



Editorial: Advanced Anomaly Detection Technologies and Applications in Energy Systems

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Editorial on the Research Topic

Advanced Anomaly Detection Technologies and Applications in Energy Systems

Anomaly detection is an important topic that has been well-studied in diverse research areas and application domains. It generally involves the detection of abnormal data, unhealthy statuses, and fault diagnosis, and is helpful to guarantee industrial systems' stability, security, and economy. With the development of intelligent industries and sensor systems, large amounts of data become easily available, but there are major challenges to industrial systems' anomaly detection. One typical case is the study on energy-related systems, like thermal energy, renewable energy (e.g., wind energy, photovoltaic), electric vehicles, and so on. These systems involve various data formats and more complex data structures making anomaly data detection a challenge. Currently, under the development of deep learning and big data analytics, many promising results have been achieved in energy systems' anomaly data detection. However, many challenging problems remain unsolved due to the complex nature of energy industries. New techniques and advanced engineering applications of anomaly detection in energy systems still appeal to a wide range of scholars and industries.

The objective of this Research Topic is to solicit papers on recent developments in anomaly detection techniques and advances in applications of energy-related systems. The topic can cover techniques related to anomaly detection algorithm development, such as machine learning, data mining, deep learning, graph theory, big data, and so on. Various aspects of energy applications can be addressed, like data cleaning, unhealthy evaluation of energy systems, condition monitoring, and faults diagnosis in energy-related industries. Special attention could be paid to energy-related systems, e.g., wind energy, photovoltaic, thermal energy, electric vehicle (EV) development, and so on.

After paper Research Topic and rigorous review, 63 high-quality articles contributed by 327 authors were finally accepted for their contributions to the study of condition monitoring and anomaly detection in power systems, renewable energy systems, and other industrial systems.

In the paper *Series Arc Fault Diagnosis Based on Variational Mode Decomposition and Random Forest*, Zhao et al. proposed a method based on variational mode decomposition and energy entropy to extract the characteristic quantity of series arc faults, and subsequently complete the fault detection.

In the paper *Sequential Detection of Microgrid Bad Data via a Data-Driven Approach Combining Online Machine Learning with Statistical Analysis*, Huang et al. proposed a sequential detection method to detect bad data in Energy Management Systems (EMS).

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Abnormal detection data of fire accidents in power cable tunnels was studied by Guo et al. in the paper *Analysis of Abnormal Detection Data of Fire Accident in Power Cable Tunnel and Field Test Study on Characteristic Parameters of Tunnel Fire*.

In the paper *Research on Fire Prediction Method of High-Voltage Power Cable Tunnel Based on Abnormal Characteristic Quantity Monitoring*, Li et al. proposed a fire early warning method for a high-voltage power cable tunnel based on abnormal characteristic quantity monitoring.

In the paper *Data-Driven Traction Substations' Health Condition Monitoring via Power Quality Analysis*, Xie proposed a data-driven approach for recognizing abnormal types of power quality problems, and developed a system with intelligent governance strategies.

In the paper *Monitoring and Identifying Wind Turbine Generator Bearing Faults Using Deep Belief Network and EWMA Control Charts*, a data-driven approach for condition monitoring of generator bearings using temporal temperature data was presented by Li et al.

In the paper *Invalid Data Rejection of Audible Noise on AC Transmission Lines Based on Moving Window Kernel Principal Component Analysis*, Cheng et al. proposed to detect outliers by using the moving window kernel principal component analysis (MWKPCA).

In the paper *Power Consumption Predicting and Anomaly Detection Based on Transformer and K-Means*, Zhang et al. combined the widely used deep learning model Transformer with the clustering approach K-means to estimate power consumption over time and detect anomalies.

In the paper *Heuristic Feature Selection for Wind Power Anomaly Events Study*, Yu and Lin took wind power ramp events as typical harmful anomaly events in wind engineering and detected them.

In the paper *Robust Vehicle Dynamics Control for a Sharp Curve with Uncertain Road Condition*, Miao et al. presented a robust control strategy for CAVs to preserve a precise tracking performance and maintain the stability of lateral dynamics.

In the paper *A Fault Signal Processing Method Based on An Improved Prony Algorithm*, Yang et al. proposed an improved adaptive Prony algorithm to detect faults in power systems.

In the paper *An Improved Solution to Generation Scheduling Problem Using Slime Mold Algorithm*, Zhu proposed a novel mathematical formulation that employs changeable weights to modify the sequence of both negative and positive propagation waves during oscillation.

Considering bird nests on transmission line towers pose a serious threat to the safe operation of power systems, in the paper *Recognition of Bird Nests on Power Transmission Lines in Aerial Images Based on Improved YOLOv4*, Zhang and He explored an effective method to detect bird nests taken by drone inspection.

In the paper *Research on STATCOM Mathematical Model of Battery Storage in HVDC Transmission System*, Xing et al. proposed research to study the possible imbalance of battery state of charge (SOC) in STATCOM/BESS.

In the paper *Power Grid Material Demand Forecasting Based on Pearson Feature Selection and Multi-Model Fusion*, a power

grid material demand forecasting model based on feature selection and multi-model fusion was proposed by Dai et al. oriented to power grid analysis.

In the paper *Power Quality Data Compression and Disturbances Recognition Based on Deep CS-BiLSTM Algorithm with Cloud-Edge Collaboration*, Xia et al. proposed a hybrid model based on distributed compressive sensing and a bi-directional long-short memory network to classify power quality disturbances data.

In the paper *Numerical Analysis on the Sub-Span Oscillation of Iced Eight-Bundle Conductors During Galloping*, Yu et al. implemented a numerical analysis method to analyze the sub-span oscillation characteristics of the eight-bundle conductor during galloping.

In the paper *A New Grounding Resistance Reduction Method for Wind Turbines by Grounding Grid Connection in Limited Areas*, a new grounding resistance reduction method is proposed by Hu et al. and verified for wind turbines by connecting nearby wind turbine grounding grids.

In the paper *Acoustic-Electrical Joint Localization Method of Partial Discharge in Power Transformer Considering Multi-Path Propagation Impact*, Jia et al. proposed an acoustic-electrical joint method for partial discharge location in the power transformer with the full consideration of the multi-path propagation impact.

In the paper *Robust Unit Commitment for Minimizing Wind Spillage and Load Shedding With Optimal DPFC*, Zhu et al. presented a novel two-stage robust model to optimize the status of the generator and location-allocation of the distributed power flow controller (DPFC).

In the paper *Improved Electrogeometric Model of UHV Transmission Line Based on Long Gap Discharge and Its Application*, an improved EGM model was developed by Hu et al. and applied to evaluate the influence of tower type and slope steepness on the shielding failure tripping rate of UHV transmission lines.

In the paper *Traction Network Protection Based on Similarity of Transient Current Waveform*, a protection scheme for the traction network of the penetrating co-phase traction direct power supply system based on the waveform similarity at both ends of the line was proposed by Chen et al.

In the article *Numerical Simulation of Galloping Characteristics of Multi-Span Iced Eight-Bundle Conductors*, the numerical model of the multi-span iced eight-bundle conductor is established by Shunli et al.

In the paper *Research on Battery Energy Storage STATCOM Suppressing HVDC Commutation Failure*, a compensation method using battery energy storage STATCOM (STATCOM/BESS) to suppress commutation failure of the transmission system is proposed by Xing et al.

In the paper *Prediction of the 3D Distribution of NO_x in a Furnace via CFD Data Based on ELM*, a novel method for the prediction of the three-dimensional (3D) spatial distribution of NO_x in a furnace is proposed and evaluated by Lv et al.

In the paper *Accurate Modeling Simulation and Experimental Study of Hybrid Multi-Terminal UHVDC Transmission System*, Xing et al. proposed a simulation model of the control system

applicable to the hybrid multi-terminal UHVDC transmission system.

In the paper *Two-Stage Optimal Location Allocations of DPFC Considering Wind and Load Uncertainty*, Zhu et al. presented a novel two-stage stochastic model for optimal location allocations of the DPFC coupled with the interactions of DPFC to search for the optimal solutions.

In the paper *Simulation Study on Lightning Impulse Characteristics of Flexible Graphite Composite Grounding Materials Applied to Grounding Grid of Power System*, Hu et al. built a frequency domain electrical network model and an equivalent radius iterative algorithm to analyze the impulse characteristics of the graphite composite grounding electrode.

In the paper *Fuzzy Weighted Echo State Networks*, a novel echo state network (ESN) was proposed by Yao and Li, which uses the structural information of data sets to improve the performance of the classical ESN.

In the paper *Mechanism of Power Quality Deteriorating Caused by Multiple Load Converters for MVDC System*, Huang et al. discussed the mechanism of power quality deterioration caused by interfacing multiple load converters as anomalies in the MVDC system.

In the paper *An intelligent governance system for traction substations' power quality problems*, Xie proposed an advanced approach for detecting power quality problems in electrified railway traction substation systems.

In the paper *Multiterminal Hybrid DC Line Protection Based on Intrinsic Mode Energy Entropy*, the boundary frequency characteristics of the UHV multiterminal hybrid DC transmission system were analyzed by Xing et al.

In the paper *Energy-Efficiency-Oriented Vision Feedback Control of QCSP Systems: Linear ADRC Approach*, Li and Feng proposed a lightweight object detection network and a linear active disturbance rejection controller (LADRC) for the quadrotor with the cable-suspended payload (QCSP) system.

For the optimal size of a hybrid renewable energy system to meet the electrical load requirement of a specified distant location in the Haryana state of India, two intelligence techniques were proposed by Zhang in the paper *Optimal Allocation Of Hybrid Energy System For Competitive Electricity Market*.

In the paper *A Multi-Agent Game-Based Incremental Distribution Network Source-Load-Storage Collaborative Planning Method Considering Uncertainties*, Yang et al. proposed an incremental distribution network source-load-storage collaborative planning method with a multi-agent game.

In the paper *Grey Wolf Optimization-Based Deep Echo State Network for Time Series Prediction*, Chen and Zhang proposed a grey wolf optimization (GWO) algorithm introduced in this study to achieve the lowest learning error.

In the paper *A Study of Protection Method for Hybrid Multiterminal UHVDC Lines Based on CEEMDAN-Teager Energy Operator*, a protection scheme for hybrid multiterminal UHVDC lines based on the CEEMDAN and Teager energy operator is proposed by Xing et al.

In the paper *Study of Capacitive Coupling Sensor Fused with High Voltage XLPE Cable Joint*, Xia et al. proposed a capacitive

coupling sensor for partial discharge detection with the fusion of high voltage XLPE cable joint.

In the paper *Bone Age Assessment Based on Deep Convolutional Features and Fast Extreme Learning Machine Algorithm*, Guo et al. proposed a new DL-based bone age assessment method based on the Tanner-Whitehouse method.

In the paper *Study on Dynamic Process Characteristics of CHP Unit with Variable Load Based on Working Point Linearization Modeling*, a CHP unit model based on working point linearization modeling was proposed by Huang et al. for the optimization scenario of an integrated energy system.

In the paper *Wind Power Prediction Based on a Hybrid Granular Chaotic Time Series Model*, Wang et al. proposed a hybrid model considering physical features of data for high-accuracy short-term wind power prediction.

In the paper *Operation State Evaluation Method of Smart Distribution Network Based on Free Probability Theory*, a method of operation state evaluation of smart distribution networks based on free probability theory was proposed by Zhang et al.

In the paper *Research on Dynamic Response of Slopes with Weak Interlayers Under Mining Blasting Vibration*, Zhang et al. constructed a slope model with a weak interlayer to investigate the influence of different factors of blasting on the internal dynamic response.

In the paper *Numerical Weather Prediction Correction Strategy for Short-Term Wind Power Forecasting Based on Bidirectional Gated Recurrent Unit and XGBoost*, Li et al. proposed a variational mode decomposition combined with bidirectional gated recurrent unit (VMD-BGRU) method for NWP wind speed correction and XGBoost forecasting model.

In the paper *Research on the Unstable Branch Screening Method for Power System With High-Proportion Wind Power*, Tang et al. proposed an unstable branch screening method for power systems with high-proportion wind power.

In the paper *Research on Conducted Disturbance to Secondary Cable Caused by Disconnect Switching Operation*, Chen et al. proposed a broadband equivalent circuit model of the potential transformer and the grounding grid based on the vector fitting method and the impedance synthesis method.

In the paper *The Influence of Humidity on Electron Transport Parameters and Insulation Performance of Air*, An et al. studied the microscopic process of electron-molecule collision in the air based on the Boltzmann equation.

In the paper *Intelligent Filling Method of Power Grid Working Ticket Based on Historical Ticket Knowledge Base*, An et al. proposed a method of intelligent filling in a power grid working ticket based on a historical ticket knowledge base.

In the paper *Lumped-Circuits Model of Lossless Transmission Lines and Its Numerical Characteristics*, aiming at the lumped-circuits model of the lossless transmission line in the digital simulation, Zhou et al. discussed and analyzed the unit step response generation of the lumped-circuits model.

In the paper *Tolerance of Electromagnetic Relay to Voltage Sags and Short Interruptions*, Zhang et al. studied the tolerance of electromagnetic relay (EMR) under voltage sag and short interruptions on the basis of response mechanism analysis and extensive tests.

In the paper *Ultra-Short-Term Wind Power Prediction Based on Bidirectional Gated Recurrent Unit and Transfer Learning*, an ultra-short-term prediction method based on multilayer bidirectional gated recurrent unit (Bi-GRU) and fully connected (FC) layer was proposed by Chen et al.

In the paper *Research on Combined Electricity and Heating System Scheduling Method Considering Multi-Source Ring Heating Network*, Ye et al. established an electrothermal coupling scheduling model and proposed a method of simplifying a multi-source cyclic heating network topology approximation.

In the paper *OC-SLAM: Steadily Tracking and Mapping in Dynamic Environments*, Wu et al. proposed an object detection and clustering assisted SLAM algorithm (OC-SLAM) to solve problems of SLAM systems.

In the paper *Research on Leakage Current Waveform Spectrum Characteristics of Artificial Pollution Porcelain Insulator*, to analyze the LC characteristics of porcelain insulators in the process of pollution flashover, artificial pollution flashover tests on porcelain insulators were conducted by Fang et al.

In the paper *Green Building Energy Cost Optimization With Deep Belief Network and Firefly Algorithm*, Liao et al. proposed a multi-objective optimization framework to minimize the energy cost while maintaining indoor air quality.

In the paper *Hosting Capacity Assessment in Distribution Networks Considering Wind-Photovoltaic-Load Temporal Characteristics*, Du et al. proposed a probabilistic assessment method of hosting capacity considering wind-photovoltaic-load temporal characteristics in distribution networks.

In the paper *Equivalent Firm Capacity Assessment of HDR-PV Hybrid Power System: A Distributionally Robust Approach*, Si et al. designed a flexible hot dry rock (HDR) hybrid power system (HPS), making full use of the potential of HDR for energy storage and power generation.

In the paper *Modeling the Heat-Hydrogen Balance Characteristic of Hydrogen Energy Storage and Cooperative Dispatch of Wind-Hydrogen Hybrid System*, Si et al. designed a hydrogen energy storage system (HESS), including waste heat utilization.

In the paper *Mapping Relation of Leakage Currents of Polluted Insulators and Discharge Arc Area*, Fang et al. carried out an experimental study on artificial pollution discharge of insulators.

In the paper *Short-Term Nacelle Orientation Forecasting Using Bilinear Transformation and ICEEMDAN Framework*, A tandem hybrid approach to improve the prediction accuracy of the wind direction data was developed by Li et al.

In the paper *Edge Intelligent Perception Method for Power Grid Icing Condition Based on Multi-Scale Feature Fusion Target Detection and Model Quantization*, Ma et al. proposed a lightweight intelligent recognition method of insulator icing thickness for front-end ice monitoring devices.

In the paper *Intelligent Frequency Control Strategy Based on Reinforcement Learning of Multi-Objective Collaborative Reward Function*, Zhang et al. constructed a multi-objective collaborative reward function by introducing a collaborative evaluation mechanism with multiple evaluation indexes.

In the paper *Insulator Contamination Perception Based on Feature Fusion of Infrared Image and Meteorological Parameters*, Wang et al. proposed a feature fusion model to perceive insulator contamination in different weather conditions.

It is seen that these papers in our Research Topic mainly involve anomaly detection in other industrial systems, as well as some advanced algorithms development, e.g., machine learning and data mining algorithms related to anomaly detection. From all contributions to this Research Topic, we see that anomaly detection in the energy system is meaningful and potential to be further developed in future research.

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