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Application of Artificial Neural Network in Power System with Examples A Review

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Abstract— Forecasting Power load is a prime function of power system planning and management. However, it has proved to be a complicated task because of many unstable factors. There are a substantial growth rate and application levels of neural network (NN) in the power system. This review paper explores the forecasting methodology derived from the specific neural network. The electric power industries are presently undergoing transformations and extraordinary reforms. The most exciting and probably profitable developments in recent times are growing Artificial Intelligence (AI) usage of techniques. Therefore, this paper takes an overview of NN techniques and their application in power sectors. According to NN growth rate statistics, in certain power system issues, this paper considers the load forecasting, security assessment, economic dispatch, fault diagnosis, and harmonic analysis. The various disadvantages and advantages of NN applications in this aspect, envisaging the major challenges in this field are explained while considering NN applications in the power system operations and control. The comparison is made regarding several published IEEE papers from 1990 onwards until the present date, which clearly showed that this subject has attracted the maximum awareness in the last one decade, concerning; Load forecasting; Fault diagnosis and fault location; Economic Dispatch; Security Assessment; and Transient Stability.

Keywords— Economic dispatch, Fault diagnosis, Harmonic is analyzing, Load forecasting, Neural network, Power system

I. INTRODUCTION

A. Neural Network

This Review paper explores the recent advances of ANN in control engineering and industrial applications, specifically the use of Neural Networks in the Electric Power Industry. The main Electric Power Industry objective is to provide electricity with steady unvarying quality, at the lowest possible cost [1].

There are several factors that bring hurdles and bring difficulties to achieve this specific goal. The inherent load variations and the quick electric power demand growth remain the foremost, while the need of clean atmosphere, environment, quality fuels, speedy plant aging and advances technology changes are a few other constant problems.
However, lately, the most promising ANN –Artificial Neural Network technological approach has helped to solve this problem in power systems and plants, together with process identification, sensor validation, fault diagnosis, tuning of controllers, monitoring in every power plant, along with load identification, security assessment, load modelling, forecasting and fault diagnosis, in the entire power systems [2].

ANN is probably the most successful technology developed in the last twenty years and it is widely applied in various applications. An ANN is the most useful information processing and dispensation paradigm [3]. It is stimulated by the means of the biological nervous system, similar to the brain, which processes information. The basic constituent of this pattern is the unique structure developed for the information generating, processing, and transfer system. They are the collection of a large quantity of highly sophisticated interlinked processing elements, called Neurons, which work all the time, in unison to attend and solve any specific problem. Like human beings, ANN also learns by illustration and example. The ANN is thus configured for any particular application, like recognition of pattern and classification of data, by the learning process. This kind of learning in the biological system involves several adjustments to the synaptic links that prevail between innumerable neurons. Recently, the ANN was applied in the application of robot vision, diagnostics, character recognition, identification, sensory prediction, process control, and forecasting [4].

B. Overview of ANN

An ANN acts like a computing system is generated out of several simple, but totally interconnected progressive

elements to process data and information by the dynamic response state to external input. Recently, the ANN model research and study have gained added importance due to their potential capability to offer an adequate solution to various problems intractable by a series of computer science areas and AI- artificial intelligence. NN- Neural networks are highly applicable to achieve human-like performance in various fields, like machine vision, speech processing, robotic control, image recognition, and so on [5].

1) ANN Working Methodology

Following are the working methodology of ANN

- ADC- Analog-to-Digital Converters;
- ANN- Artificial Neural Network;
- ANN – PSO: Artificial Neural Network - Particle Swarm Optimization
- DAQ- Data Acquisition;
- DR- Demand Response;
- DSM- Demand-Side Management;
- EMS- Energy Management Systems;
- FFT- Fast Fourier Transform;
- HEMS- Home EMS;
- IoT- Internet of Things;
- LPF- Low-Pass Filters;
- NILM- Non-Intrusive Load Monitoring;
- NI- National Instruments ™
- PSO- Particle Swarm Optimization;
- RMS- Root Mean Square
- USB- Universal Serial Bus.

Based on NILM, this Hybrid Integrated Approach is an Innovative ANN-PSO Model to evaluate Electrical Energy consumed by the Electrical Household Appliances. The proposed NILM workflow is applied in the On/Off operation status of the HEMS to identify every household electrical power demanding appliances shown in below Figure. This hybrid novel method of integrating NILM with ANN-PSO processed in a virtual house environment and utilized to measure and create a model of power-demanding household appliances so as to address the task of load classification. The proposed model of NILM is a collection of event detection, data acquisition, and data of feature extraction, so as to identify and classify the individual and total load. The process was executed in LabVIEW™ using R apps and language, on a computer laptop, linked with the NI- DAQ device, through the USB interface of Texas Instruments Inc., USA [6].

Only one minimal set of signals of the aggregate voltage and current raw analogue is sensed by of voltage/current sensors, and is LPF filtered. These filtered signals, having no high-frequency noise are ADC digitized, and signals analyzed. The proposed NILM are executed to perform for, (1) Feature extraction, event detection; and (2) Identification of total load. The aim of detection of an event to understand the abrupt changes in power, which reflect the activities the household electrical appliances, that are turned off and on [7]. When the event is detected, the NILM takes the reading, evaluates it, and thereafter works out the specific electrical appliances to be turned on to energize or put off to energize. During this characteristic extraction procedure, every individual electrical appliance is monitored in a virtual house environment, so as to extract and analyze the signals digitized. This is the task of the NILM to address a load classification, and thereafter, to propose a new hybrid ANN-PSO and NILM integrated process from a dataset training collected off-line and on-site; this kind of on-site monitoring of load can be executed on-line when the training procedure is completed [8].

This novel hybrid integration two-stage process of ANN-PSO with NILM was further elaborated and shown in another figure below. In the PSO, during this load modelling stage, the ANN solutions considered three basic design factors, and they were evolved and evaluated. Finally, the ANN was a meta-heuristically and automatically designed, provided a high quality and accuracy concerning the entire classified rates while training as well as testing procedures. This developed an innovative methodology using NILM to accurately design an ANN method for the entire load classification, which worked with an unsupervised, in a self-organized method [9].

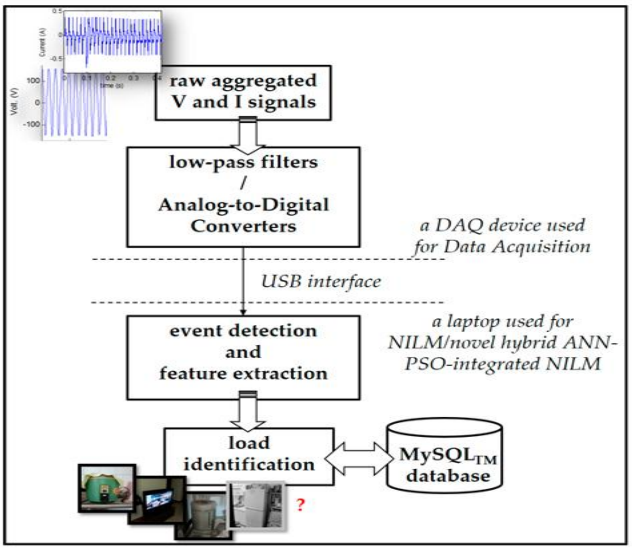

Figure 1: An innovative hybrid of the ANN-PSO-collective workflow method using NILM in the HEMS [9].

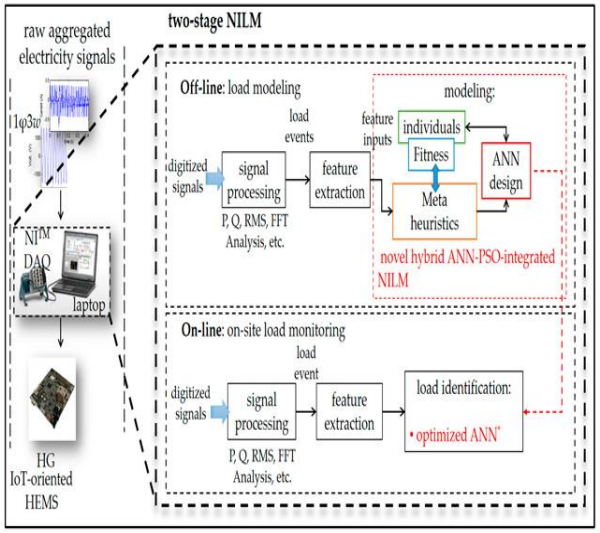

Figure 2: Illustrates NILM of two-stage to meta-heuristically and automatically design the ANN model. Here, NILM is on-site trained, load modeling for off-line is thereafter, on-line executed, for load monitoring on-site. Features used are hybrid ANN-PSO-combined NILM, giving RMS values, and FFT [9].

A network of neural normally includes many processors, which operate in parallel and set in tiers of many layers. The initial tier accepts the raw, unprocessed input information, which is equivalent to human optic nerves, visual processing. Every subsequent tier collects the output information from the preceding tier, instead of from the raw input; in the similar manner neurons thereafter receive the optic nerve signals from their closer neuron to it. The final tier generates the system output [10].

Each processing joint of node retains and maintains its individual minute section of knowledge, that includes what it has observed, experienced and any other rule, it has basically developed and clearly programmed for its own use [11]. These tiers are extensively interlinked. It means every node of tier n links to several other nodes in the subsequent tier n-1, which provides the input, and the following tier n+1, that provides the input for other nodes. There can be one single or numerous nodes on the output side of the layer, and from that, the reasonable answer is produced, which can be read [12].

C. The NN Consists of?

The standard NN has artificial neurons, something from a few dozen to thousands, or also millions of Units prearranged and set in layer sequences, and every unit and layer is connected to another layer on each side. Some of them are called the input nodes and units, which initially are intended to accept several types of information and sequences from the outer world, that the entire network prefers to recognize, learn about, and also a process [13].

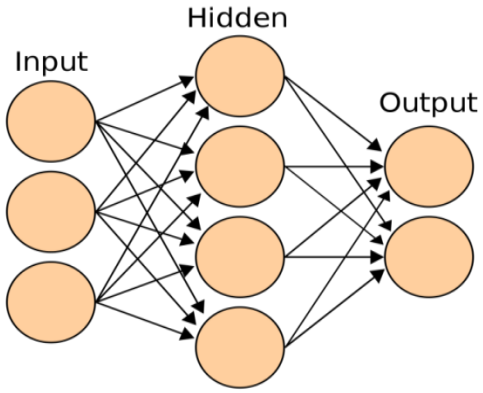

Figure 3: How an artificial NN- Neural Network works [13].

Most NN are entirely linked, which means every hidden node unit and every output node is linked to each node in the layers from every side [14].

D. Applications in General

The artificial NN- Neural Network is extensively used in commercial applications in various industries and technologies. They normally focus on working out complicated pattern recognition and signal processing problems [15], pattern classification, various structure recognition and training paradigms, all types of vector mapping, while the NN applications in various power system control and operation strategies has provided acceptable results [16].

II. HOW AN ANN IS RELATED TO ELECTRIC POWER SYSTEM?

When the electric power supply industry is enduring an extensive reform, the most stimulating and possibly profitable development is to enhance the application of AI- Artificial intelligence technology using the NN- neural network in the power systems. The NN growth rate when applied in certain power system matters, suggest that the NN system helps in security assessment, fault diagnosis, economic dispatch, load forecasting, and harmonic analyzing. Thus, ANN helps the Electric Power system in, (a) load forecasting; (b) Fault diagnosis and identifying fault locations; (c) Economic dispatch; (d) Security measures and assessment; and (e) For the Transient stability [17].

Initially, it started from 1990 until 1996 [18], while the other period commenced from 2000 until 2005 [19]. The below figure indicates the total percentage of published papers during the period 2000 and 2005 in a circular format. The details indicate certain specific fields like fault diagnosis,

load forecasting, operational planning, control and identifications, security assessment, fault locations, and transient stability. Hence, it is of concern, to review and explore how and why to apply the NN methods in such power system operations to substantiate control strategies [20].

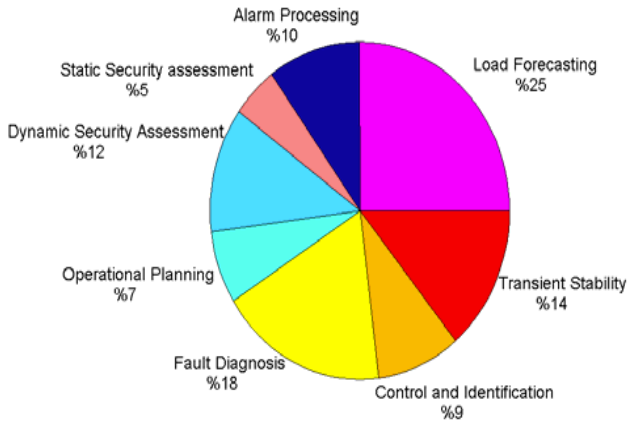

Figure 4: NN applications in power system; 2000 to 2005 [39]

A. Load Forecasting

The most common and prevalent problem, which takes a very vital role in the financial, economic, expansion, planning, and development is the power system load forecasting. Normally, the many papers are published regarding this subject and projects in many regions and they were categorized into several sections:

The load forecasting on a short-term basis over a specific interval starting from one hour to one week, and these details and specifications are important for many applications like economic dispatch with unit commitment, scheduling energy transfer for the virtual time control and management [21] A few methods were classified as Kalman filtering, Regression model, Fuzzy inference, Expert systems, Box & Jenkins model, Chaos time series analysis, and Neuro fuzzy models. Certain methods developed major hurdles showing some limitations like neglecting some specific forecasting conditions and attributes, difficulty in finding a functional relationship developed between most of the attribute variables, regarding the instantaneous demand of load, and further difficulties to upgrade the standard rules governing the expert system, and also the disability to regulate and manage themselves with a quick nonlinear system after load changes. Therefore, NN can be applied to solve these problems. Most of the electrical projects, which use NN methods, have taken into account several factors like weekends, holidays, weather condition, and special sports events and tournament days while forecasting any model to provide successful results [22].

B. Load Forecasting Accuracy

The important electric load forecasting aspect is the kind of method developed with accuracy. This type of model requires implementing the project for the future load demand to be developed as precisely as possible such that the losing revenue risk for the electric utility is minimized and the electricity generating cost is reduced. There is not a single and standard format of load forecasting, due to several uncertainties existing while predicting the future load. The accuracy in forecasting basically depends on the quantity and quality of the past available and historical data applied by those who validate the forecaster's assumptions with maximum accuracy regarding the demand-supply influencing factors taken into account, like average income of the community people, weather conditions, prices and so on [31]. It is normally measured considering the model taking the accuracy statistics and also normal deviations and errors while forecasting [32]. The basic goal of ED- Economic Dispatch is to reduce the operating expenses as much as possible subjected to various constraints and demand situation, that means, the best way to allocate and meet the requisite load demand within the possible generation units [33]. In actuality, the entire operating range units are not readily available for allocating load because of several physical operational constraints and limitation [34].

III. NEURAL NETWORKS, ADVANTAGES, AND APPLICATIONS IN POWER SYSTEM

ANN is the most feasible method to deal with and manage very ill-defined and complex electrical load assessment problems. This is because, ANN is fault tolerant considering that they can effectively manage incomplete and noisy data, can attempt and deal with non-linear issues and problems. Once properly trained, depending on historical data and examples, they can conduct predictions very rapidly regarding generalizations [23].

The range of applications is extremely large. Hence, their focus, for this study, is exclusively on electric load power system predictions and applications.

If we offer to take the insights about demand forecast and production, basically on energy sources, renewable and nonprogrammable, special aspects will include the applications of ANN on the following field of study:

- The performance estimation, diagnostic, modeling, and forecast of PV- Photovoltaic, and wind generators;
- The forecasting and modeling electricity demand;
- Forecasting market prices of electricity;
- The bidding electricity market procedures and strategies of participants;
- The power system balancing issues;

- The optimal renewable sizing of nonprogrammable sources and systems, like Wind, PV, and Hybrid;
- The energy aspects of micro size grid management programs and systems [24].

Several rural communities of Alaska presently operate their own and stand-alone, not government or state managed electrical power allotment, supply, and distribution network of the grid. Even though the power generator fossil fuel-based have become their main energy source in such isolated regions of communities, they have started a large number of these micro size grids to diversify and attain their power supply, and they have included the hydro, renewable wind, energy sources. By integrating and optimizing the multiple utility energy sources, they have effectively designed an additional power demand and management system to forecast the quantity of electricity that will be utilized by the entire community as well as the quantity of electricity will be developed from all the renewable sources available, so as to control and effectively manage, maintain the entire fossil fuel-derived generators to know, collect and meet the power demand of the community. To encounter such problems, they designed a hybrid learning algorithm machine, forecast, community electrical power required to be drawn as the first module and the same is to be applied to the micro size grid, power generation and management of next-generation system [25]. Their algorithm segregates the power load calculation task into two different models: the temporal model to predict and justify the action concerning the potential weather condition and secondary to educate and train the associated people to predict the weather conditions with respect to the power demand of the community. The final results illustrated that; (1) The possible machine building and learning algorithm applies comparatively small size of the data for model validation and training; (2) The predicting community power load ability in the near-future to operate the micro size grids in the environmental conditions, having highly dynamic and favorable weather conditions; and (3) The integration of low quality, multiple abilities, high accuracy to assess future weather conditions produced power load prediction [26].

The Electric Power Industry main objective is to provide electricity to all consumers with constant and uninterrupted service quality at the lowest possible cost within its capacity [27]. Among various factors that incite problems to achieve this goal is the inherent load variability and a constant demand growth are foremost, thereon, the need of clean weather conditions, favourable environment, quality fuel availability, apart from accelerated electricity producing plant and component aging in the middle of advanced and fast changes in technology [28].

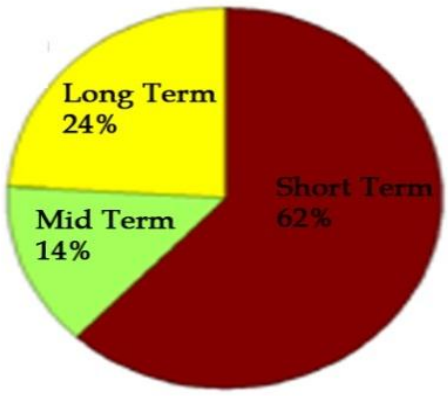

Figure 5: The load forecasting types did use NN [39].

IV. VARIOUS NEURON NETWORK APPLICATION IN ELECTRIC POWER SYSTEM SUBJECTS

The data needed for the learning of such demand assessment and the training period of the regime has to be formulated. Further, the similar type of structure needs to be formulated and structured so as to use them by several members of forecasters in the future. By formulating such ANN designed model, they have received a good recognition regarding the problems faced during the forecasting of the long-term electric load as well. The successful application of the ANN method brings further motivation and ability to educate, learn and accept the changing environment [29].

The lists of advantages associated with ANN techniques are,

- The ANN system is quick and robust;
- It provides, helps and possesses better ways of learning ability;
- It is capable of acclimatizing the requisite data;
- It is very appropriately applicable to nonlinear models;
- They do not need any mathematical model to assess the power load.

The lists of disadvantages associated with ANN techniques are,

- The ANN power load forecaster requires the capability to select the best option of the configuration out of several options available;
- The results are usually created even when the input data available are unreasonable;
- They need to select a proper training methodology to all the concerned people;
- ANN is not capable of taking decisions, which is made within the NNs [30].

V. CONCLUSION

Basically, the neural networks are developed on the biological neuron concept [35]. After the data and database normalization, another step is to train the node input, applying back propagation algorithm [36]. The most important advantages of applying NNs that they produce very quick on-line classification and processing; The implicit nonlinear model and filtering techniques in the system data, however, have generated NN for power system to be viewed as one more additional tool rather than replacing the conventional or any other AI derived power system technique. Presently, the NN methods depend on the conventional simulation method so as to develop the training vectors, while analyzing, specifically when a noisy data prevails. These are major challenges remained to be managed while applying NN technology in the power systems, within the training time, while selecting the training vector, upgrading and advancement in training people of neural nets and further integrating of technologies [37].

This paper has also highlighted the capability of learning various load demand assessing needs and capabilities in combination with ANN and that remains the most challenging, yet interesting problem. The techniques indicate their ability to forecast electrical load, which eventually reduces the operational power system development and utilization expenses and enhances the operational efficiency [38].

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