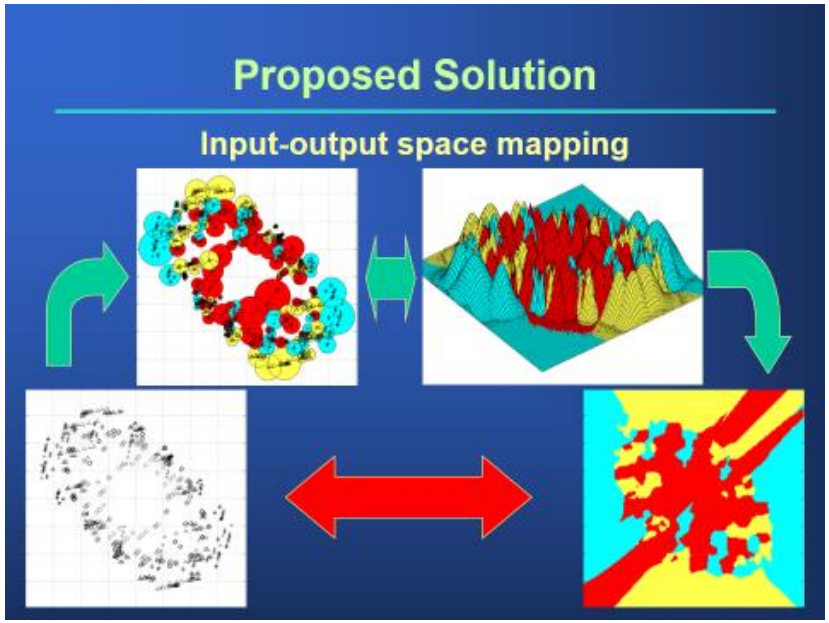
- **Predictive Protection**
  - Finds the most vulnerable lines
  - Triggers corrective layer to closely monitor relay operation
- **Adaptive Protection**
  - Neural network based fault detection
  - sends block/trip signal to distance rely
- **Corrective Protection**
  - Synchronized sampling based fault location
  - Verifies fault location or restore line

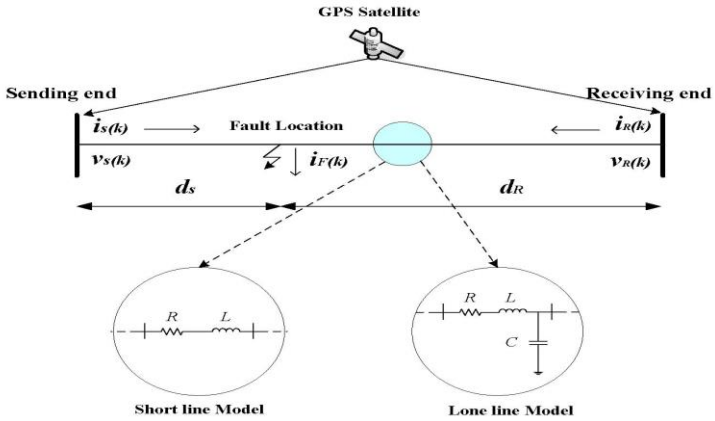
Benefits:

- Make a way for adaptive protection to be accepted as a alternative to conventional protection principle
- Several layers for disturbance verification
- Prevents line tripping due to overloading, swing…

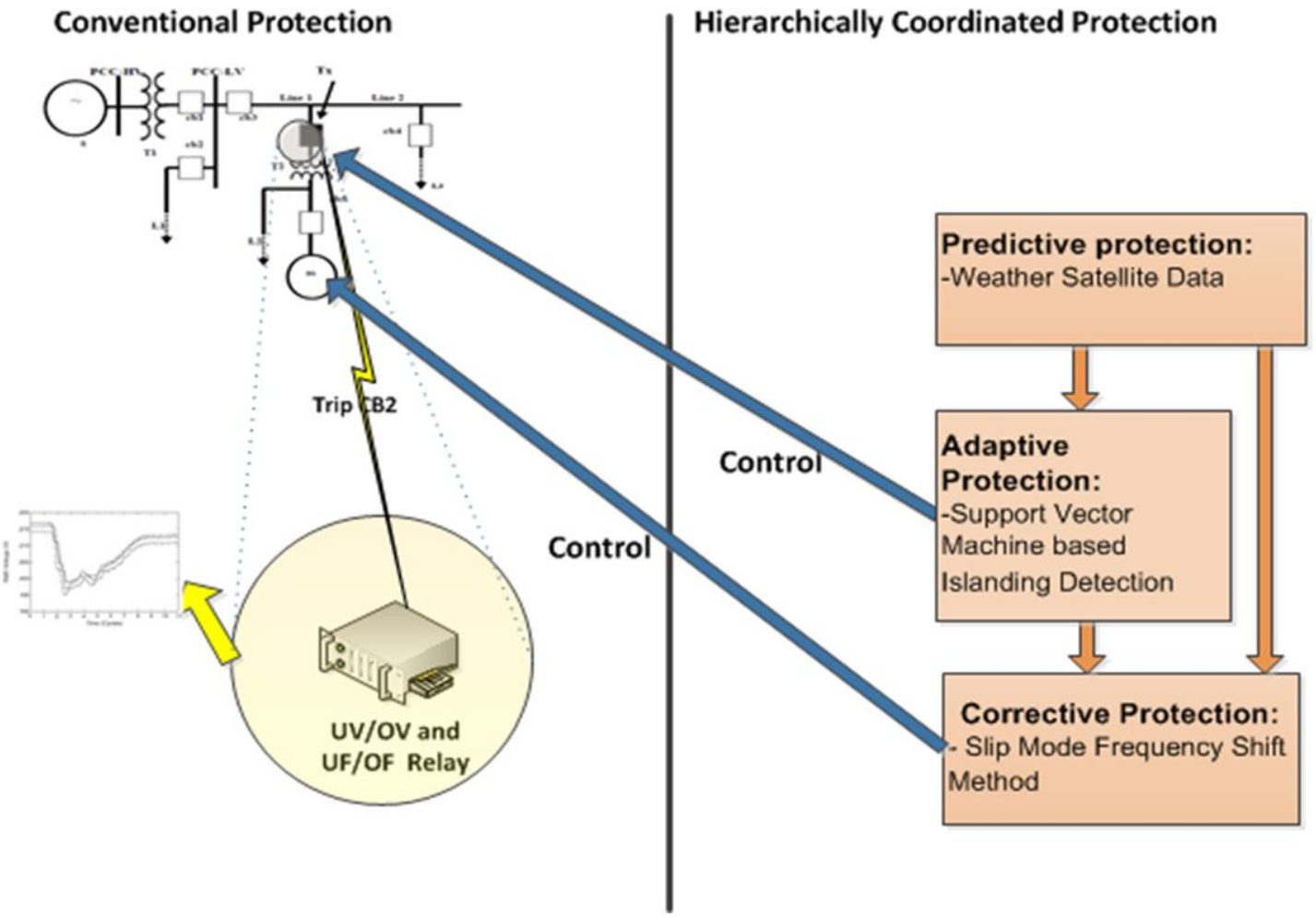
Implementation







Anti-islanding Protection



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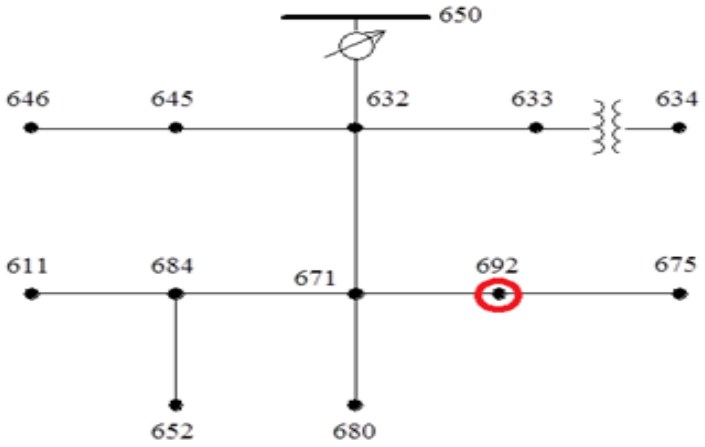
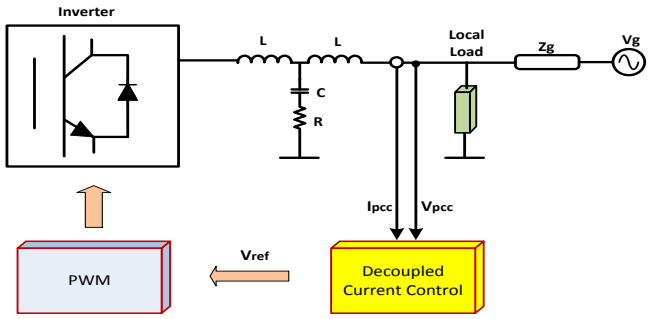


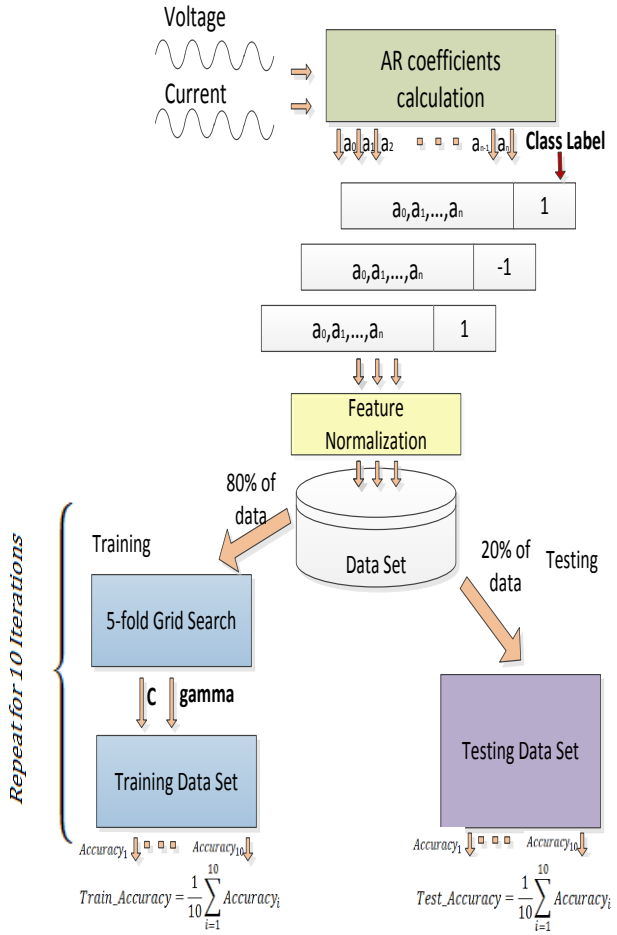


- **Predictive Protection**
  - Finds conditions that may lead to islanding
  - Triggers corrective layer to closely monitor system behavior
- **Adaptive Protection**
  - Support Vector Machine based islanding detection sends block/trip signal to OV/UV and OF/UF relays at PCC
- **Corrective Protection**
  - An active islanding method (Sliding Mode Frequency Shift) verifies islanding state

Benefits:

- Reduce negative effect of active anti-islanding method to power quality
- Has high accuracy
- Robust to switching events in the grid
- Makes way for adaptive protection to be accepted as a alternative to conventional protection principle

Implementation



Cases	No. of Data Set Samples	Description
Islanding	300	±40 % active power and ±5% reactive power mismatch
Non-islanding	25	Load Switching
Non-islanding	25	Capacitor Switching
Non-islanding	25	Motor Load Switching
Non-islanding	225	Faults
Islanding	25	Light load; various power mismatch
Non-islanding	25	Faults at different locations
Islanding	25	Second DG connected
Non islanding	25	Second DG Switching

Cases	Prediction Accuracy on the testing data set (%)
Fault Event	100
Capacitor Stitching	99.04
Static Load Switching	99.23
Motor Load Switching	98.87
Islanding	99.9%

Conclusions

Hierarchically Coordinated Protection paradigm mitigates and manages the effects of increased grid complexity on the protection of the power system is proposed. The new approach:

- has superior performance when compared to the existing solutions
- co-exists with the legacy solutions and only supplements (does not substitute) its operation
- Employs self-corrections and operation verification tools
- makes a way for adaptive protection to be accepted as a alternative to conventional protection principle
- increases penetration of renewable generation by providing adequate protection for new system conditions
- enables detection of cascading outages and offers mitigation approaches
- enables detection of power islands and mitigates negative effect of the active methods on power quality