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Big Data Analytics Application For Smart Grid Failure Detection-A survey

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Abstract: Data analytics are now playing a more important role in the modern industrial systems, driven by the development of information and communication technology, an information layer is now added to the conventional electricity transmission and distribution network for data collection, storage and analysis with the help of wide installation of smart meters and sensors**.** This paper reviews potential applications of big data analytics for smart grid failure detection.(2) Until now there has been no unified definition of Smart Grid, but some characteristics of Smart Grid are identified as self-healing, Interaction, Optimization, Compatibility, Integration. due to involvement of modern intelligent devices in the said characteristics nature of smart grid generate enormous data and this data need to be analyzed in detecting fault condtion,self healing,futre prediction of smart grid. Data analytics involve Diagnostic analytics aim to understand the cause of events and system behavior and tries to identify challenges and opportunities. and predictive analytics are used to make probabilistic predictions to identify trends with the aim to determine what might happen in the future. This paper reviews these data analytics methods which can be used in smart grid failure detection and future research opportunities in this field.(1)

Keywords: big data analytics (BDA), self healing, compatibility, Diagnostic analytics ,predictive analytics

I. NEED OF DATA ANAYLTICS IN SMART GRID

The smart grid gathers data from diverse sources and stores it to be consumable by analytics Managing smart grids to provide smart energy requires advanced machine learning techniques to collect accurate information in an automated fashion, automate decision-making and control events in a timely manner at both the local and system-wide level [1]. Important progress has been made for using field data acquired from smart devices mounted in substations, feeders, and numerous databases and models across the utility enterprise. There are several sources of data in smart grids on markets, equipment, geography and power system data which can be used to predict states, provide situational awareness, analyze stability, detect faults and provide advance warning. Therefore, analytics (comprising BDA, ML and AI) [1] have a significant role to make the grid more intelligent, efficient and productive. Analytics can be applied to signal event, state, engineering operations, and customer analytics, in sum enabling high-level and detailed insights into grid situational awareness.

II. DATA SOURCES IN SMART GRID

As an intelligent system of both energy and information, smart grid is the abundant source of information, which covers the data from process of electricity generation, transmission, distribution and consumption. These data include the electrical information from distribution stations, distribution switch stations, electricity meters, and non-electrical information like marketing, meteorological as well as regional economic data. the various data sources and their application are as follows [2]

1.Advanced metering infrastructure **(AMI):**it involves in Integration of smart meters, data management systems and communication networks to provide bidirectional communication between customers and utilities. it is applied in Remote meter configuration, dynamic tariffs, power quality monitoring and local control.

2.Phasor measurement unit **(PMU)**: it involves in Real-time measurements (30 to 60 samples/second) of multiple remote points with a common time source for synchronization. it is applied Electrical waves measurement of power grid.

3.Wide area monitoring system **(WAMS):** An application server to deal with the incoming information from PMUs

4.Remote terminal unit **(RTU):** A microprocessor-controlled device that transmitting telemetry data Information collection of system operation status.

5.Supervisory control and data acquisition**(SCADA)**: Both manual and automatic, System monitoring, event processing and alarm.

6.Intelligent electronic device **(IED)**: Monitoring and recording status changes in the substation and outgoing feeders. and it is applied in Combination of different relay protection functions with measurement, recording and monitoring.

1.Extracting value by big data analytics

The main aim of using BDA (Big data analytics) is to extract useful information (value) from the data.[1] This value can be extracted from the gathered data after performing analytics on the data as illustrated in Figure 1. the first step is to collect data on which analytics will be performed the data can be collected from various sets as mentioned advanced metering infrastructure (AMI), Phasor measurement unit (PMU),

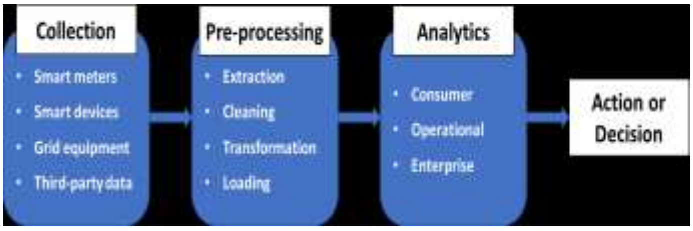


Figure1. Example of extracting value by using BDA[1].

Wide area monitoring system (WAMS), Remote terminal unit (RTU),Supervisory control and data acquisition(SCADA). Once the data are collected, the next step is data pre-processing. In this step, the data from various sources (in a variety of formats and possibly containing missing or erroneous values) are extracted. These data values are then cleaned to remove erroneous values. The data are then transformed to the target repository's format, after which data are loaded into a repository. Now data analytics techniques are applied on the pre-processed data to extract value (i.e., information) based upon which some informed actions or decisions can be made. the analytics may be of three different types consumer analytics, operational analytics and entrepreneur analytics[1].

2. **Data preprocessing techniques**

This is one of most important stage of extraction of value [2] from the big data.Data integration techniques aim to aggregate data collected from disparate sources in an effective way with a unified view as shown in Figure 2.

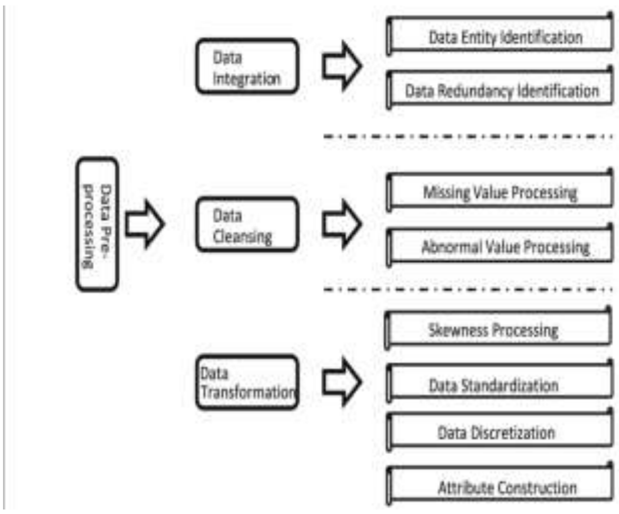


Figure2. Data Pre-processing Techniques [2]

Raw data has out of range values, and the collection process is often unrestrained, meaning datasets contain missing values or coefficients which produce ambiguous results. For that reason, initially, data requires pre-processing. This acts as a filter to remove unwanted values and clean the data prior to feature extraction. Pre-filtering the data extracts any elements that are not required by the feature extraction stage. Redundant values, which do not conform to the filter parameters and irrelevant aspects of This process includes various stages, such as: cleaning and normalization of raw data. Cleaning involves verifying that there are no missing values and smoothing data. Noisy data, which refers to corrupt and meaningless values, are also removed. The cleaning process also removes duplicated values; otherwise, the results of the data classification would be compromised. This could also include specifying a value range to cut out coefficients, which are outside the scope of our requirement this is referred from article [3].

Normalization is used to allow the classifiers to treat the data equally. In other words, the data is manipulated so that coefficients in the dataset are standardized. This prevents raw data values from over contributing to the classification process and affecting the results [3].

Consumer analytics include energy forecasting, consumption analysis and theft detection. Operational analytics include asset maintenance, outage management, and distribution optimization. Enterprise analytics include real-time grid awareness and visualization of data [1].

III. DATA PROCESSING TECHNIQUES

It is the discovery and communication of meaningful patterns in data. Data analytics is a (sometimes automated) process used to discover novel, valid, useful and potentially interesting knowledge from large data sources which is otherwise difficult to uncover[6-1], the various data processing or data analytics methods used to detect failure is as shown in fig 3.

Figure 3. Artificial Intelligence System for DMS [16]

Artificial neural network, machine learning,multi-agent system are the most important and widely used fault diagnosis and self healing of smart grid technology. Along with these methods fuzzy logic and genetic algorithm are also used as part of big data analytics of smart grid failure detection these all methods are reviewed from literature survey and future challenges are discussed in this section of paper.

1.Fuzzy logic:fuzzy controllers just belong to the category of nonlinear controllers and can produce desirable results when designed properly and more over compared to the conventional PI controllers, provide more flexibility and are more suitable to blend well with robust and adaptive control techniques. Mathematically, fuzzy sets are usually used to extract the possible outcome from a great variety of information expressed in vague and imprecise terms and treats to express these vague data in terms of membership functions. Membership functions is a certain mathematical distribution which can be effectively implemented for logical reasoning.

The above literature is used in finding the application of fuzzy set to micro grid control against fault.[4]

Due to the complexity of the smart grid and the uncertainty of the distributed generation, there is a lot of uncertain information in smart grid. The theory of rough intuitionistic fuzzy set is proposed in this article to deal with the fault diagnosis in the case of uncertain information Fault position and the fault device can be judged based on current, voltage and the action of protection device and circuit breakers under failure state, including error and incomplete fault signal caused by malfunction, bit error in signal propagation. Diagnosis rules can be extracted from the set of fault samples. Diagnosis rules obtained by this method can be used to establish the fault diagnosis knowledge base, thus provides a feasible method for the fault diagnosis of smart grid [5]

a fuzzy system with Hilbert-space-based power theory (FHSP). Implementation of this protection scheme uses the power difference between the sending and receiving ends of the feeder to distinguish faults conditions. This protection scheme has the advantage of operating in less than two cycles after the occurrence of the fault and its error detection is not dependent on the selection of threshold values. The algorithm operates correctly for all types of faults whilst preventing unwanted tripping, even in case of distorted data due to current transformer saturation or data mismatches [6].

Author[8] proposes fuzzy-logic-based BESS control scheme for a DC micro grid that consists of a solar PV and fuel cells for generation and two BESSs and a super capacitor for energy storage. The BESSs control the charging and discharging actions to keep the generation power of the overall micro grid uniformly. This paper proposes an intelligent control scheme for a BESS based on the concept of multi-agent system[7].

There have been researches for BESS control schemes based on rule and fuzzy logic based fuzzy-logic-based BESS (batterY energy storage system) control.

2.Genetic Algorithm: Genetic algorithms is a population based optimization algorithm that uses the concept of natural evolution and population genetics to search and arrive at a high quality near global solution [9]. Essential attributes of GA enhance its suitability for handling ill-structured optimization problems [10]. These essential attributes are the use pay-off (fitness or objective function) directly for the search direction, no mathematical assumption is needed and ability to discover global optimum very rapidly during searching from a population[11].The basic genetic operators are selection, crossover, mutation and inversion. These are very essential in coding the algorithm to achieve a desired result[12]. The advantages of GA includes ability to handle integer or discrete variables effectively, ability to obtain global solution within shortest possible and it can be easily coded to work on parallel computers among others [13] [14].

Genetic Algorithms are used for the identification of the optimal positioning of micro grids in an existing power grid with DG. The aim is to obtain a partition minimizing the power exchange between the micro grids in time (i.e. maximizing self consumption) Future works will be devoted to include storage systems in the network and to a better characterization of the power unbalances fluctuations [15]

3.Artificial Neural Network: An Artificial Neural Network (ANN) is a mathematical model inspired in the biological behavior of neurons and how the structure of the brain is organized The brain can be considered as a highly complex system, where it is estimated that approximately 100.000 million neurons in the brain cortex form a framework of over 500 billion of neural connections. One neuron can have up to 100.000 connections even though the average varies between 5.000 and 10.000 connections some of advantages neural network are as follows[16]

1.Adaptive Learning: Ability to learn to perform tasks based on training or an initial experience.

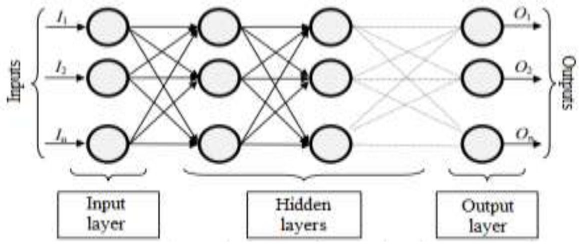
2.Self-Organization: A neural network can create its own organization or representation of the information it receives during a learning stage.

3.Tolerance to failures: The partial destruction of a network leads to a degradation of its structure; However, some capabilities of the network can be maintained, while important damages are taken.

4.Operation in real-time: Neural computations can be performed in parallel. For this purpose, machines with specialized hardware are designed and produced.

5.Easy insertion within the existing technology: Custom chips can be used to improve the capacity of neural networks in certain areas. This will facilitate the modular integration into existing systems.

The neural network block is as shown in Figure 4.



Fig,4.*Example of a totally connected neural network[16]*

There are three main layers in ANN which called the input layer, hidden layer, and output layer, which are linked with each other. They also have weighted input ingredients that are changed as the signals pass through the hidden neurons, which give their outputs using the sigmoid function [17].

To apply fault detection the current system status, historic and new big data of the inputs are needed because the behavior of the system will be different about the historic pattern. The procedure used for this process is shown in Fig. 5.[17]

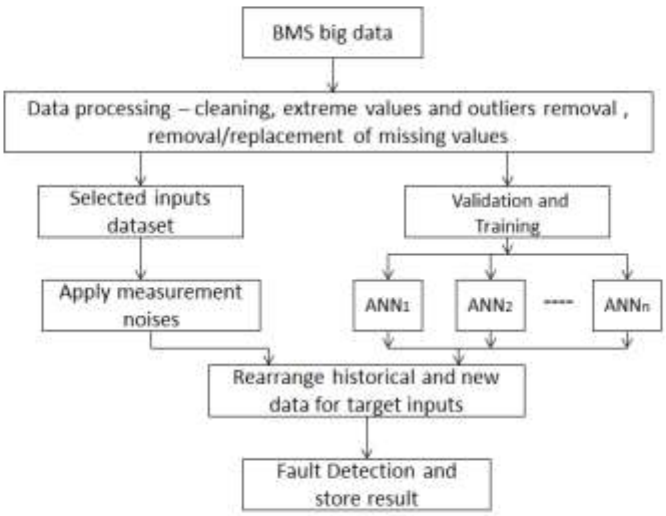


Fig 5. The integrated process of fault detection with AI.[17]

The authors [17] suggest a tool which aims to automatically detect abnormal energy consumption by using AI and big data which are produced by the Building Management System (BMS). This happens by designing a software application that is called Fault Detection Tool (FDT) which automatically detects the abnormalities of energy consumption, optimizes the use of different resources and analyzes faults, complaints and time taken to terminate them Experimental results show that with the proposed approach, it is possible to accurately detect anomalous patterns in building energy consumption. This tool will be a part of an artificial intelligent decision-making system. The suggested method uses two sets of input data, the current BMS data, and the past BMS data, and calculates similarities between them to determine if there is an abnormality in the current building energy usage pattern. Hence, the suggested FDT consists of two subtasks: ((1) fetch historical data from the datasets, (2) determine the similarity between the current BMS reading values and past values [17].

An ANN-SVM-based approach was proposed by Thukaram to locate faults in radial distribution systems based on only the voltage and current measurements at the substation [18].Fault locations along the same feeder and different fault types were successfully classified on the feature planes by SVMs and ANN [19].

The other author has revealed an automated recognition and classification of various power quality disturbance the technique is based on S transform and MLP based neural network such as sag, swell, interruption, harmonics, sag with harmonics, swell with harmonics, flicker and notches. However in order to improve the electric power quality, the sources and occurrences of such disturbances must be detected[20].

4.Game theory: Game theory is a mathematical framework that can be divided into two main branches: noncooperative game theory and cooperative game theory. noncooperative game theory can be used to analyze the strategic decision making processes of a number of independent entities, i.e., players, that have partially or totally conflicting interests over the outcome of a decision process which is affected by their actions. Essentially, noncooperative games can be seen as capturing a distributed decision making process that allows the players to optimize, without any coordination or communication, objective functions coupled in the actions of the involved players. The objective of noncooperative Nash games.

•Study the impact of variations in generation rates on the system.

•Develop algorithms for finding equilibrium in multisource, multi load games.

•Study evolutionary game models that include notions of information and time.

•Develop heterogeneous games which comprise, beyond sources and loads, additional smart grid components as players with different strategies.

Game theoretical approach is well suited for fault isolating during smart grid failure, which can be achieved in coordination with cooperative and non cooperative games the necessary algorithm are to be developed[21].

A power system is a collection of individual components that compete for system resources. This paper presents a game theoretic approach to the control decision process of individual sources and loads in small-scale and dc power systems. Framing the power system as a game between players facilitates the definition of individual objectives, which adds modularity and adaptability. The proposed methodology enhances the reliability and robustness of the system by avoiding the need for a central or supervisory control. It is also a way to integrate and combine supply and demand side management into a single approach [22].

5.Machine Learning: A kind of technique for understanding the law in the data as well as extracting useful information with the help of computers automatically instead of humanity[2]. Machine learning is such a methodology that concerned with the pattern recognition and computational learning theory in artificial intelligence (AI) [23-26]. It may be inspiring for protection and control to combine with machine learning to fulfill the object of intelligent operation/control in smart grid, which may undergo a process from huge data to meaningful information to massive intelligence. The integration for micro grids may contain distribution management system (DMS) where information layer allows for DA functions [27].

Machine learning and artificial intelligence play important role in fault detection and control of smart grid moreover all the data processing techniques are coming under AI, coordination of each one is seen in all the above literature survey. most used techniques of machine learning, such as: Vector Machine Support, Descriptive Discriminate Analysis, Decision Trees and Neural Networks, in Smart Grid applications[16].

Machine learning has become a crucial technique to solve problems. It involves two methods: supervised learning, which trains a model with previously known input and output data so it can predict future outputs and unsupervised learning, which finds hidden patterns and intrinsic structures within the input data, fig 6. shows the machine learning approach.

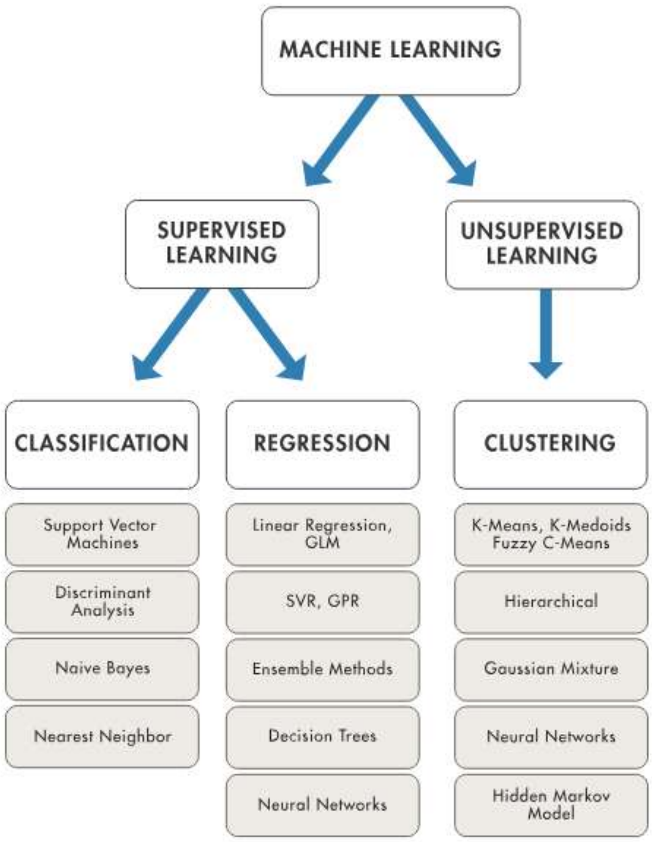


Fig6. Machine Learning techniques[16]

In data science, the term data analysis, data mining and text mining refers to the same technique of deriving hidden information using various machine learning algorithms from the data acquired. among the data mining methods the most widely used are[28]:

• Pattern Matching and Associative rule: It involves learning the frequently occurring trends in the data to Define rules for future decision making. Pattern matching algorithms includes Eclat, FP-Tree, so on.

•Classification: A supervised machine learning method in which the data is divided into training and testing sets. Then a classifier model is trained using training set in-order to predict the class labels for the given test data. Some of the most widely used classification algorithms are Decision tree, K-Nearest Neighbor (K-NN), Support Vector Machine (SVM) and Naive-Bayes.

•Clustering: It is an unsupervised learning process. The goal of clustering is to group data points in the Dataset together into a number of groups, depending upon its distribution in higher dimensional space. The choice for number of clusters depends on data and problem definition. Some of the most commonly used clustering algorithms are k-means, Expectation Maximization and Hierarchical clustering.

•Regression: It is process of identifying the relationship model between independent and dependent variables using the given data. The model is then used to predict the forthcoming values for the upcoming independent variable. It is a supervised machine learning method. Some of the widely used regression algorithms include Logistic Regression, Support Vector Regression (SVR) and Gauss-Newton algorithm:[28]

Deep learning in machine learning will bridge the gap between short-term corrective work driven by condition-based maintenance, and longer-term capital planning, as a result of which acceptance of condition monitoring will play an important role. With advances in data mining and machine learning techniques, deep learning is gaining popularity in the field of asset management and condition monitoring. Deep learning, a branch of machine learning, differs from machine learning in many forms, such as large amount of training data equipped with high performance hardware. Larger the data volume, more efficient the process is. It uses a hierarchical approach of determining the most important characteristics to compare. Based on learning multiple layers of neural network structures a deep learning algorithm comprise of two main parts: training and inferring, which is quite similar to neural networks. The training part involves labeling large amount of data from condition monitoring and extracting the right features while inferring part refers to memorizing the right features to make correct conclusions when it faces similar data next time. This is unsupervised learning as compared to supervised learning with machine learning.[29]

Adequate fault/defect detection of electrical equipment is vitally important in order to ensure reliable power system operations. In a typical power system, many sensors and monitoring systems are installed and gradual changes are analyzed. Because of the complexity of recorded data, however, defects or faults at an early stage cannot be easily recognized.DL is employed to monitor the states of three important components in power networks: insulators, transformers and transmission lines[30].

6.Multi Agent: The number of distributed energy components and devices continues to increase globally. As a result, distributed control schemes are desirable for managing and utilizing these devices, together with the large amount of data. In recent years, agent-based technology becomes a powerful tool for engineering applications. As a computational paradigm, multi-agent systems (MASs) provide a good solution for distributed control[31].

MAS are particularly more useful in micro grid applications owing to the complexity of the large networks of distributed energy resources, loads and storage units that preclude centralized control. In [32], the authors describe a MAS architecture that strikes a balance between the intra micro grid objectives defined by local operator and the situational demands of the micro grid collective. Under normal operating conditions, agents operate under self interest by maintaining power to the local vital loads at all times and will seek to export any excess power to other micro grids through communication with other local agents. In an emergency condition, after a fault is located and isolated, the agents begin the restorative phase by shedding non-vital loads and transmit surplus requests seeking additional power. Agents are capable of negotiating temporary power contracts during which the micro grids with excess generation pair with those that have shed load during the emergency. The MAS transitions to a normal operating condition under new network topology, while periodically checking to see if the emergency condition has been rectified [33] in the literature [34,35,36,37,38].

IV. FUTURE RESEARCH CHALLENGES

In this section we look forward for future research trends in big data analytics for smart grid failure detection by the survey of all the data processing techniques the major challenges lies in machine learning, neural network, and big data security,
Machine learning with IOT(internet of things) some of them are listed here

1.Challenges in application of multi agent technique to smart grid failure detection are difficulty to formulate their mathematical models and vulnerability to failures due to the priority hierarchy of agents. Therefore, most studies assume a homogeneous MAS to avoid dealing with system complexity, while heterogeneous MAS optimization and behavior is still an interesting research opportunity. one should explore the feasibility of combining multiple optimization algorithms with different objectives into the same MAS and the effect on the convergence and system stability. The study of communication delays, convergence time and collisions among agents is an interesting research opportunity. a potential research opportunity is to study the effect of collisions on MAS performance and design control mechanisms to organize agents interactions with the physical layer. Researchers should incorporate agents resources constraints in their hybrid consensus algorithms and compare their performance with their previous findings. Erroneous measurements and leader failures should be considered in the study and design phase since the impact is expected to be fatal to both MAS and the micro grid.

2) Micro grids of different types are connected to form a “smart city”, and this interconnection imposes additional control, as fluctuations and failures can affect the whole grid. In-depth research on emergency energy dispatch and transient stability in a multi-micro grid environment is necessary for the future smart city vision. Adapting existing hierarchical MAS and secondary droop control to multi-micro grids management could be a first step in this study.

3) When applying one machine learning technology to smart meter data analytics, the limitations of the method and the physical meaning revealed by the method should be carefully considered in deep learning to avoid over fitting the application of new machine learning technologies is an important aspect of smart meter analytics. existing works on smart meter data analytics rarely use online learning or incremental learning, expect for several online anomaly detection methods Note that smart meter data are essentially real-time stream data. Online learning and incremental learning are varied suitably for handling these real-time stream data [39].Many online learning techniques, such as online dictionary learning [40] and incremental learning machine learning techniques such as incremental clustering [41], have been proposed in other areas. However, existing works on smart meter data analytics rarely use online learning or incremental learning, expect for several online anomaly detection methods.

4) Barriers to adopt big data analytics in power systems

Addressing discarded data, addressing Siloed Data Supporting Real-time Analytics: Balancing Integrated and Disintegrated Systems Customized Data Management Systems to Cope with Fast Data.

5)Challenges in Deep Learning, Reinforcement Learning deep reinforcement learning. Of machine learning are many problems needed to be studied in depth, for example, which structure of deep learning is preferable for a specific use case? How many layers are suitable? How to solve the problem of partial observe ability, and small samples? In addition, DL has the shortcoming of non interpretable and this can impact the creditability of results, leading to security concerns for the power system operator.

V. CONCLUSION

All most all the data processing techniques have their own advantages and disadvantages In this paper we have revealed from the survey results such that the most important data processing technique happens to be ANN with machine learning and multi agent system are best suited smart grid fault detection, to the small extent game theory also fits in that category. At the same time fuzzy logic controller have limitation for multi grid control system but they are suited for droop voltage control and frequency droop. Genetic algorithm along with graph theory is also better data processing technique but more flexible consensus control algorithm needed to be addressed. The survey results also shows that big data analytics application to smart grid failure detection is promising area of research by mentioning in the future challenges of this paper.

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