

CHAPTER V

SOLUTION BY INTERIOR POINT INITIALIZED PARTICLE SWARM OPTIMIZATION METHOD

5.1. INTRODUCTION

The privatization creates multi-transaction structure in power markets. This structure promotes the short-term operations such as hour-ahead, minute-ahead operations in the power market. All the participants of these market structures are coordinated by some bilateral/multilateral contracts. The optimal power flow (OPF) in the system becomes a challenging task due to multi-transaction structure in power markets as already discussed in Chapter II. As the modern power system have grown with privatization, apart from proper planning and operational control, some efficient optimization techniques are also required for operations of power market. The hybrid or improved optimization techniques provide good solutions in these cases. A variety of hybrid optimization techniques, combining different optimization techniques have been identified and applied for solving the OPF problems. The various combinations of traditional and modern optimization techniques reported have been discussed in Chapter I (Section 1.5) [169-179]. These techniques have some advantages and limitations in the OPF solution processes.

In the previous chapter, the effects of conventional interior point (IP) and heuristic particle swarm optimization (PSO) techniques have been studied for the problem objective of congestion management with social welfare maximization. The obtained results show that the IP method provides a fast convergence, but it does not guarantee the global solution of the problem objective. Also, the PSO provides better optimal solution as compared to IP method. The PSO method gives good global solution for the problem objective; however it requires more iterations and additional computational time as compared to IP method. The present chapter proposes an Interior Point initialized Particle Swarm Optimization (IP-PSO) method. In the proposed approach, the solution starts with the solution obtained by IP and then followed by solutions obtained by PSO. This results into a fast search

mechanism. The accuracy of the proposed IP-PSO based DOPF has been authenticated by comparing the results with that of the centralized OPF (COPF). The results of COPF and DOPF obtained through IP-PSO are also compared with the results of them obtained through IP and PSO separately in Chapter IV. In the present study, the test systems of modified IEEE-30 bus and modified IEEE-118 bus systems which have been used in the previous chapter has been utilized. The test results of proposed IP-PSO provide superior results in terms of global solution, computational time and convergence as compared to PSO method using COPF and DOPF.

5.2. PROPOSED IP-PSO METHOD

In conventional PSO, initially the positions of the particles are randomly selected and thus the initial velocity of the particles depends upon these initial positions. In fact, the selection of initial position of a particle in a swarm is carried out by drawing a uniform random number along each dimension of the problem space. Simultaneously, the broad convergence of search space is ensured by initializing the particles so that they can be distributed throughout the search space as consistently as possible. Sometimes, the PSO yields slower convergence if the initial particles are far away from global optimal solution which may result into failure to reach global solution.

In the proposed IP-PSO method, a new initialization procedure for PSO has been investigated to obtain fast and global convergence of the optimization problem. In this method, the initial particles positions are initialized with some given values which have a good solution for the optimization problem. Then the search mechanism is started from these selected values. Using this technique, the performance of PSO improves. In IP-PSO, the initial particles positions are selected using IP and then PSO is applied for obtaining the global solution. It is a known fact that IP provides fast optimal solutions as compared to other conventional techniques, yet it does not guarantee a global solution. On the other hand, PSO provides improved global solution. With the intention of taking benefits of both the methods, the solution obtained using IP has been used as one of the particles/solutions among the initial random particles of PSO. The advantage of this method is that the problem is initially solved using IP algorithm as discussed in Chapter IV, and subsequently PSO is applied to

search the solution of the actual problem around this point. The PSO generates new search points by adding weighted difference between two search points. The newly generated search points replace the old search points, if the new objective function value is better than the earlier one; else, the old point is retained.

In the entire swarm, the particles are attracted towards the area of highest concentration found by IP and subsequently the best position is personally located by the particles. If $X_i^{Iter (IPM)}$ and $V_i^{Iter (IPM)}$ are the initial position and velocity of the i^{th} particle obtained using IP in the search space, then it can be defined as

$$X_i^{0 (IPM)} = \left(P_{G_{i1}}^{0 (IPM)}, P_{G_{i2}}^{0 (IPM)} \dots \dots \dots P_{G_{iN_G}}^{0 (IPM)}, P_{D_{i1}}^{0 (IPM)}, P_{D_{i2}}^{0 (IPM)} \dots \dots \dots P_{D_{iN_D}}^{0 (IPM)} \right) \quad (5.1)$$

$$V_i^{0 (IPM)} = \left(v_{i1}^{0 (IPM)}, v_{i2}^{0 (IPM)} \dots \dots \dots v_{iN_G}^{0 (IPM)}, v_{i1}^{0 (IPM)}, v_{i2}^{0 (IPM)} \dots \dots \dots v_{iN_D}^{0 (IPM)} \right) \quad (5.2)$$

The acceleration, direction of movement towards the fittest locations, velocity and new position of particles can be obtained using Eq. (4.28) and (4.29) of Chapter IV. Subsequently, the current searching points are modified by using Eqs. (4.40) and (4.43) of Chapter IV.

5.3. IP-PSO IMPLEMENTATION AND ALGORITHM FOR PROBLEM SOLUTION

The mathematical formulations of COPF and DOPF based rescheduling for congestion management with social welfare maximization has been explained in Chapter III, Section 3.4. In case of COPF, all the participants of transactions collectively reschedule their generators and demands for congestion management using IP-PSO. On the other hand, in DOPF, the congestion is managed by rescheduling the generators and demands of transactions individually. In DOPF, each transaction individually reschedules their generations and demands for congestion management using DOPF based congestion management algorithm as discussed in Chapter III, sub-section 3.4.4. The optimization problem of social welfare maximization in the system has been solved using IP-PSO method and obtained results are compared with results of PSO in Chapter IV. In this work, the results of IP for problem objective have been used for initialization of IP-PSO. Therefore, the IP-PSO

solution algorithm is started with IP and followed by PSO algorithm which is as follows:

Step 1) Initialization of algorithm: Set the maximum number of iterations $Iter_{max}$ and formulates the Lagrange functions for u^k and compute Jacobian and Hessian matrix of objective function, equality constraints and inequality constraints. Set the value of tolerance, 10^{-6} for present implementation of the algorithm.

Step 2) Compute the complementary gap in IPM program.

If complementary gap < tolerance, *then* set the output as initial particle of PSO and go to step 7. *Else* go to next step.

Step 3) Compute the perturbation factors in IPM.

Step 4) Solve the correction equation.

Step 5) Perform the ratio test to determine the maximum step length in primal and dual space

Step 6) Update the primal and dual variables and go to step 2.

Step 7) Choose the population size of PSO.

Step 8) Initialize the particles position $X_i^{Iter(IP)}$ by mixing the IP based solution with randomly generated PSO particles within (X_i^{min}, X_i^{max}) .

If $X_i^{Iter(IP)}$ is the initial particle position of i^{th} based on IP solution in the $Iter(IP)^{th}$ iteration (which is consider as starting iteration of PSO search mechanism) in between minimum and maximum search space, *then* it is selected as P_{best} and G_{best} .

Step 9) Set the initial velocities of all particles, $V_i^{Iter(IP)}$ using initial particles position $X_i^{Iter(IP)}$ over the dimensions of (V_i^{min}, V_i^{max}) and obtained the new particles positions according to $X_i^{Iter+1} = X_i^{Iter(IP)} + V_i^{Iter(IP)}$.

Step 10) Test the conditions of equality in both, COPF and DOPF based on the system states represented by individual particles.

If the particle does not satisfy the equality constraints, *then* it is regenerated.

Step 11) Test the inequality constraints of COPF and DOPF formulations and find the fitness values for the particles are determined.

If the particle does not satisfy the fitness requirement, *then* it is regenerated.

Step 12) Evaluate the fitness for each particle according to the objective function of COPF and DOPF. The fitness function includes the total cost functions of active power generations and benefits functions of consumer's demands in a transaction to maximize the welfare with congestion management.

Step 13) Calculate the optimal objective fitness values for each particle.

If the fitness value of each individual is better than the previous P_{best} , *then* current value is set to P_{best} , if this P_{best} is better than the previous G_{best} , *then* value is set to G_{best} ,

If previous G_{best} is better than G_{best} , *then* value is set to G_{best} .

Step 14) If maximum value of fitness function or maximum iteration number is reached, accept the individual generated latest G_{best} as the optimal solution and go to step 17, *else* go to next step.

Step 15) Update the velocity of each particle according to

$$V_i^{Iter+1} = W \times V_i^{Iter} + c_1 rand_1 \times (P_{best}^{Iter} - X_i^{Iter}) + c_2 rand_2 \times (G_{best}^{Iter} - X_i^{Iter})$$

and satisfy the following conditions:

$$\text{If } P_{G_i}^{k,Iter+1} > P_{G_i}^{k,max}, \text{ then } P_{G_i}^{k,Iter+1} = P_{G_i}^{k,max},$$

and

$$\text{If } P_{D_i}^{k,Iter+1} > P_{D_i}^{k,max}, \text{ then } P_{D_i}^{k,Iter+1} = P_{D_i}^{k,max}$$

Step 16) Update new particle positions near the previous values of P_{best} and G_{best}

using $X_i^{Iter+1} = X_i^{Iter} + V_i^{Iter+1}$ and go to step 10.

If $P_{G_i}^{k,Iter+1} > P_{G_i}^{k,max}$, then $P_{G_i}^{k,Iter+1} = P_{G_i}^{k,max}$,

If $P_{G_i}^{k,Iter+1} < P_{G_i}^{k,min}$, then $P_{G_i}^{k,Iter+1} = P_{G_i}^{k,min}$

and

If $P_{D_i}^{k,Iter+1} > P_{D_i}^{k,max}$, then $P_{D_i}^{k,Iter+1} = P_{D_i}^{k,max}$

If $P_{D_i}^{k,Iter+1} < P_{D_i}^{k,min}$, then $P_{D_i}^{k,Iter+1} = P_{D_i}^{k,min}$

Step 17) STOP program.

5.4. TEST RESULTS AND DISCUSSION

The IP-PSO algorithm for problem objective is also implemented in MATLAB on Intel (R), Core 2 Duo and 2.66 GHz processor. The IP-PSO is applied on modified IEEE-30 bus and modified IEEE-118 bus systems with multi-transaction structures to observe the performance of the proposed method over PSO. The problem of congestion management with social welfare is solved by COPF and DOPF based rescheduling of generators and demands of load buses. The problem of congestion management has been observed by seeing the power flows in the congested lines. The problem of loss allocation due to each transaction and their effects on individual welfares and social welfare has also been carried out in the present work. In this section, the results of IP-PSO are also compared with results of PSO to observe the effectiveness of IP-PSO over PSO.

5.4.1. Parameters Selection of Proposed IP-PSO Method

In this work, the proposed IP-PSO method is applied to obtain the solution for the problem objective using COPF and DOPF. In fact, the IP-PSO algorithm is a combination of IP and PSO and requires the selection of parameters of both IP and PSO. The selection criterions of IP and PSO have already been discussed in Chapter IV, Section 4.4.2. In IP-PSO, the parameters used in IP and PSO (in the previous chapter) has been used to solve the problem objective. As given in Chapter IV, the algorithm is started with selection of initialization parameters of IP which are centering

parameter, $\sigma \in (0,1)$; maximum number of iteration, $Iter_{max}$ and tolerance value, ϵ . Then the PSO parameters are initialized by the solution obtained through IP. The generalized inertia weight, W for PSO is considered as 0.5 and the values of positive constants c_1 and c_2 are set 2 for both the test systems. Simultaneously, the constants $rand_1$ and $rand_2$ are selected in the range of 0 and 1. The maximum value of iterations $Iter_{max}$ have been 100 and 200 iterations for modified IEEE-30 bus and modified IEEE-118 bus systems respectively using COPF and DOPF. In this method, the particle size has been varied in the range of 20 to 2000. The particle size is 500 and 1000 for modified IEEE-30 and modified IEEE-118 bus systems respectively.

5.4.2. Case Studies

The following studies have been carried out on test systems to find the effectiveness COPF and DOPF methods using IP-PSO method.

- Case 1:* Initial schedules of generators and demands for COPF and DOPF before congestion management.
- Case 2:* IP-PSO based economic rescheduling using COPF after congestion management.
- Case 3:* IP-PSO based economic rescheduling using DOPF after congestion management.

5.4.2.1. Case 1: Initial Schedules of Generators and Demands for COPF and DOPF before Congestion Management

The initial schedules of generators and demands at load buses in both the test systems for COPF and DOPF are same as in Case 1 of Chapter IV, Section 4.4.3.1. In the present chapter, these schedules are repeated for analyzing the effectiveness of the proposed IP-PSO method on problem objective. The generators and demands schedules of modified IEEE-30 bus and modified IEEE-118 bus systems are given in Tables 5.1 and 5.2 for COPF and Tables 5.6 and 5.7 for DOPF. The power flows in the selected lines due to initial schedules using COPF are given in Table 5.3 for both the systems. Similarly, the power flow in selected lines using DOPF is given in Table 5.8 for modified IEEE-30 bus system and Table 5.9 for modified IEEE-118 bus system.

5.4.2.2. Case 2: IP-PSO based Economic Rescheduling using COPF after Congestion Management

In this case, all the system components constraints are consider in the problem objective. The social welfare of the system is maximized based on COPF. The transfer limits of the lines are taken into account for studying the congestion management. In case of modified IEEE-30 bus system, it is observed that the lines between buses 2-5, 4-12, 6-7 and 25-27 are congested due to initial schedules of generators and demands as given in Table 5.3. These lines have their transfer limits 10, 30, 10 and 10 MW respectively and the power flows are 16.30, -33.80, 17.63, -14.23 MW respectively which causes congestion in the system. Similarly, in modified IEEE-118 bus system, it has been observed that the power flow in line between buses 80-81 with its transfer limit of 30 MW is 39.85 MW. This also indicates congestion in the system (Table 5.3). In the present case, the congestion has been managed by COPF based rescheduling of generators and demands using IP-PSO method.

In COPF, all the generators and demand buses of the system participate in the problem objective and the optimization problem is solved using IP-PSO. The parameters selection of IP-PSO has already been given in Section 5.4.1. After optimal rescheduling of generators and demands of load buses for congestion management in modified IEEE-30 bus and modified IEEE-118 bus systems using COPF, the schedules are given in Tables 5.1 and 5.2 respectively. In multi-transaction system, all the participants (generators and demands) are involved in rescheduling process to achieve the solution of the problem objective. It can be observed that the generators outputs and demands at load buses are incremented or decremented due to rescheduling process which is shown in Figs. 5.1 and 5.2 for both the test systems. The line flows in congested lines are given in Table 5.3 for both the systems. The power flows in other lines are given in Appendix III. It can be observed from the obtained results that the congestion has been effectively managed by IP-PSO based COPF.

Table 5.1

Schedules of generators and demands of load buses in modified IEEE-30 bus system using IP-PSO based COPF approach (MW)

Cases	Case 1	Case 2
	Before Congestion Management Initial Schedule	After Congestion Management IP-PSO
Generator bus	Generation Schedules	
13	38.7394	15.9300
27	21.7845	12.5513
1	19.7458	47.8815
22	4.5327	9.5032
23	12.8305	8.7933
2	15.5271	18.4803
Loss	1.3600	1.3400
Total Generation	113.1600	114.4796
Load bus	Demand Schedules	
3	18.1287	17.4908
4	16.5679	14.6737
7	13.8737	14.3842
12	10.3979	10.3211
15	16.6773	22.8934
17	11.6876	8.3132
24	10.5696	13.7521
26	13.8973	9.9715
Total Demand	111.8000	111.8000

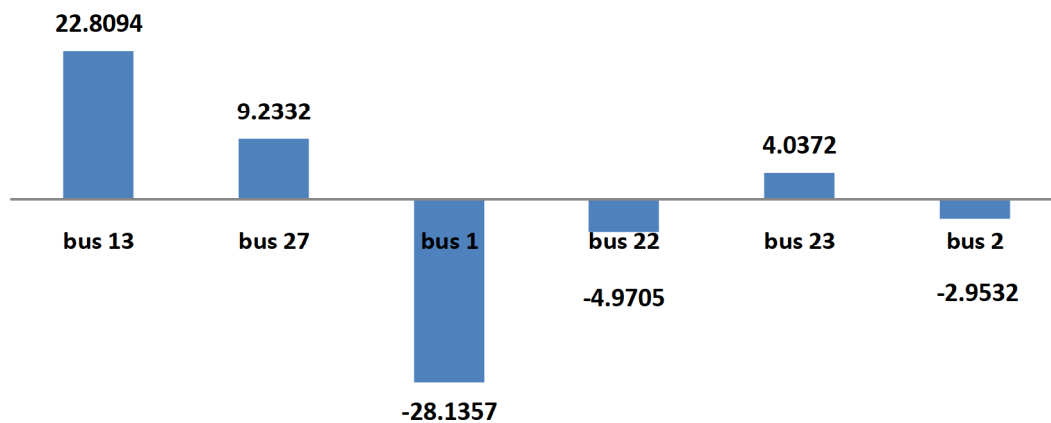
Table 5.2

Schedules of generators and demands at load buses of modified IEEE-118 bus system
IP-PSO based using COPF approach (MW)

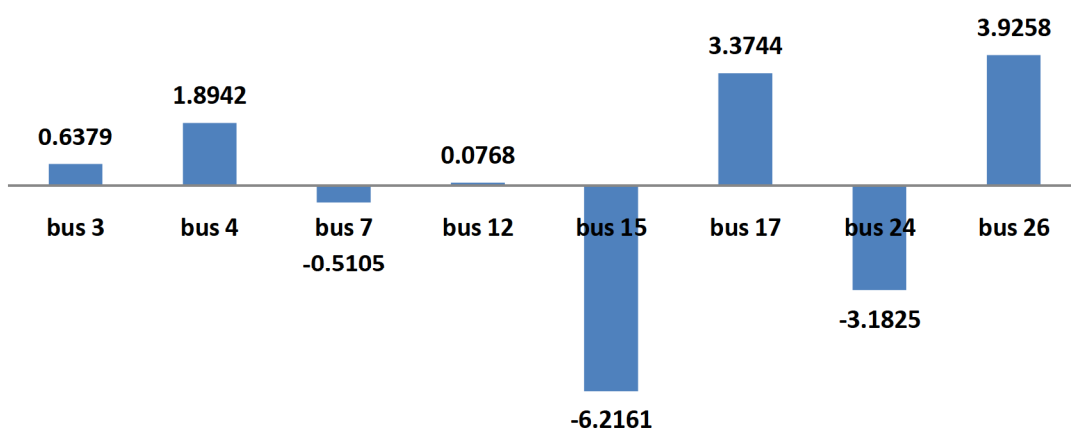
Cases	Case 1	Case 2
	Before Congestion Management	After Congestion Management
	Initial Schedule	IP-PSO
Generator bus	Generation Schedules	
4	101.07	102.9500
6	18.4232	16.6572
15	70.3606	31.5404
24	12.1120	6.3960
34	70.1272	13.8727
40	31.4836	79.5658
62	93.8231	98.3577
70	51.1017	40.5639
85	18.5101	20.8937
90	42.1635	70.6344
107	10.6043	44.1929
112	15.3412	10.9125
Loss	27.6200	29.8000
Total Generation	535.1205	536.5371
Load bus	Demand Schedules	
2	33.9815	23.6849
3	19.8300	31.8941
7	29.7385	17.3291
14	18.8414	21.9277
20	48.1015	32.7843
23	8.8415	25.0927
33	54.9743	27.4821
35	11.7093	35.7271
39	18.3715	27.5328
67	32.5323	24.3824
75	38.0277	44.9241
78	49.2100	72.5436
54	53.8354	48.3527
11	16.7340	18.6352
106	34.8301	41.7204
108	25.9837	6.0927
114	11.9573	7.3941
Total Demands	507.5000	507.5000

Table 5.3
Line flows in congested lines of modified IEEE-30 bus system and modified IEEE-118 bus systems using IP-PSO based COPF

Modified IEEE-30 bus			
Lines	Max. limit	Case 1	
		Before Congestion Management Initial Schedule	After Congestion Management IP-PSO
2-5	10	16.30	8.21
4-12	30	-33.80	27.35
6-7	10	17.63	4.27
25-27	10	-14.23	-7.18
Modified IEEE-118 bus			
80-81	30	39.85	25.09

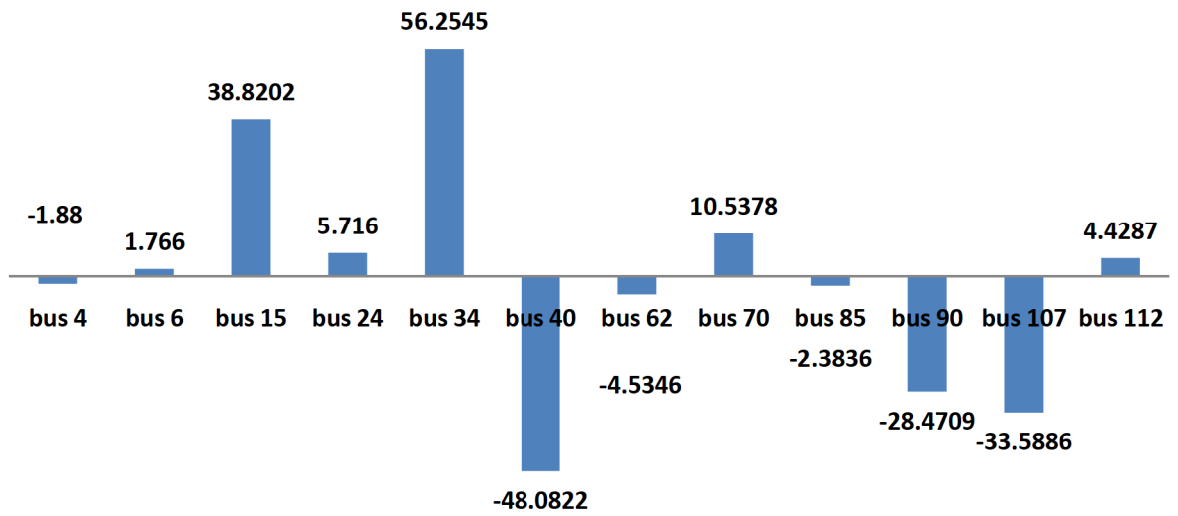


(a) Generation

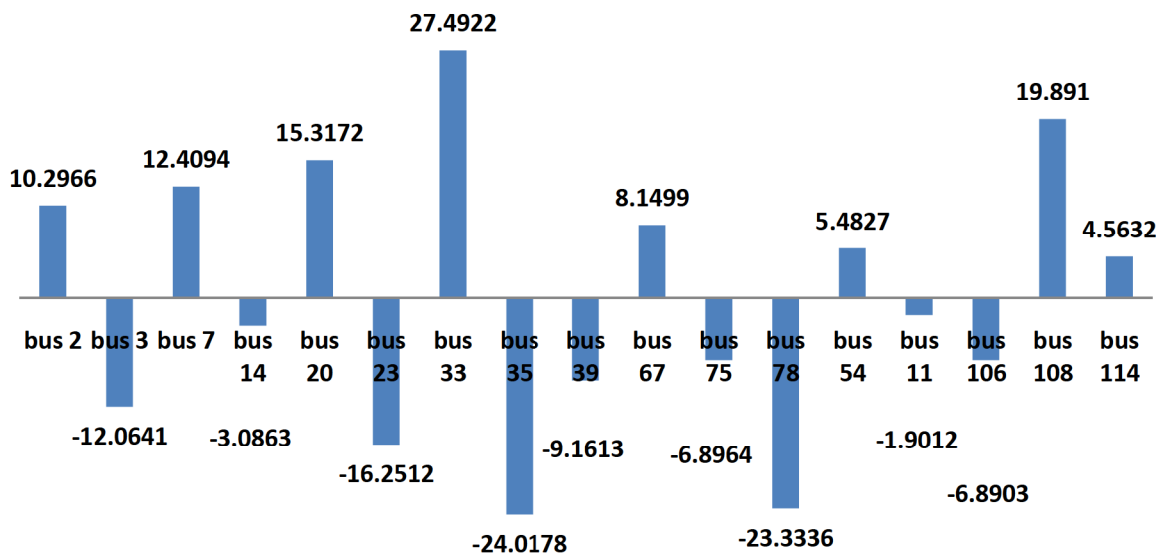


(b) Loads

Fig. 5.1 Increments and decrements of generators and demands levels using IP-PSO based COPF in modified IEEE-30 bus system.



(a) Generation



(b) Loads

Fig. 5.2 Increments and decrements of generators and demands levels using IP-PSO based COPF in modified IEEE-118 bus system.

5.4.2.3. Case 3: IP-PSO based Economic Rescheduling using DOPF after Congestion Management

In case of DOPF, modified IEEE-30 bus and modified IEEE-118 systems are used to observe the performance of IP-PSO. It is observed that the given lines of both the test systems are congested due to initial schedules of generators and loads as given in Tables 5.4 and 5.5. In modified IEEE-30 bus system, the initial power flows are 13.42, 31.00, 11.68 and -14.73 MW for lines between buses 2-5, 4-12, 6-7 and 25-27 respectively. The line flow is -33.14 MW in line between buses 80-81 for modified IEEE-118 bus system. These results show that the lines are overflowing in comparison to their respective transfer limits and this is a cause of congestion in both the systems. In this case, the IP-PSO is used to reschedule the generators and demands of various transactions individually for managing the congestion of both the test systems. The rescheduling is observed by considering the transfer limits of lines in the problem objective. It has been already delineated that the various transactions individually optimize their schedules in DOPF and serial computation technique has been used to obtain the optimal solution for the system. The PTDFs indices are used to observe the congestion in the lines of the system. These sensitivity indices calculations have already been discussed in Chapter III, section 3.4.3. The power flows in the lines due to variations of generation or demand at buses are directly obtained using PTDFs during optimization. In case of DOPF, the congestion in the lines has been managed by DOPF based congestion management algorithm (Chapter III, Section 3.5). In ORA based technique, the RAWM indices for the lines are used for allocating maximum transfer capacity of the lines for each transaction. These indices of lines for both the test systems have been given in Appendix II.

The optimal rescheduled values of generations and demands of loads in various transactions are given in Tables 5.4 and 5.5. The results show that the proposed IP-PSO based DOPF method provides effective solution for the problem objective for both the test systems. The power flows in congested lines due to the transactions in modified IEEE-30 bus and modified IEEE-118 bus systems are is given in Tables 5.6 and 5.7 respectively. The results of these tables show that after IP-PSO based rescheduling of generators and demands of loads, the lines flows in the congested lines within the limits. The power flows

in all the lines for both the test systems using DOPF are given in Appendix III. In DOPF, each transaction optimally reschedules its generators and demands at load buses to manage the congestion in the system under the transfer limits of lines decided using RAWM indices. The results show that the generations and demands values of loads of some buses are increased or decreased in each transaction due to rescheduling. The increments or decrements of generations and demands of transactions are given in Figs. 5.3 and 5.4 for both the test systems. The results of this case study reveal that the proposed IP-PSO method is also an efficient optimization method and provides good solution for DOPF based congestion management.

Table 5.4

Schedules of generators and demands modified IEEE-30 bus system using IP-PSO based DOPF approach

Transactions	Bus	Case 1	Case 3
		Before Congestion Management	After Congestion Management
		Initial	IP-PSO
Generation Schedules (MW)			
T1	13	22.3283	14.3442
	27	23.3709	28.4957
	Total	45.6385	42.8399
	<i>Allocated Loss</i>	<i>0.7600</i>	<i>0.7100</i>
T2	1	26.4731	28.3737
	22	12.2871	12.9627
	Total	37.7602	41.3364
	<i>Allocated Loss</i>	<i>0.6300</i>	<i>0.6700</i>
T3	23	11.4822	20.2486
	2	17.9577	9.2315
	Total	29.4399	29.4801
	<i>Allocated Loss</i>	<i>0.6600</i>	<i>0.4800</i>
Total Generations		113.8386	113.6564
Total Loss		2.0400	1.8600
Demand Schedules (MW)			
T1	3	18.1287	18.9142
	4	17.5674	11.3901
	7	8.9038	10.6792
	Total	44.5999	40.9835
T2	12	10.3953	7.1874
	15	15.6773	24.2084
	17	11.6876	9.9406
	Total	37.7602	41.3364
T3	24	9.5694	16.7831
	26	13.7412	8.8734
	7	6.1293	3.8236
	Total	29.4399	29.4801
Total Loads		111.8000	111.8000

Table 5.5
Schedules of generators and demands of modified IEEE-118 bus system using IP-PSO based DOPF approach

Transactions	bus	Case 1	Case 3
		Before Congestion Management	After Congestion Management
		Initial Schedule	IP-PSO
Generation Schedules (MW)			
T1	4	64.4500	58.3796
	6	43.0187	41.5214
	Total	107.4687	99.9010
	<i>Allocated Loss</i>	<i>5.6000</i>	<i>4.6300</i>
T2	15	41.2114	41.0108
	24	20.2011	18.0322
	Total	61.4125	59.0430
	<i>Allocated Loss</i>	<i>3.6100</i>	<i>3.4600</i>
T3	34	12.7687	9.8005
	40	65.9305	73.9001
	Total	78.6992	83.7006
	<i>Allocated Loss</i>	<i>6.4300</i>	<i>6.9900</i>
T4	62	86.0489	96.8299
	70	34.0461	43.9483
	Total	120.095	140.7782
	<i>Allocated Loss</i>	<i>8.1900</i>	<i>9.4700</i>
T5	85	53.9638	28.5167
	90	41.487	66.3876
	Total	95.4508	94.9043
	<i>Allocated Loss</i>	<i>4.8900</i>	<i>4.5000</i>
T6	107	51.9772	32.5189
	112	22.9027	28.8227
	Total	74.8799	61.3416
	<i>Allocated Loss</i>	<i>3.9100</i>	<i>3.1000</i>
Total Generations		540.1154	539.6687
Total Loss		32.6200	32.1700
Demand Schedules (MW)			
T1	2	31.2679	20.5369
	3	18.2631	30.4341
	7	27.4316	16.7613
	Total	76.9626	67.7323
T2	14	21.2443	26.3456
	20	27.2364	12.3678
	23	12.9318	20.3296
	Total	61.4125	59.0430
T3	33	51.2348	23.5987
	35	11.1349	33.2678
	39	16.3295	26.8341
	Total	78.6992	83.7006
T4	67	31.5691	26.4196
	75	38.2692	42.3941
	78	50.2567	71.9645
	Total	120.095	140.7782
T5	54	54.293	44.3964
	20	23.8614	27.5421
	11	17.2964	22.9658
	Total	95.4508	94.9043
T6	106	35.9671	42.6843
	108	26.3491	7.9641
	114	12.5637	10.6932
	Total	74.8799	61.3416
Total Demands		507.5000	507.5000

Table 5.6

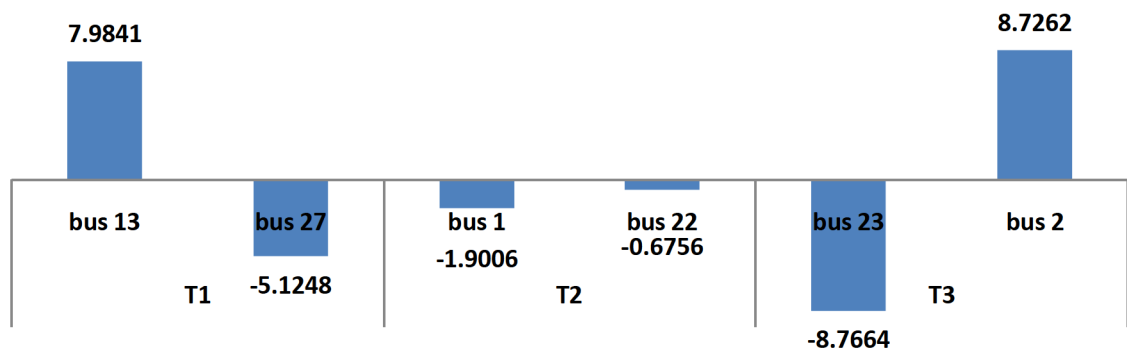
Line flows in selected lines of modified IEEE-30 bus systems using IP-PSO based DOPF approach

Lines	Max. limit	Initial Flows				IP-PSO			
		T1	T2	T3	Total	T1	T2	T3	Total
2-5	10	-17.04	-14.09	44.55	13.42	-8.04	-6.65	21.02	6.33
4-12	30	0.94	25.99	4.07	31.00	0.66	18.27	2.86	21.79
6-7	10	1.52	5.61	4.56	11.68	1.08	4.00	3.25	8.33
25-27	10	-21.80	-13.85	20.92	-14.73	-9.07	-5.76	8.70	-6.13

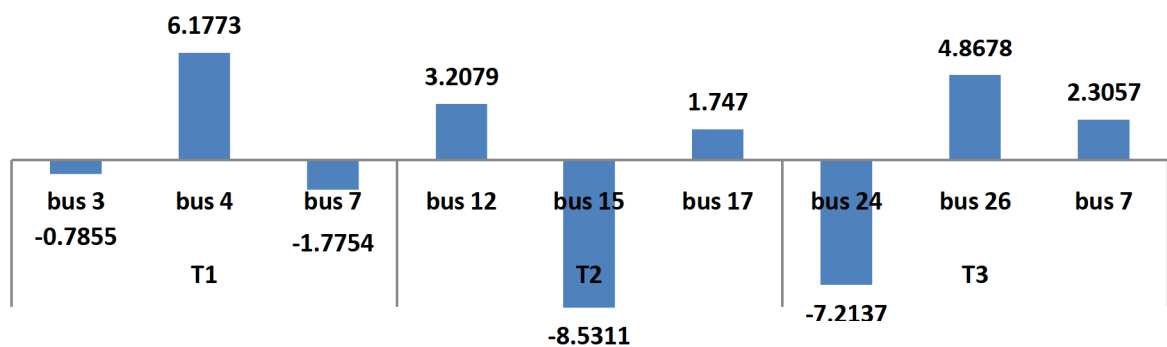
Table 5.7

Line flows in selected line 80-81 of modified IEEE-118 bus systems using IP-PSO based DOPF approach

Maximum Limit 30 MW	T1	T2	T3	T4	T5	T6	Total
Initial Flows	0.52	-33.08	-0.59	0.38	-0.12	-0.25	-33.14
IP-PSO	0.33	-20.97	-0.38	0.24	-0.07	-0.16	-21.01

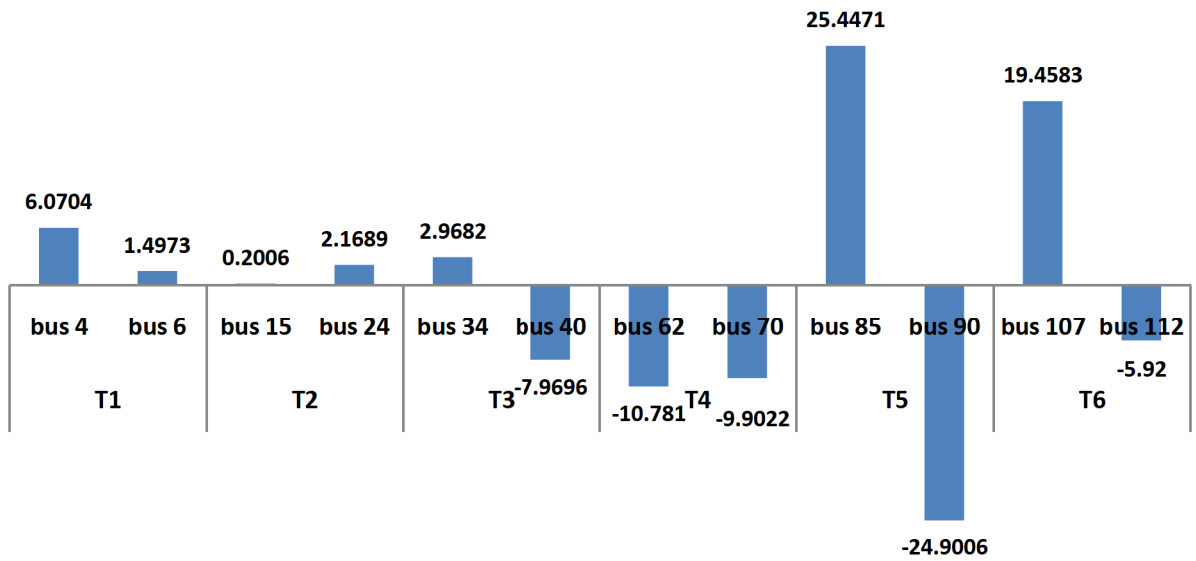


(a) Generation

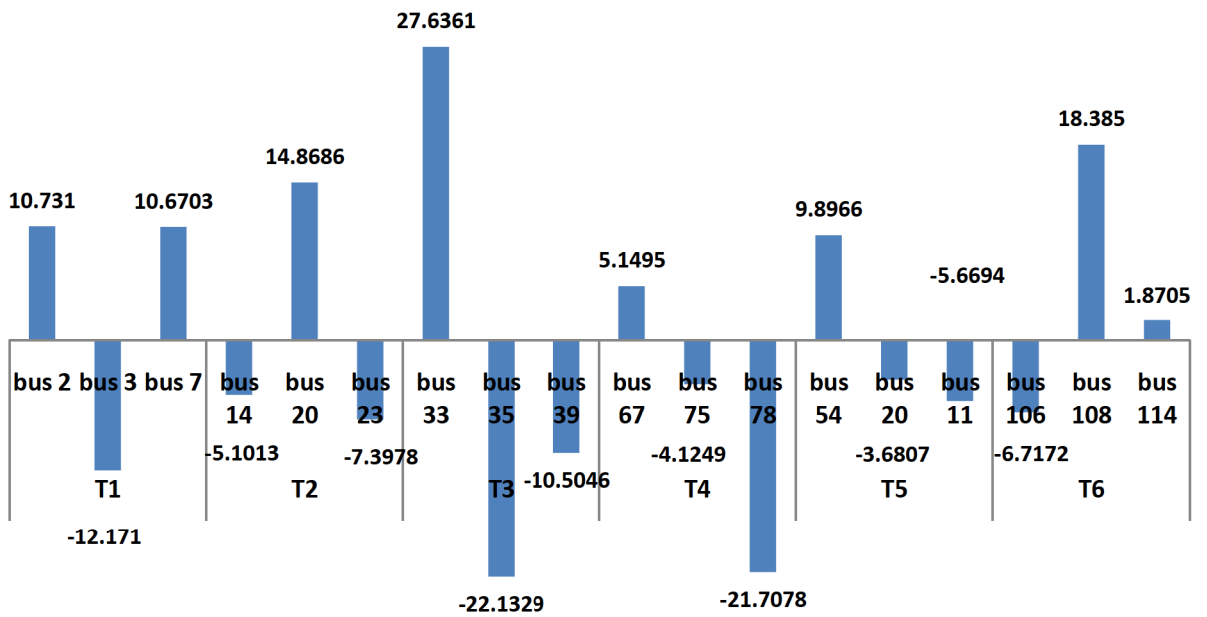


(b) Loads

Fig. 5.3 Increments and decrements of generators and demands levels using IP-PSO based DOPF in modified IEEE-30 bus system.



(a) Generation



(b) Loads

Fig 5.4 Increments and decrements of generators and demands levels using IP-PSO based DOPF in modified IEEE-118 bus system.

5.4.3. Analysis of Social Welfares for COPF and DOPF using IP-PSO

The social welfare of the system depends upon the cost of generations and benefits of demands of the load buses. After congestion management, the generators and loads are rescheduled. Thus, the obtained social welfare is also affected by COPF and DOPF based rescheduling using IP-PSO. The social welfares obtained for modified IEEE-30 bus and IEEE-118 bus systems using COPF are given in Tables 5.8 and 5.9. In addition, the social welfares obtained for modified IEEE-30 bus and IEEE-118 bus systems using DOPF are given in Tables 5.10 and 5.11. The results of these tables show that the DOPF provides more social welfare as compared to COPF for both the test systems. The results show that the social welfare of both the test systems reduces after the application of COPF and DOPF based congestion management. It has also been observed that welfares of transactions are changed after the DOPF based congestion management for both the test systems and social welfares obtained in modified IEEE-30 bus system for COPF and DOPF using IP-PSO based congestion management are 719.8432 \$/hr and 903.2448 \$/hr respectively. In modified IEEE-118 bus system, the social welfare using COPF and DOPF approaches are 1642.1949 \$/hr and 2686.6992 \$/hr respectively. These values of social welfares are less as compared to Case 1. However, the IP-PSO based DOPF provides more social welfare as compared to COPF for both the test systems. The allocation of costs of losses incurred due to transactions is also carried out in this study.

Table 5.8

Social welfare of modified IEEE-30 bus system using IP-PSO based COPF approach
(\$/hr)

Cases	Case 1	Case 2
	Before Congestion Management	After Congestion Management
	Initial	IP-PSO
Total Generation Cost	2836.2213	3031.0454
Total Demand Benefit	3735.4531	3750.8886
Social Welfare	899.2317	719.8432

Table 5.9

Social welfare of modified IEEE-118 bus system using IP-PSO based COPF approach
(\$/hr)

Cases	Case 1	Case 2
	Before Congestion Management	After Congestion Management
	Initial	IP-PSO
Total Generation Cost	21759.2526	21834.0097
Total Demand Benefit	23481.4743	23476.2047
Social Welfare	1722.2217	1642.1949

Table 5.10

Social welfare of modified IEEE-30 bus system using IP-PSO based DOPF approach
(\$/hr)

Transactions	Case 1	Case 2
	Before Congestion Management	After Congestion Management
	Initial	IP-PSO
T1 Generation Cost	999.2363	899.1506
T1 Demand Benefit	1440.5419	1377.5040
T1 Welfare	441.3056	478.3534
T2 Generation Cost	1022.7973	1103.4792
T2 Demand Benefit	1319.1768	1427.4151
T2 Welfare	296.3795	323.9359
T3 Generation Cost	806.6559	866.8015
T3 Demand Benefit	989.0635	967.7570
T3 Welfare	182.4076	100.9555
Total Generation Cost	2828.6896	2869.4313
Total Demand Benefit	3748.7823	3772.6761
Social Welfare	920.0927	903.2448

Table 5.11

Social welfare of modified IEEE-118 bus system using IP-PSO based DOPF approach
(\$/hr)

Transactions	Case 1		Case 2	
	Before Congestion Management		After Congestion Management	
	Initial		IP-PSO	
T1	Generation Cost	3363.1226		2944.2004
	Demand Benefit	3617.7549		3173.0205
	Welfare	254.6323		228.8201
T2	Generation Cost	2477.5646		2381.7905
	Demand Benefit	2968.4127		2862.0651
	Welfare	490.8481		480.2746
T3	Generation Cost	3193.0667		3403.5967
	Demand Benefit	3761.7253		4013.9308
	Welfare	568.6586		610.3341
T4	Generation Cost	4889.4355		5744.2028
	Demand Benefit	5376.0021		6269.2061
	Welfare	486.5666		525.0033
T5	Generation Cost	3864.3646		3848.3772
	Demand Benefit	4235.7886		4260.6909
	Welfare	371.4240		412.3138
T6	Generation Cost	3027.4576		2472.5463
	Demand Benefit	3530.4919		2902.4996
	Welfare	503.0343		429.9533
	Total Generation Cost	20815.0117		20794.7139
	Total Demand Benefit	23490.1755		23481.4130
	Social Welfare	2675.1638		2686.6992

5.4.4. Computational Times for COPF and DOPF using IP-PSO

The proposed IP-PSO has been used to obtain fast global solution for the problem objective for COPF and DOPF. The convergence of COPF and DOPF are shown in Figs. 5.5 and 5.6 for both the test systems. It has been observed from the figures that the numbers of iterations required for the convergence of problem solution using COPF are 17 and 67 for IEEE-30 bus and modified IEEE-118 bus systems respectively. The DOPF requires 23 and 97 iterations for modified IEEE-30 bus and modified IEEE-118 bus systems respectively. The computation times for modified IEEE-30 bus system and modified IEEE-118 using COPF are 197.66 sec and 201.31 sec respectively. On the other hand, this is 512.13 sec and 611.21 sec for modified IEEE-30 bus system and modified IEEE-118 respectively using DOPF.

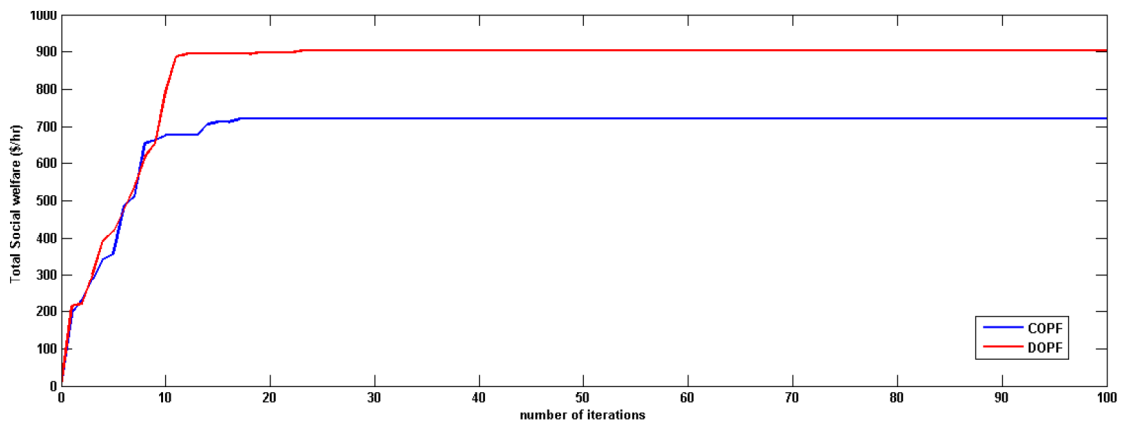


Fig.5.5 Convergence of COPF and DOPF using IP-PSO for modified IEEE-30 bus system.

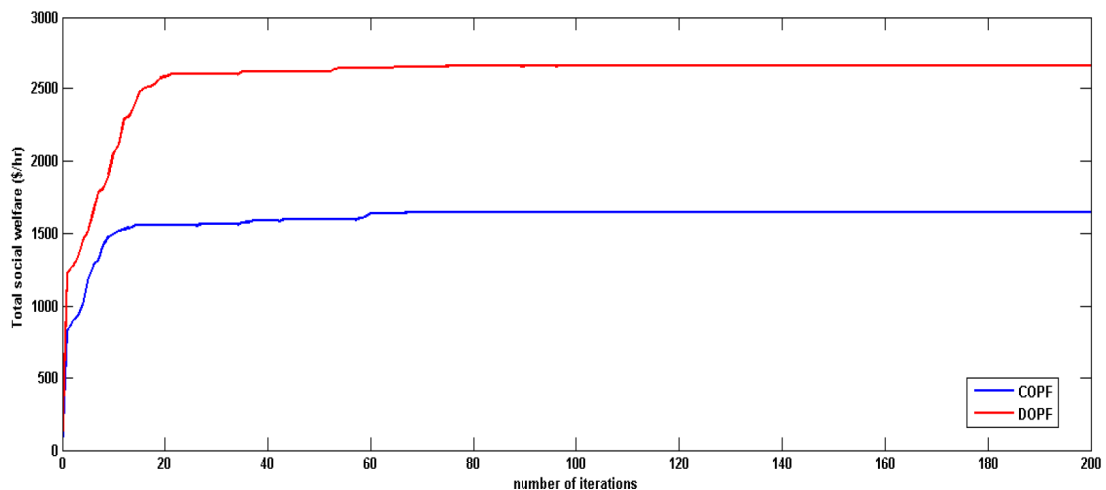


Fig.5.6 Convergence of COPF and DOPF using IP-PSO for modified IEEE-118 bus system.

5.5. COMPARISON OF IP-PSO AND PSO METHODS

In the present work, to observe the effectiveness and performance of IP-PSO over PSO using COPF and DOPF, the results of IP-PSO have been compared with the results of PSO obtained in Chapter IV. Subsequently, the analytical comparison of social welfare and computation behaviour of these methods are discussed for modified IEEE-30 bus and modified IEEE-118 bus systems. This analysis shows that the IP-PSO provides more effective and fast convergence compared to PSO.

5.5.1. Comparison of Social Welfares using IP-PSO and PSO

The comparisons of social welfare obtained by transactions using PSO and IP-PSO based COPF and DOPF for the modified IEEE-30 bus and modified IEEE-118 bus systems are shown in Figs. 5.7 and 5.8 respectively. The results of PSO obtained in Chapter IV are used in the comparison. Figs. 5.7 and 5.9 shows that the IP-PSO based DOPF provide more social welfare as compared to PSO for both the test systems. The social welfares using of IP-PSO based DOPF for modified IEEE-30 bus system is 903.2448 \$/hr and for modified IEEE 118 bus system it is 2686.6992 \$/hr, whereas for PSO based DOPF for modified IEEE 30 bus system it is 901.8887 \$/hr and for modified IEEE-118 bus system it is 2656.6777 \$/hr. These results show that the IP-PSO based DOPF gives more social welfare as compared to PSO based DOPF. It has also been observed that the total social welfare obtained using IP-PSO without loss consideration in modified IEEE-118 bus system is 2855.0356 \$/hr and 2897.4972 \$/hr for COPF and DOPF respectively. On the other hand in [102] the obtained total social welfare is 2852.1 \$/hr and 2881.3 \$/hr for COPF and DOPF. This ascertains that the result obtained using IP-PSO technique provides higher social welfare as compared to results reported in [102] for modified IEEE-118 bus system.

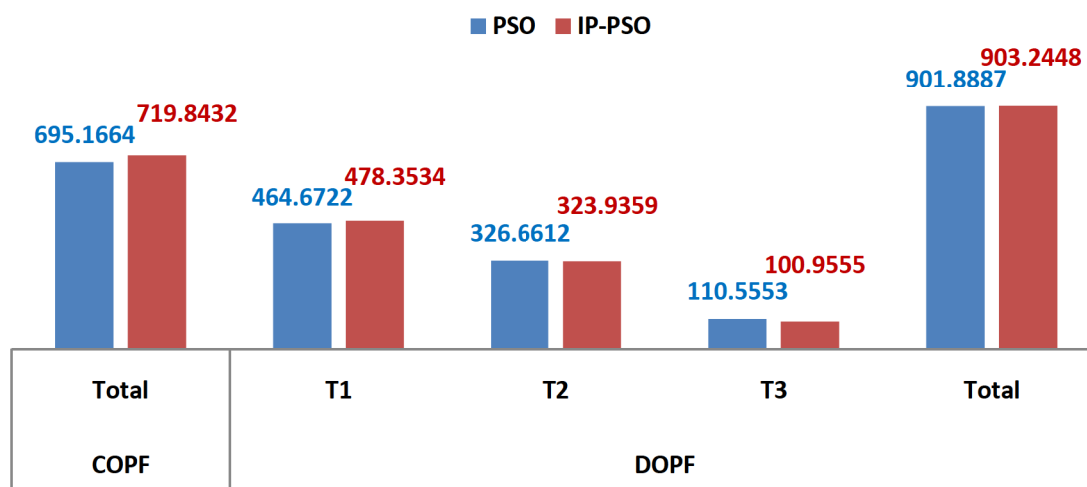


Fig. 5.7 Comparisons of welfares in modified IEEE-30 bus system using IP-PSO and PSO based COPF and DOPF.

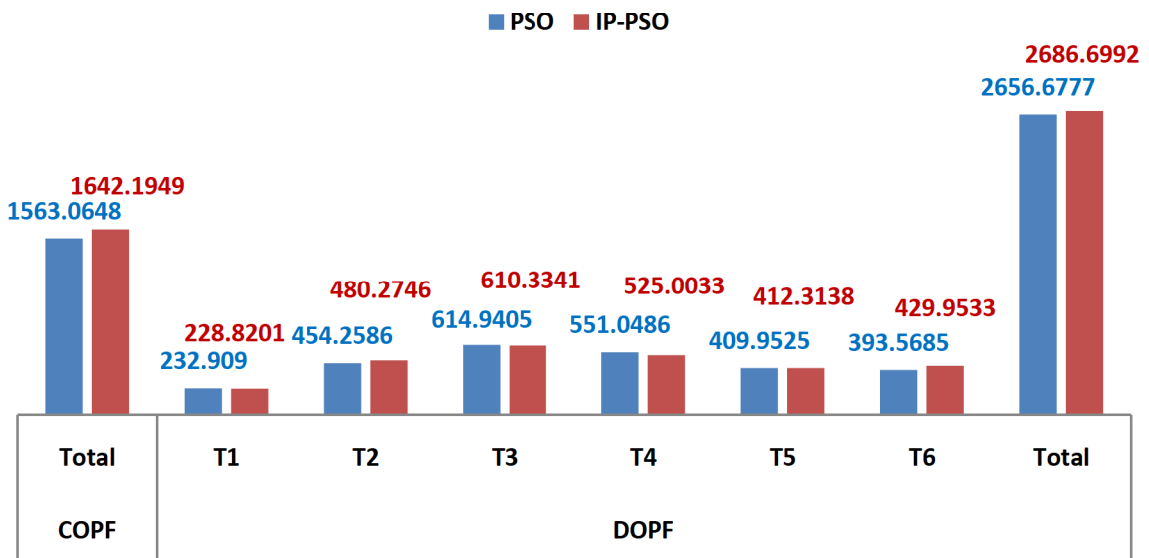


Fig. 5.8 Comparisons of welfares in modified IEEE-118 bus system using IP-PSO and PSO based COPF and DOPF.

5.5.2. Comparison of Computational Times for IP-PSO and PSO

This section presents the comparison of computational behaviour of PSO and IP-PSO methods for COPF and DOPF. The convergence of PSO and IP-PSO based solution using COPF and DOPF for both the test systems are shown in Figs. 5.9 and 5.10 respectively. The computational times and number of iteration required for the solution using both the approaches for modified IEEE-30 bus and modified IEEE-118 bus systems are given in Table 5.12. It can be observed from the test results that IP-PSO converges fast and the solution obtained by this technique is superior as compared to PSO. The results obtained using IP-PSO provides faster convergence as compared to the reported work of ref. [102] for modified IEEE-118 bus system. The exact computational time could not be compared due to different computational platforms in present method and method of reported in ref. [102]. However, on the basis of computational complexities of IP-PSO and that of method in ref. [102], it can be safely stated that the proposed IP-PSO method would produce faster result.

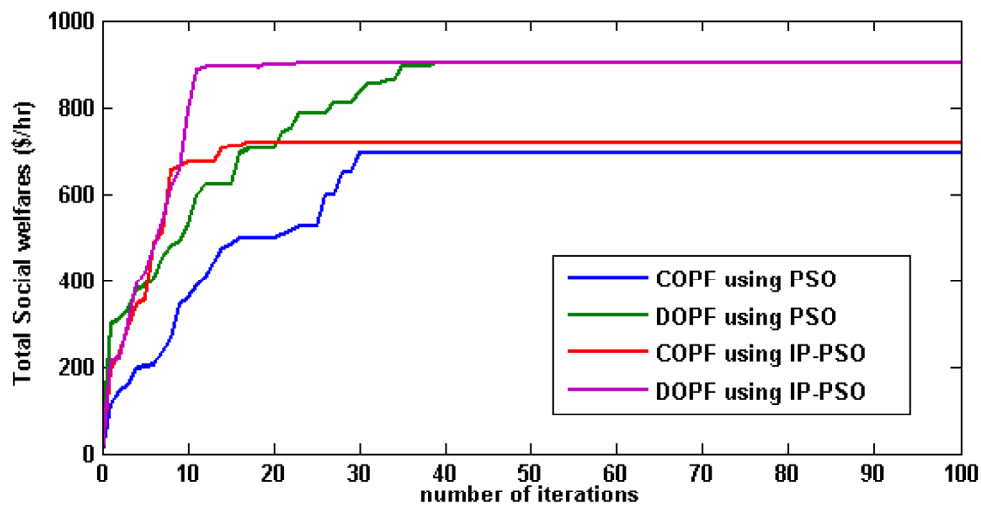


Fig.5.9 Comparison of convergence of COPF and DOPF using PSO and IP-PSO for modified IEEE-30 bus system.

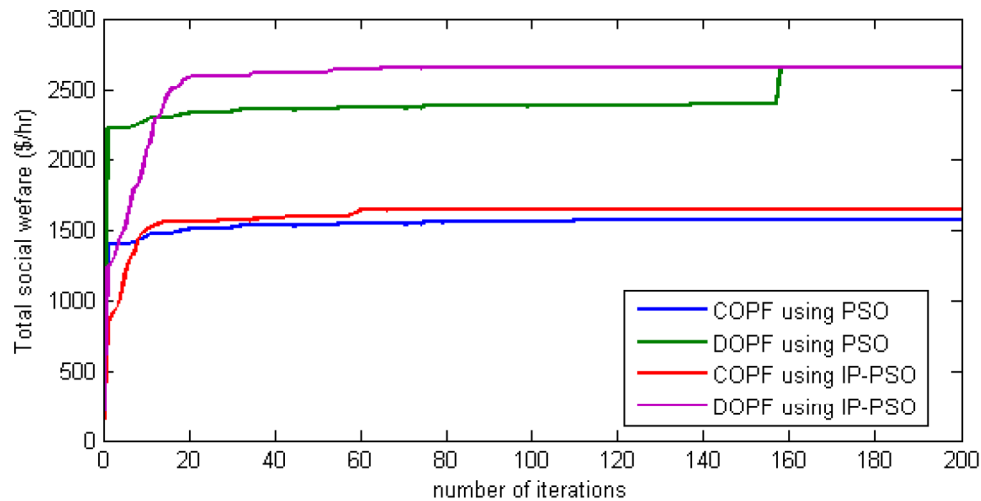


Fig.5.10 Comparison of convergence of COPF and DOPF using PSO and IP-PSO for modified IEEE-118 bus system.

Table 5.12

Computational times and number of iterations

		COPF	
System	Technique	Number of Iterations	CPU Time (s.)
IEEE-30 bus	PSO	34	323.16
	IP-PSO	17	197.66
IEEE-118 bus	PSO	110	358.19
	IP-PSO	67	201.31
DOPF (Series Computation)			
IEEE-30 bus	PSO	39	841.67
	IP-PSO	23	512.13
IEEE-118 bus	PSO	158	892.57
	IP-PSO	97	611.21

5.6. CONCLUSION

This chapter proposes a hybrid IP-PSO method to solve the problem objective of congestion management with social welfare using COPF and DOPF. The solution of optimization problem has been obtained by optimal rescheduling of generators and demands using COPF and DOPF based on proposed IP-PSO method. This method has been applied in modified IEEE-30 bus and modified IEEE-118 bus systems to observe the effectiveness of the solution methodology. In the present chapter, the performance of IP-PSO has also been compared with PSO. This comparison shows that the IP-PSO provides superior results as compared to PSO. The social welfare obtained by IP-PSO is more as compared to PSO and also this requires less computational time for both the approaches (COPF and DOPF).