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A Review of Machine Learning Techniques for Power System

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***Abstract*—The electrical power system is considered as one of the most dynamic energy sector where, the generation, transmission and distribution of power should be carried out optimally. For this, effective planning and coordination is necessary. This will be effective if we can avoid or predict any of the astonishing events in the system. There lies the importance of Machine Learning (ML) techniques in this sector where, it is possible to predetermine the major parameters of the power system so that an effective planning is possible in accordance with the predicted parameter values. This paper gives an overview of various ML techniques which are applicable to the system, mainly focusing on electrical load forecasting, power system stability and protection.**

***Index Terms*— Artificial Intelligence, Machine Learning, Deep Learning, Electrical load forecasting, Power system stability and Power system protection.**

I. Introduction

Electrical power system is the most suitable example for a dynamic system which needs a continuous monitoring of its variables since they may get easily affected by different factors, both inside as well as outside the system. Being a huge interconnected system, a small change in the value of even one of the system variables may propagate and may adversely affect other parameters in the system and the system performance may get degraded. Therefore, an efficient monitoring and controlling is inevitable for the efficient operation of the power system. This is ensured with the help of various computational techniques employing artificial intelligence and its variants.

The demand and usage of electricity is increasing drastically nowadays. In order to meet this, there is a huge dependency on various renewable energy sources. Also there is a tremendous increase in the usage of electric vehicles worldwide. As a result of this, the power system planning, scheduling, operation, protection and forecasting needed to be executed in a fast manner. The development of information technology together with artificial intelligence and machine learning had helped a lot towards this.

This paper focuses on various ML techniques applicable to various sectors in electrical power system. The areas identified includes Electrical load forecasting, Power system stability and Power system protection. The rest of the paper is organized as follows. Section II gives an idea about machine learning and various techniques and its applications. Section III deals with applications of ML in power system with specific concentration towards

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electric load forecasting, power system stability and power system protection. Lastly Section IV gives conclusion.

II. MACHINE LEARNING

Being a subset of Artificial Intelligence, which enables the machines to think, a Machine Learning algorithm learns the data, then it builds a prediction model and when a new data comes in, it can be easily predicted. The machine will learn from its own past experience without being programmed. The exploration of data is carried out with the help of some statistical tools. When the number of data is increased, the accuracy level of the prediction will also be high. Basically the learning is carried out in Supervised, Unsupervised or Reinforcement learning.

Supervised learning uses labeled data for training so that the machine knows the features as well as the labels associated with them while training. It is always assisted by an external supervision. Learning with unlabeled data are called Unsupervised learning. Here, clusters are formed based on the similarity index of the data and with the help of these clusters the prediction is made. There is no external supervision for Unsupervised Learning. Reinforcement learning is a reward based learning in which learning strategy of the machine can be corrected with the help of a feedback so that the accuracy of prediction is good. The machine has to learn a series of actions in order to make a prediction with the help of trial and error method.

Deep Learning is a sub-branch of ML which works based on the human brain working. It uses multi-neural network architecture like Artificial Neural Network (ANN), Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN), Long Short Term Memory Network (LSTM) and its advanced variants. Data Science uses some of the mathematical tools like, statistics, probability, linear algebra etc., to work on DL, ML and AI. The various algorithms and applications of different ML types are listed in table I.

TABLE I. APPLICATIONS AND ALGORITHMS FOR ML TECHNIQUES

Type of ML	Algorithms	Application
Supervised Learning	Linear Regression Logistic Regression Support Vector Machine K-nearest Neighbor Random Forest	Risk Evaluation Forecast Sale
Unsupervised Learning	K-means clustering C-means clustering Apriori	Recommendation system Anomaly detection
Reinforced Learning	Q-Learning SARSA	Self driving cars Games solving

III. APPLICATIONS OF MACHINE LEARNING IN POWER SYSTEM

Three problems in electrical power system are identified and a thorough literature survey was conducted based on the various ML techniques applied to these problems.

A. Electrical Load Forecasting

Good planning and operation is necessary for improving the efficiency of the Power system. Electrical load is a continuously varying parameter which determines the planning and control of operations in the power system industry. The variation of load depends on various factors like consumers, time of usage, external environmental conditions etc. An efficient forecasting of electrical load results in better planning and control of power system. Load forecasting mainly depends upon the period of planning and operation of the system. Based on that the load forecasting in electrical power sector can be classified as;

- Short Term Load Forecasting (STLF): load forecasting for a period from few hours to few days.
- Medium Term Load Forecasting (MTLF): load forecasting for a period from several days to few months.
- Long Term Load Forecasting (LTLF): load forecasting for a period greater than or equal to one year.

The STLF based on varying load as well as on the weather conditions are done by [1]. They performed the domestic load forecasting and the data collected are anlyzed through the IOT –Microcontroller based system. The programming of the data was carried out in two stages. The load power was sensed using the microcontroller and the data is sent to the cloud. In the next stage the processing of data is carried out using the

ML algorithm and was implemented through MATLAB. The data was analyzed using six ML algorithms like Linear regression, Fine tree regression, Support vector machine, Ensemble boosted tree, Ensemble bagged tree and Gaussian process regression. The Root Mean Square Error (RMSE), Mean Square Error (MSE) and Mean Average Error (MAE) were used as the anlysing parameters for the performance of the algorithms and was found that the Linear Regression method was superior compared to the other algorithms.

The energy based short term load forecasting was done based on Linear regression, Gaussian process regression, Neural networks, Auto-regression with exogenous variables by [2] and found that the Gaussian process performs good for the problem considered. The authors also make note that the proposed method takes long computational time when the number of data is more. Hence they make a comment that the method does not hold good for large industrial applications. The Levenberg Marquardt algorithm was used to solve the STLF for a day by [3]. The hourly load forecasting was done using MATLAB and the results obtained are compared for the Mean Absolute Percentage Error (MAPE) and RMSE and obtained the values of 0.029 and 0.170 respectively. Load and Price forecasting methods are identified and an intensive review on various ML methods were done by [4].

B. Power System Stability

The second problem identified to incorporate the ML technique is stability in power system, which is having huge importance in this sector. Recently the demand for electrical energy is increasing on a daily basis which is inevitable for a growing society. The problem associated with the utilities in this regard is not only with the increase in generation, but also with the stability of the entire system. So power system stability has a major role in the electrical power sector industries. Researches were conducting at a high rate to find a feasible solution to this issue worldwide. The major stability issue lies with the integration of renewable energy sources and other energy storage systems. Also there must be concern regarding the operation side also [5].

The long term random data was used by XGboost algorithm in order to analyze the low frequency oscillations in the stability calculations [6]. Stability analysis was done on the basis of damping ratio as negative, weak and strong damping and an online evaluation model was developed.

Four major power system resilient problems were addressed by [7] and studied their solution methodologies using ML techniques. A detailed review of the solution techniques was given for important problems like power outage, stability assessment and stability control. Transient stability analysis of the modern power system on the frame work of artificial intelligence and machine learning topology was given by [8] which explain the various ML techniques in detail specifically for the transient stability analysis problem.

The application of ML techniques in integrated power system was given by [9]. They addressed important instability issues like fault detection and diagnosing, generation forecasting, smart grid applications etc. Synchro phasors based power system transient stability prediction was done by [10] based on optimized extreme learning machine (OELM) using Improved Particle swarm optimization (IPSO). Probabilistic method using enhanced feature selection and extraction was used to solve the transient stability assessment of the power system by [11] and obtained accurate results with minimum time.

C. Power System Protection

Protection is necessary and is one of the most important factor that should be considered for the power system. Microprocessor controlled relays are fast acting with maximum accuracy in operation. The back up protection scheme should also be well defined and must aid the primary protection system for the better functioning of the power system. It is also necessary that all the components in the power system are given a suitable protection scheme.

The protection for TCSC (Thyristor Controlled Series Compensated) transmission line is provided by means of Support Vector Machines (SVM) in [12]. Single line to ground, double line to ground, line to line, triple line and triple line to ground faults are considered for the analysis with Gaussian and Polynomial kernal function used for the analysis. Three variants of SVM namely, SVM1, SVM2 and SVM3 are used for different types of faults namely fault classification, ground detection and for TCSC on the line respectively. Altogether an error less than 5% were obtained. The effect of Artificial Neural Network (ANN) and Fuzzy Logic (FL) was studied by [13] for the fault classification, transformer protection and CT and CVT transients correction. Authors presented the explanation of the two AI techniques with suitable examples. In [14], different types of faults; both symmetrical and unsymmetrical faults are analysed with the help of various machine learning based techniques ranging from the conventional to the recent methods.

The impact of ML techniques based on the utilities perspective is given by [15]. The demerits of ML techniques like Expert systems, Decision tree, ANN, K-Nearest Neighbor (KNN) and SVM are described in detail. The authors listed the major issues with ML techniques as, non operation consequences, coordination issues, lack of quality data for training the models, reliability concerns and lack of debugging options. In [16], authors specify the reasons for the lack of credibility of ML techniques in the commercial equipments used for the protection scheme. The major reason they have pointed out was the performance of ML techniques becomes unreliable when a data which was not there in the training process comes. Other draw backs are lack of back up, need of system specific training and collection of data needed for training.

IV. CONCLUSIONS

A comprehensive review on various machine learning techniques related with electrical power system is proposed. The focus of study includes the electric load forecasting, power system stability and power system protection. From the study it was found that the machine learning techniques provides quick and faster computation and closeness to the true value compared to other conventional methods. However, some demerits are also reported in two papers of study. This was related to the utility side and can be taken as future research and can be rectified.

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