# Artificial neural network based generation scheduling: a case study for Belgium's national grid

**Iyir Nyodu[1], Bikramjit Goswami[2]**

Don Bosco College of Engineering and Technology, Assam Don Bosco University
*Airport Road, Azara, Guwahati - 781017, Assam. INDIA.*
*[1]i.nyodu869@gmail.com, [2]bikramjit.goswami@dbuniversity.ac.in*

**Abstract:** ***Modem power system energy management system involves generation scheduling as one of the core components. Generation scheduling function has to satisfy the main objective of economics, which involves an optimization of cost over a future period of time. Also it depends on the availability of the various types of generation. The present paper describes an artificial neural network (ANN) based method for scheduling of generation for the national grid of Belgium. The supervised multilayer perceptron based training produces satisfactory results in scheduling of non-renewable energy sources, with prior information on the availability of renewable energy sources.***

**Keywords:** Artificial neural network, generation scheduling, non-renewable energy, renewable sources.

## 1. Introduction

The generation scheduling is one of the important components of a modem power system management scheme. The scheduling helps in the determination of the generation level required from each unit, by minimizing utility wide production costs, while meeting system and unit constraints. The constraints are the generation capacities of both renewable and non-renewable types. However, the main objective of generation scheduling is the economics, which involves an optimization of cost over a future period of time. The economic dispatch functions essentially assume that the appropriate load forecasts are available.

Artificial neural network (ANN)s are composed of simple elements operating in parallel, which are inspired by biological nervous systems. ANNs can be trained to solve problems that are difficult for conventional computers or human beings. ANNs have been used for the scheduling of hydroelectric generations in order to find the optimal level of generated power for the units in the system for next 24 hours [1]. There the input data included hourly loads of the system and the natural inflow of each reservoir. Typically in such training programs the days with similar hourly load patterns and natural inflows are identified. ANN has been found to be faster in reaching the target of proper hydro generation scheduling, as compared to conventional dynamic programming approach.

A three layer feed forward ANN was also used to solve the problem of pumped-storage scheduling where faster and more accurate solution was obtained [2]. Another similar work presented the use of ANN for the automation of power generation scheduling, based on the consumer's load profile [3]. A multilayered neural network with backpropagation learning algorithm was used in the work to predict the required power generation to meet the consumer's demands and results confirmed that the ANN model can automatically perform generator scheduling accurately. In the paper of Alireza Khotanzad et al. [4] they described about the third generation of an hourly short-term load forecasting system known as artificial neural network short-term load forecaster (ANNSTLF) generation tree. Their forecaster was accepted by many electric power system utilities and they used it; across US and Canada 35 utilities used their forecaster. According to the publication of R. Naresh and J. Sharma [5] they presented two-phase ANN approach for finding optimal scheduling of interconnected hydro plants. Their prime target was to maximize hydropower generation and to meet the irrigation requirements.

In the paper of Kittipong Methaprayoon et al. [6], they discussed about the development of ANN based wind power forecasting and integration of wind forecaster results into unit commitment scheduling, considering forecasting uncertainty by the probabilistic concept of confidence interval.

Thus for a multi generation system for a larger area, like a large country, the ANN can prove to be a useful tool in deciding about the generation required from a particular type. Such as, given the amount of generation, available from the renewable sources, the minimum generation to be scheduled from non-renewable sources would be found by the trained ANN automatically, by training with historical data. This paper analyses such a case and explores the possibility of generation scheduling for the whole country of Belgium, in short term basis, by

considering the available levels of generation by the renewable sources as prior information.

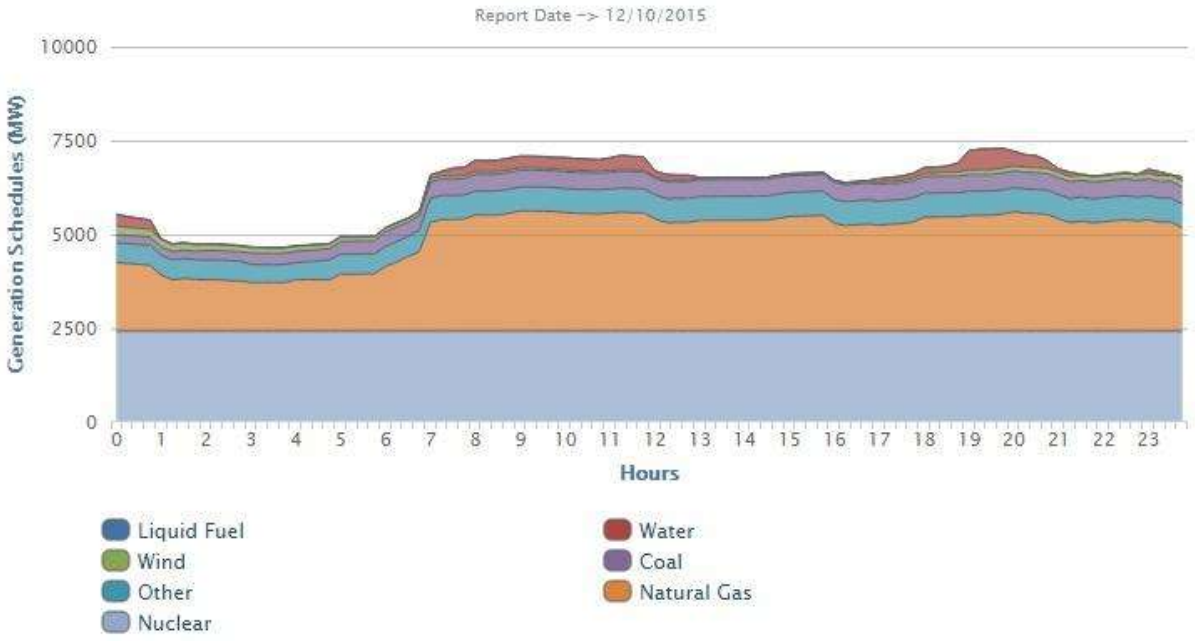


**Figure1:** Hourly scheduled electricity demand (collected from ELIA, Belgium on 12/10/2015)

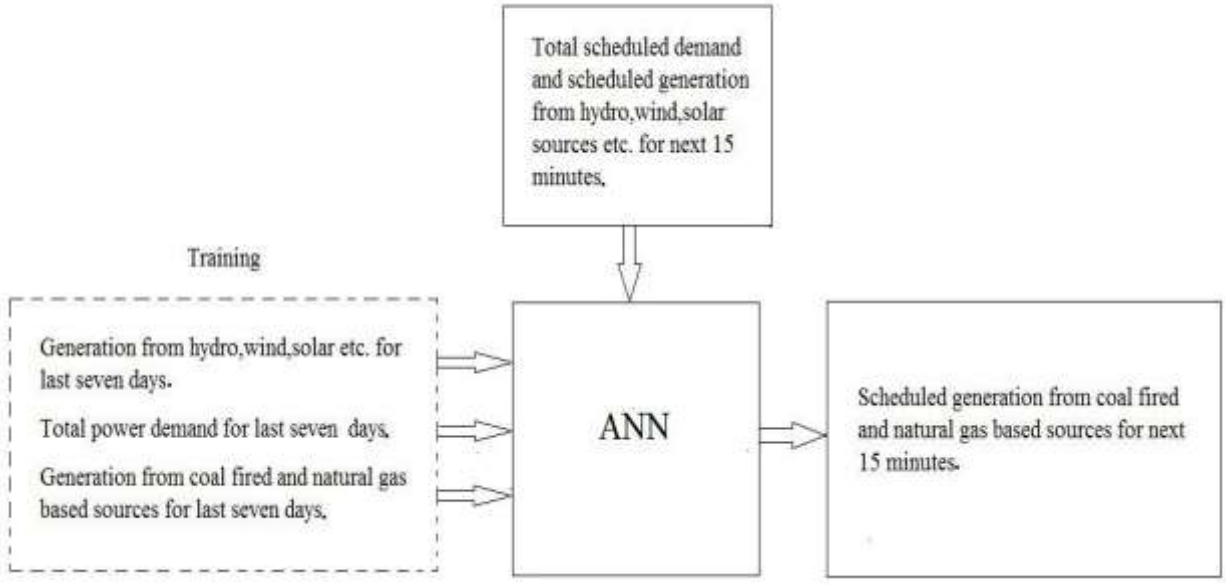


**Figure2:** Methodology for generation scheduling using ANN

## 2. Data set and methodology

The data which was used for the analysis was taken from ELIA, Belgium's electricity transmission operator.

Data was collected online, for seven successive days. The data consists of generation schedules of total power, liquid fuel based power, natural gas based power, hydro power, wind power, coal power, nuclear power and other power consisting of mainly solar. A typical one day hourly data graph obtained from ELIA, Belgium is shown in Figure 1. The actual

generation in Belgium is done exactly as per the schedule, unless there is any unplanned outage of any unit, which is very rare. Hence, this data can be reliably used as the generation data for training the ANN to predict the generation in future.
The methodology adopted for training the ANN and then to use it for generation scheduling is shown in Figure2. The training of the ANN is done using data containing generation levels of hydro, wind, solar and nuclear for seven days. Electricity generated using liquid fuel in Belgium is negligible, hence not shown in the schedule provided by ELIA. On the other hand, the nuclear power generated during the period remains constant. Hence, it's values are not necessary for training the ANN.

The next quantity used for training is the total power demand for the days. Finally, the generation levels required from coal fired and natural gas based sources to meet the total demand is applied to the ANN as the target during the training phase. Once the training is over, the schedule of generation from coal fired and natural gas based sources can be obtained for the next fifteen minutes, if the total scheduled demand of power as well as the scheduled generation from hydro, wind and solar sources are provided to the ANN as input. This methodology can be used for any electricity grid to predict the use of non-renewable sources, when the information regarding total scheduled demand as well as the scheduled availability of the renewable sources are available.

## 3. Results and discussion

ANN based method is applied for optimum generation scheduling problem in Belgium, where a multilayer feed forward neural network is selected for the purpose and for training the network resilient backpropagation was used, which gives faster training. The Multi layer perceptron based supervised training is done, based on which the generation scheduling has been done. The ANN is constructed with four input layers, five hidden layers and two output layers. The learning rate was kept at 0.001 with the targeted maximum number of iterations is 100 and acceptable mean square error level is $10^{-3}$. The input to the neural network contains total scheduled demand, scheduled generation from hydro, wind, solar sources for next 15 minutes. The output from the network is scheduled generation from coal fired and natural gas based sources for next 15 minutes. The tan-sigmoid transfer function has been used in the designed ANN model.
The first six hours' data used for training are shown in TABLE 1 as sample. Such hourly data for 24 hours and for seven days have been used to train the network.

The trained network was then checked for its readiness to predict scheduled generation by coal based and natural gas based generating stations. The applied input and output from the ANN are shown in TABLE 2. TABLE 3 shows the actual scheduled generation as anticipated by ELIA versus the ANN predicted generation values. The error percentages are also shown in the table for the particular case. The error percentage for all the schedules predicted by the designed ANN is found to be within a limit of ±10%.

Hence the designed ANN can be used effectively for scheduling the generation for short-term cases. If the input applied to the trained ANN is a set of multiple values from different types of generators, for different blocks of time, then the output for those time blocks from the ANN would give the scheduled generations by the other types of generating units.
The ANN based method used for generation scheduling results into a simpler and faster way of doing so for large area network. Hence, this method can be useful for a country wide generation scheduling, as demonstrated, considering the case of the whole country of Belgium.

**TABLE 1:** GENERATION SCHEDULE DATA OF FIRST SIX HOURS ON 12/10/2015

| *Hr.* | *Total power (MW)* | *Coal power (MW)* | *Natural gas power (MW)* | *Hydro power (MW)* | *Wind power (MW)* | *Other power (MW)* |
|---|---|---|---|---|---|---|
| 1 | 4875.6 | 222.0 | 1492.3 | 18.2 | 193.2 | 530.4 |
| 2 | 4749.2 | 248.0 | 1369.3 | 18.2 | 163.8 | 530.4 |
| 3 | 4665.7 | 299.0 | 1299.4 | 18.1 | 147.5 | 482.2 |
| 4 | 4699.3 | 299.0 | 1373.5 | 18.0 | 130.5 | 458.8 |
| 5 | 4945.3 | 344.0 | 1521.1 | 18.0 | 112.3 | 530.4 |
| 6 | 5182.1 | 389.0 | 1731.3 | 18.0 | 94.9 | 529.4 |

**TABLE 2:** GENERATION SCHEDULING USING ANN

| *Input types* | *Scheduled Generation values in MW applied as input* | *Output types* | *Scheduled Generation values in MW obtained from ANN* |
|---|---|---|---|
| Total demand | 7210 | Coal power | 484.6 |
| Hydro power | 385 | | |
| Wind power | 135 | Natural gas based power | 3296.7 |
| Other power | 640 | | |

**TABLE 3:** ACCURACY OF GENERATION SCHEDULING USING ANN

| *Type of generation* | *Scheduled Generation values in MW obtained from ANN* | *Scheduled Generation values in MW as computed by ELIA, Belgium* | *Percentage of error* |
|---|---|---|---|
| Coal power | 484.6 | 447 | 8.4% |
| Natural gas based power | 3396.7 | 3182.5 | 6.7% |

## 4. Conclusion

Non-Renewable energy is the energy which is taken from the sources that are available on the earth in limited quantity and will vanish fifty-sixty years from now. To optimize their use, it is necessary to schedule their generation levels to meet the required demand by computing the available renewable sources. The results of the present work showed the effectiveness of the ANN based technique to schedule non-renewable generation based on the availability of the renewable generation levels with an accuracy of ±10%. This technique yielded consistent results when crosschecked with data of different dates for different periods of time.

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**Author Profile**


**Iyir Nyodu,** is an M.Tech. student at Assam Don Bosco University, Guwahati, India. She received her bachelor degree in Electrical and Electronics Engineering from Assam Don Bosco University (India) in 2014. She has published two papers on Microwave Remote Sensing and currently doing research work in the field of economics of power generation and scheduling.



**Bikramjit Goswami,** is working as an Assistant Professor in the department of Electrical and Electronics Engineering at Assam Don Bosco University, Guwahati, India. He received his masters degree in Electronics and Communication technology from Gauhati University (India) in 2012. He has published several papers in reputed journals and proceedings of conferences on Microwave Remote Sensing, Reconfigurable antenna, Electromagnetic safety and Electrical power systems.