Optimal Dispatch for Deregulated Power Systems using Fuzzy Logic Decision Making Technique

Amninder Singh
Dept. of Electrical Engineering
DAVIET Jalandhar, India

Shivani Mehta
Deptt. of Electrical Engineering
DAVIET Jalandhar, India

Chintu Rza
Deptt. of Electrical Engineering
DAVIET Jalandhar, India

ABSTRACT

Economic Dispatch (ED) optimization problem is the most important issue which is to be taken into consideration in power systems. In this paper, the economic dispatch problem has been modified to minimization of network congestion. The problem has been sub divided into two parts: (i) minimization of generation cost and (ii) minimization of network congestion; subject to power balance constraints. As the two sub-problems have conflicting objectives, fuzzy decision making multi-objective optimization has been applied to obtain single optimal solution from conflicting objectives of generation cost and network congestion. To the proposed approach, it has been tested on IEEE 57-bus system. The results describe the capability of the proposed approach of reducing network congestion while maintaining economy in the load dispatch...

Keywords— *Economic Load Dispatch, Fuzzy Decision Making, Multi-Objective Optimization, Network Congestion*

1. INTRODUCTION

Economic load dispatch is an important function of the energy management system, which aims at minimization of the operating cost of power generation from thermal power plant subject to the satisfaction of power demand of the consumers and losses in transmission system. Network congestion occurs when there is overload of transmission lines; as a result it obstructs desired trading of power among suppliers and consumers. Occurrence of congestion may also increases the cost of electricity delivered at consumer end. Hence, it becomes necessary to incorporate the network congestion problem within economic load dispatch, so that power is delivered to the consumers with reliability and at optimal cost.

Niimura T., and Nakashima T.[1] introduce indices to represent environmental impacts and network congestion in the deregulated power system, and analyze the tradeoff relations among the different aspects of power system operation. In addition to social welfare maximization, the minimization of the environmental impact of thermal power generation, and the minimization of network congestion are incorporated into the multiobjective optimization framework.

Prasanna. S.T. and Somasundaram. P[2] presents an efficient and simple approach for solving the emission constrained economic dispatch problem using FMEP. The convergence and usefulness of the proposed FMEP is demonstrated through its application to a test system.

Gong.-D.and Zhang Y.[3] presents a hybrid multi-objective optimization algorithm based on PSO and DE (MO-DE/PSO) is proposed for solving the constrained EED problem. An improved PSO algorithm that emphasizes on exploring the entire search space and a local version of DE algorithm that emphasizes on exploiting the sub-space with sparse solutions, are proposed respectively and are combined to achieve better performance. Finally, several optimization trials of the proposed algorithm are carried out on the IEEE 30-bus test system.

Bisen D.and Dubey H..M [4] proposed to solve the objective of the collective problem can be expressed by taking the total production cost, losses and total emission into account with required constraints for 24 hour time interval. It provides a brief description and mathematical formulation of DED problems. The concept of General Algebraic Modeling System (GAMS) is discussed and performance of General Algebraic Modeling System (GAMS) and the simulation studies are discussed Ramyasri N.and Reddy G.S. [5] proposed the data of four problems are fuzzified using fuzzy Min-Max approach and then Particle swarm optimization is used to determine the final trade off solution from all these Fuzzified values. This method is tested on IEEE 30 bus system

Rajangam K., Arunachalam V.P, Subramanian R.[6] present a novel implementation of the AIS algorithm is based on pattern recognition and anomaly detection proposed to solve the economic dispatch problems. The effectiveness of proposed algorithm is demonstrated using IEEE 30 bus six generator system considering emission constraints.

Bhuyan S., Hazarika S. and Bardalai A. [9] develop an user friendly software to perform load flow analysis for IEEE 57 bus system. The software will be helpful for researchers, practising engineers, students of power system of various levels to carry out power flow quickly and efficiently as per their requirement. The software is developed using MATLAB programming.

Anand R. and Balaji V. [10] proposed to conducting the power flow analysis for an IEEE 57 bus test system to obtain fast and accurate results. Also the system network must be editable for different load conditions with different elements to add or remove for different analysis2. This will help for many researchers; those are interested on power system stability and enhancement.

Kaur G., Kumar D. and Kaur M.[11] Fuzzy Decision Making technique is applied to economic power generation for six generating units. Fuzzy Decision Making Technique was employed to solve the ELD problem for four cases of six generating unit system without losses, with losses, with minimization of line flow and fuzzy decision making technique with linear membership function.

Tejlavwala A. A[12] The simulation of a Load flow analysis on IEEE-30 bus system was conducted and the effects of load modelling. The reactive power modelling greatly affected the voltage difference, whereas the active power modelling has a greater effect on phase angle differences. load flow models in load flow analysis is advantageous than conventional load flow analysis as generation cost and losses are reduced and security and stability of the system increases.

.In this paper fuzzy decision making technique has been applied to solve the multi-objective optimization problem with conflicting objectives of generation cost and network congestion. Fuzzy decision making technique is considered to be more effective than other techniques as far as conflicting objectives are included in the optimization problem [13]. The proposed technique optimizes the said objective functions under a set of system constraints such as real and reactive power balance equations and generating capacity limits. The performance of proposed technique is tested on IEEE 57-bus system.

The performance of proposed technique on IEEE 57-bus system has been presented in section 3. Section 4 presents the conclusion.

2. PROBLEM FORMULATION

The aim of the proposed multi-objective optimization problem is to determine the generation levels, which will minimize the conflicting objectives of generation cost and network congestion, subject to real and reactive power balance and generation capacity constraints. The problem formulation has been sub-divided into following parts:

- To minimize the fuel cost and line flow parameters (V, δ, P,Q,θ,Y) for economic load dispatch problem for IEEE 57 bus system.
- To minimize the fuel cost & Line Flow for IEEE 57 bus system by implementing Fuzzy Decision Making Technique.

To compare the results obtained with other method & Fuzzy Decision Making Technique for IEEE 57 bus system.

2.1 FORMULATION OF PROBLEM

2.1.1 Economic Load Dispatch

As the main objective minimize the conflicting objectives of generation cost and network congestion, subject to real and reactive power balance and generation capacity constraints. Hence the objective function is taken equivalent to the total cost for supplying the indicated load which is represented by $F_i(P_{gi})$. It can be formulated as follows

Minimize

$$F_i(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i \qquad (1)$$

Where

a_i, b_i, c_i are the fuel cost coefficient.

P_{gi} is the real power output of the generator.

Mathematically, the problem is defined as

$$_{pi} = \sum_{i=1}^{n} F_i\left(P_{gi}\right) \qquad (2)$$

F_{pi} is the total operating cost over the whole dispatch period.

Subject to:

a) Real power dispatch in constraint

The real power dispatch is used to schedule the output of thermal generating units, so that our system meet with system load at least cost. RPD is defined as following by using load flow equations.

$$P_{gi} - P_{di} - V_i \sum_{k=1}^{n} V_k Y_{ik} \cos(\theta_{ik} + \delta_k - \delta_i) = 0 \qquad (3)$$

Where I=1, 2, 3…..n

P_{di} is load demand of real power at the i^{th} bus

P_{gi} is generation of real power at the i^{th} bus

V_i is magnitude of votage at bus i^{th}

δ_i is voltage phase angle at bus i^{th}

Y_{ik} is admittance matrix of bus i^{th} and k^{th}

b) Reactive power dispatch in the network

The reactive power dispatch is an optimization problem which reduces the grid congestion by minimizing the grid power losses. The reactive power dispatch is used to solve the power flow equations. Hence as a result an improved voltage profile can be obtained. RPD is defined as following by using load flow equations.

$$Q_{gi} - Q_{di} + V_i \sum_{k=1}^{n} V_k Y_{ik} \sin(\theta_{ik} + \delta_k - \delta_i) = 0 \qquad (4)$$

Where I=1, 2, 3…..n

Q_{di} Is total system demand of reactive power bus

Q_{gi} is total system generation of reactive power bus

V_i is magnitude of votage at bus i^{th}

δ_i is voltage phase angle at bus i^{th} Bus.

Y_{ik} is admittance matrix of bus i^{th} and k^{th} Bus.

c) Generating capacity constraints

To stabilize the operation, the generator output, bus voltage magnitudes and voltage angles are restricted by upper and lower limits. These upper and lower bounds are defined as following

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \quad I=1,2,3\ldots..n \qquad (5)$$

Where

P_{gi}^{min} is mini. O/p power of the gi^{th} unit

P_{gi}^{max} is mini. O/p power of the gi^{th} unit

Voltage magnitude satisfy the inequality

$\le V\_i \le V\_(i)\text{^}max$ I=1, 2, 3…..n (6)

Where

V_{gi}^{min} = mini. Voltage of the gi^{th} unit

V_{gi}^{max} = maxi. Voltage of the gi^{th} unit

Voltage angle also satisfy the inequality

$$\delta_i^{min} \le \delta_i \le \delta_i^{max} \quad I=1, 2, 3\ldots..n \qquad (7)$$

Where

δ_{gi}^{min} = mini. Voltage angle of the gi^{th} unit

δ_{gi}^{max} = maxi. Voltage angle of the gi^{th} unit

d) Computation of line flows

Consider that line is connecting the buses I and m. The Real power is injected from bus I to k and is given as following.

$$P_{im} + jQ_{im} = V_i[(V_i^* - V_m^*)Y_{im}^* + V_i^* Y_{im\,0}^*] \qquad (8)$$

Reactive power is injected from bus k to bus I as following

$$P_{mi} + jQ_{mi} = V_m[(V_m^* - V_i^*)Y_{mi}^* + V_i^* Y_{mi\,0}^*] \qquad (9)$$

Where

Y_{im}^* Is the series admittance

$Y_{im\,0}^*$ Is the shunt admittance

V_i is the voltage at the i^{th} bus

$$S_{im} = P_{im} + jQ_{im} \qquad (10)$$

$$S_{mi} = P_{mi} + jQ_{mi} \qquad (11)$$

Power losses in the (I-k) th line is the sum of the power flows in the (I-k) th line from the i^{th} bus and the k_{th} bus.

$$P_{Lik} = S_{im} + S_{mi} \qquad (12)$$

2.1.2 Network congestion

When transmitted power increase the capacity or transfer limit of the transmission line then network congestion is produced .Congestion is managed at the dispatch stage. In this paper to reduce the network congestion we minimized the line flow in branch 2 from bus 1 to bus 3.From section 2.1.1, calculate the computation of line flows.

2.1.3 Application of fuzzy decision making technique

According to fuzzy decision making technique we differentiate decision problems that involve an optimization problem under multi-objective criteria. To find out the membership function of cost and line flow first step is to find the minimum and maximum values of cost and line flow.

1) Linear Membership function

The membership function for cost is defined as following:-

$$\mu_{f_i(x)} = \begin{cases} 1 & f_i(x) \le f_i^{\,1} \\ \dfrac{(f_i(x) - f_i^{\,0})}{(f_i^{\,1} - f_i^{\,0})} & f_i^{\,1} < f_i(x) < f_i^{\,0} \\ 0 & f_i(x) \ge f_i^{\,0} \end{cases} \qquad (13)$$

1

Where

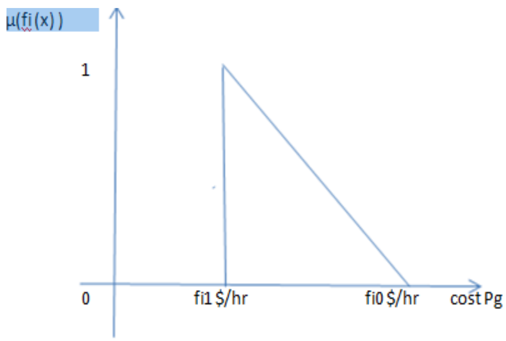
$f_i^{\,1}$=value of an original fuel cost that is completely satisfactory

$f_i^{\,0}$= value of an original fuel cost that is completely unsatisfactory

$f_i(x)$ = value of an original fuel cost which is varying

$$\text{Minimize} f_i(x) = \frac{1}{1+\min(\text{membershipfunction of multi objectives})} \quad (14)$$

By using this function we minimize the several objectives such as cost, line flow.



2.4 Methodology

Step1. Input parameters of system, fuel cost co-efficient and specify lower and upper boundaries and define minimum fuel cost function.

Step2. Get the power generation for seven generating units and total fuel cost and total losses.

Step3. For minimizing line flow we have to check whether any line is overloaded or not.

Step4. If overload exists, find the minimum value of line flow by using equations

Step5.As the fuel cost and line flow are the conflicting objectives so an optimal solution cannot be obtained, hence to obtain the optimal solution linear membership function is applied.

Step 6.The Value of membership function is obtained using equation (2.12) for fuel cost and line flow which lies on one optimal point.

3. RESULTS AND DISCUSSIONS

The fuzzy decision making technique is tested on four different test cases of a single seven unit system of the economic load dispatch and network congestion problem. The test case 1 considers only operating cost without network congestion and loss, test case 2 considers operating cost with losses, test case 3 considers losses with network congestion and without operating cost and test case 4 considers operating cost with network congestion and losses. The cost coefficients of IEEE-57 bus system are slightly modified to incorporate non smooth fuel cost functions with ramp rate coefficients as given in Table3.1.The base power value is on 100 MVA base. For all analysis on this system V_i^{min}, V_i^{max}, δ_i^{min} and δ_i^{max} for i_{th} bus are considered to be 0.9 p.u, 1.I p.u., -45 degree and 4 5 degree respectively.

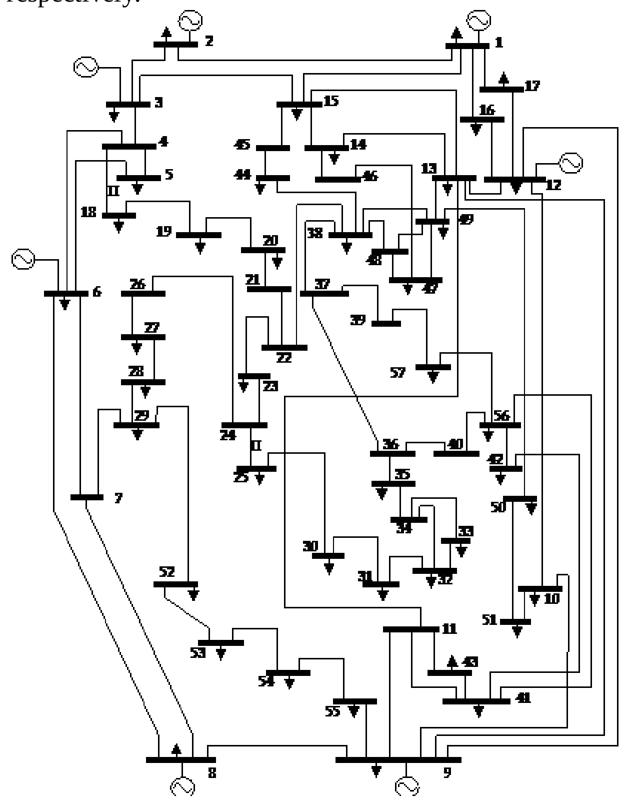


Fig 3.1 single line diagram IEEE 57 bus test system [13]

P_{gi}^{min} (MW)	P_{gi}^{max} (MW)	a_i ($/MW^2 h)	b_i ($/MW^2 h)	c_i ($/MW^2 h)
0	576	0	0.07750	20
0	100	0	0.01000	40
0	140	0	0.25000	20
0	100	0	0.10000	40
0	550	0	0.02222	20
0	100	0	0.01000	40
0	410	0	0.32258	20

Test Case	Total Fuel Cost ($/hr)
Without losses	569.84

Table3.1: Generation and Fuel Cost Coefficient

Bus no.	Load		Bus no.	Load	
	P(MW)	Q(MVAR)		P(MW)	Q(MVAR)
1	0.5500	0.1700	30	0.0360	0.0180
2	0.0300	0.8800	31	0.0580	0.0290
3	0.4100	0.2100	32	0.0160	0.0080
4	0.0000	0.0000	33	0.0380	0.0190
5	0.1300	0.0400	34	0.0000	0.0000
6	0.7500	0.0200	35	0.0600	0.0300
7	0.0000	0.0000	36	0.0000	0.0000
8	1.5000	0.2200	37	0.0000	0.0000
9	1.2100	0.2600	38	0.1400	0.0700
10	0.0500	0.0200	39	0.0000	0.0000
11	0.0000	0.0000	40	0.0000	0.0000
12	3.7700	0.2400	41	0.0630	0.0300
13	0.1800	0.0230	42	0.0710	0.0440
14	0.1050	0.0530	43	0.0200	0.0100
15	0.2200	0.0500	44	0.1200	0.0180
16	0.4300	0.0300	45	0.0000	0.0000
17	0.4200	0.0800	46	0.0000	0.0000
18	0.2720	0.0980	47	0.2970	0.1160
19	0.0330	0.0060	48	0.0000	0.0000
20	0.0230	0.0100	49	0.1800	0.0850
21	0.0000	0.0000	50	0.2100	0.1050
22	0.0000	0.0000	51	0.1800	0.0530
23	0.0630	0.0210	52	0.0490	0.0220
24	0.0000	0.0000	53	0.2000	0.1000
25	0.0630	0.0320	54	0.0410	0.0140
26	0.0000	0.0000	55	0.0680	0.0340
27	0.0930	0.0050	56	0.0760	0.0220
28	0.0460	0.0230	57	0.0670	0.0200
29	0.1700	0.0260			

Table 3.2 load bus data[13]

3.1 Test case 1

Here generation limit of seven unit system and the generation cost coefficients are taken from table 3.1.For this test case network congestion and losses are not considered .In this test case operating cost of seven unit systems is calculated. For this test case condition used as

$$\sum P_g = \sum P_d$$

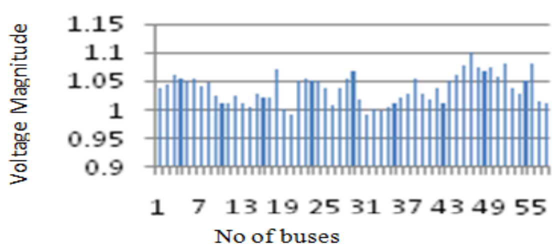
Table 3.4: Result of Test Case 1

3.2 Test Case 2:

Here generation cost coefficients and generation limit of seven units system are taken from table3.1.In this test case operating cost with losses of seven unit systems is calculated at different power demand. We use line flow equations when losses are considered

$$P_L = \sum P_g - \sum P_d$$

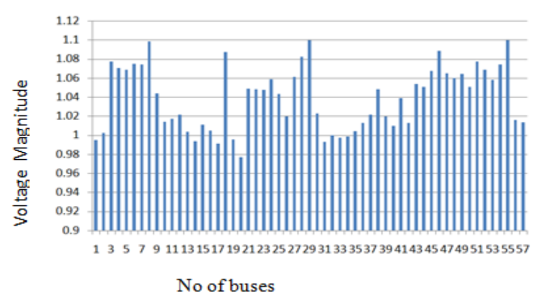
Different values of voltage magnitude for different load buses in test case 2 are given as following.



Graph 3.1: Voltage when losses are included

3.3 Test Case 3:

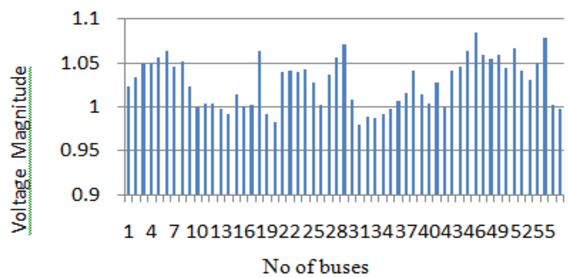
Here generation cost coefficients and generation limit of seven unit system are taken from appendix. In this test case operating cost with losses of seven unit systems is calculated. For minimizing the Line Flow equation of branch 2 from bus 1 to bus 3, load flow equations are applied.



Graph 3.2 Voltage when line flow is minimized In branch 2(1-3)

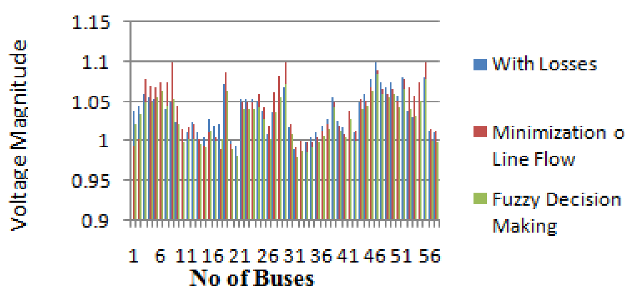
3.4 Test Case 4

In this test case operating cost including line flows with power losses of seven-unit system is calculated at different power demand using fuzzy decision making technique. Different values of voltage magnitude for different load buses in test case 4 are given as following



Graph 3.3 when fuzzy decision making technique is applying then graph of voltage is following

3.5 Comparison between different voltages



Graph 3.4 for power generation of seven units for different cases

Table 3.6 Performance Parameters for IEEE 57-bus system

Cases	Power Losses P_L(MW)	Line Flow (MW)	Fuel cost ($/h)
With Losses	.28	53.72	591.29
With Minimization of Line Flow in Branch 2(1-3)	.94	20.24	1687.86
When Fuzzy is Applied	.25	42.99	662
Membership Function		.9	.9

CONCLUSION

In this paper, fuzzy decision making technique have been used for solving the economic load dispatch and to minimize the network congestion. Four different test cases of single seven unit system for above problems are taken. The conclusion describes the capability of the proposed fuzzy decision multi-objective technique to solve the problems of economic load dispatch and network congestion

REFERENCES

[1] Niimura T., and Nakashima T., "Multi-objective trade-off analysis of deregulated electricity transactions," sciences direct Electrical Power and Energy Systems vol.25 pp. 179–185 (2003).

[2] Prasanna. S.T. and Somasundaram. P., "Fuzzy -Tabu Search Algorithm For Combined Economic and Emission Dispatch," National Systems Conference **4.** (NSC 2008), Chennai, India, Dec 2008, pp. 542-547

[3] Gong.-D.and Zhang Y., "Environmental/economic power dispatch is using a hybrid multi-objective optimization algorithm," science direct Electrical Power and Energy Systems vol32, pp. 607–614 (2010).

[4] Bisen D.and Dubey H..M, "Dynamic Economic Load Dispatch with Emission and Loss using GAMS," Inter. J.of engg. Research & Tech., vol. 1, May 2012.

[5] Ramyasri N.and Reddy G.S., "Fuzzified PSO for Multiobjective Economic Load Dispatch Problem," International Journal of Research in Engineering and Technology, Volume: 02 Issue: 08, pp. 157-162, (2013).

[6] Palaniyappan S.,Ilayaranimangammal I., "An Optimistic Solution Technique For Economic Load Dispatch Problem Using Immune Inspired Algorithm" , International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 12, pp. 6191-6195, (2013).

[7] Rajangam K., Arunachalam V.P, Subramanian R., "Fuzzy Logic Controlled Genetic Algorithm to Solve The Economic Load Dispatch For Thermal Power Station", European Scientific Journal , edition vol. 8, No.7, pp 172-184, (2013).

[8] Kothari D.P., Dhillon J.S. "Power System Optimization", PHI, (2013).

[9] Bhuyan S., Hazarika S. and Bardalai A., "Power Flow Analysis on IEEE 57 bus System using MATLAB", International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 8,(2014)

[10] Anand R. and Balaji V. "Power Flow Analysis of Simulink IEEE 57 Bus Test System Model using PSAT" Indian Journal of Science and Technology, Vol 8(23), (2015)

[11] Kaur G., Kumar D. and Kaur M. " Multi-Objective Optimization using Linear Membership Function" International Conference on Advancements in Engineering and Technology,(2015)

[12] Tejlavwala A. A. " Load Flow Analysis & Simulation on IEEE 30 Bus System" International Journal of Innovative and Emerging Research in Engineering Volume 3, Issue 4, (2016)

[13] Appendix 18, "Data Sheets for IEEE 57 Bus System" pp. 129-134.