Computer Aided On-Line Economic Load Dispatch

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ON-LINE ECONOMIC LOAD DISPATCH

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SYNOPSIS

Electrical power is being generated in large thermal, hydro and nuclear power stations. Usually, these stations are located for away from the load centres. Large and long transmission networks are wheeling the generated power from the generating stations to sub-stations in the load centres. Power is distributed to the consumers from the sub-stations by means of distribution network.

Economic Dispatch is an important aspect of Power System Engineering. The purpose of economic dispatch is to reduce fuel costs for the operation of power system. Reduction of fuel costs result in reduction of overall cost of operation of the power system. This is beneficial to the consumers as the tariff charged on them will be low.

For interconnection of thermal plants, the reduction of fuel costs becomes the objective. But if hydro plants are also connected to the system, the amount of water used should be minimised as the fuel costs are negligible for hydro plants.

In this project, it is proposed to develop a software for solving the economic dispatch problems based on Incremantal cost method. The software is written in 'C' language and it can be run on C, C++ or Visual C++ compilers. The program is tested on sample systems and the results are presented in this report.

NOMENCLATURE

Pd	- Total Power demand in MW
Num	- Number of plants in the system
Pcon[i] [2]	- Coefficients in Incremental Cost Equation 'i'
Pg[n]	- Power generated by n^{th} plant in MW
Lambda	- Incremental Cost Rate in Rs/MW hr
Tot Pg1	- Total Power Generated by all the plants in the system during the current iteration in MW
Tot PgO	- Total Power Generated by all the plants in the system during the previous iteration in MW
Lambda 1	- ICR calculated in present iteration in Rs/MWh
Lambda O	- ICR calculated in previous iteration in Rs/MWh
B[ ] [ ]	- Loss formula coefficients
Pl	- Power loss in the system in MW
Plin [i] [2]	- The minimum and maximum generating capacity for 'i' th plant in MW
Wat Use[i]	- Water Used by 'i'th hydro plant in m^3
Epsi 2	- Convergence Criterion Used for hydro plants in m^3.
num P_T	- Number of Thermal Plants in the system
num P_H	- Number of Hydro Plants in the systems
gamma[i]	- IWR to ICR conversion coefficient of the 'i' th Hydro Plant

CONTENTS

CHAPTER - 1

INTRODUCTION

1.1 ECONOMIC LOAD DISPATCH

The economic load diapatch problem involves the solution of two different problems. They are

1. Unit commitment or pre-dispatch problem

2. On-line Economic Dispatch

1.1.1 Unit Commitment Or Predispatch Problem

In this problem, it is required to select optimally out of the available generating units in a plant to operate, to meet the expected load in such a way so as to minimise the fuel cost.

1.1.2 On-line Economic Dispatch

Here, it is required to distribute the load among the generating plants actually paralled with the system in such manner as to minimize the total cost of operations, i,e reduce the fuel consumption for meeting a particular load demand. This project deals with On-line economic dispatch only using the method of incremental costs.

1.1.3 Classical Methods for Economical Operation

The following classical methods were employed for load scheduling. But, IC method has been found to be more accurate.

1. Base loading to Capacity

The hydro - generators were succesively loaded to their rated capacities in the order of their efficiencies.

2. Base Loading to Most Efficient Load:

The turbo generator units were successively loaded to their most efficient loads in increasing order of their heat rates.

3. Proportional Loading to Capacity:

The turbo-generator sets were loaded in proportion to their rated capacities without consideration to their performance characteristics.

1.2 COMPUTER AIDED SOLUTION:

The digital computer has completely revolutioned the field of Power Systems Engineering. The computer is faster than the Network Analysers previously used and also more accurate.

The advantages of use of digital computer in economic dispatch are

1. It has the capabilities to store large amount of data.
2. Any number of iterations can be easily performed
3. High Speed
4. Accuracy
5. There is no limit to the amount of plants that can be connected to the system.

CHAPTER - II

ON-LINE ECONOMICAL LOAD DISPATCH

2.1 THERMAL PLANTS

2.1.1 INPUT-OUTPUT

The input-output curves for any thermal plant can be obtained from the operating data. Shows fuel input in KCAL/hr versus power output in MW.

2.1.2. Incremental Fuel Rate.

From the input-out curve, the incremental fuel rate can be defined as ratio equal to a small change in input to the corresponding small charge in output.

$$I.F.R. = \frac{d(input)}{d(output)} = \frac{dF}{dP}$$

The IFR versus power output curve is shown in Fig. 2.2

2.1.3 Incremental Fuel Cost.

I.F.C. = Incremental Fuel Rate (dF/dP) x Cost of fuel.

The unit of I.F.C is Rs. / MW hr

2.1.4 Incremental Production Cost

I.P.C. consists of I.F.C. plus the Incremental cost of labour, supplies, maintenance and water. For practical purposes, the other costs are neglected and Incremental Production Cost is equal to Incremental fuel cost.

2.1.5 Economic Load Dispatch Neglecting Losses

Transmission losses can be neglected in case of an urban area where load density is very high and the transmision distances are very small.

The economic dispatch problem is defined as

Minimise $$C = \sum_{i=1}^{n} c_i \qquad \text{.............................(2.1)}$$

Subject to $$P_D = \sum_{i=1}^{n} P_{Gi} \qquad \text{.............................(2.1)}$$

Where, C	->	Total Operating Cost
Ci	->	Cost of operation of 'i'th plant
P_D	->	Total Load Demand
P_{GI}	->	Power Generated by 'i' the plant
n	->	Number of plants in the system

The condition for Optimum operation is

$$\frac{dC_1}{dP_{Gi}} = \frac{dC_2}{dPG_2} = \frac{dC_n}{dPG_n} = \lambda \qquad \text{.......................(2.3)}$$

Where, λ --> Lagrangian Multiplier

$$\frac{dC_n}{dPG_n} = \text{IPC of plant'n' in Rs. / MW hr.}$$

The I.P.C. of a given plant over a limited range is

$$\frac{dC_n}{dP_{Gn}} = C_{nn} Pn + c_n$$

Where, c_{nn} - > Slope of I.P.C. curve

c_n -> Intercept of I.P.C curve.

2.1.6 Economic load dispatch Including Transmission losses.

For almost all practical cases, transmission losses have to be included. A plant far away from the load has to supply in addition to the load, transmission lossses also and there fore, the plant must be penalized. The transmission losses are calculated by making use of B - Coefficients.

2.1.6.1 Transmission loss formula

The transmission loss formula is given by

$$PL = \sum_m \sum_n Pm \; Bmn \; Pn$$

Where, Pmj Pn --> Source loadings

Bmn - > Transmission loss coefficients.

2.1.6.2 Coordination Equation

The optimal load dispatch problem including transmission losses is defined as minimize

Minimise $C = \sum_{i=1}^{n} c_i$

Subject to $P_D + P_L = \sum_{i=1}^{n} P_{Gi}$

Where, C -> Total Operating Cost

c_i -> Cost of operation of 'i'th plant

P_D -> Total Load Demand

P_{GI} -> Power Generated by 'i' the plant

P_L -> Total System Loss

n -> Number of plants in the system

The condition for Optimum operation is

$$L_n \frac{dC_n}{dP_{Gn}} = \lambda \qquad \text{..........................(2.7)}$$

Where $L_n = \frac{1}{1-(ITL)_n}$ is known as the penalty factor of the n^{th} plant.

λ -> Lagrangian multiplier

$\frac{dC_n}{dP_{Gn}}$ -> IPC of plant 'n' in Rs. / MW hr.

The above equation is called coordination equation

2.2 Hydro-Thermal Co-ordination.

Hydro and Thermal plants may be interconnected to supply power to a load. For hydro units, operating cost is almost insignificant. The optimal solution involves minimization of fuel cost for the thermal plants with the constraints of water availability for the hydro plants over a period of operation.

2.2.1 Water Input - Power Output Curve

For the hydro system, the input/ output curve is in m^3/Sec as a function of power output in magawatts. A typical input/output characteristics of a hydro-plant is shown in fig. 2.3

2.2.2 Incremental Water Rate

From the input-output curve, the IWR can be defined as the ratio of a small change in input to a corresponding change in output.

$$IWR = \frac{d(input)}{d(output)} = \frac{dW}{dP_G}$$

The Incremental Water Rate Curve shown in Fig. 2.4 is drawn between IWR in m^3/Mw hr and power output in MW

The objective is to make

$$\int_0^t C\,dt = \text{Minimum} \qquad ....(2.8)$$

$$\int_0^t Wj\,dt = K_j \qquad ....(2.9)$$

and $$\sum_{i=1}^{\alpha} P_{Ti} + \sum_{j=1}^{\beta} E = P_D + P_L \qquad ....(2.10)$$

Where,

C -> Total Cost

W_j -> Water input to the j^{th} plant in m^3/sec

K_j -> Water availability in m^3 to j^{th} Hydro plant in time period t

a -> Number of thermal plants

b -> Number of hydro plants

P_{Ti} -> Power generated by i^{th} thermal plant.

P_{Hj} -> Power generated by j^{th} hydro plants

P_D -> Total load demand

Pl -> Total System Loss

The coordination equations for hydro - thermal coordination is given by

$$(IC)_i \, L_i = \lambda$$

$$\gamma j (IW)_j \, L_j = \lambda \qquad \text{...... (2.11)}$$

$(IC)_i$ -> ICR of i^{th} thermal plant

$(IW)_j$ -> IWR of j^{th} hydro plant

γ_j -> IWR to ICR conversion coefficient

L_i, L_j -> Penalty factors of the i^{th} thermal and j^{th} hydro plant.

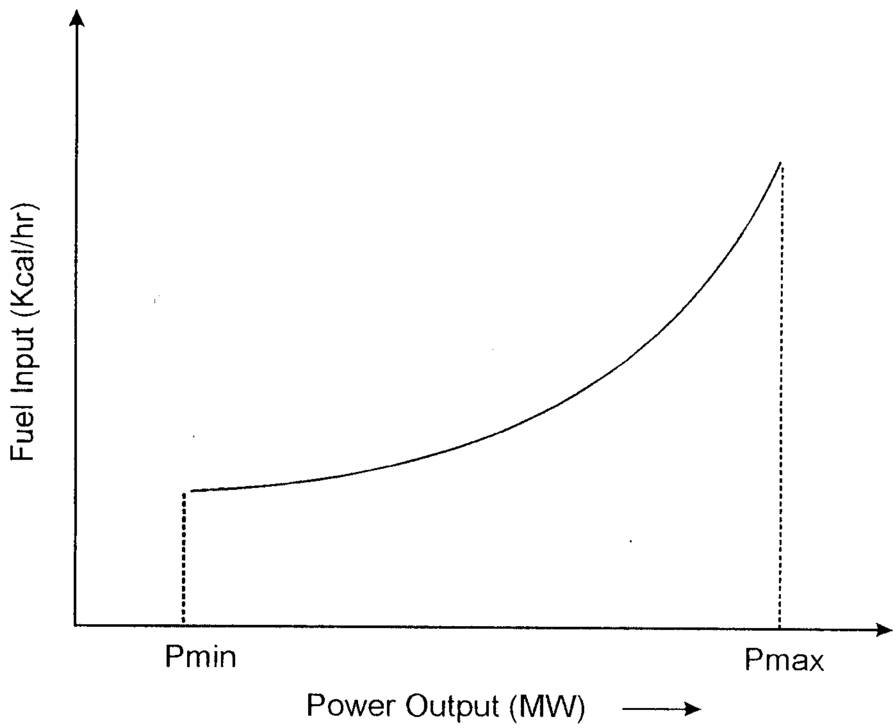

Fig. 2.1
Fuel Input as a functioning
of power generation

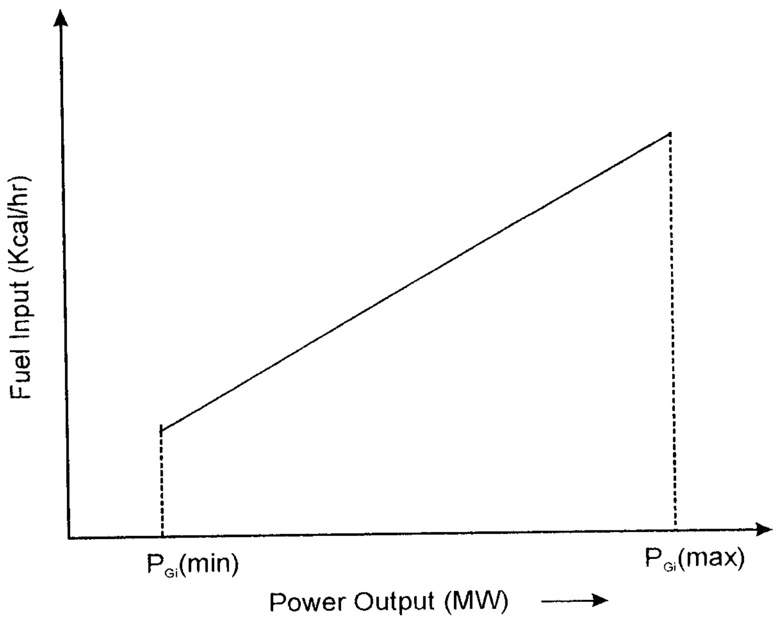

Fig. 2.2
Incremental Fuel rate
against power output

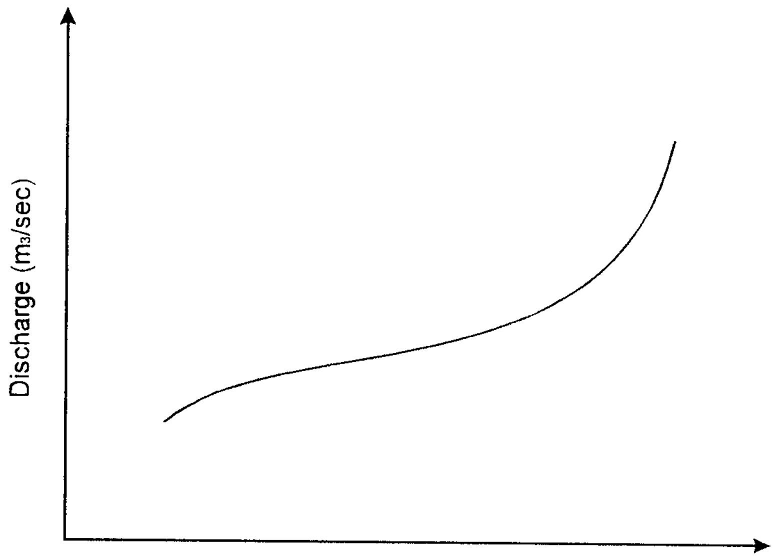

Fig. 2.3
Water Input - Power output Characteristic
of the equivalent hydro unit of the plant

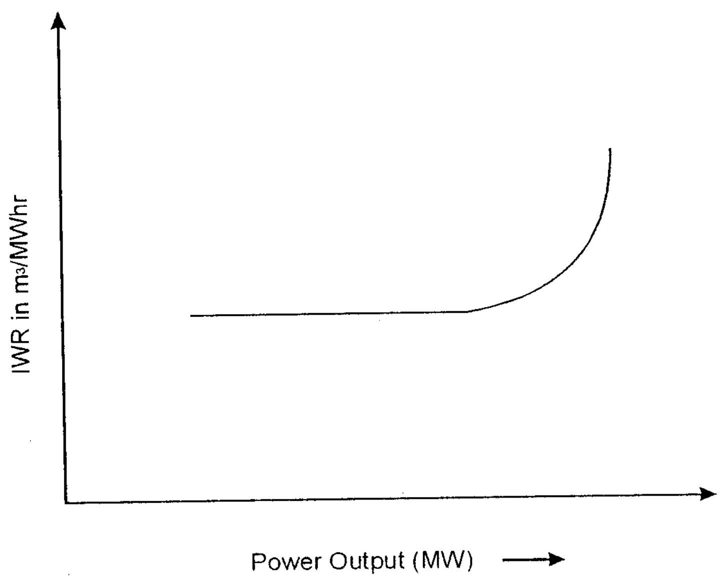

Fig. 2.4
IWR Characteristic
of the equivalent hydro unit of the plant

CHAPTER III

COMPUTER AIDED OPTIMAL ECONOMIC LOAD DISPATCH

The use of computer gives accurate results for optimum generation scheduling without excessive time. The coordinatoin equations for the various problems given in Chapter II are incorporated in the software. Program is in C language and Incremental Cost Method is used.

3.1 OBJECTIVE FUNCTION

The main objective of the program is to divide the total load demand on the system among the different generating plants in the system in such a way so as to minimise the operating cost of the system as a whole.

3.2 CONSTRAINTS

3.2.1 Equality constraints :

In terms of load flow studies, the real power balancing equation is written as

and $\sum_{i=1}^{n} P_{Gi} - P_D - P_L = O$ ....(3.1)

Where P_{Gi} - > Power generated at i^{th} plant ;

P_D - > System Load

P_L - > Transmission losses

The real power balancing equation is the equality constraint to be satisfied.

3.2.2 Inequality constraints

3.2.2.1 Generator Constraints

The plant has to generate power within the two specified limits.

$$P_{gmin} \leq Pg \leq P_{gmax} \qquad \text{....................(3.2)}$$

The maximum power generation is limited by thermal consideration and the minimum is limited by the stability limit.

3.3 Economic Load Dispatch Neglecting Losses

3.3.1 Algorithm

1. The inputs such as the total power demand, Incremental cost characteristics, number of plants are given.

2. Assume a suitable value of lambda. The value should be more than the largest intercept of IC characteristics of the various plants.

3. Compute the individual generation P_1, P_2 ....P_n using

$$P_{Gi} = P_{Gi} = \frac{\text{Lambda} - C_i}{C_{ii}} \qquad \text{.............(3.3)}$$

In case generation limits are violated, the generation of that plant is fixed at the limit violated during that iteration and the remaining load is distributed among the remaining generators.

4. Check if $\sum_{i=1}^{n} P_{Gi} = P_D$ is satisfied. If yes, print the results. Otherwise.

5. Calculated a new value of lambda using the formula.

$$\text{Lambda}^{(i+2)} = \text{Lambda}^{(i+1)} + \left[\frac{(P_D - P_t^{(i+1)})\,(lambda^{(i+1)} - lambda^{(i)})}{P_t^{(i+1)} - P_t^{(i)}} \right]$$

and repeat from step 3 ....(3.4)

3.3.2 Flow chart

The sequence of steps given in the algorithm is represented in the form of a flowchart shown in Fig. 3.1.

3.4 Economic Load dispatch Including Losses

3.4.1 Algorithm

1. The inputs such as power demand, number of plants, IC characteristics, loss formula coeffieients, Generating limits are given.

2. Assume an initial value of lambda which is greater than the largest intercept of IPC of the various plants.

3. Calculate generations at the plants using the formula.

$$P_{Gi} = \frac{\dfrac{1 - C_i}{\text{Lambda}} - \sum_{i=1}^{n} 2 B_{mn} P_m}{\dfrac{C_{ii}}{\text{lambda}} + 2 B_{ii}} \quad \text{...........(3.5)}$$

In case generation limits are violated, the generation of that plant is fixed at the limit violated during that iteration and the remaining load is distributed among the remaining generators.

4. The losses are calculated using the relation

$$P_L = \sum_m \sum_n P_m B_{mn} P_n \quad \text{...........(3.6)}$$

5. Calculated ($\Sigma P_{Gi} - P_D - P_L$). If $\Sigma P_{Gi} - P_D - P_L = 0$, print the generation.

6. Otherwise, update value of lambda and go to step 3.

3.4.2 Flow chart

The sequence of steps given in the algorithm is represented in the form of a flow chart shown in Fig. 3.2

3.5 Hydro-Thermal Co-ordination.

3.5.1 ALGORITHM

1. The inputs such as load demand, loss formula coeffieicnt, number of thermal and hydro plants.

IC and IW Characteristics, loss formula coefficents, water usage restriction, the number of hours the plant is in operation are given.

2. Make an initial guess of lagrangian multiplier lambda, conversion coefficient gamma for each hydro plant.

3. Calculate P_{Ti} and P_{Hi} for i = 1, 2, ...α and j = 1,7........β usings

4. Check whether any P_{ti} is beyond the stupulated limits and suitably fix the limiting value if necessary.

5. Calculated losses as given by

$$P_L = \sum_{m=1}^{\alpha} \sum_{n=1}^{\alpha} P_{Tm} B_{mn} P_{Tn} + \sum_{i=\alpha+1}^{num} \sum_{j=\alpha+1}^{num} P_{Hi} B_{ij} P_{Hj} + \sum_{m=1}^{\alpha} \sum_{i=1}^{\beta} P_{Tm} B_{mi} P_{Hi}$$

.........(3.9)

6. Check whether the equality constraints is satisfied or not

$$\sum_{i=1}^{\alpha} P_{Ti} + \sum_{j=1}^{\beta} P_{Hj} - P_D - P_L = 0 \quad ....(3.10)$$

If the result is affirmative goto step 8.

7. Else, update lambda and repeat from Step 3.

8. Calculate water consumption with the help of expression for IWR.

9. Check whether the equality constant related to water consumption is satisfied or not

$$\left| \int_0^t W_j \, dt = K_j \right| \leq \text{Epsi2} \qquad \text{.........(3.11)}$$

If result is affrimative, print generation results.

10. Else, update gamma j and repeat from Step 3.

3.5.2 FLOW CHART

The sequence of steps given in the algorithm is represented in the form of a flowchart shown in Fig. 3.3

3.6 PROGRAM :

A program to solve optimum ecomomic despatch problem is developed in 'C' language and it is given below.

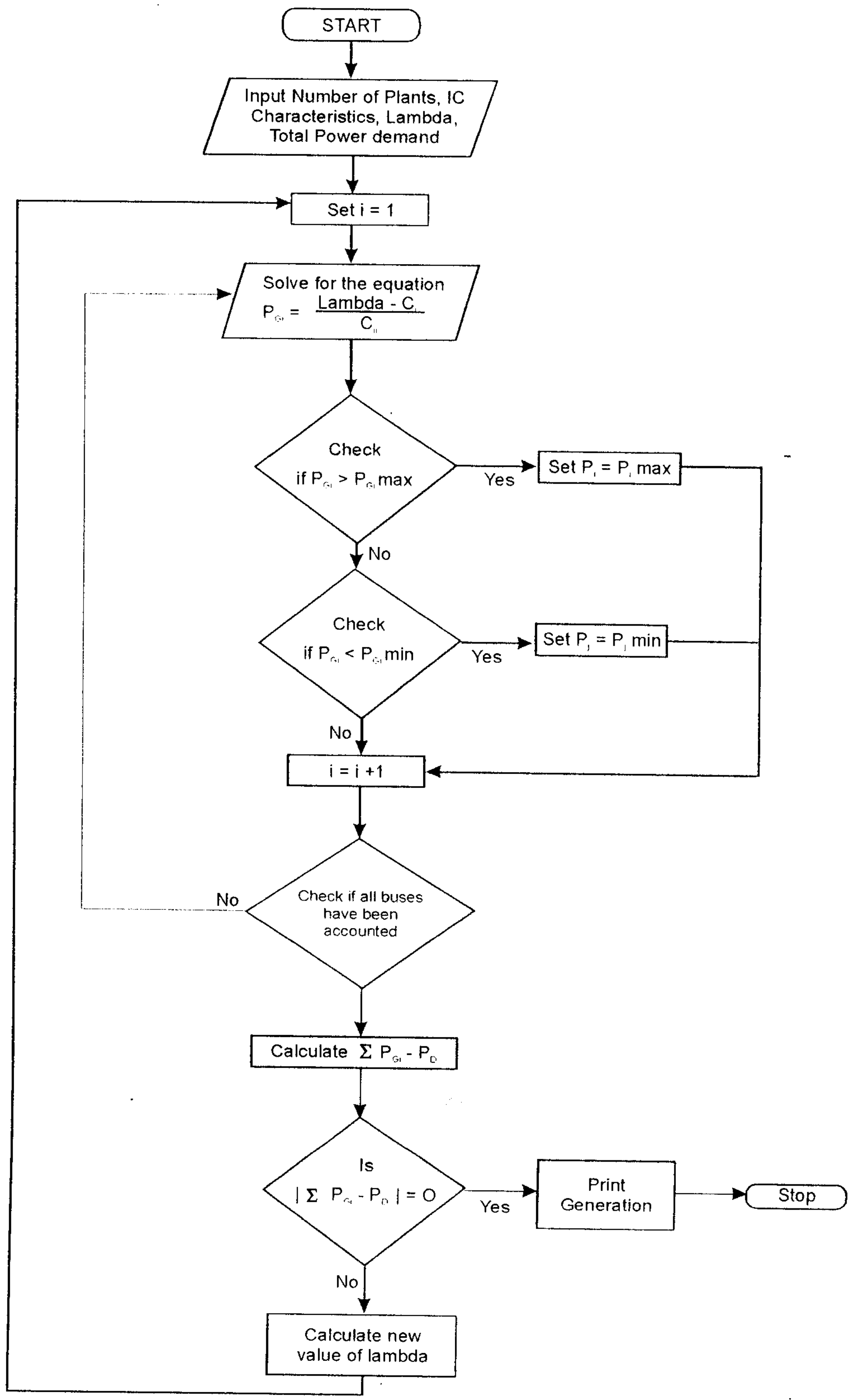

Fig. 3.1 ECONOMIC LOAD DISPATCH NEGLECTING LOSSES

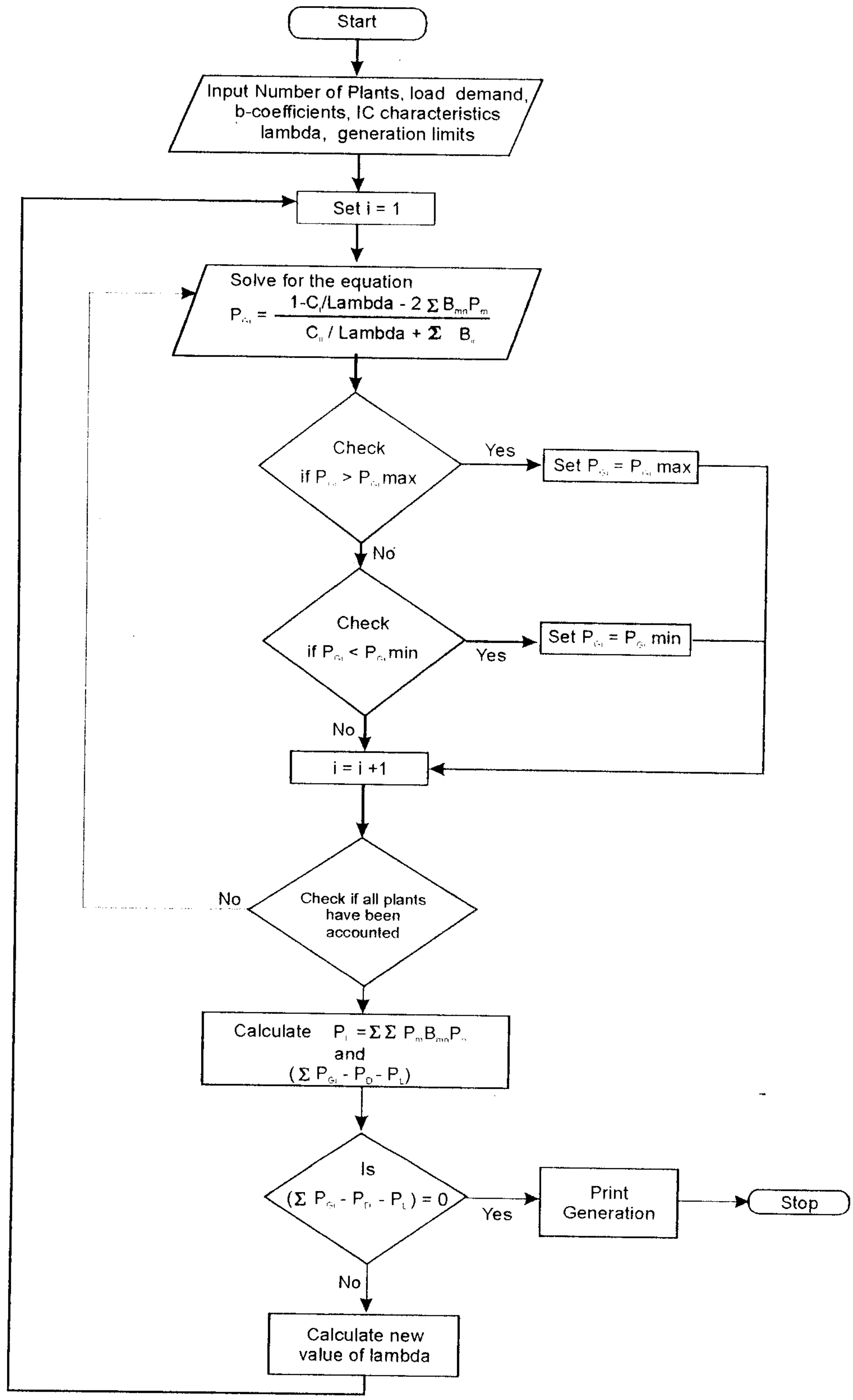

Fig. 3.2 ECONOMIC LOAD DISPATCH CONSIDERING LOSSES

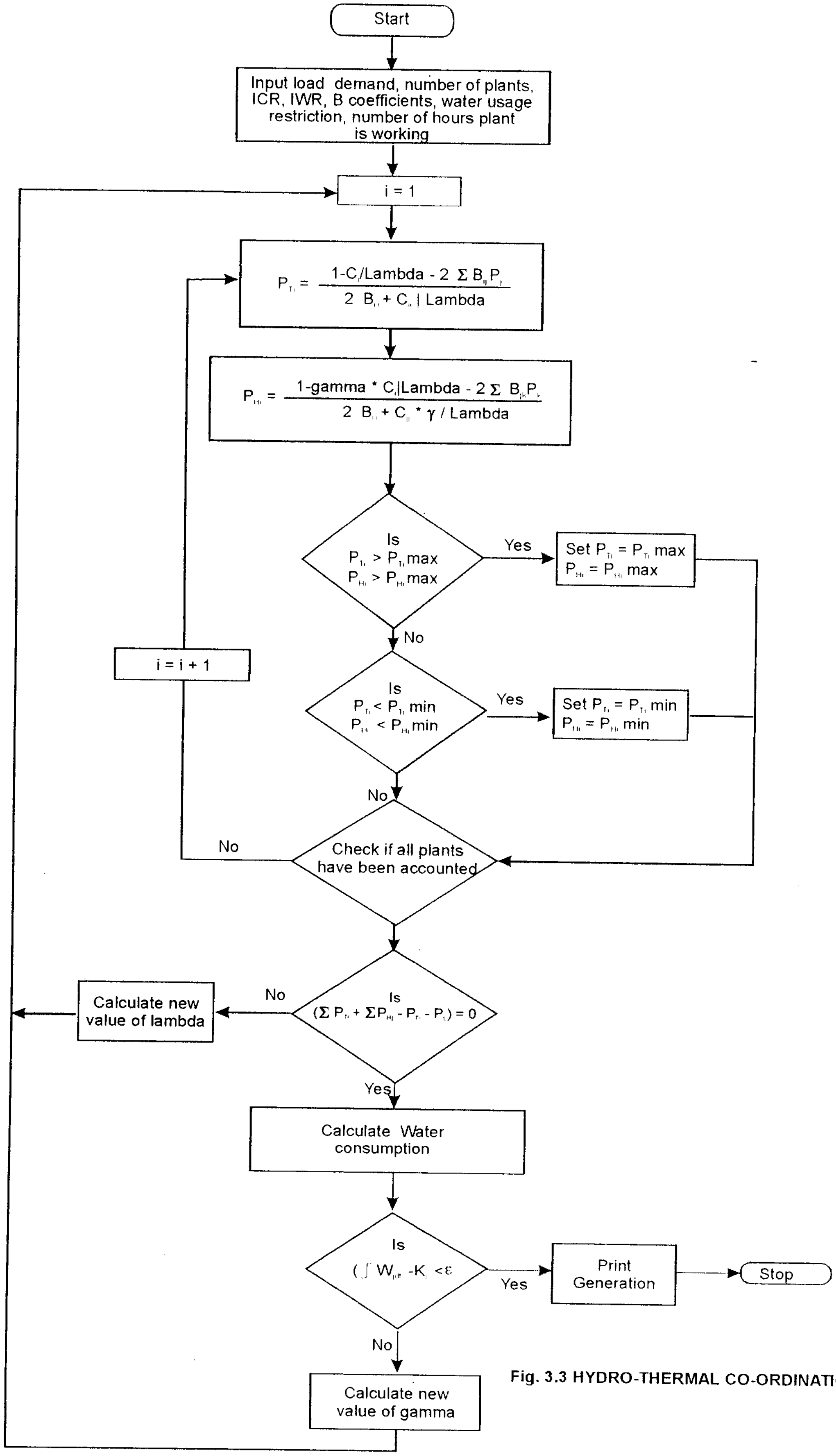

Fig. 3.3 HYDRO-THERMAL CO-ORDINATION

```
#include<stdio.h>
#define max 3
                /* TRANSMISSION LOSSES NEGLECTED.*/


/*
Pd       -----> TOTAL LOAD DEMAND
num      -----> TOTAL NUMBER OF PLANTS IN THE SYSTEM
Pg[]     -----> POWER GENERATED BY EACH PLANT
Pcon[]   -----> CONSTANTS FOR THE PLANTS
Plim[][]-----> GENERTAING LIMITS FOR EACH PLANT
lambda   -----> INCREMENTAL COST RATE
TotPg    -----> TOTAL POWER GENERATED
i,j      -----> COUNTERS
*/


main()
{
 float   /* input variables */
                   Pd,Pcon[max][2],lambda,Plim[max][2],
                   /* temporary  variables */
                   lambda0=0,TotPg0=0,lambda1,TotPg1,
                   /* output variable */
                   Pg[max];
 int     /* input variable */
                   num;
                   /* counter variables */
              int  i,j;


 char choice;


 clrscr();
```

/* GETTING INPUTS */

```
printf("\t\t**ECONOMIC LOAD DISPATCH NEGLECTING LOSSES**\n\n");

printf("ENTER THE POWER DEMAND.\n");
scanf("%f",&Pd);

printf("ENTER THE NUMBER OF PLANTS.\n");
scanf("%d",&num);

printf("ENTER THE INCREMENTAL COST CHARACTERISTICS.\n");

for(i=0;i<num;i++)
{
 for(j=0;j<2;j++)
 {
        scanf("%f",&Pcon[i][j]);
 }
}

printf("ENTER INITIAL ASSUMED VALUE OF LAMBDA.\n");
scanf("%f",&lambda1);

printf("DO THE PLANTS HAVE GENERATION CONSTRAINTS(y/n)?\n");
choice = getch();

if(choice == 'y')
{
 printf("ENTER THE MINIMUM AND MAXIMUM
                    CAPACITIES OF THE PLANTS.\n");

 for(i=0;i<num;i++)
```

```
 {
  for(j=0;j<2;j++)
  {
        scanf("%f",&Plim[i][j]);
  }
 }
}

lambda = lambda1;

L1: TotPg1=0;

            /* CALCULATION OF POWER GENERATED BY EACH PLANT */

for(i=0;i<num;i++)
{
 Pg[i] = (lambda-Pcon[i][1])/Pcon[i][0];

 if(choice == 'y')
 {
  if(Pg[i]<Plim[i][0])
  {
        Pg[i] = Plim[i][0];
  }
  if(Pg[i]>Plim[i][1])
  {
        Pg[i] = Plim[i][1];
  }
 }

 TotPg1 += Pg[i];
}
```

```
/* CALCULATION OF NEW VALUE OF LAMBDA FOR THE NEXT ITERATION */

lambda=lambda1+((Pd-TotPg1)*(lambda1-lambda0)/(TotPg1-TotPg0));
if(lambda == lambda1)
{
 goto L2;
}

/* SWAPPING OF VALUES OF LAMBDA AND TOTAL GENERATED POWER */

lambda0 = lambda1;
lambda1 = lambda;
TotPg0 = TotPg1;
goto L1;

clrscr();

/* PRINTING THE RESULTS */

L2: printf("THE OPTIMUM GENERATION IS\n\n");

 for(i=0;i<num;i++)
 {
        printf("Pg[%d] = %f\n\n",i+1,Pg[i]);
 }
getch();
return 0;
}
```

```
#include<stdio.h>
#define max 3

/* TRANSMISSION LOSSES CONSIDERED */
/*
Pd        -----> TOTAL POWER DEMAND
num       -----> NUMBER OF PLANTS IN THE SYSTEM
Pg[]      -----> POWER GENERATED BY EACH PLANT
Pcon[][]  -----> CONSTANTS OF THE PLANTS
B[][]     -----> LOSS FORMULA CO-EFFICIENTS
lambda    -----> INCREMENTAL COST RATE IN Rs/MWh
Plim[][]  -----> POWER GENERATION LIMITS FOR THE PLANTS
Pl        -----> POWER LOSS
TotPg     -----> TOTAL POWER GENERATED FOR EACH PLANT
i,j              -----> COUNTERS
*/
main()
{
 float  /* input variables */
            Pd,Pcon[max][2],B[max][max],lambda,Plim[max][2],
            /* temporary variables */
            TotPg0=0,TotPg1,lambda0=0,lambda1,NumPg[max],
            /* loss variable */
            Pl,
            /* output variable */
            Pg[max];
int    /* input variables */
            num,
            /* counter variables */
            i,j;
```

```
char choice;
clrscr();

/* GETTING INPUTS */

printf("*****ECONOMIC LOAD DISPATCH INCLUDING LOSSES*****\n\n");
printf("ENTER THE POWER DEMAND.\n");
scanf("%f",&Pd);

printf("ENTER THE NUMBER OF PLANTS IN THE SYSTEM.\n");
scanf("%d",&num);
printf("ENTER THE INCREMENTAL COST CHARACTERISTICS.\n");
for(i=0;i<num;i++)
{
 for(j=0;j<2;j++)
 {
	scanf("%f",&Pcon[i][j]);
 }
}

printf("ENTER THE LOSS FORMULA COEFFICIENTS.\n");
for(i=0;i<num;i++)
{
 for(j=0;j<num;j++)
 {
	scanf("%f",&B[i][j]);
 }
}
printf("ENTER THE INITIAL ASSUMED VALUE OF LAMBDA.\n");
scanf("%f",&lambda1);
```

```
printf("DO THE PLANTS HAVE GENERATING CONSTRAINTS(y/n)?\n");
choice = getch();
if(choice == 'y')
{
 printf("ENTER THE MINIMUM AND MAXIMUM CAPACITIES
                                    OF EACH PLANT\n");
 for(i=0;i<num;i++)
 {
  for(j=0;j<2;j++)
  {
   scanf("%f",&Plim[i][j]);
  }
 }
}
/* THE INITIAL VALUES ARE ASSUMED AS ZERO*/
for(i=0;i<num;i++)
{
 Pg[i] = 0;
 NumPg[i] = 0;
}
lambda = lambda1;
clrscr();
/* CALCULATION OF POWER GENERATED BY EACH PLANT */
L1: TotPg1 = 0;
for(i=0;i<num;i++)
{
 for(j=0;j<num;j++)
 {
        if(i!=j)
```

```
          {
           NumPg[i]+=(B[i][j]*Pg[j]);
          }
  }
Pg[i] = (1-(Pcon[i][1]/lambda)-(2*NumPg[i]))/(2*B[i][i]+
Pcon[i][0]/lambda);
 if(choice == 'y')
 {
  if(Pg[i]<Plim[i][0])
  {
   Pg[i] = Plim[i][0];
  }
  if(Pg[i]>Plim[i][1])
  {
   Pg[i] = Plim[i][1];
  }
 }

 TotPg1 += Pg[i];
}
/* CALCULATION OF LOSSES */
Pl = 0;
for(i=0;i<num;i++)
{
 for(j=0;j<num;j++)
 {
        Pl += (Pg[i]*B[i][j]*Pg[j]);
 }
}
```

```
/*CALCULATION OF NEW VALUE OF LAMBDA FOR THE NEXT ITERATION*/
lambda=lambda1+((Pd-TotPg1+Pl)*(lambda1-lambda0)/(TotPg1-TotPg0));
if(lambda == lambda1)
{
 goto L2;
}
/* SWAPPING OF THE VALUES OF LAMBDA AND TOTAL GENERATED
POWER */
lambda0 = lambda1;
lambda1 = lambda;
TotPg0 = TotPg1;
goto L1;

clrscr();
/* PRINTING THE RESULTS */
L2:  printf("THE OPTIMUM GENERATION IS\n\n");
 for(i=0;i<num;i++)
 {
        printf("Pg[%d] = %f MW\n",i+1,Pg[i]);
 }
 getch();
}
```

```
#include<stdio.h>
#include<math.h>
#define max 3

/* HYDRO THERMAL COORDINATION.*/
/* Pd          -----> TOTAL POWER DEMAND
   numPt       -----> NUMBER OF THERMAL PLANTS
   numPh       -----> NUMBER OF HYDRO PLANTS
   num         -----> TOTAL NUMBER OF PLANTS IN THE SYSTEM
   Pg[]        -----> POWER GENERATED BY EACH PLANT
   Pcon[][]    -----> CONSTANTS OF EACH PLANT
   B[][]       -----> LOSS FORMULA CO-EFFICIENTS
   Plim[][]    -----> MINIMUM AND MAXIMUM GENERATING CAPACITY
                           OF EACH PLANT
   i,j         -----> COUNTERS
   lambda      -----> INCREMENTAL COST RATE
   gamma[]     -----> INCREMENTAL WATER RATE  OF EACH PLANT
   Pl,Pl1,Pl2,Pl3 ----> LOSSES
   NumH        -----> THE NUMBER OF HOURS THE PLANT WORKS
   K[]         -----> WATER USAGE RESTRICTION OF EACH HYDRO PLANT
   WatUse[]    -----> WATER USAGE FOR EACH PLANT
   Epsi2       -----> CONVERGENCE CRITERION
*/

main()
{
 float /* input variables */
  Pd,Pcon[max][2],B[max][max],lambda1,Plim[max][2],NumH,Epsi2,
  gamma[max],K[max],
        /* temporary variables */
        NumPg[max],TotPg1,lambda0=0,TotPg0=0,lambda,
        WatUse[max],WatC[max],WatCheck[max],
```

```
        /* loss variables */
        Pl1,Pl2,Pl3,Pl,
                /* output variable */
                Pg[max];
int   /* input variables */
                numPt,numPh,num,
                /* counter variables */
                i,j;
char choice;
clrscr();

/* GETTING INPUTS */

printf(" ********HYDROTHERMAL COORDINATION********\n\n");
printf("ENTER THE TOTAL DEMAND.\n");
scanf("%f",&Pd);
printf("ENTER THE NUMBER OF THERMAL PLANTS.\n");
scanf("%d",&numPt);
printf("ENTER THE NUMBER OF HYDRO PLANTS.\n");
scanf("%d",&numPh);
num = numPt+numPh;
printf("ENTER THE INCREMENTAL COST CHARACTERISTICS.\n");
for(i=0;i<numPt;i++)
{
 for(j=0;j<2;j++)
 {
       scanf("%f",&Pcon[i][j]);
 }
}

printf("ENTER THE INCREMENTAL WATER CHARACTERISTICS.\n");
for(i=numPt;i<num;i++)
```

```
{
 for(j=0;j<2;j++)
 {
        scanf("%f",&Pcon[i][j]);
 }
}

printf("ENTER THE LOSS FORMULA COEFFICIENTS.\n");
for(i=0;i<num;i++)
{
 for(j=0;j<num;j++)
 {
        scanf("%f",&B[i][j]);
 }
}

printf("GIVE THE INITIAL ASSUMED VALUE OF LAMBDA.\n");
scanf("%f",&lambda1);
printf("GIVE INITIAL GUESS OF GAMMA FOR EACH HYDRO PLANT.\n");
for(j=numPt;j<num;j++)
{
 scanf("%f",&gamma[j]);
}

printf("ENTER THE NUMBER OF HOURS THE PLANT IS WORKING.\n");
scanf("%f",&NumH);

printf("ENTER THE WATER USAGE RESTRICTION FOR EACH
                              HYDRO PLANT.\n");

for(i=numPt;i<num;i++)
```

```
{
 scanf("%f",&K[i]);
}
printf("ENTER THE CONVERGENCE CRITERION 2.\n");
scanf("%f",&Epsi2);

printf("DO THE PLANTS HAVE ANY GENERATING CONSTRAINTS(y/n)?\n");
choice = getch();

if(choice == 'y')
{
 printf("ENTER THE MINIMUM AND MAXIMUM CAPACITY OF
                              THERMAL PLANTS.\n");

 for(i=0;i<numPt;i++)
 {
  for(j=0;j<2;j++)
  {
   scanf("%f",&Plim[i][j]);
  }
 }

printf("ENTER THE MINIMUM AND MAXIMUM CAPACITY OF
                              HYDRO PLANTS.\n");

for(i=numPt;i<num;i++)
{
 for(j=0;j<2;j++)
 {
  scanf("%f",&Plim[i][j]);
 }
}
```

```
}

/* THE INITIAL VALUES ARE ASSUMED AS ZERO. */
for(i=0;i<num;i++)
{
        NumPg[i] = 0;
        Pg[i] = 0;
}

lambda = lambda1;

/* CALCULATION OF POWER GENERATED BY EACH THERMAL PLANTS */

L1: TotPg1 = 0;
for(i=0;i<numPt;i++)
{
 for(j=0;j<num;j++)
 {
  if(i!=j)
  {
   NumPg[i] += B[i][j]*Pg[j];
  }
 }

Pg[i] = (1-(Pcon[i][1]/lambda)-(2*NumPg[i]))/
            ((Pcon[i][0]/lambda)+(2*B[i][i]));

if(choice == 'y')
{
 if(Pg[i]<Plim[i][0])
 {
  Pg[i] = Plim[i][0];
```

```
 }
 if(Pg[i]>Plim[i][1])
 {
  Pg[i] = Plim[i][1];
 }
}
 TotPg1 +=Pg[i];
}

/* CALCULATION OF POWER GENERATED BY EACH HYDRO PLANT */

for(i=numPt;i<num;i++)
{
 for(j=0;j<num;j++)
 {
        if(i!=j)
        {
         NumPg[i] += B[i][j]*Pg[j];
        }
 }

        Pg[i] = ((1-Pcon[i][1]*gamma[i]/lambda)-(2*NumPg[i]))
          /((Pcon[i][0]*gamma[i]/lambda)+(2*B[i][i]));

        /* CHECKING FOR INEQUALITY CONSTRAINTS */

        if(choice == 'y')
        {
        if(Pg[i]<Plim[i][0])
        {
        Pg[i] = Plim[i][0];
        }
```

```
        if(Pg[i]>Plim[i][1])
        {
         Pg[i] = Plim[i][1];
        }
       }
        TotPg1 +=Pg[i];
}

/* CALCULATION OF LOSSES */

Pl1 = 0;
for(i=0;i<numPt;i++)
{
        for(j=0;j<numPt;j++)
        {
         Pl1 += Pg[i]*B[i][j]*Pg[j];
        }
}

Pl2 = 0;
for(i=numPt;i<num;i++)
{
        for(j=numPt;j<num;j++)
        {
         Pl2 += Pg[i]*B[i][j]*Pg[j];
        }
}

Pl3 = 0;
for(i=0;i<numPt;i++)
```

```
{
        for(j=numPt;j<num;j++)
        {
         Pl3 += Pg[i]*B[i][j]*Pg[j];
        }
}

        Pl = Pl1+Pl2+(2*Pl3);

        /* CALCULATION OF LAMBDA FOR NEXT ITERATION */
        lambda = lambda1+((Pd-TotPg1+Pl)*(lambda1-lambda0)/
                              (TotPg1-TotPg0));
        if(lambda == lambda1)
        {
         goto L2;
        }

/* SWAPPING OF VALUES FOR LAMBDA AND TOTAL POWER GENERATED */

        lambda0 = lambda1;
        lambda1 = lambda;
        TotPg0 = TotPg1;
        goto L1;

/* CHECKING FOR WATER USAGE CONSTRAINT */

L2:  for(j=numPt;j<num;j++)
   {
       WatUse[j] = ((Pcon[j][0]*Pg[j]*Pg[j]/2)+
                 Pcon[j][1]*Pg[j])*NumH*3600;
       WatCheck[j] = WatUse[j]-K[j];
       WatC[j] = fabs(WatCheck[j]);
```

```
        if(WatC[j]>Epsi2)
        {
         if(WatCheck[j]<0)
         {
          gamma[j]-=1;
         }
         else
         {
          gamma[j]+=1;
         }
         goto L1;
        }
 }

        clrscr();

        /* PRINTING THE RESULTS */

        printf("THE OPTIMUM GENERATION IS\n\n");

        for(i=0;i<numPt;i++)
        {
         printf("PT[%d] = %f MW\n",i+1,Pg[i]);
        }

        for(i=numPt;i<num;i++)
        {
         printf("PH[%d] = %f MW\n",i+1,Pg[i]);
        }

        getch();
}
```

CHAPTER IV

SIMULATION RESULTS

Simulation results for the four economic dispatch problems are presented in this report.

Problem I : (Without Considering Losses and inequality Constraints).

Total Load Demand (P_D) = 200 MW

Number of plants in the system = 2

$(IC)_1 = 0.2\ P_{G1} + 60$

$(IC)_2 = 0.3\ P_{G2} + 40$

Solutions:

******* Economic load dispatch Neglating Losses *********

The optimum Generation is

Pg[1] = 80.000000 MW

Pg[2] = 119.99992 MW

Problem IV (Hydro - Thermal Coordination).

Total load demand = 200 MW

One thermal plant is interconnected with Hydro plant

$(IC)_1 = 0.2\ PG_1 + 60$

$(IW)2 = 0.00067\ PG_2 + 0.8.$

$$B = \begin{pmatrix} 0 & 0 \\ 0 & 0.001 \end{pmatrix}$$

Use the restriction of 10 million m^3 of water usage.

Solution :

************ Hydro- Thermal Coordination **********

The optimum generation is

PT[1] = 83.581429 MW

PT[2] = 134.512054 MW

CHAPTER V

CONCLUSION

A Computer software has been developed for the economic dispatch problem. The program can take into account the losses in the system and inequality constraints. The program has been developed in 'C' language. The simulated results have also been presented in this report. The results obtained are found to be accurate when compared with the values given in standard text books. The program is flexible enough to incorporate any future modifications.

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