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Amalgamate Economic & Emission Dispatch Applying Radial Basis Function Backboned Neural Network

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Abstract

The efficient and optimum economic operations of electric power generation systems have always occupied an important position in the electric power industry. This involves allocation of the total load between the available generating units in such a way that the total cost of operation is kept at a minimum. In recent years this problem area has taken on a suitable direction as the public has become increasingly concerned with environmental matters, so that economic dispatch now includes the dispatch of systems to minimize pollutants, as well as to achieve minimum cost. In addition, there is a need to expand the limited economic optimization problem to incorporate constraints on system operation to ensure the security of the system, thereby preventing the collapse of the system due to unforeseen conditions. The purpose of the traditional Economic Dispatch (ED) problem is to find the most economical schedule of the generating units while satisfying load demand and operational constraints. This involves allocation of active power between the units, as the operating cost is insensitive to the reactive loading of a generator, the manner in which the reactive load of the station is shared among various on line generator dos not affect its economy.

Keywords- Economic Dispatch (ED), Electric Power Generation Systems, Redial Neural Network, Economic Emission Dispatch (EED), RBF, BPA

I. INTRODUCTION

A. Overview

In this work, centers which are chosen randomly from input space are chosen such that they are fairly far apart from each other and covering the whole of input space. Here centers and weights memorization was done which resulted in improving RBF Network convergence and computation time. The results obtained from lambda-iteration, the conventional technique was taken as basis for neural network approaches, BPA and RBF methods. Problem formulated was implemented on 3 test systems; obtained results are compared in terms of the solution quality and computation efficiency.[3]

The economic dispatch problem involves the solution of two different problems. The first of these is the Unit Commitment or pre-dispatch problem wherein it is required to select optimally generating units out of the available generating sources to operate, to meet the expected load and provide a specified margin of operating reserve over a specified period of time. The second aspect of economic dispatch is the on-line economic dispatch wherein it is required to distribute the load among the generating units actually paralleled with the system in such a manner as to minimize the total cost of supplying the minute - to - minute requirements of the system. [2]

B. Motivation and Objective

The purpose of the traditional Economic Dispatch (ED) problem is to find the most economical schedule of the generating units while satisfying load demand and operational constraints. This involves allocation of active power between the units, as the operating cost is insensitive to the reactive loading of a generator, the manner in which the reactive load of the station is shared among various on line generator dos not affect its economy.
The cost of electrical energy produced depends on two factors
1) Fixed Cost
These are the costs which are independent of plant operation. This consists of:
1) Capital cost of power plant

2) Interest on capital, taxes and insurance
3) Salaries of management and clerical staff
4) Depreciation
2) Running Cost

This cost is proportional to the Electric energy produced in kWhr and includes

1) Cost of fuel usage
2) Operation cost of the plant in terms of the salaries of the labour and technical staff
3) Maintenance cost

Here we are discussing with an existing installation, so we do not concern ourselves with those cost components that are fixed. The major component of generator operating cost is the fuel cost, while labour and maintenance cost contributes only to a small extent. Hence attention is focused only to the cost of fuel.

The efficient use of the available fuel is growing in importance, both in monetary terms and because most of the fuel used represents irreplaceable natural resources.

C. Economic Load Dispatch - Various Stations

A power system is a mix of different types of generation, out of which thermal, hydro and nuclear power generations contribute the principal share. However, economic operation has conveniently been considered by proper scheduling of thermal or hydro-generation only. As for the safety of nuclear station, these types of stations are required to run at their base loads only and in practice there is a little scope for the schedule of nuclear plants.

Economy of operation, in particular, is more significant in case of thermal stations, as the variable costs are much higher compared to other type of generations. This can be substantiated by looking at various costs of different stations.

Table 1: Anomaly of Prices for Various Generating Stations

Nature of Cost	*Thermal stations*	*Hydro stations*	*Nuclear stations*
1. Fixed costs	*20%*	*75%*	*70%*
2. Fuel cost	*70%*	*0*	*20%*
3. Other operational costs	*10%*	*25%*	*10%*

Obviously the cost of fuel form the major portion of all variable costs and the purpose of economy of operation is to reduce the cost of fuel. This is a static optimization problem. This project deals with the economic dispatch of thermal plants alone.

II. COMBINED ECONOMIC AND EMISSION DISPATCH PROBLEM FORMULATION

A. Economic Dispatch

The thermal scheduling involves the optimization of a problem with non-linear objective function, with a mixture of linear, non-linear and dynamic network flow constraints.

Broadly speaking there are two types of system constraints: (1) Equality constraints, and (2) Inequality constraints. Inequality constraints are two types: (a) Hard type and (b) Soft type. The hard type are those which are definite and specific like the tapping range of an on-load tap changing transformer whereas soft type are those which have some flexibility associated with them like the nodal voltages and phase angle between the nodal voltages, etc. Soft inequality constraints have been very efficiently handled by the penalty function [9].

The objective of Economic Dispatch (ED) is to minimize the total generation cost of a power system over some appropriate period, while satisfying various constraints. Fuel cost is the principal factor of generation cost and the reactive power do not have any measurable influence on generation cost because they are controlled by varying the field current.

The economic dispatch problem is a constrained optimization problem and it can be mathematically expressed as follows:

$$Minimize\ F = \sum_{i=1}^{n} f_i\left(P_i\right) \qquad (1)$$

Where, F: total generation cost (Rs/hr)
n: number of generators
P_i: real power generation of i^{th} generator (MW)
f_i (P_i) : generation cost for P_i

Subject to a number of power systems network equality and inequality constraints. These constraints include:

1) System Active Power Balance

The total active power generation must balance the predicted demand plus losses, at each time interval over the scheduling horizon. Here losses in the system are neglected.

$$\sum_{i=1}^{n} P_i = P_D + P_{loss} \qquad (2)$$

Where, P_D: total system demand (MW)
P_{loss}: transmission loss of the system (MW)

2) Generation Limits

The maximum active power generation of a source is limited by thermal consideration. Unless we take a generator unit off-line it is not desirable to reduce the real power output below a certain minimum value Pmin. For example, in fossil fuel plant minimum boiler temperature must be maintained to prevent liquidation [21]. These constraints reduce our permissible generator operating region to within two bounds.

$$P_{i,\min} \le P_i \le P_{i,\max} \qquad (3)$$

Where, $P_{i,min}$: minimum power output limit of i^{th} generator (MW)
$P_{i,max}$: maximum power output limit of i^{th} generator (MW)
The generation cost function $fi(P_i)$ is usually expressed as a quadratic polynomial:

$$f_i(P_i) = a_iP_i^2 + b_iP_i + c_i \qquad (4)$$

Where, ai, b_i and c_i are fuel cost coefficients.

3) Network Losses

Since the power stations are usually spread out geographically, the transmission network losses must be taken into account to achieve true economic dispatch. Network loss is a function of unit generation. To calculate network losses, two methods are in general use. One is the penalty factors method and the other is the B coefficients method. The latter is commonly used by the power utility industry. In the B coefficients method, network losses are expressed as a quadratic function:

$$P_{loss} = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j \qquad (5)$$

Where, B_{ij} are constants called B coefficients or loss coefficients. The B coefficients method can be used to find P_{loss}

B. Emission Dispatch

There is urgency to protect environment from harmful emissions out of Thermal Generation Companies, thereby there is need for study of amount of harmful emissions into environment. So, Emission Dispatch has been formulated. Below figure shows that even the Current Technology will not protect Environment from Carbon emissions and there is need for most advanced technologies to Stabilize Atmospheric CO_2

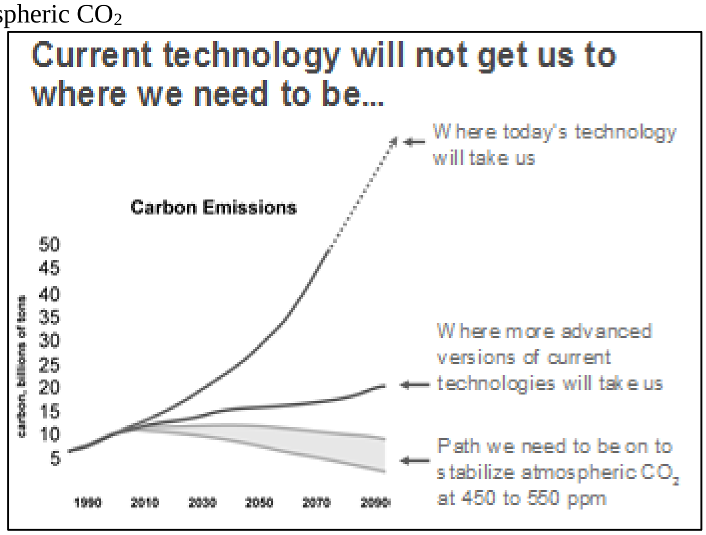


Fig. 1: Plot showing CO2 emissions w.r.t technologies employed

The solution of economic dispatch problem will give the amount of power to be generated by various generating units of a power system for a minimum total fuel cost. But limitation on emission release is not considered by this problem. The emission of pollutants affects not only human beings, but it is harmful to other life forms. It also causes global warming. These effects may be interpreted as cost, as they degrade the environment in one or other form.

The emission dispatch problem can be defined as the following optimization problem,

$$Minimize\, E = \sum_{i=1}^{n} \alpha_i P_i^2 + \beta_i P_i + \gamma_i \qquad (6)$$

Where
E : total emission release (Kg/hr)
α_i, β_i, γ_i : emission coefficients of the i^{th} generating unit
Subject to demand constraint (2.6b) and generating capacity limits (2.6c).

C. Combined Economic and Emission Dispatch

The economic dispatch and emission dispatch are considerably different. The economic dispatch deals with only minimizing the total fuel cost (operating cost) of the system violating the emission constraint. On the other hand emission dispatch deals with only minimizing the total emission of NO_X from the system violating the economic constraints. Therefore it is necessary to find out an operating point, that strikes a balance between cost and emission. This is achieved by combined economic and emission dispatch (CEED).

The multi-objective combined economic and emission dispatch problem is converted into single optimization problem by introducing price penalty factor *h* [12] as follows

$$\text{Minimize } \Phi = F + h^* E \quad \text{(Rs./hr)} \qquad (2.8)$$

Subject to demand constraint (2.6b) and generating capacity limits (2.6c).

The price penalty factor *h* blends the emission with the normal fuel costs and *Φ* is the total operating cost of the system (i.e., the cost of fuel + the implied cost of emission).

Once the value of price penalty factor is determined, the problem reduces to a simple economic dispatch problem. By proper scheduling of generating units, comparative reduction is achieved in both total fuel cost and NOx emission.

1) Procedure to Find Price Penalty Factor

The price penalty factor hi is the ratio 2between the maximum fuel cost and maximum emission of corresponding generator

$$h_i = \frac{F\left(P_{i,\max}\right)}{E\left(P_{i,\max}\right)} \text{ (Rs/Kg), i = 1, 2…n.} \qquad (2.9)$$

The price penalty factor for a particular load demand P_D (MW) is computing as follows:

1) Find the ratio between maximum fuel cost and maximum emission of each generator.
2) Arrange the values of price penalty factor in ascending order.
3) Add the maximum capacity of each unit ($P_{i,max}$) one at a time, starting from the smallest h_i unit until $\sum P_{i,max} \geq P_D$.
4) At this stage, h_i associated with the last unit in the process is the price penalty factor for the given load.

2) Procedure to Find Modified Price Penalty Factor

The procedure just shown gives the approximate value of price penalty factor computation for the corresponding load demand. Hence, a modified price penalty factor hm is used in this project to give the exact value for the particular load demand. The first two steps of computation remain same for the calculation of modified price penalty factor. The remaining steps are modified as follows:

3) Form an array, m by adding $P_{i,max}$ one by one from the lowest h_i value unit.
4) Add the elements of m_i one at a time, starting from the smallest h_i unit until $\Sigma m > P_D$
5) The modified price penalty factor h_m is computed by interpolating the values of h_i for last two units by satisfying the corresponding load demand.

A numerical example of the computational procedure of proposed modified price penalty factor is explained as follows:

1) The ratio between the maximum fuel cost and maximum emission of three generating units were found and arranged in ascending order
   $h_i = [h_3\ \ h_2\ \ h_1]$;
   $h_i = [1.1909\ \ 2.6221\ \ 3.1057]$
2) The corresponding maximum limits of generating units are given by
   $P_{i,max} = [180\ \ 150\ \ 200]$
3) m is formed by adding maximum capacity of the units one by one
   m = [180 330 530]
4) For a load P_D MW, add the elements of m_i one at a time, starting from the smallest h_i unit until $\Sigma m > P_D$.
   For P_D = 259MW; (180+330) MW >259MW
5) The modified price penalty factor h_m is computed by interpolating the values of h_i for last two units by satisfying the corresponding load demand.
   i.e., $h_m = 1.1909 + ((2.6221- 1.1909)/(330- 180))*(259- 180)$
   therefore $h_m = 1.9446$

III. COMBINED ECONOMIC AND EMISSION DISPATCH USING LAMBDA ITERATION METHOD

A. Introduction

A main objective in the operation of any of today's complex electric power system is to meet the demand for power at lowest possible cost, while maintaining the safety, reliability and continuity of service. Economy of operation of power system is achieved when the units/ stations in the system share load to minimize overall cost of generation. Optimal dispatch is an economical approach of catering load in this fashion.

For a power system to return maximum profit on the capital invested, proper operation is very important. Rates fixed by regulatory bodies and the importance of conservation of fossil-fuel place extreme pressure on power companies to achieve maximum efficiency of operation and to improve efficiency continuously. Constantly rising prices for fuel, labor, supplies and maintenance compelled the power companies to maintain reasonable relation between the cost of KWh generated and the cost of delivering a KWh.

B. Incremental Costs

Achieving minimum fuel cost for supplying the power requirements of a system requires, an accurate knowledge of the manner in which the total cost of operation of each energy source available to the system varies with the time of operation of the equipment as well as with instantaneous output. In economic dispatch the term "incremental cost", describes the rate of change of cost with respect to change in power delivered to the load centre.

C. Unit Input-Output Curve

The unit input-output curve establishes the relationship between the energy input to the driving system and the net energy output from the electric generator. The input to thermal equipment is generally measured in Btu's per hour and the output is measured in megawatts.

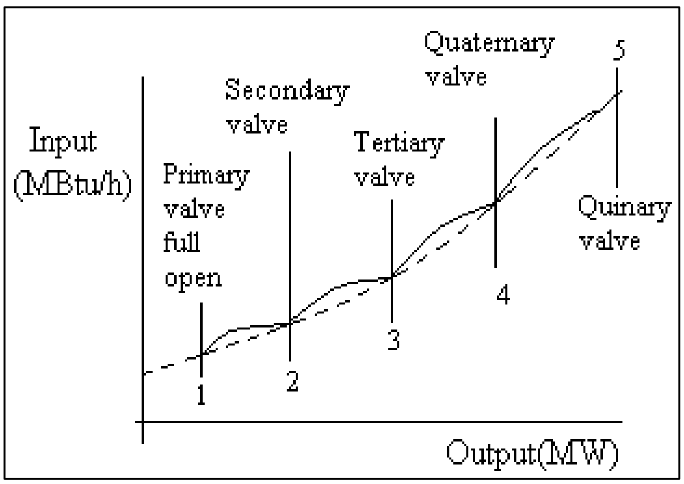


Fig. 2: Thermal unit-input versus output

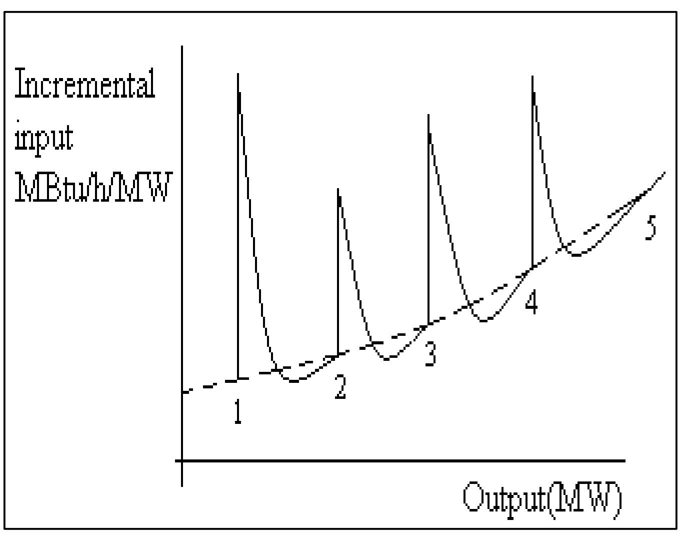


Fig. 3: Thermal unit-incremental heat rate

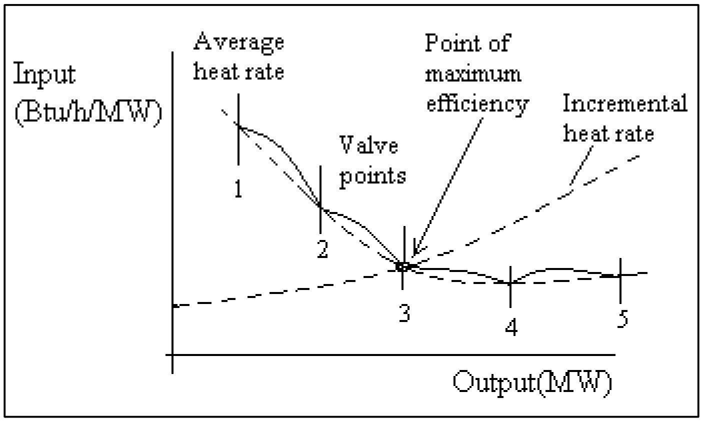


Fig. 4: Thermal unit performance

In the present economic dispatch problem, the fuel cost curve is modeled as a quadratic in active power generation. This can be expressed as

$$f_i(P_i) = a_iP_i^2 + b_iP_i + c_i$$

The slope of this curve $\partial F_i / \partial P_i$ is called the incremental fuel cost (λ_f).

D. Effect of Varying Fuel Costs

The shapes of input-output and incremental fuel rate curves are not changed by different fuels or by changes in the cost of same fuel. Consequently, if the incremental curves are plotted with incremental cost as the vertical scale, the ratio of the cost of the fuel being burned to the cost of the fuel for which the curves are drawn can be used as a multiplying factor. This factor is employed to correct for fuel cost changes for any or all of the units. By this means it is possible to solve economic loading problem under all conditions of fuel cost.

E. Objective Functions

1) Fuel Cost Objective

The classical economic dispatch problem of finding the optimal combination of power generation, which minimizes the total fuel cost while satisfying the total required demand, can be mathematically stated as follows

$$\text{Minimize } F = \sum_{i=1}^{n} f_i\left(P_i\right) \quad (3.1)$$

where

$f_i(P_i) = a_iP_i^2 + b_iP_i + c_i$

Incremental fuel cost (λ_f) curve data was obtained by taking the derivative of the unit input-output equation (above) resulting in the following equation for each generator:

$$\partial F_i / \partial P_i = 2a_iP_i + b_i \quad (3.2)$$

2) Emission Objective

The minimum emission dispatch optimizes emission objective, which can be modeled using second order polynomial functions

$$\text{Minimize } E = \sum_{i=1}^{n} \alpha_i P_i^2 + \beta_i P_i + \gamma_i \quad (3.3)$$

Incremental emission (λ_e) curve data was obtained by taking the derivative of the emission equation (above) resulting in the following equation for each generator:

$$\partial E_i / \partial P_i = 2\alpha_iP_i + \beta_i \quad (3.4)$$

3) Multi-objective Formulation

The multi-objective economic dispatch optimizes the above classical economic dispatch and emission dispatch simultaneously which can be formulated as:

$$\text{Minimize } \phi = \sum_{i=1}^{n} f_i\left(F, E\right) \quad (3.5)$$

where

$f_i(F, E) = (a_iP_i^2 + b_iP_i + c_i) + h_m(\alpha_iP_i^2 + \beta_iP_i + \gamma_i)$

Incremental cost ($\lambda_{f,e}$) curve data was obtained by taking the derivative of the combined equation (above) resulting in the following equation for each generator:

$$\partial f_i / \partial P_i = (2a_iP_i + b_i) + h_m(2\alpha_iP_i + \beta_i)$$
$$= P_i(2a_i + 2h_m\alpha_i) + (b_i + h_m\beta_i) \qquad (3.6)$$

In this work the transmission losses are expressed as a function of generator powers through B-coefficients.

$$P_{loss} = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j \qquad (3.7)$$

Now, the co-ordination equation [8] can be written as:

$$P_i\left(2a_i + 2h_m\alpha_i\right) + \left(b_i + h_m\beta_i\right) + \lambda_{f,e}\sum_{j=1}^{n} 2B_{ij}P_j = \lambda_{f,e} \qquad (3.8)$$

Collecting all terms of P_i and solving for P_i, we obtain

$$P_i = \frac{1 - \frac{(b_i + h_m\beta_i)}{\lambda_{f,e}} - \sum_{\substack{j=1 \\ j\neq i}}^{n} 2B_{ij}P_j}{\frac{(2a_i + 2h_m\alpha_i)}{\lambda_{f,e}} + 2B_{ii}} \qquad (3.9)$$

F. Algorithm and Flow Chart

The detailed Algorithm for solving the combined economic and emission dispatch problem using lambda iteration method as basis and for generating training patterns is given below

1) Read generator data, emission data, P limits, itermax, epsilon, no of patterns.
2) Read Power demand P_d and userdefined weights w_1 and w_2.
3) Compute the modified price penalty factor h_m as per steps discussed above in 2.3.1 and 2.3.2. and initialize iter = 1;
4) find λ_{fe}

$$P_i = \frac{1 - \frac{\left(b_i + h_{pd}B_i\right)}{\lambda_{f,e}}}{\frac{\left(2c_i + 2h_{pd}C_i\right)}{\lambda_{f,e}}}$$

5) Solve the equation .

for P_i's and enforcing P_i limits

6) Check for convergence and maximum iteration correspondingly vary λf,e or stop the process and go for next pattern generation

1) $\left|\sum_{i=1}^{n} Pi - PD\right| < \in (a\ specified\ value)$

or

If iter > = itermax

the optimal solution is reached. Print the optimal schedule.

Otherwise,

Increment iteration count Iter = Iter + 1

2) If $\left|\sum_{i=1}^{n} Pi - PD\right| < 0$, increment $\lambda_{f,e}$ by $\Delta\lambda_{f,e}$ (a suitable step) or
3) If $\left|\sum_{i=1}^{n} Pi - PD\right| > 0$, decrement $\lambda_{f,e}$ by $\Delta\lambda_{f,e}$ (a suitable step) and go to step 5 repeat process.

7) Stop the process when no of iterations reaches maximum iterations or required convergence is reached
8) Print the optimal schedule of Power generations.
9) Repeat all the above steps from 2 – 8 for each Power Demand, user defined weights of w1and w2 to generate required no of training patterns as basis for neural network approaches.

IV. ARTIFICIAL NEURAL NETWORKS

A. Fundamentals of ANN Computing

Artificial Neuron is a single processing element whose output is calculated by multiplying its inputs by a weighted vector, summing the results and applying an activation function to the sum.

Mathematically: $$y = f\left[\sum_{k=1}^{n} x_k w_k + b_k\right]$$

Types of Activation Functions:

1) Linear: f(x) = x
2) Differentiable non-linear activation functions:
   a. Hyperbolic-Tangent:

$$f(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$ (output ranging from -1 and 1)

   b. Logistic:

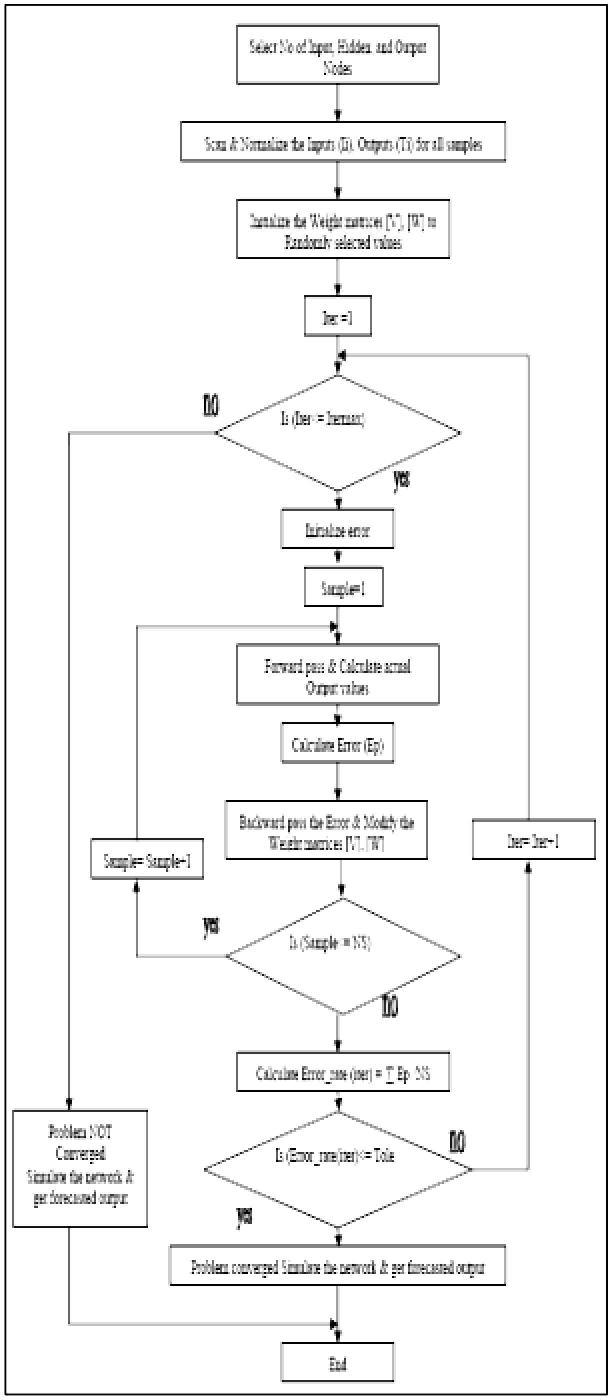
$$f(x) = \frac{1}{1 - e^{-\beta x}}$$ (output ranging from 0 and 1)

3) Non-differentiable non-linear activation functions
   a. Threshold function:

$$f(x) = \left\{\begin{matrix} 1 \text{ if } x >= 0 \\ 0 \text{ if } x < 0 \end{matrix}\right\}$$

   b. Signum function

$$f(x) = \left\{\begin{matrix} 1 \text{ if } x > 0 \\ -1 \text{ if } x <= 0 \end{matrix}\right\}$$



B. Implementation of Back Propagation Neural Networks

The neurons are arranged as some layers in BP network. The BP network is composed by one input layer and one or more hidden layers and one output layer. The learning process of network includes two courses, one is the input information transmitting in forward direction and another is the error transmitting in backward direction. In the forward action, the input information goes to the hidden layers from input layer and goes to the output layer. If the output of output layer is different with the wishful output result then the output error will be calculated, the error will be transmitted backward direction then the weights between the neurons of every layers will be modified in order to make the error as minimum as possible. Then the network is said to be trained for the given data or application.

A three layers BP network is shown as follow Fig. 4.4.5. It may be noted that the numbering of input layer is i, the numbering of hidden layer is j, and the numbering of output layer is k.

Each hidden unit output z_j is obtained by calculating the "closeness" of the input $\boldsymbol{x}$ to an n-dimensional parameter vector $\boldsymbol{\mu}_j$ associated with the j^{th} hidden unit.

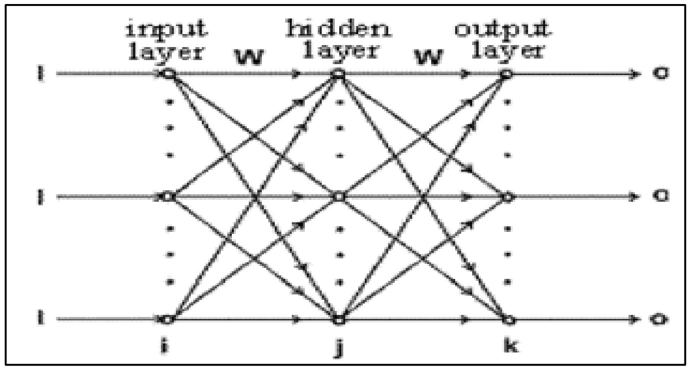


Fig. 5: Back Propagation Algorithm based Neural Network structure

A three layers BP network is shown as follow Fig. 4.4.5. It may be noted that the numbering of input layer is i, the numbering of hidden layer is *j*, and the numbering of output layer is k.

V. RADIAL BASIS FUNCTION NETWORKS

A. Radial Basis Function Networks - Introduction

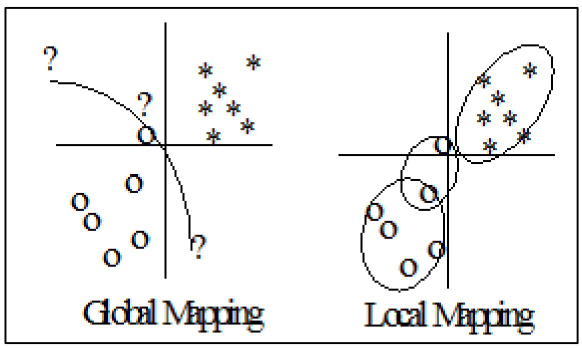


Fig. 6:

Radial Basis Functions (RBF) represent alternative approach to MLP's in universal function approximation.
RBFs were first used in solving multivariate interpolation problems and numerical analysis. Their prospect is similar in neural network applications, where the training and query targets are rather continuous.

B. RBF Network Design

1) Choice of Activation Functions

In this thesis work Gaussian function as mentioned below is taken as activation function for centres.

$$h_j(x) = \exp\left(\frac{-(x-\mu_j)^2}{w_j^2}\right)$$

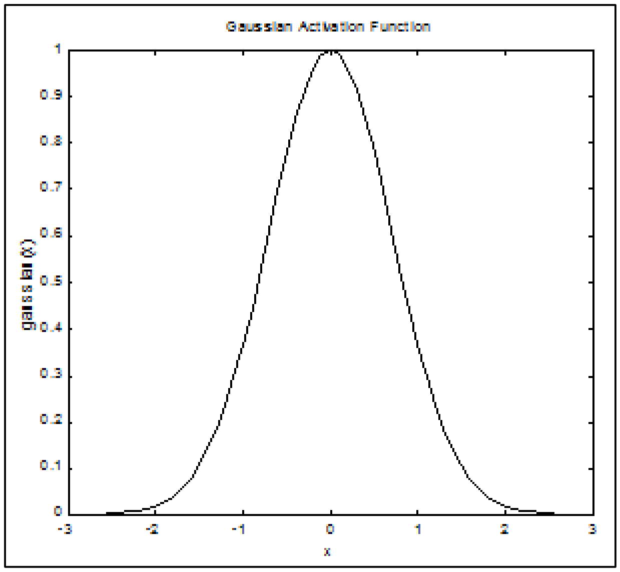


Fig. 7(a): Multivibrater curve

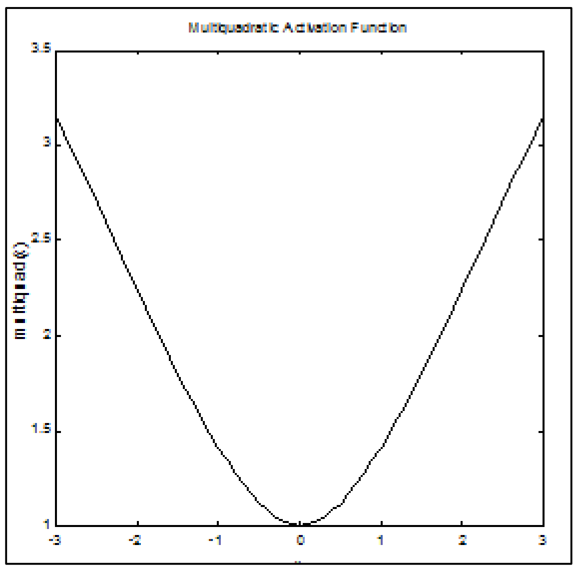


Fig. 7(b): Multiquadratic Function

C. Alternative RBF Network Designs

Instead of creating as many hidden neurons as there are input vectors, an alternative approach may be applied where the neurons are added one at a time until the sum-squared error of the network falls beneath an error goal or a maximum number of neurons allowed has been reached.

Matlab Implementation: At each iteration, the input vector which will result in lowering the network error the most is after the neuron insertion is low enough, the design stops. Used to create a new hidden neuron. If the current error

1) Example Using Linear Basis Functions

Assume a linear basis network with only two hidden neurons, such that:

$$h_1(x) = 1$$

$$h_2(x) = x$$

The linear model becomes: $f(x) = w_1 h_1(x) + w_2 h_2(x)$

Training input (with noise): $\{(1,1.1),(2,1.8),(3.31)\}$

Target Output: $\mathbf{y} = [1.1, 1.8, 3.1]^{\mathrm{T}}$

The design matrix then becomes:

$$\mathbf{H} = \begin{bmatrix} h_1(x_1) & h_2(x_1) \\ h_1(x_2) & h_2(x_2) \\ h_1(x_3) & h_2(x_3) \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{bmatrix}$$

Calculation of weights is done analytically:

$$\mathbf{H}^{\mathrm{T}}\mathbf{H} = \begin{bmatrix} 3 & 6 \\ 6 & 14 \end{bmatrix}, \quad \mathbf{A}^{-1} = (\mathbf{H}^{\mathrm{T}}\mathbf{H})^{-1} = \begin{bmatrix} -7/3 & -1 \\ -1 & 1/2 \end{bmatrix}, \ \mathbf{w} = \mathbf{A}^{-1}\mathbf{H}^{\mathrm{T}}\mathbf{y} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

The output may be predicted as:

$$f(x) = w_1 h_1(x) + w_2 h_2(x) = 0 \cdot h_1(x) + 1 \cdot h_2(x) = x$$

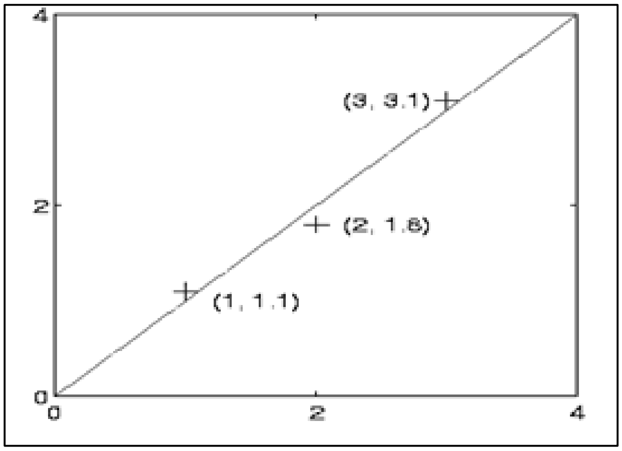


Fig. 8: RBF GRAFF

D. Advantages of an RBF

Many advantages are claimed for RBF networks over Multi-Layer Perceptions (MLPs). It is said that a RBF trains faster than a MLP and that it produces better decision boundaries. Another advantage that is claimed is that the hidden layer is easier to interpret than the hidden layer in an MLP. Some of the disadvantages that are claimed for an RBF are that an MLP gives better distributed representation. Although the RBF is quick to train, when training is finished and it is being used it is slower than a MLP, so where speed is a factor a MLP may be more appropriate.

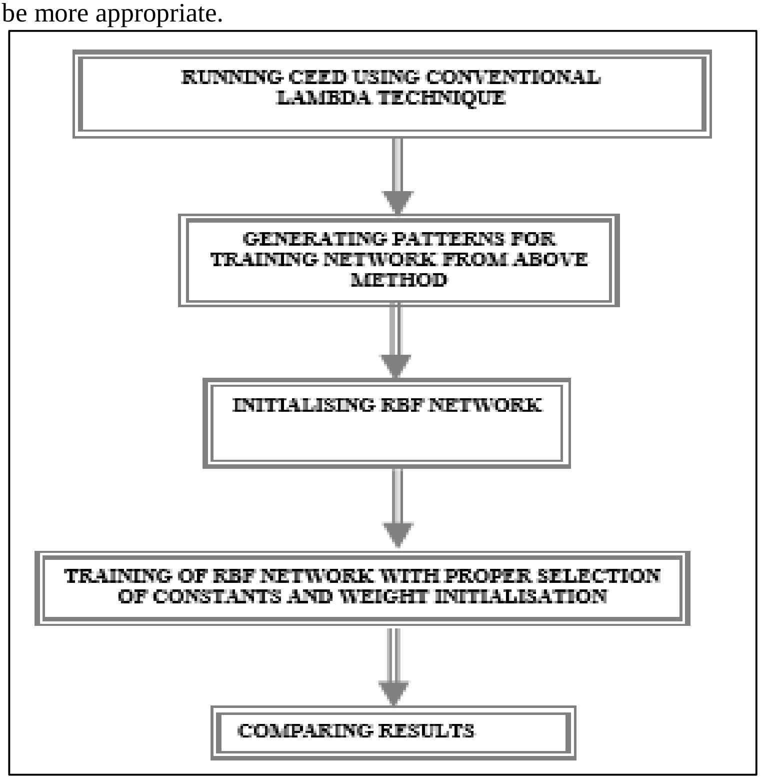


Fig. 9: Formulated process in general

VI. CASE STUDIES AND RESULTS

The method, Combined Economic and Emission dispatch using RBF network was implemented on WSSC 9 Bus 3 Generator System, IEEE 30 Bus system that has 6generators [12] , Indian utility Practical System of Uttar Pradesh State Electricity Board (UPSEB) that is of 75 Bus, 15 generators [12]. Mentioned 3 systems related data is provided in APPENDIX.

Power Demand (MW) W1 w2	Method	P1 (MW)	P2 (MW)	P3 (MW)	Total Fuel Cost (Rs/hr)	Total Emission Release (Kg/hr)	Total cost Rs/hr	APAE %
610 0.80 0.20	Lambda iter.	145.2789	234.0502	230.6709	30016.1922	451.0365	28188.3322	
	RBF	145.6566	233.7527	230.3347	30005.1615	450.549279	28174.9973	0.0043
570 0.20 0.80	Lambda Iter.	144.8022	212.7760	212.4217	28175.6457	389.4735	19992.2859	
	RBF	145.4145	212.3038	211.2764	28131.4432	388.018104	19929.7954	0.2128
630 0.75 0.25	Lambda Iter.	152.1468	240.1697	237.6834	30962.7347	483.04240	28824.1774	
	RBF	153.5925	239.8800	237.4552	31009.6389	484.3965	28875.0603	0.1445

Table Comparison of costs for 6generator system for test case (i)

	Lambda Iter	RBF	DIFF
TOTAL FUEL COST $/hr	1040.195961	1032.840539	-7.355422
TOTAL EMISSION lb/hr	494.605464	490.589418	-4.016046
TOTAL COST $/hr	997.402970	989.849605	-7.553365

	Lambda Iter	RBF	DIFF
TOTAL FUEL COST $/hr	583.012387	583.259366	0.246979
TOTAL EMISSION lb/hr	250.622047	250.792972	0.170925
TOTAL COST $/hr	478.844577	479.125934	0.281357

S.No	Lambda Iter $P_{generator\ (MW)}$	RBF $P_{generator\ (MW)}$
1	331.1324	331.1961
2	297.7298	290.7176
3	200.0000	201.1689
4	170.0000	171.0384
5	240.0000	241.4921
6	120.0000	121.5157
7	100.0000	100.2106
8	100.0000	99.8010
9	297.4392	297.4031
10	250.0000	252.1001
11	200.0000	198.9616
12	381.5344	381.9169
13	331.1302	331.1220
14	150.0000	152.2316
15	277.4469	277.3163

Table Comparison of costs for 6generator system for test case (ii)

VII. CONCLUSION AND FUTURE SCOPE

A. Conclusion

An algorithm has been developed for the determination of the global or near-global optimal solution for the Combined Economic and Emission Dispatch (CEED). The formulated algorithm of RBFNN has been tested for three test systems with three, six generating units and fifteen generating units. The results obtained from RBFNN method are compared with conventional lambda iteration method considering Average Percentage Absolute Error. The results obtained for three test systems are found to be in good agreement with conventional generation values from lambda technique. The RBFNN approaches provide a global optimal solution than the BPANN approach providing accurate and feasible solutions within reasonable computation time.

B. Scope for Further Work

This project gives solution of economic dispatch problem for thermal units only, can be used as a sub-problem for hydrothermal scheduling. In this project it is assumed that the unit commitment is known priori. So unit commitment problem can be integrated to this part for complete economics w.r.t load dispatch.

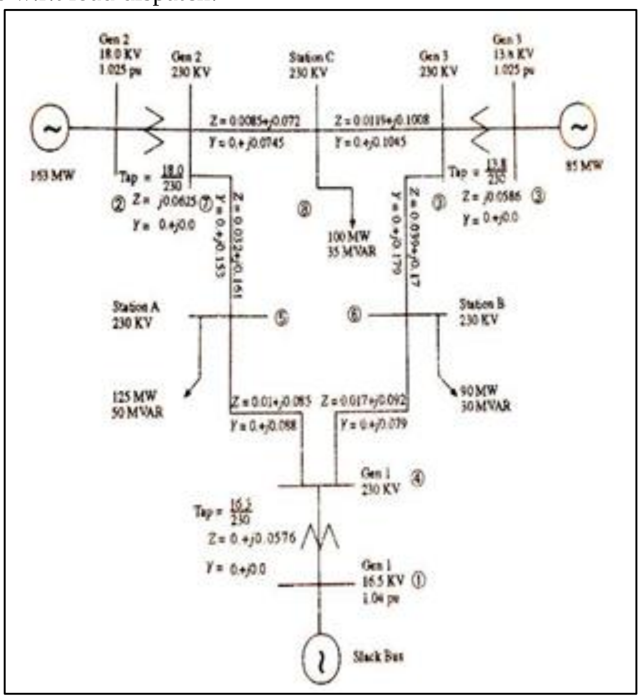


Fig. 10: Bus 3Generator System

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