Science and Technology Publishing (SCI & TECH)
ISSN: 2632-1017
Vol. 8 Issue 1, January - 2024

Optimizing Power System Protection Using Machine Learning Techniques: A Review

Dickson, Peter Akpan[1]
Department of Electrical Electronics Engineering,
University of Uyo, Nigeria
peterdickson.pgs.meng@uniuyo.edu.ng

Okpura, Nseobong[2]
Department of Electrical Electronics Engineering,
University of Uyo, Nigeria

Udofia, Kufre M[3]**.**
Department of Electrical Electronics Engineering,
University of Uyo, Nigeria).

***Abstract*— The reliability and resilience of the power system from generation, transmission and distribution value chain depends on the efficient operation of the protection system. When faults occur in the electricity network, it require an efficient protection system to isolate the faulty section of the network timeously, while the healthy section remain operational, such is the principle of discrimination or selectivity, sensitivity and speed, protection engineering terminology. International best practice in power protection engineering demands that the protection relay also act to safeguard both the network and the equipments connected to the network, thus ensuring safe, reliable and available electricity for the consumers. Various approach in protection system techniques have been practiced, from the mechanical relays, to the use of digital relays and smart metering in conjunction with supervisory control and data acquisition (SCADA) and phase measurement units (PMU) and the novel Artificial intelligence (AI). Accordingly, this paper presents a review on optimizing power system protection using machine learning techniques.**

***Keywords*— Protection System, Artificial Intelligence, Smart Metering, Machine Learning, Supervisory Control and Data Acquisition (SCADA)**

1. Introduction

Power system protection ensures that faulty part of the system is disconnected from the healthy part to improve the resilience and stability of the network. Since the role of the power protection system is to disconnect in the event of fault, to prevent damage due to faults, prevent the fault from degrading the security and to protect the surrounding equipment, lives and properties from danger, the optimal operation of power system protection mechanism is therefore very essential. Accordingly, this paper presents a review on optimizing power system protection using machine learning techniques.

Particularly, this paper reviewed new technology in power system protection relaying using machine learning algorithms (Fang and Zhang, 2019, Kumbhar et al. 2021 and Eslamian *et al*., 2023), which is generally categorized into three categories namely, supervised learning, unsupervised learning and reinforcement learning. Supervised learning gas main feature like labelled data, and it is task driven classification /regression algorithm which is suitable for diagnostic / prediction application, Unsupervised learning with main feature of unlabeled data, data driven, clustering/dimensionality reduction algorithm, is suitable for pattern/structure recognition. Reinforcement learning with main features such as reward/punishing mechanism, clustering/association algorithms is suitable for decision making processes (Aminifar *et al*. 2021). Fang and Zhang, 2019, Rajora *et al*. 2022 and Stock *et al.* 2022 described machine learning application in power system asset management, power distribution network and power system protection to be data eccentric, because it requires good data sources and good data support, as such, the effectiveness of power system protection could be achieved through machine learning algorithm. The large data source could be gotten from electronic smart sensor devices, smart meters where real-time data of current, voltage, switching status in the power system network could be obtained, analysed and sent to the power data support platform through communication network, after analysis it is imported into the machine learning algorithm as part of Artificial intelligence application needed to optimise the power system protection and control to reduce the frequency of system collapse and blackout due to the cascading faults from the electricity network (Uddin et al., 2022, Xiang, *et al*. 2023, Wang, 2020 and Ghani, 2019)

1.1 Significance of the research

Power system protection ensures that faulty part of the system is disconnected from the healthy part to improve the resilience and stability of the network. Since the role of the power protection system is to disconnect in the event of fault, to prevent damage due to faults, prevent the fault from degrading the security and to protect the surrounding equipments, lives and properties from danger, the optimal operation of power system protection mechanism is therefoe very essential.

Notably, the paper is aimed at providing insight that can be used for optimizing power system protection to reduce electric power system collapse using machine learning algorithm (Ayalew et al., 2018 and Wang, 2020). As such, the paper review machine learning techniques which include supervised, unsupervised and reinforced learning techniques will relieve human intervention in the setting up of protection relays as machine learning algorithm will be used to provide the principle of speed, selectivity and discrimination in the protection functions. Also, machine learning approach will bring forth unprecedented opportunities for developing adaptive and reinforcing solutions for power system protection problems (Aminifar *et al*. 2021).

2. Review of Relevant Literatures

In the last 40 years artificial intelligence has impacted massively in the power sector, in operation and maintenance, generator protection, transmission line fault classification and location, distribution network protection and power system optimization, (Ayalew et al., 2018, Heymann et al., 2023) and one of the branches of AI is the machine learning techniques.

2.1 Practical application of Artificial intelligence / Machine learning in power system protection and control

According to Hu *et al*. (2023), in their introduction defined intelligence as advanced comprehension, a capacity to further the existing reasoning, demonstrative knowledge and learned decision-making. Machine can demonstrate intelligence similar to the natural human intelligence. These require adaptive development at various stages, such as cognition, manipulation, rationalization, communication, and reaction to any common transaction.

Artificial intelligence (AI): As defined by the author, is the simulation of human intelligence in machine that think and act like humans. A very effective AI application requires many skill set such as cognition, manipulation, rationalization, communication and reaction to be incorporated into the scheme.

Machine learning: AI according to the author, utilizes machine learning and other related techniques such as heuristics to resolve real challenges. Computational tools that are needed to implement these skill sets are Search and Optimization, Artificial neural network, Fuzzy logic, probabilistic methods for uncertain reasoning, reinforcement learning, and other supervised and unsupervised learning method. Machine learning is a subfield of Artificial intelligence that enables the gathering and analysing volumes of data to extract representative feature based on appropriate training (learning) and develop an equation or algorithm for deriving useful information or action. Machine learning has been practiced within the power system industries for operation, workforce management, and planning for example in forecasting, optimization, scheduling and unit commitment, and currently in power system protection.

2.2 Learning by experience:

According to Hu et al, (2023) and Osisanwo et al., (2017), the technique and algorithms that accomplishes learning by experience are broadly considered as machine learning methods. In learning by experience, machine learning techniques or algorithm process input data in order to perform classification, pattern recognition, clustering, regression tasks, and more, based on experience learned from the data.

A. **Artificial Neural Networks (ANN):** ANNs are at the forefront of machine learning as enablers to learning by experience.

Warren McCulloch and Walter Pitts laid the framework for artificial neural networks while Frank Rosenblatt created the Perceptron model (Osisanwo, et al.,2017) to replicate the human brain both in 1943 and 1957 respectively. Figure 1 ashows the diagram of the commonly used model of artificial neuron and the description follows as shown in Figure 1(a) and (b). As shown in Figure 1a. An artificial neural network is a network of neurons consisting of an input layer which receives data from outside sources (data files, sensors, etc.), one or more hidden layers that process the data, and an output layer that provides one or more output data points based on the function of the network.

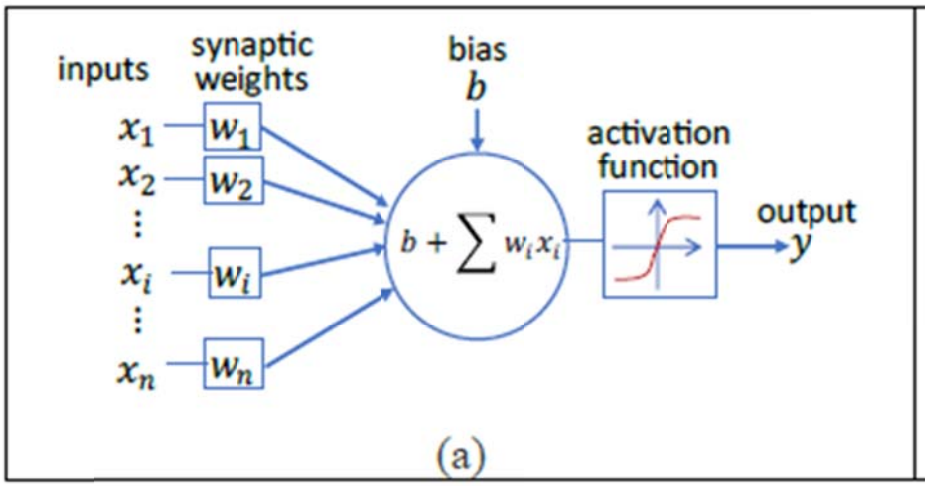

Figure 1a: Model of an artificial neuron
Source: Hu et al., 2023

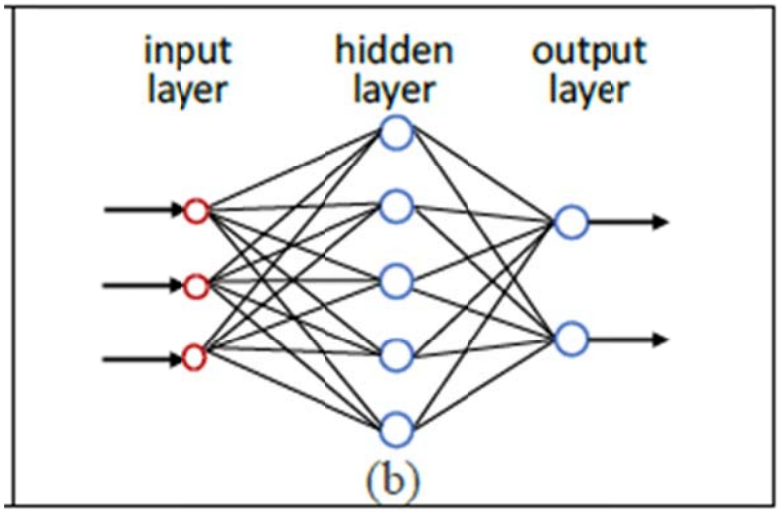

Figure 1b: Example of a feedforward neural network
Source: Hu et al., 2023

The diagram in Figure 1b shows an example of a feedforward neural network. The weights of the neurons are adjusted considering the relationship between the inputs and the outputs as defined by the experience data. The different types of ANN architectures, among others are:

i. Single layer feedforward architecture
ii. Multiple layer feedforward architecture
iii. Recurrent or feedback architecture
iv. Mesh architecture.

Several approaches for training ANN are:-

Supervised learning: In this approach, data used for training are tagged by a human or are available as pairs of input and the corresponding expected outputs. Typically used for Classification and Regression application.

Unsupervised learning: It is self organizing to capture patterns in input data as neuronal predilections or probability densities. The three main domain of application of unsupervised learning are: - Clustering, Dimensionality reduction and Association rules learning.

Reinforced learning: As in a model-free Reinforced learning, the machine learned by interacting with the environment as an agent and is given a numerical performance score called reward, after performing the action as its guidance. This is popularly used in Robotics; it is used in situations where the environment is better known, such as playing chess. As in the case of Model-based Reinforced learning algorithm can model the environment to predict the outcomes of action before performing them and optimized iteratively from these predictions.

According to the author, the availability of the input data used to train the algorithm will be different for each application, sometimes the entire dataset is available from the beginning, however, the data that algorithm need will grow overtime. As a result, the learning by experience considers taken considers the data availability and is broken down into offline and online learning. When there is not enough data (experience) to perform offline learning, as discuss by the author, the focus is normally recognition of

types or classes (example Clustering) by learning online with the input data.

Offline learning: Is referred to batch learning techniques which generate the best ANN parameters by learning on the entire training dataset at once.

Online learning: Is a sequential learning in which data becomes available in a sequential order and is used to update the ANN weights at each step. Online learning is used where it is necessary for the algorithm to dynamically adapt to new patterns in the data (distribution shift) or when it is infeasible to learn from an entire dataset.

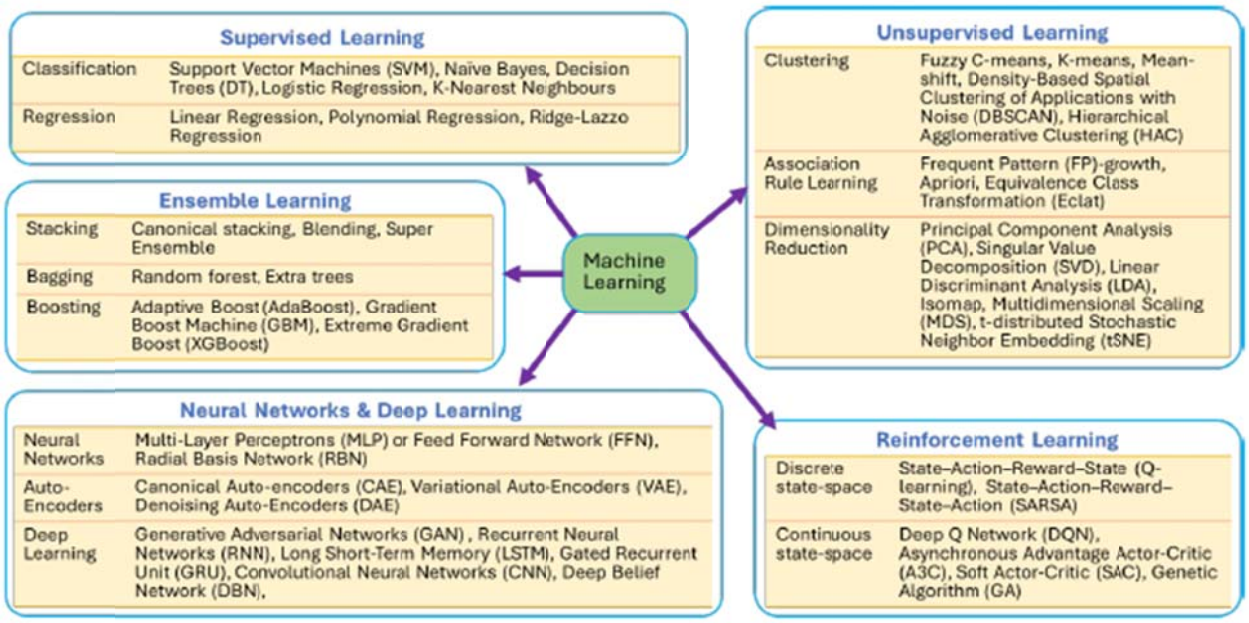

Figure 2: Types of Machine learning algorithm

Source: Hu et al., 2023

Hu et al., 2023 in his research stated that neural network architecture will normally be chosen based on the intended application and available data. The type size and number of layers within the network along with the optimization strategy and loss equation being carefully chosen to allow the network to sufficiently map the input data to the application goal. Figure 2 demonstrates the various types of machine learning algorithm that can be explored.

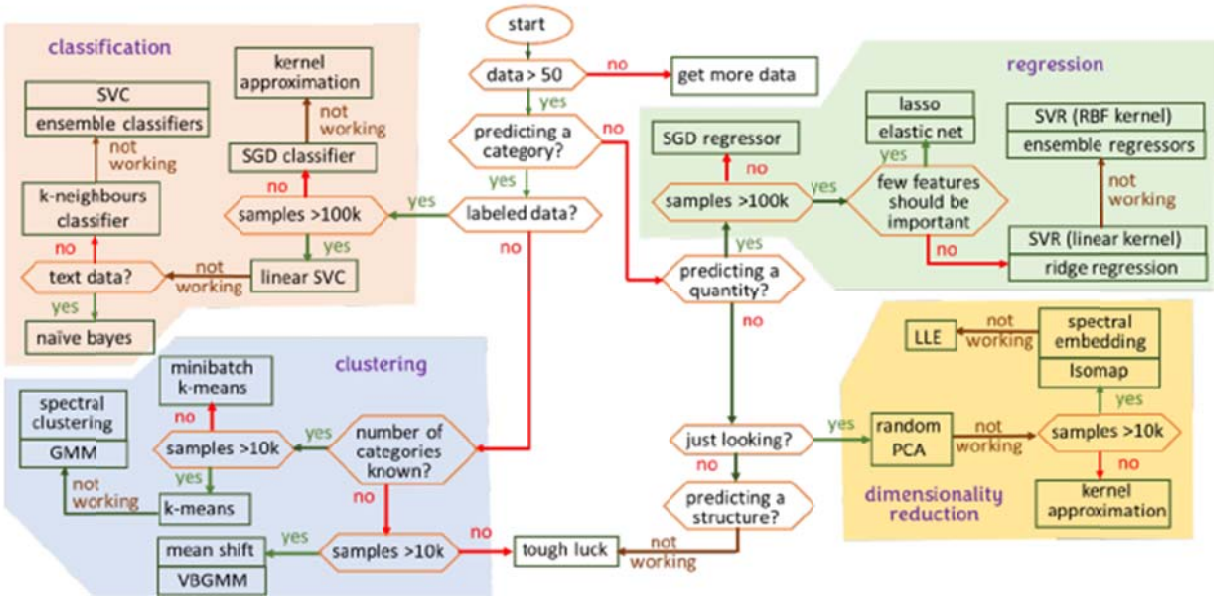

Figure 3: Scikit-Learn Algorithm Chat Sheet

Source: Hu et al., 2023

Learning by evolution: According to Hu et al., 2023, trial and error approaches have been a key part to human learning. Several techniques have been developed to imitate this human skill and focus on an objective while using the experience to find a solution to a problem by mean of the evolution of a population. The population in the context of evolutionary learning refer to a set of potential solution to a

problem. For instance, the problem of finding setting of a non-directional overcurrent relay (ANSI 51), a solution could be a pair of values representing the pickup current and the time dial. The objective for application of device 51 to a transformer could be to ge a reference operating time for the internal and external faults. Given the a range of short circuit current it is possible to evaluate the operating time function for potential solution for this individual in the population. Hu et al, 2023 explained in their research that learning by evolution algorithm applies random changes guided by Smarm intelligence, Colony behaviour, Physical / Chemical processes to find a group of solution (in this case settings) to meet the objective (the required operating time) or the best possible solution. Starting with an initial population (often randomly generated) evolution algorithms can find better solutions for complex problem by making variations in every population.

Hu et al., 2023 further described metaheuristic algorithms as set of techniques or algorithms applied to solve optimization and search problems. Some of the algorithms are:-

- Simulated Annealing
- Ants Colony
- Bees Colony
- Genetic Algorithms
- Differential Evolution
- Particle Swarm Optimization
- Harmony Search
- Bat Algorithm, and
- Taboo Search

The author concluded that the Metaheuristic are widely used to solve complex optimization problems with a single objective or multi-objectives focus and the capability of problem generalization.

Deep Learning: Deep learning, according to Hu et al., 2023 is a subfield of machine learning and its backbone is built on neural networks. The number of node layers or depth of a neural network differentiates a shallow neural network from a deep learning algorithm. Usually a deep neural network has more than three layers, these algorithms use multiple layers to progressively extract high level features from the raw input, with minimal human intervention. This kind of learning can be supervised, semi-supervised or unsupervised. According to Hu et al., 2023, the following traditional machine learning algorithm finds mapping between structured representation of data (specific data with predefined format) and an outcome that is often seen as a prediction. They includes:-

- Linear Regression
- Shallow neural network, and
- Decision Tree.

These traditional machine learning algorithms often fail to create good mappings between data and an outcome when the data is of unstructured or of complex nature Conglomeration of different types of data that are stored in their native format) such as images, waveform, videos etc., and to tackle this problem, data scientists usually conducts data processing and feature engineering process to find data representations that are suitable for traditional machine learning of algorithms.

However, in deep learning, suitable representations of data (features) are found in a more automated way. They are able to understand concepts on their own and this is referred to as representation learning.

2.3 A systematic review of machine learning applications in the operation of smart distribution system.

Matijasevic et al., (2022) in a research on the application of machine learning techniques in the operation of smart distribution network with special emphasis on the system protection, resilience and reliability provided a review of various published literatures pointing to the novel approach of resolving challenges in the power system network using different machine learning algorithms and techniques.

According to the research by Matijasevic *et al.,* (2022), planning and operation of power system distribution networks are becoming more demanding, and to meet this demand, machine learning methods are emerging and it is increasingly being used in numerous analyses of the distribution network due the their ability to process large amount of data without needing any complex and time-consuming models. We now have smart distribution systems (SDS) with focus on the application of artificial intelligence / machine learning algorithm in resolving issues.

2.3.1 Research Methodology Adopted: Matijasevic *et al.,* (2022) presented a paper which was in the form of a review of several approaches on the application of machine learning algorithm for handling smart distribution power system network challenges.

According to Matijasevic *et al.,* (2022) the electricity network have been modernized into what is known as smart distribution network. Distribution networks are the main connection between the transmission networks and the most electricity customers and are the forefront for energy transition from the source to the user due to the dynamic nature. The Distribution System Operators (DSO) managed the distribution network and their related equipments, and since electric power cannot be massively stored, operation planning becomes imperative, making the DSO (and in other clime Distribution Service Provider, DSP) primarily responsible for the maintenance, system operation, retrofitting and more, in order to provide high quality services to the growing number of customers within the electricity networks.

Matijasevic et al., (2022) also confirmed that the distribution network planning has been known to be

"predict and provide" process and these process have been performed by the DSOs, and using the traditional distribution system, for instance, the DSOs relied on historical data and behavioural pattern, they could create good operational plans that never required real data and intensive real-time (RT) intensive operational activities.

Matijasevic *et al.,* (2022) also inferred that distribution networks were observable when the entire network could be monitored. Any grid could be ranked observable, if and only if, all system state, which includes, voltage magnitudes and angles, can be calculated for the given measurements and topology.

This paper by Matijasevic *et al.* (2022) SDS operators relies on high share installed smart meters capable of collecting and processing large number of data which are important for the planning and operation of the SDSs. The necessity for real-time (RT) decision in the operation of the SDSs arose from the conglomerate of active customers at the heart of the SDS who have started implementing new solutions, which changes the power flow in the distribution network (Matijasevic et al., 2022), all of this contributed to the objective of a smart distribution system network shown in Figure 4 and described a modernized electricity grid as one that uses information and communication technology to gather and act on data, such as statistics about the behaviour of suppliers and consumers in an automated fashion to improve reliability, efficiency, economics, and sustainability of the use of electricity (Matijasevic et al., 2022).

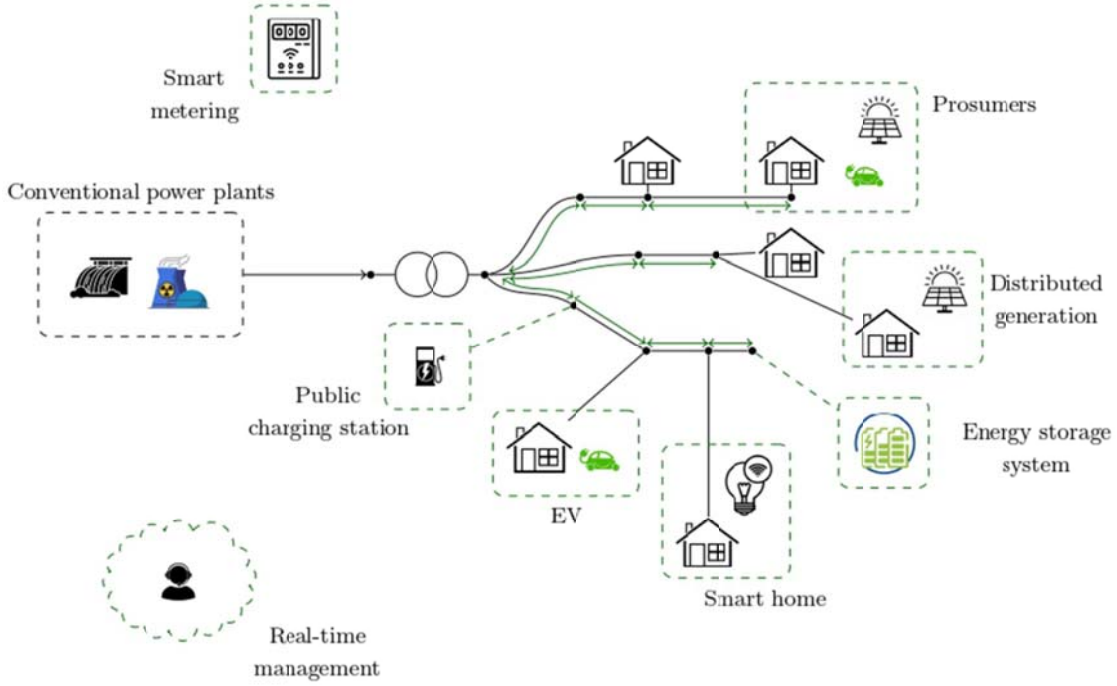

Figure 4: Development of a smart distribution system
Source: Matijasevic *et al.,* (2022)

2.3.2 Importance of machine learning-based algorithms

The introduction of newer technologies in electric power system has contributed to the complexity of the smart distribution system, leading to the change in the planning and operation paradigm. The flow of large data from smart meters encouraged the system operators to re-invent the wheel, by employing newer tools for real-time network management and monitoring to reduce system insecurity and instability. The traditional techniques have been abandoned as the newer tool provides high degree of accuracy within a very short time. This new tool is the machine learning algorithm. It has a set of input and output data and the algorithm finds a relationship between the data, thus ensuring the speed of data processing and the indifference of the model to variation in the data, (Matijasevic et al., 2022).

2.3.3 Machine learning applications in the (operational) planning of smart distribution system: According to the authors, the application of machine learning algorithm includes forecasting. Forecasting, according to the authors the important component of forecasting is data, proper data selection improves forecasting models and give more accurate forecast.

Data processing schemes can be clustered into:-

- Decomposition,
- Feature selection and extraction,
- Noise cancelling,
- Residual error modelling, and
- Filter-based adjustment.

According to the authors, state–of-the-art metering infrastructure, such as, smart meters, plays a vital role in generating an enormous amount of data to support various operations in smart distribution system, like distributed energy management, generation forecasting and fault detection in the network.

A lot of data could be found in the public sphere to encourage energy forecasting research, highlighted below are six essential sources of data.

i. ISO / RTO data: Data from Independent system operators and Regional transmission operators.
ii. NWP and reanalysis data: Numerical Weather Prediction (NWP) data is generated by national weather centres: reanalysis data is a special instance of NWP data, which is a return of a weather model using a consistent of assimilation design.
iii. Remote sensed data: gridded weather data obtained by remote sensing.
iv. In-situ weather data: in-situ measurements of weather variables, comes from ground-based weather station.
v. Smart meter projects: data gathered from smart meters, some of the frequently used data sources are Pecan Street, low carbon London.
vi. Data published with ties to research papers (Matijasevic et al., 2022).

2.3.4 Protection

Matijasevic et al., (2022) stated that, the integration of many new technologies into the distribution networks while improving network conditions also create potential threat to the system itself. There are various security concerns such as cyberattecks, voltage instability, and PQ (power quality) disturbances. The authors also stated that the distribution network were protected with current sensing devices such as overcurrent relays, reclosers, and fuses. Their primary goal was to monitor current flow through the protected element and to generate signals to the circuit breaker when it is necessary for a trip.

The authors affirmed that to eliminate possible danger in the smart distribution system network, the ideal tool was the machine learning algorithm with smart meter that can display the future state of the network and thus enable a timely response to potential inconveniences.

The diagram in Figure 5 detailed various methods and techniques of the machine learning algorithm that have been in use as described by the authors.

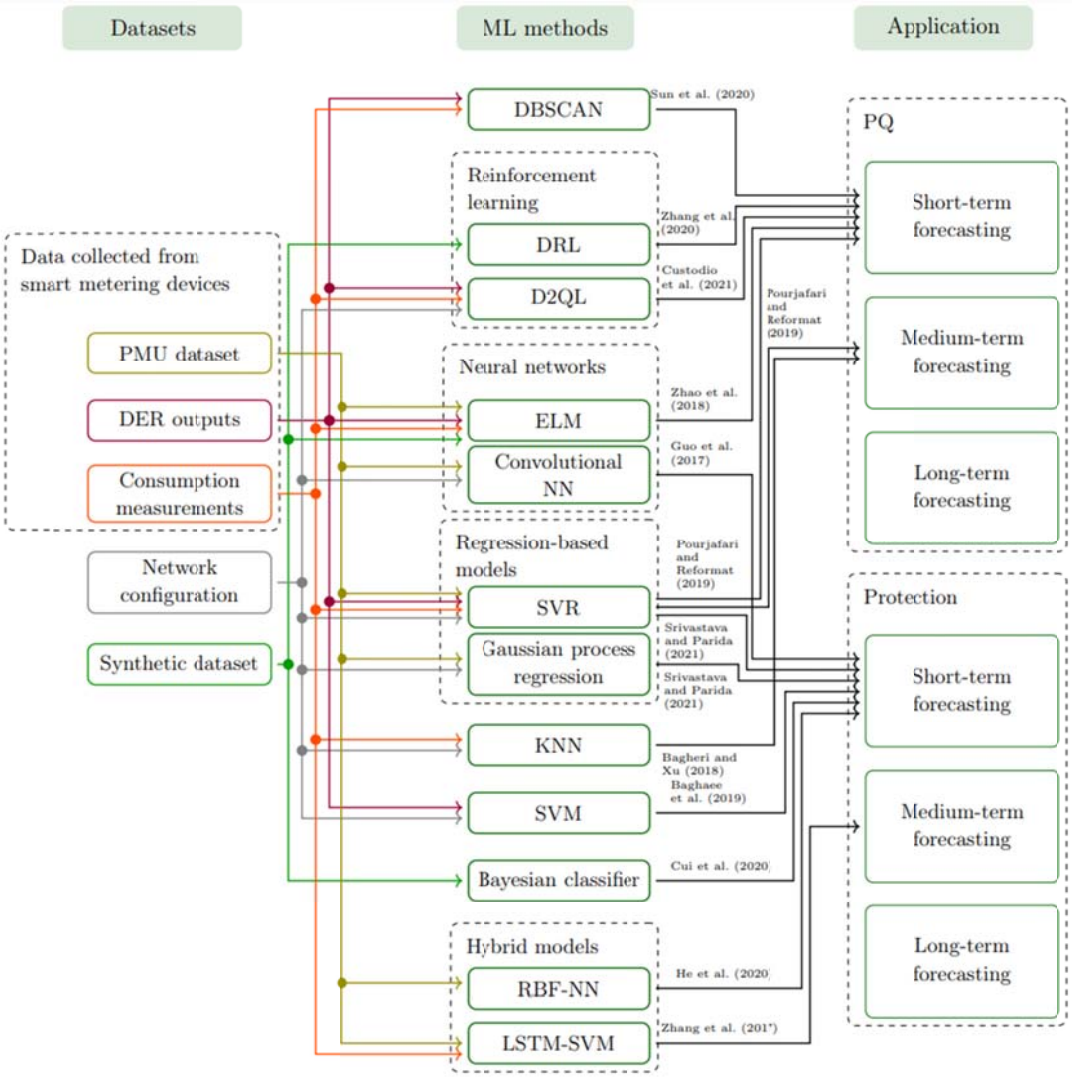

Figure 5: Machine learning methods for short, medium and long-term power quality and protection management

Source: Matijasevic *et al.*, (2022)

2.3.5 Major findings

The authors Matijasevic *et al.* (2022) in their research provided clue as to what machine learning algorithm could be applied to power system protection forecasting and by extension solutions to other challenges in the power system network using machine learning-based algorithm. Some are listed below:

Convolutional Neural Networks: Machine learning algorithm used for short-term forecasting of the protection system for the electricity distribution network. It got its data from phasor measurement unit (PMU) dataset and from consumption measurements.

Support Vector Regression (SVR): Machine learning algorithm used for short-term protection forecasting for the electricity distribution network. Data sources are distributed energy sources (DER), phasor measuring unit (PMU), consumption measurement, and network configuration.

Gaussians Process Regression: Used for short-term protection forecasting and obtain its data from phasor measurement unit (PMU) dataset and from network configuration.

Support Vector Machine: SVM was shown also to be applicable for short-term protection forecasting and the source of its data are from distributed energy sources (DES) and from network configuration.

Our findings during the literature review was that the majority of the machine learning algorithm according the research work of the authors were for short-term protection forecasting and non-was used for long-term system protection forecasting, this may be due to the unpredictable event that hovers around the electricity network making every protection approach to be short lived.

2.3.6 Research Gap: Since machine learning algorithm is new and very wide, it was expected that the author would discuss how these different algorithms are applied to achieve power system protection.

3.0 CONCLUSION

The above review of literatures and research work done by several authors in this paper provide a basis for adopting machine learning techniques to build algorithm that can facilitate optimal applications for power system protection. The papers under review demonstrated different approach that machine learning can be employed for transmission line protection through fault identification, classification and prediction to mitigate the occurrences of system collapse due to faults in the transmission lines.

REFERENCES

Rehman A., (2022). Protection Scheme for Electrical Power Systems. *Retrieved from internet on November 10th, 2023.*

Aibangbe, J.O., and Eyenubo, O.J. (2017). Evaluation of Power System Outages of the 330 kV Transmission Network in Nigeria, A Case study of the Benin Region. Journal of the Nigerian Associations of mathematical Physics, 1(1): 441-446.

Phadkhe A.G., Wall P., Ding L. and Terzija V. (2016). Improving the Performance of Power System Protection using Wide Area Monitoring Systems. *Journal of Modern Power System.*

Bo, Z. Q., Lin, X. N., Wang, Q.P., Yi, Y.H., and Zhou, F.Q., (2016). Developments of power system protection and control. *Springer open journals.*

Chinwuko, E. S., Mgbemena, C. O., Ebhota, W. S., and Aguh, P. S. (2011).Electricity generation and distribution in Nigeria: Technical issues and solutions. *International Journal of Engineering Science and Technology,* 7(12): 183 – 199.

Dickson, P. A, Udofia, K.M., and Okpura N. (2023). Augmentation of Power System Distribution Network and Capacity Inadequacy: Literature Review. *Science and Technology Publishing,* 7(1):1397-1410.

Aminifar F., Abedini M., Amraee T., Jafarian P., Samini M.H. and Shahidehpour M. (2021). A review of power system protection and asset management with machine learning techniques. Springer-Verlag GmbH Germany, part of Springer open journals.

Fang J. and Zhang X. (2019). Research on power system relay protection method based on machine learning algorithm. *EDP Science.*

Joseph, I. O. (2014). Issues and challenges in the privatized power sector in Nigeria. *Journal of Sustainable Development Studies,* 6(1): 161-174p.

Jeremiah,K. (2022). Blame Federal Government for Power Sector Woes, Stakeholders Tells Nigerians. *The Guardians Newspaper*, 30th November, 2022.

Kocaman, B and Akca, U. (2019). Adaptive relaying in electric power system protection. *The Online Science and Technology*. 9(1): 110-120p

Kumbhar, A., Dhawale, P.G., Kumbhar, S., Patil, U., and Magdum, P., (2021). A comprehensive review: Machine learning and its application in integrated power system. Elsevier Journals. *Energy Report*, 7(1): 5467-5474p

Raza,M.A. Khatri, K.L., Hussain, A., Khan,M.H.A., Shah, A., and Taz, H. (2022). Ananlysis and Proposed Remedy for Power System Blackout around the Globe. *Engineering Proceedings. www.mdpi.com/journal/engproc.*

Rajora L.G., Sanz-Bobi M.A., Domingo C.M. (2022): Application of machine learning method for asset management on power distribution networks. Institute of Research Technology, *International journals of the Emerging Science Journals*.1(1);905-920p

Slatem R.R., (2021). Modern Trends in Power System Protection. *IFAC Proceedings (Power Generation, Distribution and Protection)*, Volume 13.

Sitharthan R., Geethanjali M., Karpaga T. Pandy S. (2016). Adaptive protection scheme for smart microgrid with electronically coupled distributed generations. *Alenzandra Engineering Journal, Elsevier publication.*

Sabzebin S., Noghabi A.S. and Mazlumi K. (2022). Evaluation of power system reliability incorporating protection system miscoordination. *Research Square Publications.*

Wang,W. (2021). Advanced wide-area monitoring system design, implementation and application, *Tennessee Research and Creative Exchange, University of Tennessee, USA.*

Xiang, S., Zhen,C., peng,J., Zhang,L., and Pu,Z., (2023). Application of artificial intelligence technology in power system stability assessment. Elsevier, Science Direct Journals. *Procedia Computer Science 3rd, International Conference on machine learning and and big data analytics for IoT, security and privacy*. 228(1);79-88p.

Hu, Y.,Mulawarman, A., and Cheng Z., (2023). Practical application of artificial intelligence / machine learning in power system protection and control. PSRC Working Group. C43 Report.

Yang, X., Liu X.,Zhang, D., Chen, T., Li, C., and Huang, W., (2020). Machine learning for power system and control. Robert W. Galvin Centre for Electricity Innovation, Illunois Institute of Technology.

Tsimotsios, A.M., (2020). Design of protection schemes for power distribution networks with distributed generation. Doctoral Thesis,

Nasser, T., (2017). System protection and coordination. GPL Ghostscript. 9(25) PP:1-11.

Li, H., (2013). Wide area voltage monitoring and optimization. Dessatation submitted for Ph.D Washinton State University.

Palizban, A., (2015). Wide area monitoring and control utilizing PMU measurements, for a system protection schemes. University of British Columbia.

Ntambara, B., and Umuhoza, R. (2022). Opmization of Rwanda power system protection in power blackouts and cascading events. SN Applied Science, Spencer Nature Journals.

Volten, K. (Prof.) (2009). Book. Wiley-VCH Verlag GmbH & Co. Deutsch. Nationalbibliothek Publication.

Bielaire, M. (2018). Optimization: Principles and algorithm,
GPL Ghostscript. 1(1). PP:738-742.

Ma,M. (2021). Power system optimization: Convex relaxation and benders decomposition. Electrical and Computer Commons. University of South Florida.

Das,K., Behena, R.N.(2017). A survey on machine learning: Concept, algorithms and applicatios. International Journal of Innovation Research in Computer and Communication Engineering. 5(2). PP. 1-30.

Musa, H. (2015). A review of distributed generation resources types and their mathematical model for power flow analysis. International Journal of Science, Technology and Society. 3(4). PP: 174-182.

Yaday, G, and Paul, K. (2021). Architecture and security of SCADA system: A review. Indian Institute of technology, Research-Gate Publication.

Faryal, A., Umer, F., Aryad, M., Rashid, Z., and Mohammad, A.(2021). Modelling and simulation of SCADA and PLC system for power system protection laboratory. Electrical Control and Communication Engineering. Sciendo Publication. 17(1). PP: 19-25.

Cousineau, D., Mentre, D.,Inoue, H. (2019). Automatic deductive verification of ladder programming. Proceeding F-IDE 2019, EPTCS. 1310(1). PP: 7-12.

Janssen, C.P., Donker, S.F., Brumpy, D.P., and Kan, A.L., (2019). History and future of human –automation interaction. International Journals for Human and Computer Studies. 1(31). PP: 99-107.

Lin, C., Min, X., and Junru, J. (2019). Exploration on educational reform of electrical engineering and automation professional. Assian Conference on Advance in Education, Learning and Teaching. PP:1321-1325.

Vazquez-Gonzakz, J.L., Barrios-Aviles, J., Rosada-Munoz, A., and Alejos-Palomares, R., (2018). Adaptive protection scheme for smart micro-grid with electronically coupled distributed generations. Elsevier Alenaxdria Engineering Journal 55(1). PP: 2539-2550.

Bhattacharya, D., and Nigam, M.K.,(2023). Energy efficient fault detection and classification using hyperparameter-tuned machine learning classification with sensors. Elsevier, Science Direct Publication.

Rehman, A., (2022). Protection scheme for electric power system. Training lecture Note. Retrieved from google website November 17th, 2023.

Anderson, P.M. (1999). Power system protection e-book. Power Math Associate Inc. Retrieved from Google search engine on November 17th, 2023.

Meskin, M., Domiyan, A., and Grinberg, I., (2020). Impact of distributed generation on the protection system of distributed networks: analysis and remedies-review paper. Journals of the Institute of Engineering Technology. 14(24). PP: 5944-5960.

Osisanwo, F.I., Akinsola, J.E.T., Awodele, O., Hinmikaiye, J.O., Olakanmi, O., and Akinjobi, J. (2017). Supervised machine learning algorithms: Classification and comparison. International Journal of Computer Trends and Technology. 48(3). PP: 128-138.

Sarker, I.H., (2021). Machine learning algorithm, real-world application and research directions. SN Computer Science, Springer Nature Journal. 2(160). PP: 1-22.

Nasteski, V., (2018). An overview of the supervised machine learning methods .ResearchGate Publications and Journals.

Muzzammel, R., and Raza, A. (2020). A support vector machine learning-based protection technique for MT-HVDC systems. Multidisciplineary Digital publishing institute.

Liu, Z., Gao, Y., and Liu, B. (2020). An artificial intelligence-based electric multiple units using a smart power grid system. Energy Report. Elsevier Journals Publication.

Matijasevic, T., antic, T., and Capuder, T., (2022). A systematic review of machine learning application in the operation of smart distribution system. Elsevier Journal Publication. Energy Report. 8(1). PP12379-12407.

Mehdi, A., Hussain, A., Haider, W., Hassan, S.T., Saad, M., and Kim, C. (2021). Classification of power

system faults using random forests. Research-Gate Publication.

Wasnik, P.P., Phadkule, N.J., and Thakur, K.D., (2020). Fault detection and classification in transmission line by using decision tree. Journals of Emerging technologies and Innovative Research. 7(5). PP: 481-485.

Venkata, P., Pandya, V., vala, K., and Sant, A.V., (2022). Support vector machine for fault detection and classification in modern power system using quarter cycle data. 7Th International Conference on Advances on Clean Energy Research. 7(21). PP:92-98.

Shingade, G., and Shah, S., (2023). Fault detection and location based on SVM for three phase transmission lines utilizing positive sequence fault components. Transdiscipline Journals of Engineering and Science. 14(1). PP: 238-302.

Subashini, A., and Clanet, S.P.A., (2022). A literature survey on fault identification and classification system using machine learning. 2nd International Conference on Mathematical Technique and Applications. 10(1). PP:1-9.

Bon, N.N., and Dai, L.V., (2021). Fault identification, classification and location on transmission lines using combined machine learning methods. International Journal of Engineering and Technology Innovation. 12(2). PP: 91-109.

Kulikov, A., Loskutov, A., Bezdushniy, D., (2022). Relay protection and automation algorithms of electrical networks based on simulation and machine learning method.

Kumbhar, A., Dhawale, P.G., Kumbar, S., patil, U., and magdum, P., (2021). A comprehensive review: machine learning and its application on integrated power system. Elsevier, Science Direct, Energy Report. 7(1). PP: 5467-5474.

Tiwari, S., (2023). Artificial intelligence technologies for the power system. International Conference on Evolving Trend in Interdisciplinary Research and practices. Researchgate Publication. 1(0). PP: 193-196.

Walker, R., and Dillar-Wright, J., (2023). Algorithm biase in artificial intelligence is a problem – and the root issue is power. Elsevier Journal Publication.

Xiang, S., Zhen, C., Peng, J. Zhang, L and Pu, Z., (2023). Application of artificial intelligence technology in power system stability assessment. 3rd International Conference on Machine Learning and Big Data Analytics for IoT Security and Privacy. 228(3). PP: 79-88.

Stock, S., Babazadeh, D., and Becker, C. (2021). Application of artificial intelligence in distribution power system operation. Institute of Electrical Power and Energy Technology. IEE Access. 1(1). PP: 1-22.

Abdelfattah, W., Nagy, A., Salama, M.M., Lofty, M.E., and Abdelhadi, H. (2024). Artificial intelligence based optimal coordination of directional overcurrent relay in distribution system s considering vehicle to grid technology. Al Shams Engineering Journals. 1(1). PP:1-18.

Shuvo, S.S., (2023). Deep reinforced learning based optimization techniques for energy and socioeconomic systems. Digital commons, University of South Florida. PP:1-52.

Lu, Q., Gao, Q., Li, J., Guo, W., and Wang, J., (2023). Distributed cyber-physical intrusion detection using stacking learning for wide-area protection system. National Natural Science Foundation. 10(106). PP: 1-14.

Habib, A.K.M.A., Hasan, M.K., Hassan, R., Islam, S., Thakkar, R., and Vo, N., (2023). Distributed denial-of-service attack for smart grid wide area measurement system: A hybrid machine learning technique. 3rd International Conference on Power and Electrical Engineering. Singapore. Elsevier Publications. 1(1). PP638-646.

Alassaf, A.A., (2021). Dynamic system and parameter identification for power system. Digital Commons, University of South Florida. PP:1-112.

Elsamian, H., Javidi, M., Zamani, M.H., Dana, M.M., and Mansoori, E., (2023). Effect of pulse current carthodic protection on pipeline steel API 5L X65 corrosion mitigation: An investigation and machine learning-assisted modelling. Science Direct. Elsevier Publications. 12(1). PP: 29-45.

Ghani, A.M., (2019). Improving stability by enhancing fault clearing time. Digital Commons, University of South Florida. PP: 1-68.

Wang, X., (2020). Machine learning application in power system. Southern Methodist University. PP: 1-184.

Uddin, M.S., Hossain, M.Z., Fahim, S.R., Sarker, S.K., Bhuiyan, E.A., Muyeen, S.M., and Das, S.K., (2022). On the protection of power system: Transmission line fault analysis based on an optional machine learning approach. Elsevier Journals. Energy Report. 8(1). PP: 10168-10182.

Ayalew, F., Hussen, S., Pusam, G.K., (2018). Optimization techniques in power system: Review International Journal of Engineering applied Science and Technology. 3(10) PP: 8-16.

Ma, Z., Li, H., weng, Y., farantatos, E., (2024). Power system transfer learning to identify event types with or without event labels. International Journal of electrical Power and energy Syatems. 155. PP: 1-14.

Tsotsopoulou, E., karagiannis, X., Papadopolous, T, Chrysochos, A., Dysko, A., and Tzelpis, D., (2023). Protection scheme for multiterminal HVDC system with superconducting cable based on artificial intelligence algorithms. International Journal for Electrical Power and Energy System. 149(1). PP: 1-15.

Heymann, F.,Quste, H., Garcia, T.L., Balif, C., and Galus, M., (2023). Reviewing 40 years of artificial intelligence applied to power systems – a taxonomic perspective. Energy and AI, Elsevier Journals. PP: 1-34.

Xu, Z., Zhu, D., Chen, J., Yu, B., (2022). Splitting and placement of data – intensive applications with machine learning for power system in cloud computing. Digital Communication and Networks. 8(1). PP: 476-484.

Murshida, A.A., Chaithra, B.K., Nishmitha, B., Pallavi, P.B., Raghavendra, S.,and Prassana, k.M., (2019). Survey on artificial intelligence. International Journals of Computer Science and Engineering. 7(5). PP: 1-14.

Sonwani, L., and Rathore, S. (2021). Use of artificial intelligence in improvement of power quality. International Journals of Engineering Research and Application. 11(2). PP: 22-27.