

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & MANAGEMENT**Power System Optimization through Committed Generation using PSO****Sukanya Mishra¹, Arpan Dwivedi²**¹ME ScholarDepartment of Electrical and Electronics Engineering
Shri Shankaracharya Institute of Technology And Management, Bhilai²Sr. Asst.Prof. & HeadDepartment of Electrical And Electronics Engineering
Shri Shankaracharya Institute of Technology And Management, Bhilai¹sukanya.03mishra@gmail.com²arpandwvd@gmail.com**Abstract**

The economic load dispatch is a very important nonlinear improvement operation. It will facilitate the generating units to control in economic method, and handle the constraints of the system. The economic load dispatch involves the answer of totally two different of issues. The primary of those is that the Unit Commitment ought to choose optimum accessible generating units to control and meet the expected load demand and supply such margin of operational reserve over a time. The second objective of economic dispatch is that the on line economic dispatch. ELD is needed to distribute the load amongst accessible generating units paralleled with the system in such a way thus on minimize the entire generation price of the thermal power plant.

The main aim of economic dispatch reduce the entire price of generating real power at varied stations, whereas satisfying the demand alongside operational and physical constraints. Recently the improvements techniques have received a lot of attention and were accustomed solve the nonlinear improvement issues. The aim of the planned work is to search out the benefits of application of the biological process computing technique i.e. New Particle Swarm improvement (Novel weight improved PSO) especially to the economic load dispatch problem.

Particle swarm Optimization is a population based algorithmic. The validity and efficiency of the new PSO algorithm is tested for various data of generating units. Thus, results measure taken for different population sizes like 5, 10, 15, 20, 25 and 30. For every testing fifty runs are taken, and best result of them is taken as global result of the problem. Results obtained measure usually compared with the previous results accessible in literature and notice superior in terms of objective perform and value of generation furthermore.

Keyword: -Economic load dispatch, particle swarm optimization (PSO)

Introduction

The efficient optimal economic operation and planning of electric power generating system has always occupied an important position in the electric power industry. With large interconnection of the electric networks, energy crisis in the world, continuous rise in fossil fuel and tariff structure necessitate the optimal operation of power generating units. A small saving in the operation of generating system results a significant reduction in operating cost of the power plant. The main objective of the economic load dispatch of generating systems is to achieve minimum operating cost of thermal power plant. This problem has taken a subtle twist in modern generating system, as consumers have become concerned with environmental matters, so that economic dispatch now includes the dispatch of systems to minimize environmental emission as well as achieve minimum cost. In addition, there is a need to expand the limited economic optimization problem to incorporate constraints on system operation in order to ensure the security of the system, for preventing collapse of the system due to unforeseen conditions. However closely associated problem with this economic load dispatch, is the commitment of any unit out of a total array of units to serve the expected load demands in an optimal way. For the purpose of optimum economic operation of this large scale interconnected system, modern optimization techniques are being applied with the expectation of considerable cost savings. The Economic Load Dispatch is an important part of modern electrical power system such that Unit commitment, Load forecasting, Available Transfer Capability (ATC) calculation, Security Analysis (SA), scheduling of fuel purchase etc. A bibliographical survey on ELD methods reveals that various numerical optimization techniques have been employed to obtain the solution of the ELD problem. ELD problem solved traditionally using mathematical programming based on optimization techniques such as Particle Swarm Optimization (PSO) with valve point effect and its variants i.e. Self-Organizing Hierarchical Particle Swarm Optimization [2][3], Hybrid Particle Swarm Optimization Approach [4], Quantum-Inspired Particle Swarm Optimization (PSO) with valve loading [5] and Bacterial Foraging Optimization Based Dynamic with Non-Smooth Cost Function [6]. Economic load dispatch with piecewise linear cost functions is a highly heuristic, approximate and extremely fast form of economic dispatch [2]. As power demand increase and fuel cost booms in recent years, reduction the operation costs of power system becomes an important issue. One of the choices is to operate generators efficiently and economically.

Nevertheless, economic dispatch problems with multiple-unit and piecewise quadratic cost functions will exist many local extreme points [4]. As a result, conventional optimization techniques are no longer the best choice since they may fail to locate the optimal solution and result in considerable errors. Recently, the advances in computation and the search for better solution of complex problems have lead to using stochastic optimization techniques, such as ant colony optimization [4-5], Evolutionary algorithm [6-7], particle swarm optimization [8], differential evolution, and etc., for solving economic dispatch problems. The objective of the economic load dispatch (ELD) problem is to control the committed generator’s output such that the total fuel cost is minimized, while satisfying the power demand and other physical and operational constraints. Traditionally, fuel cost function of a generator is represented by single quadratic function. Economic dispatch problems with quadratic cost functions are well solved by optimization methods.

The objective of this work is to calculate the optimal power generation schedule through committed generating units for three, six, thirteen and fifteen generating units using inertia weight improved Particle Swarm Optimization.

Methodology

In present work optimal power through committed generation units has been calculated using PSO. The brief methodology is given below:

- 1) Exhaustive Literature review has been done in the subject area.
- 2) Identify the test systems for which optimal generation schedule has been obtained.
- 3) Optimization problem has been formulated including objective function & constraints.
- 4) Finalized optimization algorithm.
- 5) MATLAB coding has been done for all test system for economic load dispatch using Linearly Decreasing Inertia Weight PSO.
- 6) As PSO is a population based algorithm hence results are obtained at various population Sizes.
- 7) Results for all test systems are compared at different population sizes.

Problem Formulation

The important aspect of economic load dispatch is the formulation of practical problem in standard mathematical optimization format which is acceptable to the optimization algorithm .This section is focused on economic load dispatch problem formulation of the test system [19] subjected to various physical & operational constant which are given below:

Objective function

An objective function expresses the main aim of the model which is either to be minimized or maximized [4]. It is expressed in terms of design variables & other problem parameters. In present work the goal is to minimize the generation cost of committed generating units i.e. three, six, thirteen & fifteen which are represented as given below;

$$\text{Minimize } FC_T = \sum_{i=1}^N FC_i(P_i) \dots\dots\dots 1$$

$$FC_i(P_i) = a_i P_i^2 + b_i P_i + c_i \dots\dots\dots 2$$

The cost coefficients for the three, six, thirteen & fifteen generating units test systems are mentioned in Table (1.1)-(1.2) respectively.

Table 1.1 Cost coefficients of 3 generating units

Units	a_i	b_i	c_i
1	0.008	7	200
2	0.009	6.3	180
3	0.007	6.8	140

Table 1.2 Cost coefficients of 6 generating units

Units	a_i	b_i	c_i
1	0.007	7	240
2	0.0095	10	200
3	0.009	8.5	220
4	0.009	11	200
5	0.008	10.5	220
6	0.0075	12	190

Table 1.3 Cost coefficients of 13 generating units

Units	a_i	b_i	c_i
1	0.00028	8.1	550
2	0.00056	8.1	309
3	0.00056	8.1	307
4	0.00324	7.74	240
5	0.00324	7.74	240
6	0.00324	7.74	240
7	0.00324	7.74	240
8	0.00324	7.74	240
9	0.00324	7.74	240
10	0.00284	8.6	126

11	0.00284	8.6	126
12	0.00284	8.6	126
13	0.00284	8.6	126

Table 1.4 Cost coefficients of 15 generating units

Units	a_i	b_i	c_i
1	0.000299	10.1	671
2	0.000183	10.2	574
3	0.001126	8.8	374
4	0.001126	8.8	374
5	0.000205	10.4	461
6	0.000301	10.1	630
7	0.000364	9.8	548
8	0.000338	11.2	227
9	0.000807	11.2	173
10	0.001203	10.7	175
11	0.003586	10.2	186
12	0.005513	9.9	230
13	0.000371	13.1	225
14	0.001929	12.1	309
15	0.004447	12.4	323

Constraints

The optimal value of objective function as mentioned in equation (1) is computed subjected to equality & inequality constraints.

Equality Constraints

Load balance equation-above objective function should be minimized with fulfillment of equality constraints i.e. load balance equation as given below

$$\sum_{i=1}^n P = P_D + P_L$$

P_D is the demand and P_L is transmission loss.

Inequality Constraints

Actual power generation from each thermal unit should be within bounds of minimum & maximum generation limits [11] [16] which is represented by eq. given below

$$P_i^{\min} \leq P_i \leq P_i^{\max}$$

$$i = 1, 2, 3$$

The minimum & maximum generation limits of 3, 6, 13 & 15 generating units are mentioned in Appendix I (a)-(d) respectively.

Optimization using PSO

The PSO method is applied to four test systems i.e. three, six, thirteen & fifteen generating units, while satisfying load demand [19], Here for all cases transmission losses are neglected & program has been coded in MATLAB 7.5 and run on Intel Pentium(R) Dual Core CPU, 2.30 GHZ, RAM-2 GB, 64 bit OS, Window 2007 Dell PC. Standard data's of 3,6,13 & 15 units test system are taken from reference [14, 19,21, 25] & results obtained by proposed method are typically compared with [19, 25, 29] .

Experimental Settings

PSO is a population based stochastic optimization algorithm, hence results are taken as different population sizes i.e. 5,10,15,20,25 & 30. For each population size, at least 30 trials have been taken & minimum, maximum & average cost of 30 trials are noted. PSO parameters also effects the performance of proper selection of PSO, so in present work $c1=c2=2$, No. of iteration=100, $\omega_{\min}=0.4$ & $\omega_{\max}=0.9$ are considered.

Results & Discussion

For the above experimental settings results of various test systems considered are given below:

Three unitstestsystem

In 3 units test system, whose cost coefficients, min & max power generation limits are mentioned Appendix I (a). For the above test system optimization problem has been formulated & MATLAB program for the solution of economic dispatch as given in Appendix II (a) has been coded. Optimal results are taken for 30 trials at different population sizes as mentioned in Table 1.5 and its corresponding optimal power generation schedules are mentioned in Table 1.6. Frequency to obtain the best possible solutions at all population sizes are given in Table 1.7.

Table 1.5: Minimum, maximum & average costs obtained for 3 units test system at Different population sizes

Costs(\$/h)	Population sizes					
	5	10	15	20	25	30
Min cost	1580.260	1582.449	1580.853	1580.249	1579.774	1580.666
Max. cost	1623.400	1613.908	1631.879	1625.763	1621.907	1620.085
Aver. Cost	1597.183	1597.283	1599.419	1596.093	1594.275	1594.991

Table 1.6: Optimal power generation schedule for 3 units test system at different Population sizes

Generating units	Optimal power at different pop sizes(MW)					
	5	10	15	20	25	30
P1	38.5168	32.7759	41.7812	36.7517	32.6484	38.348
P2	65.9303	80	62.8486	69.2945	69.0501	59.0179
P3	45.5538	37.2241	45.3698	43.954	48.3015	52.6341

From above Table (1.6) it clearly indicates that minimum cost has been achieved at population size of 25 & its corresponding generation schedule is P1=32.6484MW, P2=69.0501MW & P3=48.3015MW. Fig.1.1 (a)-(f) show the convergence characteristics of objective function at different population sizes.

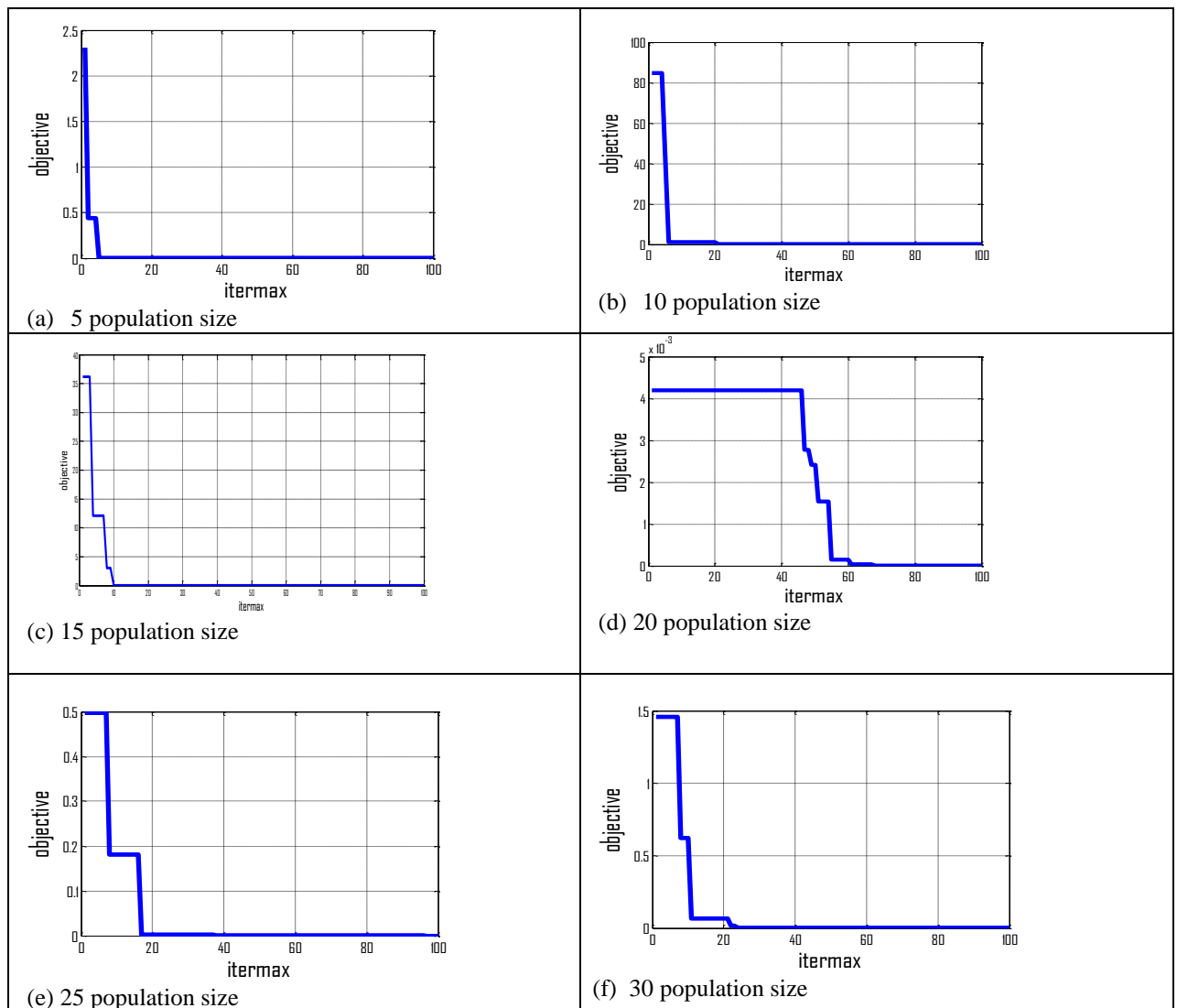


Fig. 1.1 (a)-(f): Convergence characteristics of LDIW_PSO for three units test system at different population sizes

Six units test system

In 6-unit test system, whose cost coefficients, min & max power generation limits are mentioned Appendix I (b). For the above test system optimization problem has been formulated & MATLAB program for the solution of economic dispatch as given in Appendix II (b) has been coded. Optimal results are taken for 30 trials at different population sizes as mentioned in Table 1.7 and its corresponding optimal power generation schedules are mentioned in Table 1.8. Frequency to obtain the best possible solutions at all population sizes are given in Table 1.9.

Table 1.7: Minimum, maximum & average cost obtained for 6 units test system at different population sizes

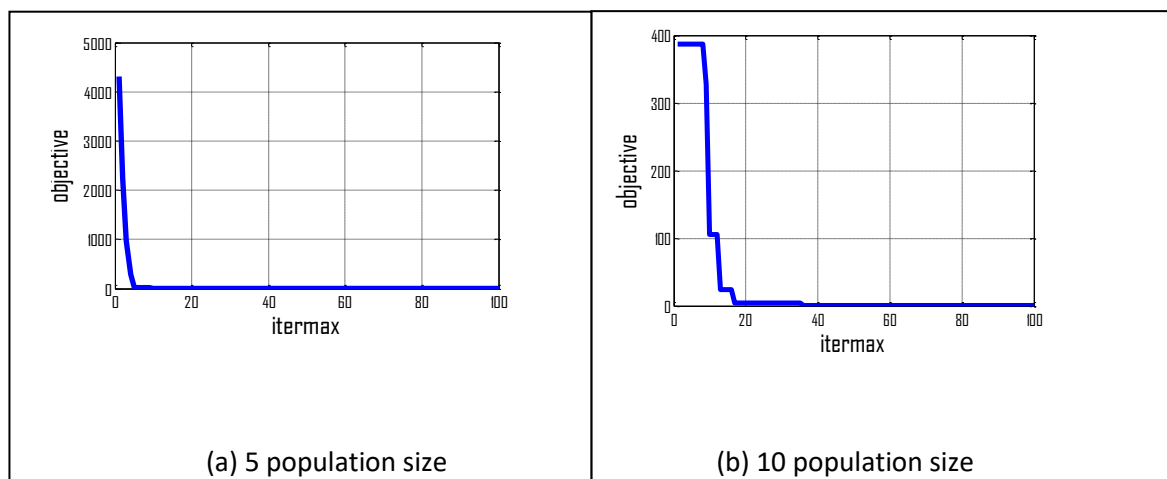
Costs(\$/h)	Population sizes					
	5	10	15	20	25	30
Min. cost	15282.976	15292.891	15290.384	15300.216	15283.757	15281.656
Max. cost	15423.231	15375.257	15357.536	15515.031	15422.025	15394.327
Aver. Cost	15348.018	15328.825	15325.591	15375.387	15357.265	15337.824

Table 1.8: Optimal power generation schedule for 6 units test system at different Population sizes

Generating units	Optimal power at different pop sizes(MW)					
	5	10	15	20	25	30
P1	450.718	442.039	453.508	427.849	435.834	427.643
P2	177.844	200.000	142.647	162.698	176.956	166.918
P3	264.714	238.499	270.585	294.324	259.374	266.574
P4	128.329	112.747	118.631	145.122	109.975	125.197
P5	146.117	186.499	167.221	139.403	195.505	173.285
P6	95.279	83.217	110.408	93.605	85.357	103.384

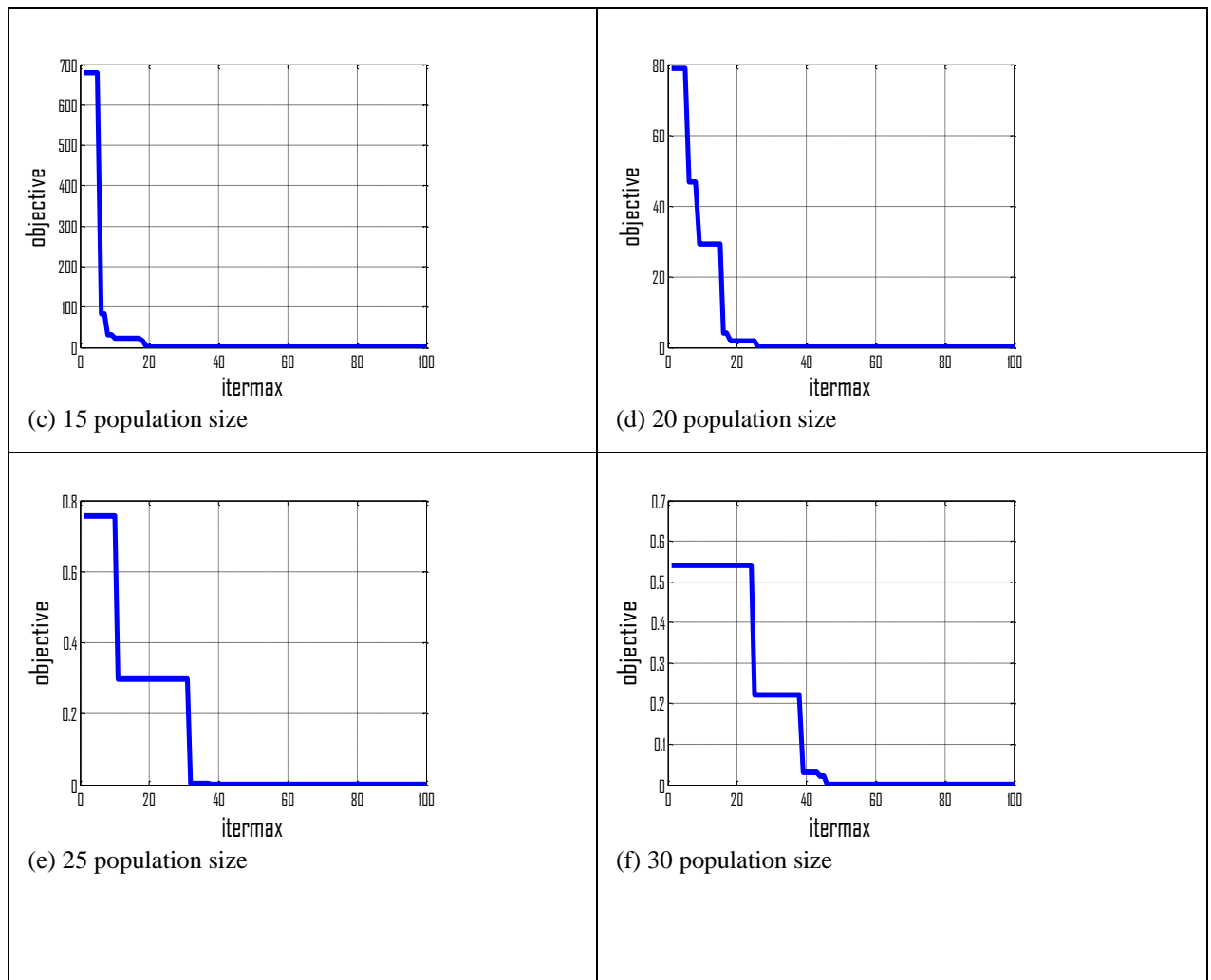
From above Table (1.8) it clearly indicates that minimum cost has been achieved at population size of 30 & its corresponding generation schedule is P1= 427.643MW, P2=166.918MW & P3=266.574MW, P4=125.197MW, P5=173.285MW & P6=103.384MW. Fig.1.2 (a)-(f) show the convergence characteristics of objective function at different population sizes.

Fig. 1.2 (a)-(f): Convergence characteristics of LDIW_PSO for six units test system at different population sizes



Thirteen units test system

In 13-unit test system, whose cost coefficients, min & max power generation limits are mentioned Appendix I



(c).For the above test system optimization problem has been formulated & MATLAB program for the solution of economic dispatch as given in Appendix II (c) has been coded. Optimal results are taken for 30 trials at different population sizes as mentioned in Table 1.9 and its corresponding optimal power generation schedules are mentioned in Table 2.1. Frequency to obtain the best possible solutions at all population sizes are given in Table 2.2.

Table 1.9:Minimum, maximum & averagecost for 13 units test system at different population sizes

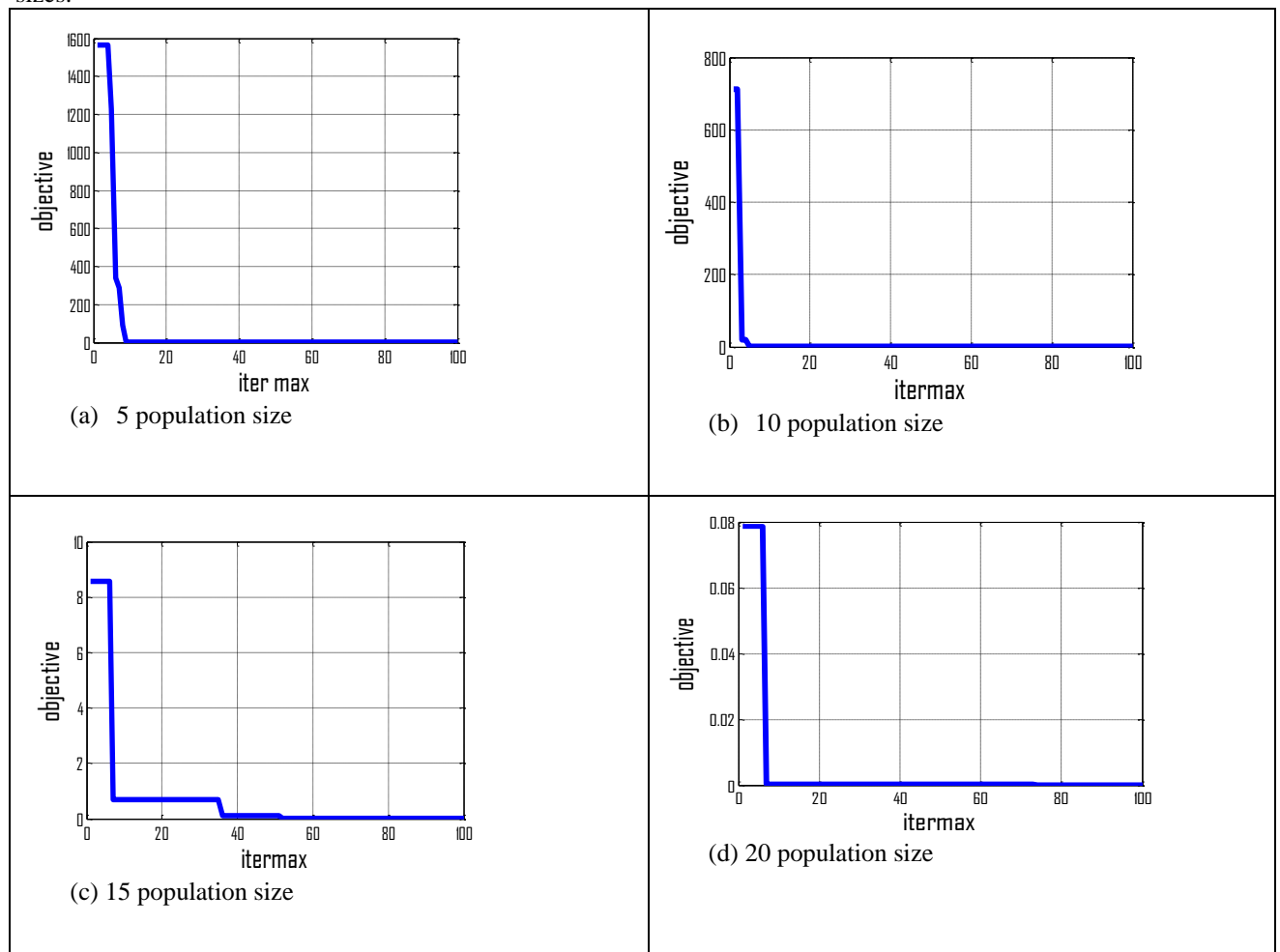
Costs(\$/h)	Population sizes					
	5	10	15	20	25	30
Min. cost	18012.908	18041.682	18030.671	17996.538	18020.977	18010.729
Max. cost	18210.673	18121.586	18128.090	18148.639	18971.936	19016.021
Aver. cost	18085.576	18080.181	18076.795	18065.198	18170.175	18170.648

Table 2.1:Optimal power generation schedule for 13 units test system at different population sizes

Generating units	Optimal power at different pop sizes(MW)					
	5	10	15	20	25	30
P1	504.007	362.465	364.445	608.053	546.310	491.488
P2	64.549	196.089	216.171	159.379	165.511	147.763
P3	264.761	249.547	147.959	131.241	188.978	187.060
P4	119.699	102.211	152.501	123.523	74.668	92.359
P5	118.208	89.462	126.587	83.858	61.792	146.924

P6	165.909	125.019	137.534	148.946	151.697	164.302
P7	88.669	163.216	170.295	102.915	101.829	81.265
P8	82.692	108.129	84.060	80.559	104.030	107.509
P9	129.113	75.170	119.924	103.628	99.236	108.206
P10	76.564	75.153	64.278	64.141	85.778	81.827
P11	51.554	62.980	73.095	67.496	81.594	54.005
P12	60.851	81.324	55.451	55.393	71.747	81.999
P13	73.426	109.235	87.703	70.869	66.830	55.296

From above Table (2.1) it clearly indicates that minimum cost has been achieved at population size of 20 and its corresponding generation schedule is P1=608.053MW,P2=159.379MW,P3=131.241MW,P4=123.523MW, P5=83.858M P6=148.946MW,P7=102.915MW,P8=80.559MW,P9=103.628MW, P10=64.141MW, P11=67.496MW,P12=55.393MW & P13=70.869MW. Fig.1.3 (a)-(f) show the convergence characteristics of objective function at different population sizes.



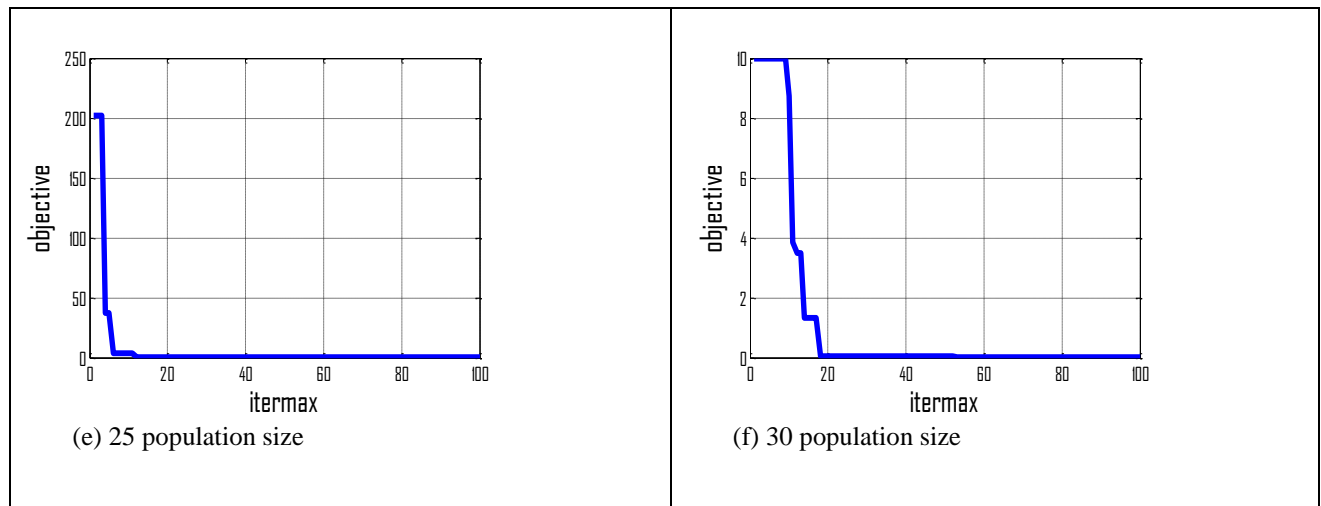


Fig. 1.3 (a)-(f): Convergence characteristics of LDIW_PSO for thirteen units test system at different population sizes

Fifteen units test system

In 15-unit test system, whose cost coefficients, min & max power generation limits are mentioned Appendix I (d). For the above test system optimization problem has been formulated & MATLAB program for the solution of economic dispatch as given in Appendix II (d) has been coded. Optimal results are taken for 30 trials at different population sizes as mentioned in Table 2.2 and its corresponding optimal power generation schedules are mentioned in Table 2.3. Frequency to obtain the best possible solutions at all population sizes are given in Table 2.4.

Table 2.2: Minimum, maximum & average cost for 15 units test system at different population sizes

Costs	Population sizes					
	5	10	15	20	25	30
Min. cost	32678.899	32358.122	32489.779	32514.283	32393.437	32607.052
Max. cost	33076.399	32978.894	32925.224	32944.190	32863.369	32926.041
Avg. cost	32854.926	32713.144	32695.788	32751.349	32695.544	32786.037

Table 2.3: Optimal power generation schedule for 15 units test system at different population sizes

Generating units	Optimal power at different pop sizes(MW)					
	5	10	15	20	25	30
P1	322.558	351.148	316.271	455.000	404.574	257.352
P2	386.999	451.541	393.785	443.032	406.714	397.712
P3	92.291	130.000	87.996	45.119	103.939	80.326
P4	98.023	95.981	99.776	111.417	126.446	82.527
P5	372.093	437.225	377.467	240.130	342.212	431.351
P6	357.609	460.000	414.897	428.471	460.000	457.341
P7	432.975	341.482	455.862	375.322	372.526	374.696
P8	226.943	60.000	80.623	69.318	89.686	179.181
P9	46.264	44.402	66.758	94.566	25.000	78.516
P10	105.635	57.150	107.455	106.835	141.163	59.936
P11	25.823	45.135	56.287	67.251	40.394	44.078
P12	68.581	70.496	53.607	66.672	34.673	63.704
P13	25.203	39.396	48.674	73.917	29.943	66.232
P14	27.938	31.044	27.944	29.178	23.020	31.484
P15	41.067	15.000	42.599	23.774	29.698	25.565

From above Table (2.3) it clearly indicates that minimum cost has been achieved at population size of 10 & its corresponding generation schedule is P1=351.148MW,

P2=451.541MW,P3=130.000MW,P4=95.981MW,P5=437.225MW,P6=460.000MW,P7=341.482MW, P8=60.000MW, P9=44.402MW, P10=57.150MW, P11=45.135MW, P12=70.496MW, P13=39.396MW, P14=31.044MW, P15=15.000MW. Whereas Fig.1.4 (a)-(f) show the convergence characteristics of objective function at different population sizes.

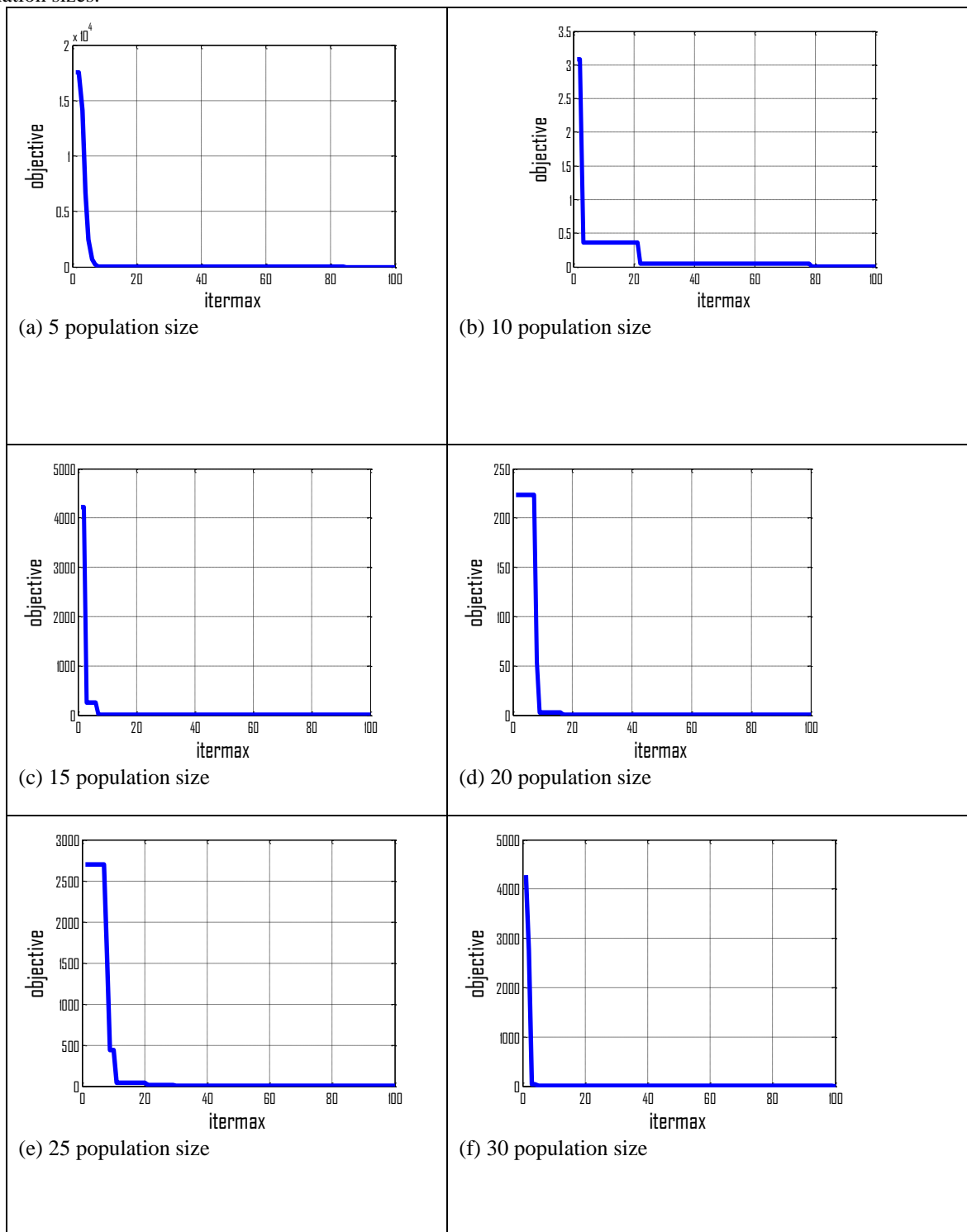


Fig. 1.4 (a)-(f): Convergence characteristics of LDIW_PSO for fifteen units test system at different population sizes

Validation of results

Best value of objective function for all test systems considered at different population sizes are mentioned in previous sections. Here optimal results for three, six, thirteen and fifteen unit's systems are typically compared with [14], [21], [29] and [19] respectively.

Table 2.4: Comparison of optimal results with previous results for different test systems

Test system	Load Demand	Generation cost corresponding objective function by PSO method	Generation cost by literature review by PSO method
3 units	150 MW	1579.774 \$/h	1596.00 \$/h
6 units	1263MW	15281.656 \$/h	15450.00 \$/h
13 units	1800MW	17996.53 \$/h	18014.16 \$/h
15 units	2630MW	32358.122 \$/h	32515.87 \$/h

IWIPSO has been successfully applied to determine the economic load dispatch of test systems and it has been observed that proposed algorithm is properly converged and provides best optimal solution.

Conclusion

Detailed results of the economic load dispatch for all above test systems at different population sizes using LDIW PSO are given in previous chapter. Here test system wise conclusions are derived based on those and are given below:

- In case of three units test system, for 30 trials of each population size i.e. 5, 10, 15, 20, 25 and 30 min. value of objective function achieved are 1580.260 \$/h, 1582.449 \$/h, 1580.853 \$/h, 1580.249 \$/h, 1579.774 \$/h and 1580.666 \$/h respectively. However amongst above population sizes, 25 is giving best value objective function for a generation schedule of 32.6484MW, 69.0501MW & 48.3015MW.
- In case of six units test system, for 30 trials of each population size i.e. 5, 10, 15, 20, 25 and 30 min. value of objective function achieved are 15282.976 \$/h, 15292.891 \$/h, 15290.384 \$/h, 15300.216 \$/h, 15300.216 \$/h and 15281.656 \$/h respectively. However amongst above population sizes, 30 is giving best value objective function for a generation schedule of 427.643MW, 166.918 MW, 266.574MW, 125.197 MW, 173.285MW & 103.384MW.
- In case of thirteen units test system, for 30 trials of each population size i.e. 5, 10, 15, 20, 25 and 30 min. value of objective function achieved are 18012.908 \$/h, 18041.682 \$/h, 18030.671 \$/h, 17996.538 \$/h, 18020.977 \$/h and 18010.729 \$/h respectively. However amongst above population sizes, 20 is giving best value objective function for a generation schedule of 608.053MW, 159.379MW, 131.241MW, 123.523MW, 83.858MW, 148.946MW, 102.915MW, 80.559MW, 103.628MW, 64.141MW, 67.496MW, 55.393MW & 70.869MW.

In case of fifteen units test system, for 30 trials of each population size i.e. 5, 10, 15, 20, 25 and 30 min. value of objective function achieved are 32678.899\$/h, 32358.122\$/h, 32489.779\$/h, 32514.283\$/h, 32393.437\$/h and 32607.052 \$/h respectively. However amongst above population sizes, 10 is giving best value objective function for a generation schedule of 351.148MW, 451.541MW, 130.000MW, 95.981MW, 437.225MW, 460.000MW, 341.482MW, 60.000MW, 44.402MW, 57.150MW, 45.135MW, 70.496MW, 39.396MW, 31.044MW & 15.000MW.

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APPENDIX I

(a) For 3 units test system

Plant No.	Pmin (MW)	Pmax (MW)	ai (\$/MW ²)	bi (\$/MW)	ci(\$)
P1	10	85	0.008	7	200
P2	10	80	0.009	6.3	180
P3	10	70	0.007	6.8	140

(b) For 6 units test system

Plant No.	Pmin (MW)	Pmax (MW)	ai (\$/MW ²)	bi (\$/MW)	ci(\$)
P1	100	500	0.007	7	240
P2	50	200	0.0095	10	200
P3	80	300	0.009	8.5	220
P4	50	150	0.009	11	200
P5	50	200	0.008	10.5	220
P6	50	120	0.0075	12	190

(c) For 13 units test system

Plant No.	Pmin(MW)	Pmax(MW)	ai(\$/MW ²)	bi(\$/MW)	ci(\$)
P1	0	680	0.00028	8.1	550
P2	0	360	0.00056	8.1	309
P3	0	360	0.00056	8.1	307
P4	60	180	0.00324	7.74	240
P5	60	180	0.00324	7.74	240
P6	60	180	0.00324	7.74	240
P7	60	180	0.00324	7.74	240
P8	60	180	0.00324	7.74	240
P9	60	180	0.00324	7.74	240
P10	40	120	0.00284	8.6	126
P11	40	120	0.00284	8.6	126
P12	55	120	0.00284	8.6	126
P13	55	120	0.00284	8.6	126

(d) For 15 units test system

Plant No.	Pmin(MW)	Pmax(MW)	ai(\$/MW ²)	bi(\$/MW)	ci(\$)
P1	150	455	0.000299	10.1	671
P2	150	455	0.000183	10.2	574
P3	20	130	0.001126	8.8	374
P4	20	130	0.001126	8.8	374
P5	150	470	0.000205	10.4	461
P6	135	460	0.000301	10.1	630
P7	135	465	0.000364	9.8	548
P8	60	300	0.000338	11.2	227
P9	25	162	0.000807	11.2	173
P10	25	160	0.001203	10.7	175
P11	20	80	0.003586	10.2	186
P12	20	80	0.005513	9.9	230
P13	25	85	0.000371	13.1	225
P14	15	55	0.001929	12.1	309
P15	15	55	0.004447	12.4	323