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Artificial Intelligence Techniques to Fulfill Consumer Power Demand in Smart Grid

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Abstract

Consumers power demand, usages of electrical appliances and electronic gadgets has increased tremendously in the last few years. In general, the power grid system is over stressed and more utilized due to high usage of the electrical appliances and goods. The present electrical system could not withstand the increase in demand and it is very old to deal by active consumer awareness and participation. In addition to that, service providers are introduced various pricing strategy, incentives and other attractive methods to maintain the power grid in stable condition. This article deals to manage the consumers demand and supply under control during the peak periods in a day and effectively reducing the energy usage bill.

Keywords: *Artificial Intelligence, Neural Network, Smart Grid .*

I. INTRODUCTION

In past couple of decades, existing power grid could not find any major changes and improvements when compared to the domains like automotive, biomedical instrumentation, Nano technology, aeronautics, space research and ICT (Information and Communication Technologies). Now a days, the power grid system is facing most important challenges due to increase in population, buildings, residential homes and industries,. Like this present power grid is intricate in nature and interconnected by different energy sources as well as different transmission voltages. If any failure occurs in a small region, then it will affect the entire region by cascading will failure happening simultaneously. So, service providers would not be able to satiate, the consumers' power need and consumers will face major issues like brownout, blackout and power fluctuations.

In the present power grid system, the power outages are ordinary issues, moreover people are habituated to these power cognate issues. These mentioned issues engender astronomically immense break in the electrical appliances and it is awfully arduous task for the consumers to manage it. Consequently, there is a requirement to manage the entire energy system to function at low cost and optimize the energy consumption.

Electrical appliances have been treated as a separate inactive device which is connected to the power system in the sharing end. Moreover, the consumers are considered as a passive component because they consume the power and pay the bill blindly with no any erudition of energy tariff models. However, there is an essential need to convert these passive components into active to create the energy system perspicacious and build the consumer as an active player to gain the erudition about tariff, billing and power incentives provided by the service providers. The impeccable and timely approach solution is smart grid which provides a consummate solution to above mentioned power similar issues by active consumer participation. Smart grid is a solution for the Aforementioned issues by greatest challenges in

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the implementation. In order to use the smart grid technology in a better and efficient mode, there is necessitate upgrading the electrical devices used and securing communication infrastructure of the exiting power grid system.

II. SMART GRID

Smart grid is a modernization of the subsisting power grid using the latest advancements in the ICT whose objectives include the features like demand side management, efficient power supply, bidirectional flow of power as well as information, self-healing, integration of renewable energy sources, reduction of manual intervention during the faults, delivery of power to consumer by low operating cost, security in the smart grid communication & customer satisfaction. At present, power faults, outages and failures pose grave social and economic problems to both developed and developing countries. The latest technologies are employed into the existing power grid network which permits to carry out the aforementioned features among the service providers & consumers. These latest technologies like computer networks, actuators, sensors, automation and digital components will effort together to build the existing power grid system to convene the demand side management requirements of next generation power grid.

III. SIGNIFICANCE OF THE STUDY

The architecture of the existing power grid is built a couple of decades ago. It does not fully help to latest communication, technologies and automation techniques. Computation is done at all parts of the power network: for optimizing utilization of the grid, processing of field data, fast local control of equipment, and demand side management. But coordination across the network happens on a slower timescale. Some coordination occurs under system control, but a lot of it is still based on phone calls between system operators at the utility control center due to passive components in the existing system. Due to passive components and low coordination in between interconnected devices, faults & power outages are very common in the current power grid system. To avoid the aforementioned issues in the demand side management, in this research we focus on the following works to maintain the grid stability, over and under utilization of the power grid, maintains the demand of market by using the scheduling mechanism and generation and distribution of power through proper prediction.

IV. OBJECTIVES OF THE STUDY

The major objective of this article is to contribute to improve the latest technologies in DSM and discuss the basic challenges and opportunities. In particular, employing the scheduling mechanism reduces the energy consumption cost effectively. Load forecasting supports the planning of future gird by high adaptability.

Load forecasting is an important system to build the power network based on the previous requirements. The production and usage cost is high during the peak hour, average in mid-peak hours and low cost during the off-peak periods. So that the consumer can plan to consume the energy whenever the tariff cost is low that is to operate their electrical appliances during the low tariff times. Some of the energy usage forecasting approaches are reported in the existing literature by RTP and ToU based model. The dynamic property of the renewable energy sources and uncertain use of appliance by consumers builds the energy usage forecast as well as the reduction of the RTP based billing for the consumers difficult. The prediction error is decreased into certain level and it can be reduced further by using ANN models. The properties of RES like wind and solar are presented in the following sub-section.

Wind: Wind energy forecasting has many challenges due to its unpredictability & variability of wind power generation. It is also considered as a one of the favorite RES source due to its cleanness and efficiency. While it is tough to forecast wind energy,

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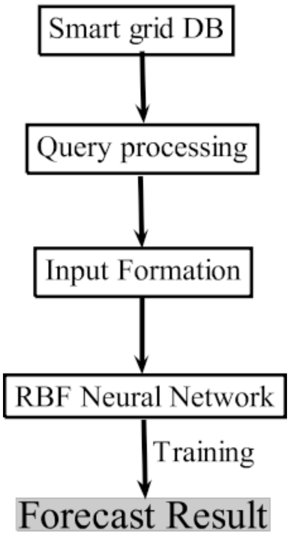
it helps in scheduling conventional power plants and spot market trading in electricity. Wind power forecasts play a vital role to address the operation challenges in electricity supply.

Solar: Solar irradiance or PV power is called the output of solar forecasting. From the perspective of smart grid energy management, very short-term and short-term prediction of solar power are particularly useful for PV plant operations, storage control, real-time unit scheduling, automatic generation control (AGC) and electricity trading. The summary of prediction process is shown in Figure 6.1 and it comprises of the following steps: Smart grid DB, Query processing (PostgreSQL), Formation of input data and RBF neural network model.

Smart grid database is a collection of data that are monitored in real time smart grid network. In this work, the real time dataset is taken from Pecan Street. Then the data are cleaned and processed using PostgreSQL a query processing technique. Using the processed data, the input dataset is formed which is used to train the neural network.



RBF Neural Network prediction process

V. RADIAL BASIS NEURAL NETWORK

A general neural network model has the following components: (i). Input, (ii). Weight (iii). Bias and its transfer function. Let X is the input to the input layer for the neural network. From the theory of function approximation, the RBF neural network is traced. RBF neural network is a three layered (input, output and hidden layer) feed forward network. The first layer forms the input parameters. These inputs are supplied to the next layer (hidden layer). Hidden layer starts processing the part of training by the support of radial basis function and passed the output to the final layer. The output layer is connected and it forms hidden nodes by corresponding weight values. Output layer performs the sum of weights for all the nodes connected between hidden and output layer to gain the expected prediction. It can be used to forecasting issues, classification, stock market prediction and load prediction in smart grid.

All point in the dataset will determine the value of the hypothesis at every point *x*. i.e for each (*tn*, *un*) belongs to *D* which determines *H* (*t*), where *H* denotes the hypothesis, (*tn*, *un*) denotes the inputs and *D* represents the data dimension. However, the hypothesis will get affected by the data. It may also get affected through the distance. Obviously a point in the dataset will affect the nearby points than far away points. i.e for each (*tn, un*) belongs to *D* influences *H* (*t*) depends on the distance of the two points *tn*- *tn*−1. The standard form of

RBF model is

$$H(t) = \exp(-\gamma(||tn - tn-1||^2)) \qquad \text{equation 1}$$

where γ is a positive parameter which is constant. It completely depends on the input component distance *tn*- *tn*−1. The exponential value reflects on the hypothesis function *H* (*t*) according to the dataset. All the input points have a parameter that is represented by a value and those values affects the target value *un*. To sum up all these connections from the network model then the standard form equation is represented by

$$H(t) = \sum_{i=1} wi\exp(-\gamma(||tn - tn-1||^2)), \qquad \text{equation 2}$$

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Where i denotes the initial data value; N denotes the number of inputs and wi denotes the weight value which is used for learning process. An RBF network has one more neurons in the space described by the predictor variable (tn−1, tn) which has many dimensions as the prediction parameters. From the center of each neuron, the Euclidean distance is computed. From RBF function is applied to compute the distances which influence (weight) each neuron.

Dataset are collected from the pecan street database which is a real time data (Pecan Street 2014). The active users are selected from the database and their energy usage values are stored in tables. Structure Query Language (SQL or Post gre SQL) is used to gather the energy consumption data in the required time series format and it is used for prediction. Thus, real time data plays a vital role in consumer's energy usage prediction. Now, we have data of consumer's energy usage behavior. Passing the previous energy usage input (t − 1) and the present energy usage input (t) to the input layer of the neural network. Through proper training, it produces the more accurate output of next expected energy consumption (t + 1).

The available Dataset is divided into three sets.Training, testing and validation. Let T be the input to the input layer for training the network.

$T = t1, t2, t3, ..., tn,$ equation 3

Where $t1, t2, t3, ...,tn$ denotes the scalar inputs to the input layer and n represents the number of scalar inputs which is n dimensional. Let W be the weight values between the hidden layer and output layer which is also an n dimensional. Based on the neuron numbers in the hidden layer, it may be optimized for improving the efficiency of the RBF.

$W = w1, w2, w3, ...,wn,$ equation 4

where$w1, w2, w3, ..., wn$denotes the weight values. In RBF NNs each hidden neuron computes the distance from its input to the neurons central point, C and applies the RBF to that distance, as shown below

$H(T) = \Phi(||X - C||2/R2),$ equation 5

where$H(T)$ is the output of hidden layer, Φ is the RBF and R is the radius. Present in the output layer, weighted sum Y is calculated using the output of the hidden neurons and the weights of links as follows

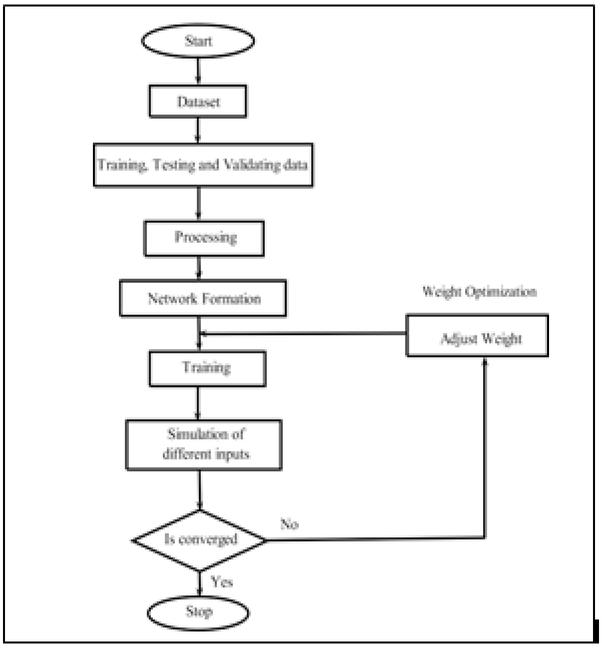
$Y = \sum(W * H(X)) + B.$ equation 6

VI. FLOW SEQUENCE OF RBF NEURAL NETWORK

Test the trained output value by the testing data Td and calculate the

Error E as

$E = Td - Y$ equation 7



Based on the obtained error value, update the weight matrix using optimization algorithm.

VII. GENETIC ALGORITHM

Genetic Algorithm is an evolutionary algorithm. It may be termed as a search method for the linear and non-linear problems Genetic Algorithm selects the fittest among the initial population based on the weights validation from the obtained population. It

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begins by initial creation of populations (weights). The Genetic Algorithm selects, the fittest weight mate to create the new offspring.

Then there is a chance for the mutation and end up by the obtained population. Thus, during this process, Genetic Algorithm can able to produce the better weights each iteration consistently. Genetic Algorithm mimics the process of natural selection or called as survival of the fittest.

VIII. IMPLEMENTATION OF FIREFLY

Heuristic algorithms are more specific to solve a problem and it is not efficient in solving the all kind of the optimization problems. But the met heuristic algorithm provides a solution for solving wide range of problems. It is simply replaces the heuristic algorithm when it is unable to solve the issue. But met heuristics algorithms are not being very a great deal efficient for problem specific. Firefly is one of the insect that sufficient to emit nature lights due to its bioluminescence property to draw each other in the mating process. The light intensity or brightness of the light plays a very important role while finding the optimum solutions. Firefly algorithm belongs to one of the met heuristic type. The following assumptions are considered to implement the firefly algorithm: a) Fireflies are unisexual and each firefly tries to attract others. b) Based on the light intensity, fireflies are attracted to each other. and c) The objective function determines the light intensity of the firefly.

Initialize the number of fireflies n, control parameters such as light intensity l, absorption coefficient r, spatial coordinates of firefly x, and maximum number of iterations max. Evaluate the objective function F. And calculate the distance in between fireflies fi and $f j$. If $fi < f j$ then move fi towards

$f j$, else move randomly. Check whether goal is reached, if so, terminate the process, otherwise, and evaluate the objective function by new set of inputs.

Algorithm .1 Firefly Algorithms

n: Number of Fireflies

l: Light Intensity

γ: Light absorption coefficient

x: Initial population

max: Maximum generation

Initialization of population for xi(i = 1, 2, ...,n)

while(!$count$ = max) do

build a copy of the generated firefly population for move function

loop(i := 1 to n)

loop(j := 1 to n)

if($li > l j$) then

Move i to j

Evaluate new solutions

Update l for new solutions

end if

end loop

end loop

Sort to find current best

$count$= $count$ + 1

end while

Obtain best result

IX. SIMULATION RESULTS

The existing conventional neural network model, neural network based on evolutionary optimization technique and the proposed RBF neural network based firefly optimization algorithm are compared here. And the real time dataset has been taken from Pecan Street. The available data are separated into training, testing and validation data. For training

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data (70 %), testing data (15 %) and the remaining data is used for validation.

The predicted energy using conventional neural network model, neural network based Genetic Algorithm, Neural network based PSO and RBF neural network based firefly optimization algorithm are compared against the energy consumed during winter and summer seasons. The energy usage is measured in kW and it is monitored in hourly basis. In Figure The predicted energy using conventional neural network model, Neural network based Genetic Algorithm, Neural network based PSO and RBF neural network based firefly optimization algorithm are compared by the help of energy consumed throughout winter and summer seasons. The energy usage is measured in kW and it is monitored in hourly basis. In Figure., X-axis represents time slot in minutes for an hour. The measure of instantaneous electricity usage/generation is represented in kilowatts (kW) in the graph. The results show that the RBF neural network based firefly optimization algorithm is more superior in very short term energy forecasting.

X. SHORT TERM LOAD FORECASTING

It can be cleared that the energy pattern ends at 96. Because, the day is divided into 96 slots where each slot is 15 minutes (so that a full day can be totally divided into 96 slots). The predicted energy using conventional neural network model, Neural network based Genetic Algorithm, Neural network based PSO and RBF neural network based firefly optimization algorithm are compared and the results are plotted it may be seen that the RBF neural network based firefly optimization algorithm yields better prediction in short term forecasting. The prediction accuracy is best by firefly algorithm when compared by other evolutionary algorithms like Genetic Algorithm and PSO due to its meta-heuristic approach.

XI. MEDIUM TERM LOAD FORECASTING

Here, the energy consumption is monitored in terms of hours for a quarter year. Figure illustrates the comparison between predicted and consumed energy for the proposed RBF neural network based firefly optimization algorithm and neural network based evolutionary model and conventional neural prediction model for load forecasting. The energy prediction has executed for three months (Comparison is made for 91 days). In medium term prediction, RBF neural network based on firefly optimization algorithm predicts better than the other compared algorithms. Further, the comparison result shows that, Firefly optimization method consistently produces accurate result during the solution.

Long term forecasting predicts the energy usage in terms of months and years. Figure illustrates the comparison graph for prediction accurateness of neural network algorithm for 365 days (one year). RBF neural network based firefly optimization algorithm prediction is compared by the conventional neural network model. Neural network based Genetic Algorithm, Neural network based PSO. The simulation results present that the RBF neural network based on firefly optimization algorithm is the best. From this simulation result observed that the RBF neural network based firefly optimization algorithm technique yields better recital for the long term load forecasting. Firefly is extra superior due to its exploration property in the search space to find a better result.

XII. CONCLUSION

Short-term load prediction is suitable for avoiding the overloading situations in the power network from estimating &analysing the accurate load flow. Long-term prediction is also very much obliging for finding the inevitability to make the power generation station, construction as well as designing of transmission different lines. On time, prediction avoids the network unreliability and utilization of the power grid during the peak hours. The simulation results shows that for the RBF neural network based firefly optimization algorithm load forecast consistently yields superior presentation compared to the conventional neural network model, Neural network based Genetic Algorithm, Neural network based PSO. In addition, the combination of neural network and firefly optimization yields quick, cheap, and more accurate results for different types of load forecasting. Comparison between the neural network based evolutionary optimization (Genetic Algorithm and PSO) and the implemented meta-heuristic neural network based firefly optimization algorithm is discussed and displayed. So, this forecasting mechanism supports to keep away from power network component failures, blackouts and brownouts.

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