Event Stream Processing for Improved Situational Awareness in the Smart Grid

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Preventive Model of Operation
- Based on forecasted load, generation and contingencies
- Safe operation point established to sustain contingencies
- Contingencies can never occur
- Not prepared for unforeseen contingencies
- Vertically integrated requirement driven industry
- Not optimal

Uncertainties in Power System
- Distributed generation
- Renewable energy integration (solar/wind)
- De-regularization (generation/transmission/distribution)
- Market driven industry (bidding for rights)
- Electric vehicles

Corrective Model of Operation
- Industry should be able to handle unforeseen problems
- Real time surveillance of Power system needed
- Identification and action needed on real time
- Efficient, Environment Friendly
- Complements existing model of operation
- Handle uncertainties introduced in the system

Situational Awareness
- Prevent cascading failures
- Real time decision making using Synchrophasor data
- Mathematical methods/Machine learning methods
- Information extraction for effective decision making
- Coordinated actions to prevent cascading of failures

Problems with Analytical Solutions
- Mathematical models cannot meet latency requirement of real time applications
- Utilize synchrophasor data for quick decisions
- Machine learning algorithms emulate power system behavior

Machine Learning
- SVM, ANN, Decision Trees etc. for static/dynamic security assessment and fault detection/classification
- Consume synchrophasor data
- Expected to meet the latency requirements

Challenges
- Massive Data
  - 30 samples / second ( >2 million samples/day)
  - Exponential increase with increase in deployed devices
  - Model may not fit in memory
  - Hampers latency
- Dynamic Behavior of Power system
  - Changes the operating condition
  - Should be able to update knowledge
  - Incremental learning is required
  - Downsampling NOT an Option
  - Important information lost
  - Cannot portray dynamic behavior of Power systems
  - Undermines use of high speed synchrophasor

Experimental Setup
- Hardware-in-the-loop Simulation
- SEL421 and GE N60
- 28 PMU measurements used as features
- Single Line to Ground, Transmission line loss, Generation Loss

Strategy
- Event stream mining algorithm
  - Event detection
  - Process synchrophasor data without exceeding memory and computational requirement
  - Incremental learning
  - Hoeffding Tree
    - Creates a decision tree from data stream
    - Analyzing each sample only once
    - Stores sufficient statistics (required to grow itself) in its leaves
    - Finds the best attribute considering only a small subset of the training examples
    - Number of examples necessary at each node is solved using Hoeffding bound

Evaluation Measures
- Kappa Statistics
  - Normalizes the accuracy by that of the chance predictors
- Ram Hours
  - Every GB of RAM deployed for 1 hour
- Runtime
  - Time (seconds) required for algorithm to run.

Results
- Performance measures of hoeffding tree in changing load
- Performance measures of hoeffding tree in constant load
- Performance Measure in comparison to multi scan algorithms

Other Applications
- Useful in any massive data analysis
- Synchrophasor data
- Advanced Metering Infrastructure (AMI) data processing
- Online pricing signal processing
- Process Demand Response data processing

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References

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