Review and Prospects of Machine Learning for Power System Analytics and Operation

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Big Data in Power Systems

We have only seen the tip of the “big data” iceberg 😞

Immense Untapped Values
Big Data Analytics and Machine Learning (ML)

“Machine learning is to big data as human learning is to life experience”

- Regression and prediction
- Dimensionality reduction
- Clustering
- Classification
- Pattern and anomaly detection
- Learning from experience
Google cut energy for cooling in data centers by up to 40% using ML [1]

Utilities already use or plan to use ML in their key management and operation areas [2]

Gartner predicted mainstream adoption of ML in 2-5 years [3]
From application perspective

- Preventive and corrective control actions
  - Optimal load shedding [5]
- Controlled islanding
- Fault detection and classification
- Optimal Power Flow (OPF) applications
  - 1) proxy of OPF solution [6]; 2) security constraints [5]
- Measurement data analytics
  - 1) dimension reduction [7]; 2) pattern detection; 3) anomaly detection [7]
- Forecasting
  - Load/generation/price/weather
- Predictive maintenance [8]
- Electricity theft detection
- Non-Intrusive Load Monitoring (NILM)
## Review of Applications of Machine Learning in Power System Analytics and Operation (2)

<table>
<thead>
<tr>
<th>Category</th>
<th>Techniques</th>
<th>Applications</th>
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| Supervised learning       | Regression techniques, neural network (MLNN, SOM, CNN, RNN), support vector machine (SVM), decision tree (DT) | **Regression or Prediction** (security assessment, generation/load/price/weather forecast, predictive maintenance, theft detection, demand response)  
**Classification** (security assessment, fault detection, Non-Intrusive Load Monitoring) |
| Unsupervised learning     | PCA, K-means, generative adversarial networks (GANs), autoencoders           | **Dimensionality reduction**, **Clustering**, Anomaly detection, Scenario generation, etc. |
| Semi-supervised learning  | Graph based algorithms, self-learning                                        | **Regression or Prediction**  
**Classification** (fault detection) |
| Reinforcement learning    | Q-Learning, Temporal difference learning                                     | Optimized Control, Control strategy/action selection, Parameter tuning, Procedure optimization |

► Used in a toolbox fashion [5]  
- e.g., Unsupervised learning + Supervised learning
Recent R&D in Machine Learning for Power System Analytics and Operation

- Stability control with reinforcement learning [9]
- Speed up OPF solution (MISO R&D work):
  - adaptive selection of constraints; learn to branch and bound
- Renewable energy scenario generation using GANs [10]
- On-going work in the industry

Source: SAS white paper “The Autonomous Grid: Machine Learning and IoT for Utilities”
Open platform for exploring applications of ML for power system analysis

► Developed by integrating InterPSS and TensorFlow

► Developed for
  - Generating training data set via simulation
  - Providing a simulation environment for reinforcement learning
  - Applying trained ML models to power system analysis

► Open-source on GitHub: https://github.com/interpss/DeepMachineLearning
Development of big data, machine learning (e.g., deep learning) methods and tools will help address some critical issues: usability, accuracy and confidence.

Applications for power system analytics
- On-line, real-time dynamic security assessment (DSA)
- Preventive and corrective control
- Fault detection
- OPF approximation and speed up OPF solution

Applications for power system operation
- Outage management
- Asset management
- Customer modeling and engagement
  - NILM → customer behaviors → personalized services and offerings
- Demand response
- Cyber security
Challenges

- Isolated databases/sources in power industry
- Scarcity of labeled data (input-output)
- Usability and out-of-the-box learning
- Confidence in ML results
- Technology adoption barrier and bias: physical products vs unseen algorithms

Source: SAS white paper “The Autonomous Grid: Machine Learning and IoT for Utilities”
The state-of-the-art ML provides effective solutions to (big) data analytics for the smart grid.

There is a long history of R&D in application of ML in power systems:
- Showed promising results and the potential of a wide range of applications of ML in power systems.
- Industry applications were sparse in the past due to lack of data, computing capabilities and domain experts.

Recent development of big data, computing and machine learning techniques provides enabling technologies for successful applications of ML in power systems.

Challenges ahead: data quality, usability of ML, confidence issue, familiarity with ML in power industry.
For further information


Question?

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