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The Economic-environmental Neural Network Model for Electrical Power Dispatching

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Abstract: The main objective of this study is to give the pollution issue the priority in terms of cost calculations and optimizations. This paper presents an effective method based on using the neural networks to reduce the impact of air pollution by rearranging the stations within the system by its minimizing the emissions based on a penalty-pollution function, as a mitigation measure which reflect the environmental situations. Therefore satisfy the optimum economic dispatching loads between the stations. The neural network solves multi complex problems of the electrical system adapting with continuous varying of conditions in real time.

Key words: Optimization, economic-environmental model, neural network

INTRODUCTION

Recently, the environmental issue is focusing on political and economic issues. However, rapid economic development coupled with high population growth rate and rising standard of living, has made environmental protection a major concern to governments and the public life. Ambient air measurements that can be taken in the summer time (the peak time) indicating high air pollution level.

Japan's Central Research Institute of the Electric Power Industry has published life cycle carbon dioxide emission figures for various generation technologies[1]. Finland also has published a popular account of life cycle studies based on the previous few years experience and its certified Environmental Product Declarations (EPDs). In Sweden too for nuclear power stations, reported a similar exercise[1]. They show the CO_2 emissions in Table 1.

In Jordan too, thermal stations are one of the main reasons of the air pollution and high-energy cost. There are external costs to be considered regarding environmental and health consequences of energy production that do not appear in the financial accounts. As it is well known that the more we produce the electrical energy, the more fuel consuming, thereby increasing the total ash emission rate (or garbage flings out).

For example the environmental measurements taken by the environment research center of Royal Scientific Society between 1st March, 1994 and 28th Feb, 1995 have shown that the air in the area contains excessive amounts of SO_2 and H_2S. The measurements are as follows: Higher proportion of (SO_2) and (H_2S) in the air resulted from burning heavy fuel Al-Hussein Power Station[1].

The optimum economic dispatching of generating and transmission of the electrical energy is not in full concern with ecology pollution factors, which means that the optimum economic dispatch is not the best environmentally. Nowadays, the necessity for implementing of pollution controls standards and laws in industries arises. The expansion by principle of economic-environmental dispatch can be fairly easily extended to handle this problem.

Even when a high quality filtration equipment are suggested to reduce the emissions ratio (COx and others), the best method to reduce the emission is to:

- Arrange all the system power plants (stations) not only according to the incremental cost but with a definite pollution side effect.
- Create a penalty-pollution function, which reflect the environment damages in terms of money as (cost in $/MWH), even though, it is partially satisfy the optimum economic dispatching, as the pollution issue cant be compared in one hundred percentage.
- Optimize, the amount of power that is taken from the most polluted ones, as possible.

The optimal distribution of load between plants is on the basis of the incremental fuel cost at one plant may be lower than another plant for a given distribution of load between the plants. The plant with the lower incremental cost at its bus may be much further from the load center.

When the electrical energy costs are defined, the optimization mode issue is concerned in defining the load distribution between the different electrical station. As the stations are coordinated in different geographical locations, with different fuel costs according to the

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transpiration and other active and reactive power transmission losses.

The general optimization mathematical model: In general the optimization of the electrical power system is ruled by the criterion of minimum fuel consuming, as:

$$\sum_{j=1}^{m} C_j\ (P_{Gj}) \rightarrow \min \tag{1}$$

or

$$C = \int_0^T \sum_{j=1}^{m} C_j\ (P_{Gj})\, dt \rightarrow \min$$

with the limitation quality constraint of the active power, is:

$$\sum_{j=1}^{m} P_{Gj} - \sum_{i=1}^{n} P_L - \Delta P = 0 \tag{2}$$

where P_{gj} is the active generated power, P_L is active loads. ΔP is active power losses. C_j is the fuel costs to generate P_{Gj} in j power station.

As it well known[2,3] in this case, the required minimum fuel consumption should satisfy the equality constraints. A standard approach to obtain the necessary condition of optimality is by formula La Grange, defined as:

$$L = \sum_{j=1}^{m} C_j\ (P_{Gj}) + \lambda \left(\sum_{j=1}^{m} P_{Gj} - \sum_{i=1}^{n} P_L - \Delta P\right) \tag{3}$$

where λ- La Grange multipliers.
Hence, the necessary conditions of optimality

$$\left.\begin{aligned} \frac{\partial L}{\partial P_{G1}} &= \frac{\partial C(P_{G1})}{\partial P_{G1}} + \lambda\left(1 - \frac{\partial \Delta P}{\partial P_{G1}}\right) = 0 \\ \frac{\partial L}{\partial P_{G2}} &= \frac{\partial C(P_{G2})}{\partial P_{G2}} + \lambda\left(1 - \frac{\partial \Delta P}{\partial P_{G2}}\right) = 0 \\ &\dots\dots\dots\dots\dots\dots \\ \frac{\partial L}{\partial P_{Gm}} &= \frac{\partial C(P_{Gm})}{\partial P_{Gm}} + \lambda\left(1 - \frac{\partial \Delta P}{\partial P_{Gm}}\right) = 0 \end{aligned}\right\} \tag{4}$$

from the equation (4)

$$\frac{\dfrac{\partial C(P_{G1})}{\partial P_{G1}}}{1 - \dfrac{\partial \Delta P}{\partial P_{G1}}} = \dots\dots = \frac{\dfrac{\partial C(P_{Gm})}{\partial P_{Gm}}}{1 - \dfrac{\partial \Delta P}{\partial P_{Gm}}} = \text{idem} \tag{5}$$

Symbolizing the derivative $\dfrac{\partial C(P_{Gj})}{\partial P_{Gj}} = b_j$, which is the comparative incremental fuel costs of the j generator. From the physical point of view, the incremental cost represent the cost (in $/MWH) of generating the next MWH at the generation level of P_{gj}. and $\sigma_j = \dfrac{\partial \Delta P}{\partial P_{Gj}}$ is the comparative active losses in electrical system.

Table 1: The CO_2 emissions in Japan, Sweden and Finland

g/kWh CO_2	Japan	Sweden	Finland
Coal	975	980	894
gas thermal	608	1170 (peak-load, reserve)	-
gas combined cycle	519	450	472
solar photovoltaic	53	50	95
Wind	29	5.5	14
Nuclear	22	6	10-26
Hydro	11	3	-

Using these symbols, it create the optimal solution

$$\frac{b_j}{1 - \sigma_j} = \text{idem (constant)}$$

The function that is the sum of the all considered effects for station of the electrical system is by the equation:

$$C = \int_0^T \sum_{j=1}^{m} C_j\ P_{Gj}\, dt \rightarrow \min \tag{6}$$

or

$$C = \int_0^T \sum_{j=1}^{m} B_j . C_u\ P_{Gj}\, dt \rightarrow \min$$

where is the fuel costs of energy in j station,
B_j-the fuel consuming in j station,
C_u- cost of fuel per unit. m- stations number.
The C_j=B_j.C_u-is a nonlinear function for the active power P_{Gj}.

In Fig. 1 an overall flow-chart for iteratively computing optimal generation levels with a loss function. The k refers to the k iteration in the flow chart.

The mathematical model with ecological consideration: If the pollution criterion (as a penalty function) can be represented as:

$$C_p = \sum_{i=1}^{N_G} E_i(P_{Gi}) \tag{7}$$

where $E_i\ (P_{Gi})$ describes the level of pollution of station (generators) i as a function of generating level. So the general function will be a sum of equation (6) and (7):

$$\left[\int_0^T \sum_{j=1}^{m} B_j . C_u\ P_{Gj}\, dt + \sum_{i=1}^{N_G} E_i(P_{Gi})\right] \rightarrow \min \tag{8}$$

In addition to the above mentioned model, the optimization issue taking into account the flowing criterion:

- The security criterion $C_s = \sum_{line\ k} S_k(T_k)$, (9)

where $S_k(T_k)$ is the security penalty function

$$S_k(T_k)\begin{cases} 0 & \text{if} |T_k| \le \bar{T}_k \\ \alpha_k(|T_k| - \bar{T}_k)^2, & \text{otherwise} \end{cases}$$

where, the coefficient α_k is control the desired penalty levels.

- The load shedding criterion: If the load cannot be met, then the loads P_{di} can become control variables to cost shedding criterion can be expressed as

$$C_{Shed} = \sum_{i=1}^{N_L} \beta_i (P_{Di} - P_{Di}^0)^2 \quad (10)$$

where P_{Di}^0 are the given loads before load shedding and β_i are assigned weights to different load busses. The general cost function can be expressed as:

$$C_G = w_1 C + w_2 C_p + w_3 C_s + w_4 C_{shed} \quad (11)$$

or

$$C_G = \sum_{\substack{i=1 \\ j=1}}^{N_{i,j}} w_i C_j \to \min \quad (12)$$

where w_1,w_2, w_3, w_4 are constants that provides a proper relative weights between economics, pollution, security and load shedding. Minimizing the equations (11) and (12), is considered to be the optimal condition.

Proposed method: From the equation (12) it is clear that the optimization problem is a sophisticated one, with its large number of nonlinear related and unrelated variables, in a various values, from which solving this problem was in deferent methods. They can be classified into: Statistical methods (regressions models, time series, etc.), Intelligent systems, Neural Network and Fuzzy logic[4,5].

All of these methods are used in separate or in combination. But as it was mentioned, the evaluating of the pollution damages and side effects is a difficult problem and it depend on the human appreciation's of the weights, which is easily differs form one to anther and from time to time.

To overcome this problem, there was a great need to use an efficient model. So the optimal choice was the neural network as one of the superior methods that simulate the human brain and his biological nervous system.

Neural network considered to be the most promising area in artificial intelligence as it is based on human experiences and on link of the input and output sets, learning or training concepts and a pattern recognition function. The neural network adopts various learning mechanisms and self-organization. They have been successfully applied to problems in the fields of pattern

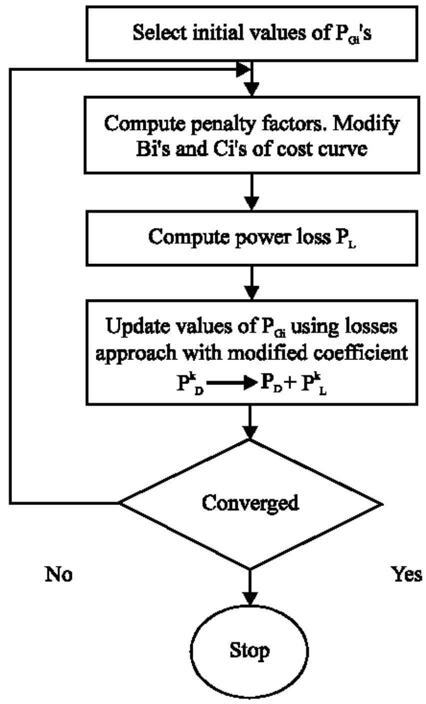

Fig. 1: Flow chart for the optimal generation with losses function

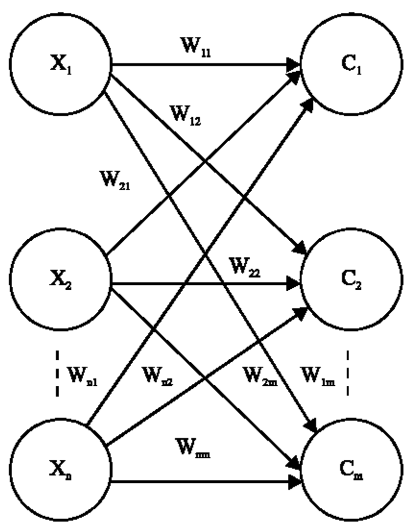

Fig. 2: The costs function as a single layer forward network

recognition, image processing, data compression, forecasting and optimization[6-8].

The neural network allows not only solving multi complex mass problems in the electrical system, but also to adapt with continuos variation of conditions in real time. There are many different neural network types that can be widely used in applied different cases.

Cost function using neural networks: Figure 2 illustrates, a simple example of single layer feedforward neural network that can be used to get the equations (11) and (12) in minimum:

$$C_i = \sum w_{ij}\, o_j + x_i - \theta_i \quad (13)$$

where:

x_i: External input to the ith node,
o_j: Output from the neurons (after the non-linearity),
θ_i: The threshold value of the ith neuron,
w_{ij}: Connections (weights).

A lot of types of the neural networks can be suggested and used, for example: multi-layers neural networks, adaptive linear Element, many adaptive linear elements backpropagation one and the nonlinear autoregressive moving average. According to the complexity of the cost function parameters the choice can be made[8,9].

The following main conclusions were carried out:

- Theoretical background indicate the necessity of placing the pollution issue to the top priority in the optimization process.
- Suggest the pollution criterion in optimization process to be considered as a penalty function, which allow to create the environmental-economic model.
- The basics of the economic-environmental model have been proved.
- Sets and weights of the variables in the power electrical systems, which are varying in real time, can be achieved successfully, using the neural networks.
- Nevertheless, the method of neural networks modeling can be used as a very effectivetool for determination and estimation of all power system parameters.

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