International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 2, Issue 6 (April 2013) PP: 98-101

Electrical Energy Management and Load Forecasting in a Smart Grid

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Abstract: *Artificial Neural Networks (ANN) has been applied to many fields in recent years. Among them, the neural networks with Back Propagation algorithm appear to be most popular and have been widely used in applications such as forecasting and classification problems. This paper presents a study of short-term load forecasting using Artificial Neural Networks (ANNs) and applied it to the Sudan National Electric Company NEC. Neuroshell2 software was used to provide back-propagation neural networks. ANN model used to forecast the load with the performance error as a measure characteristic. The error obtained by comparing the forecasted load data with actual load data.*
Keywords: *Demand Forecasting, Energy Management, Generation Dispatch, Neural Networks, Smart Grid,*

I. Introduction

The Smart energy generation as a concept can be defined as the matching electricity production with demand using multiple identical generators which can start, stop and operate efficiently at chosen load, independently of the others, making them suitable for base load and peak power generation. Electricity produced and delivered to customers through generation, transmission and distribution systems. Reliable electric power systems serve customer loads without interruptions in supply voltage. Generation facilities must produce enough power to meet customer demand. Matching supply and demand called load balancing and is essential for a stable and reliable supply of electricity. Operators of power transmission systems are charged with the balancing task, matching the power output of all the generators to the load of their electrical grid. The load balancing task has become much more challenging as increasingly intermittent and variable generation resources such as renewable energy when we need to add it to the grid through the smart grid concept.

One element of the smart grid that related to the efficient production of electricity has to do with condition monitoring and assessment [1]. In condition monitoring and assessment, sensors and communications are used to monitor plant performance and to correlate that performance to historic data, theoretical models and comparable plant performance. The concept of the expanded use of sensor, communications and computational ability is part of the smart grid concept. The improvement in the power delivery system (electric transmission and distribution) through the use of smart grid technologies can provide significant opportunities to improve energy efficiency in the electric power.

Neural networks are often used for statistical analysis and data modeling, in which their role is perceived as an alternative to standard nonlinear regression or cluster analysis techniques. Thus, they are typically used in problems that may be couched in terms of classification, or forecasting. Some examples include image and speech recognition, textual character recognition, and domains of human expertise such as medical diagnosis, geological survey for oil and mining, and financial market indicator prediction [2-8].

The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

II. Generation Dispatch And Demand Forecast

The Demand Forecast and the Generation Expansion Plan form the basic input data for planning the activity. The indicated levels of demand and generation are important to consider the extreme power transfer cases to ensure that the infrastructure is adequate to accommodate any credible operational scenario within the studied cases.

a. Generation Dispatch and Scheduling

As power resources become more distributed, systems more conducive to demand-response, and generation more intermittent, efficient and robust system operation will depend critically on the ability of new dispatch methods to provide a better predictive, forward-looking and holistic view of system conditions and generation patterns. Automatic Generation Control (**AGC**), Economic Dispatch (ED) and Reserve Monitoring (RM) are among techniques used today for the generation dispatch and scheduling.

The AGC is related to Area Control Error (ACE) which defines as a combination of the deviation of frequency from nominal, and the difference between the actual flow out of an area and the scheduled flow. Ideally the ACE should always be zero and because the load is constantly changing, each utility must constantly change its generation to chase the ACE. The Major objectives of AGC is to regulate the system frequency to a specified nominal value, maintain the net interchange power across the boundaries of the operation area at the scheduled value and to adjust each unit's generation at the most economic level. Automatic generation control (AGC) is used to automatically change generation to keep the ACE close to zero.

b. Demand Forecast

Currently the demand or load forecasting is become very essential for reliable power system operations and market system operations. It determines the amount of system load against which real-time dispatch and day-ahead scheduling functions need to balance in different time horizon.

The Demand forecasting technique typically used three different time frames:-

1. Short-Term load forecast (STLF):- Next 60-120 minutes by 5-minute increments.
2. Mid-Term load forecast (MTLF): Next n days (n can be any value from 3-31), in intervals of one hour or less (e.g., 60, 30, 20, 15 minute intervals).
3. Long-Term load forecast (LTLF): Next n years (n can be any value from 2-10), broken into one month increments. The LTLF forecast is provided for three scenarios (pessimistic growth, expected growth, and optimistic growth). Demand forecasting play an increasingly important role in the restructured electricity market and it is challenge for smart grid environment due to its impacts on market prices and market participants.

In general, demand forecasting is a challenging subject in view of complicated features of load and effective data gathering [9]. With Demand Response being one of the few near-term options for large-scale reduction of greenhouse gases, and fits strategically with the drive toward clean energy technology such as wind and solar, advanced demand forecasting should effectively take the demand response features/characteristics and the uncertainty of intermittent renewable generation into account. Many load forecasting techniques including extrapolations, auto regressive model, similar day methods, fuzzy logic, and artificial neural networks have been used.

III. DESIGN OF NEURAL NETWORK FOR DAY LOAD FORECASTING

Neural networks are applied widely for solving different problems which in general are difficult to solve by humans or conventional computational algorithms. In order to design a neural network for addressing the one day load forecasting problem, several different training data and training time are studied. As a pre-processing step the training and the testing data generated from the Load Dispatch Centre of National Electrical Corporation (NEC) Sudan, base from years 2008 and 2009 are used for training and implemented in the Neural Network (see Appendix :).

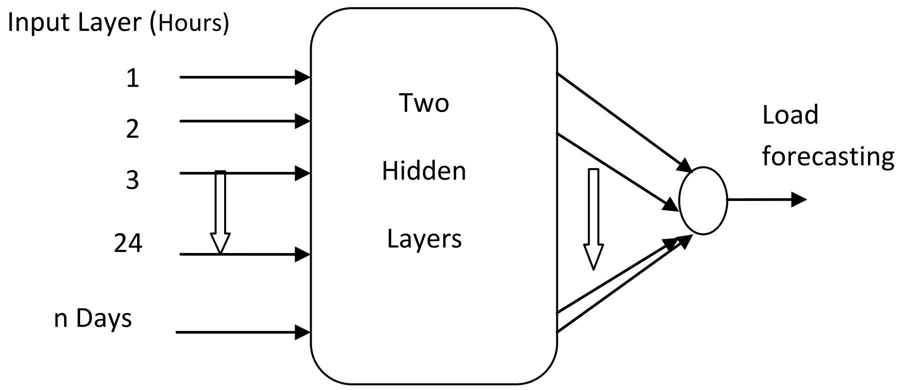

Fig 1 Neural Network Architecture for Load Forecasting

Selecting the right size of the network training data is not only important for obtaining good results but also significantly impacts the generalization and representational capabilities of the trained network. The Neural Network architecture used is shown in Fig 1; which has one layer for the inputs, two hidden layer and one output layer. A back-propagation neural network is used for learning the neural. The network has one output to determine the load value at specific time during the day.

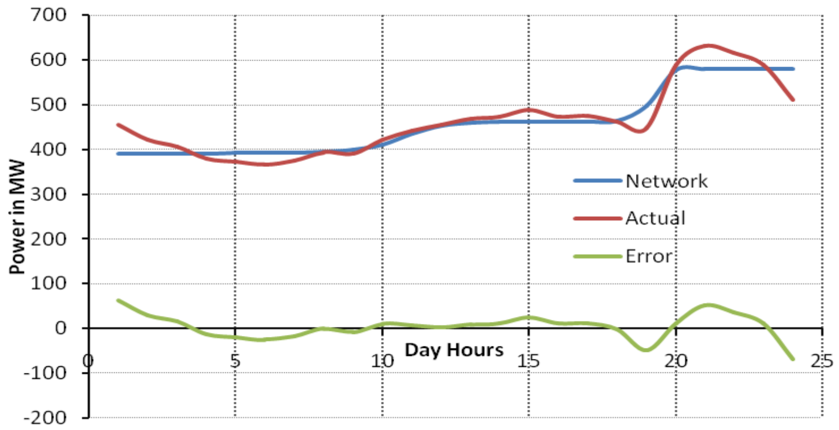

Fig 2 One Day Load Forecasting and Error

In order to determine the size of training data, error and performance of network are considered as two main measures factors. Day load data (Performance and Error plots) shown in Fig 2 is used to train the network. 5 and 10days load data are implemented. The performance of the selected training data size and errors plots associated with this architecture are given in Fig 3&4. The ten days load data gives the best result of minimum error as shown in Fig 3.

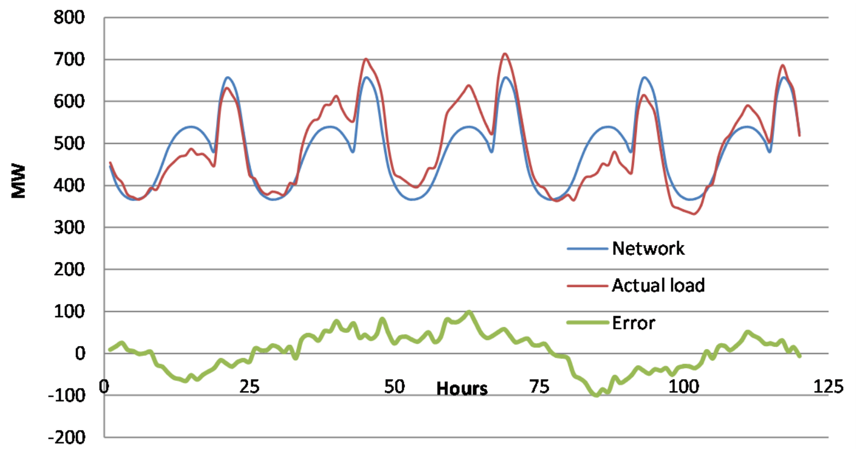

Fig 3 Mid-Term load forecast (5Days Load Forecasting)

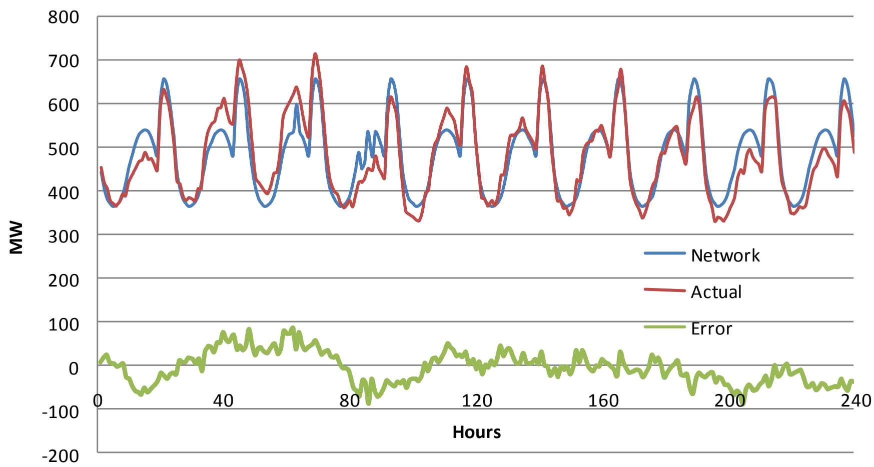

Fig 4 Mid-Term load forecast (10Days Loads Forecasting)

IV. CONCLUSION

Neural networks provide a reliable and an attractive approach for the load forecasting and it was able to predict the nonlinear relation exist between the historical data. The results obtained demonstrate that in general the performance of the back-propagation neural network (BP) architecture was highly satisfactory in producing the expected load.

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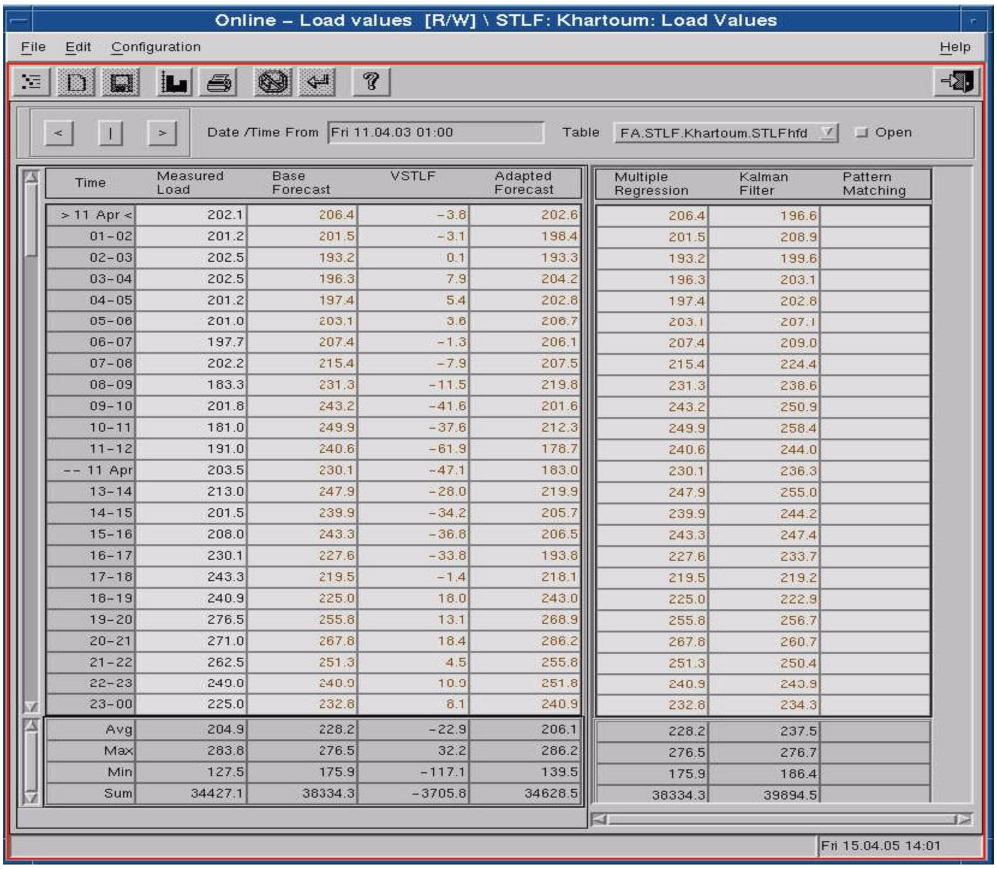

Time	Measured Load	Base Forecast	VSTLF	Adapted Forecast	Multiple Regression	Kalman Filter	Pattern Matching
> 11 Apr <	202.1	206.4	-3.8	202.6	206.4	196.6	
01-02	201.2	201.5	-3.1	198.4	201.5	208.9	
02-03	202.5	193.2	0.1	193.3	193.2	199.6	
03-04	202.5	196.3	7.9	204.2	196.3	203.1	
04-05	201.2	197.4	5.4	202.8	197.4	202.8	
05-06	201.0	203.1	3.6	206.7	203.1	207.1	
06-07	197.7	207.4	-1.3	206.1	207.4	209.0	
07-08	202.2	215.4	-7.9	207.5	215.4	224.4	
08-09	183.3	231.3	-11.5	219.8	231.3	238.6	
09-10	201.8	243.2	-41.6	201.6	243.2	250.9	
10-11	181.0	249.9	-37.6	212.3	249.9	258.4	
11-12	191.0	240.6	-61.9	178.7	240.6	244.0	
-- 11 Apr	203.5	230.1	-47.1	183.0	230.1	236.3	
13-14	213.0	247.9	-28.0	219.9	247.9	255.0	
14-15	201.5	239.9	-34.2	205.7	239.9	244.2	
15-16	208.0	243.3	-36.8	206.5	243.3	247.4	
16-17	230.1	227.6	-33.8	193.8	227.6	233.7	
17-18	243.3	219.5	-1.4	218.1	219.5	219.2	
18-19	240.9	225.0	18.0	243.0	225.0	222.9	
19-20	276.5	255.8	13.1	268.9	255.8	256.7	
20-21	271.0	267.8	18.4	286.2	267.8	260.7	
21-22	262.5	251.3	4.5	255.8	251.3	250.4	
22-23	240.0	240.9	10.9	251.8	240.9	243.9	
23-00	225.0	232.8	8.1	240.9	232.8	234.3	
Avg	204.9	228.2	-22.9	206.1	228.2	237.5	
Max	283.8	276.5	32.2	286.2	276.5	276.7	
Min	127.5	175.9	-117.1	139.5	175.9	186.4	
Sum	34427.1	38334.3	-3705.8	34628.5	38334.3	39894.5	

Appendix: Online Forecasting Load Value Sudan NEC Khartoum Area