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Implement the Particle Swarm Optimization Algorithm with Optimum Location of Capacitor Sizing to Control the Reactive Power on Interconnected Bus System

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Abstract

This paper presents an efficient and reliable Particle Swarm Optimization (PSO) algorithm for solving Reactive power optimization including voltage deviation in Power System. Voltage deviation is the capability of a power system to maintain up to standard voltages at all buses in the system under standard conditions and under being subjected to a disturbance. Reactive power optimization is a complex combinatorial programming problem that reduces power loses and improves voltage profiles in a power system. To overcome this shortcoming, a multi objective PSO is proposed and applied in reactive power optimization on IEEE-30 bus, Here the RPO problem has been formulated as a constrained multi-objective optimization problem by combining of two objective functions (real power loss and voltage profile improvement) linearly shows that the PSO more effectively solve the reactive power optimization problem in power system.

Keywords: Graphical User Interface Tool, Multiobjective Particle Swarm Optimization, Reactive Power – Pso –Ieee 30 Bus –Sizing of Capacitor, Reactive Power Optimization, Voltage Deviation and Loss Minimization

1. Introduction

Electric transmission system is the intermediary stage in the exchange of electrical energy from the essential generating station to the customary and dissemination system is the last stage in conveyance of energy to the customer by the utility. With the approach of setting up of expansive pit begin thermal power plants and atomic power plants the electric transmission and appropriation systems are getting to be troublesome. The stream of reactive power in an electric system produces supplementary power thrashing and expands the voltage drop. In India, group of all states, in 2007 the specialized and non-specialized loss was accounted as 24% of the total input energy. The shunt capacitors are productive apparatuses in

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power and energy losses diminish. These are typically utilized as a part of power system for reactive power pay. They diminish the transmission and circulation losses and enhance the general influence variable of the system whose outcome is found regarding higher continues in income metering. A roundabout advantage of capacitor arrangement is seen as a diminishing in the measure of MVAR transport required at prevalent voltage levels on transmission system. They additionally help in keeping up the voltage profile inside acceptable cutoff points[1].The measure of preferred standpoint that can be accomplished by setting the capacitors relying upon how much and how the capacitors are situated in the conveyance and transmission systems. The issue of finding and estimating shunt capacitors in the power system has been a test for power system organizers and analysts. By and large, capacitor banks are introduced in power systems for voltage support, reactive power control, power element revision, system limit increment, loss reduction and charging charge diminishment. This procedure includes deciding capacitor size, area, control technique, and association type (Wye or Delta). Majority of loads in force systems use reactive power, to control the reactive power in power system by utilizing Synchronous condenser, Static Var Compensator (SVC), and capacitor[2]. Om Prakash Mahela Devendra Mittl and Lalit goyal[4] introduced about different ideal capacitor position methods on transmission and appropriations lines for line losses decrease and improvement of voltage solidness in the influence system[3]. A. A. E. Shammah, Ahmed M. Azmy and A. About EIEla[5] presented proposed a technique to solve the optimal placement and sizing problem of fixed capacitor banks in radial distribution systems in smart grid environment.[6] In the middle of this equipment, capacitor has the slowest and stepped speed reaction while establishment and working expenses of capacitor are fundamentally lower than the other reactive power sources. Inspite of reactive power control, specialized points of confinement of capacitor are recognizably lower than the other reactive power sources.[7] Despite the fact that is specialized in cut off points of capacitors, a capacitor may maybe be a superior alternative to create reactive power in any event for the financial compensation.[8] The best area and size of capacitor issue has been illuminated by numerous systems. In this work, a strategy is accessible to reduce the reactive and active power losses by having a planned and controlled streamlining approach[9]. The improvement issue is planned and enhanced utilizing molecule swarm streamlining algorithm. An IEEE 30 bus system[10] is considered as experiment and the wellness of the proposed methodology is approved. The PSO algorithm gives the ideal size and area of the capacitor, the proposed methodology is additionally concentrated on for reproduced reactive load increase.

2. Problem Formulation

Best control of reactive power is an enhancement issue which is troublesome having connections between vast quantities of parameters in the distribution systems. The reactive power can be controlled by numerous parameters like reactive power contribution of the generator bus voltages, fluctuating the tap proportions of the transformers and so forth., conspiring the reactive power output of shunt compensators like capacitors take an interest an exceptionally dynamic part in the mischievous the power loss. In this work a hindered streamlining methodology is taken after to diminish the active power loss by advancing the capacitor worth to abatement influence losses. Such a controlled enhancement methodology is unsurprising to give better results in procurement of union of the arrangement furthermore in perspective to loss minimization by getting the multifaceted landscape of reactive power control.

The constraints take in an active and reactive power flow in slack and load buses. The inequality constraint includes reactive power generation limit for each generator bus and voltage magnitude limit for every bus. The optimization problem can be formulated to solve the fitness function as describe below.

$$\text{Min} \sum_{k\epsilon N} P_{kloss} = \sum_{k\epsilon N} g_k \left(v_i^2 + v_j^2 - 2\, v_i v_j \cos\theta_{ij}\right) \qquad (1)$$

Where

$k = (i, j)$; $i\epsilon N$ (Total number of buses)

$j\epsilon N$, (number of buses adjustment to bus i, including bus i)

$\sum_{k\epsilon N} P_{kloss}$ = Total active power losses in the transmission system

g_k= conductance of branch k (pu)

v_i, v_j = voltage magnitude (pu) of bus i and j respectively

θ_{ij} = load angle difference between bus I and j(rad)

The Equality constraints are defined as follows
Active power flow balance equations at all buses excluding slack bus

$$P_{gi} - P_{di} - v_i (g_{ij}\cos\theta_{ij} + B_{ij} \sin\theta_{ij}) = 0 \quad (2)$$

Reactive power flow balance equations at all PQ buses (load buses)

$$Q_{gi} - Q_{di} - v_i \Sigma_{j\epsilon N} v_j(g_{ij}\sin\theta_{ij} + B_{ij} \cos\theta_{ij} = 0 \quad (3)$$

The inequality constraints are defined as mentioned below
Reactive power generation limit for each generator bus
$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}$, iϵN

Voltage magnitude limit for each bus

$v_i^{min} \leq v_i \leq v_i^{max}$, i$\epsilon$N

3. Particle Swarm Optimization (PSO)

PSO is a quick, easy and well-organized population-based optimization method which was proposed by Eberhart and Kennedy. A populace of particles is initially haphazardly produced. Every molecule speaks to a potential solution and has a position spoke to by a spot vector. A swarm of particles move from start to finish the issue space, particle represented by a velocity vector. At every time step, a capacity speaking to a quality measure is figured by utilizing as information. Every molecule monitors its own best position, which is connected with the best wellness it has accomplished so far in a vector.

The implementation of PSO in this work is described below in fig.1. with the help of a flow chart.

Each particle update its position based upon its own best position, global best position among particles and its previous velocity vector according to the following equations:

$$V_i^{k+1} = w * v_i^k + c_1 * r_1 * (p_{besti} - X_i^k) + c_2 * r_2 * (g_{best} - X_i^k) \quad (4)$$

$$X_i^{k+1} = X_i^k + \chi * v_i^{k+1} \quad (5)$$

Where

V_i^{k+1}: The velocity of i^{th} particle at $(k+1)^{th}$ iteration

w=Inertia weight of the particle

v_i^k: The velocity of i^{th} particle at $(k+1)^{th}$ iteration

c_1, c2= Positive constants having values between [0, 2.6]

r_1, r_2: Randomly generated numbers between [0, 1]

p_{besti} : The best position of the i^{th}particle obtained based upon its own experience

g_{best} : Global best position of the particle in the population

x_i^{k+1}: The position of i^{th} particle at $(k+1)^{th}$ iteration

x_i^k : The position of i^{th} particle at k^{th} iteration

χ: Construction factor, It may help assure convergence.

Suitable selection of inertia weight w provides good balance between global and local explorations.

$$w = w_{max} - \frac{\mathbf{Wmax - Wmin}}{\mathbf{iter\ max}} * iter$$

Where, w_{max} is the value of inertial weight at the beginning of iterations,

w_{min} is the value of inertial weight at the end of iterations,

iter is the current iteration number

$iter_{max}$ is the maximum number of iterations

4. Graphical User Interface

In order to make the research work delivered in the form of a tool, a GUI is made. The goal of the GUI can be recorded as below:

1. To be a powerful Research tool that can be utilized to examine the appropriateness of the proposed optimization approach on various test bus system and constant system.
2. To give generalized and characterized structure to giving input and analyzing different PSO parameters.
3. To give the user flexibilities and usability.

The Graphical user has the degree for inputting different Particle swarm streamlining parameters. These parameters are particle populace, number of cycles and particle speed (Both forward and switch heading). Once the appropriate Particle swarm advancement parameter is chosen utilizing the parameters load push catch, the client can include these parameters for succeeding particle swarm optimization. By operation pre optimization instrument, ideal force stream algorithm can make known the measure of real power loss and reactive power loss before improvement. By tapping the Particle swarm enhancement catch, the user can start the system of proposed optimization and the outcomes are organized. The arranged results counting real and reactive power losses post enhancement and the variety amongst pre and post streamlining. It likewise gives the capacitor values that ought to be included request to understand that measure of loss of real and reactive power. A general examination of cost looking at the expense of capacitor fitting and cost spared by falling the force misfortunes is likewise given. This gives a decent marker towards the measure of capital that might be contributed and spared. A plot which depicts the decrease of real power in the due course of optimization is also provided.

5. Case Study and Results

The anticipated methodology is coded utilizing Mat lab Version 12 and Mat Power Version 5 is utilized to run the best power stream solver utilizing Newton –Rap son technique. The emphasis settings for PSO incorporate 100 most extreme quantities of emphases, with increasing speed steady of 2 and 2.6 and maximum and minimum inertia weights at 1 and 0.2 separately. The most maximum and minimum speed of particles is settled at 0.1 and - 0.1 separately. The reenactments are completed in a system having center 2 Duo processor shrouding a velocity of 2GHz with a RAM of 2 GB.

An IEEE 30 (Appendix-1) transport framework is purposeful to accept the proposed approach and the outcomes thought. The IEEE-30 bus system has 6 generator transports, 24 load buses and 41 transmission lines of which four branches are (6-9), (6-10), (4-12) and (28-27) are with the tap setting transformers. The lower voltage extent limits at all buss are 0.95 p.u. what's more, as far as possible are 1.1 for all the PV buss. As far as possible is set at 1.05 p.u for all the PQ buss and the reference bus. The system has absolute generation limit of 900 MW with a dynamic heap of 283MW and reactive load of 126.20 MVAR. To check the validity of the methodology the shunts are at first expelled from the standard test bus systems. The outcomes introduced are the best results accomplished after 25 numbers of keeps running for every case.

The results of the base case before optimization are given below in Table1.

The reactive load is enhanced by 20 percent consistently at all the exhibited reactive loads. Presently the active load stand at 283 MW and reactive load of the total system is 151.4. In development of BUS Data, Active and Reactive force of one Bus injection to another Bus injection and active and reactive power losses under such load increment before molecule swarm enhancement are arranged below in Table 2.

The reactive load is expanded by 20 percent consistently at all the current reactive loads. Presently active load remains at 283 MW and reactive load of the total system is 151.4. Details of Bus Data, active and Reactive power of one Bus injection to another Bus infusion and the active and reactive power losses under such load increment after PSO are arranged below in Table 3:

The optimization algorithm has placed three shunts in buses 3, 10 and 24 with values as given below in Table 4.

The active and reactive power losses in the system are tabulated below in Table 5:

The plot of active power loss over the quantity of cycles is delineated below in Figure 2. It can be watched that there is a huge lessening in the power loss as the optimization algorithm progress.

The consolidated result of the proposed method is given below in Table 6. It can be observed that there is a striking Net sparing and cost of capacitors after optimization.

It can be seen from the outcomes the improvement comes about a critical lessening in both active and reactive power loss. At the point when the reactive load is expanded by 20 percent, it can be seen that prior to optimization and suitable allocation and sizing capacitors there is 1.1 percentage increase in active power loss and 1.8 percent expansion in reactive power loss. The optimization technique results in the lessening of dynamic force misfortune by 9.20 percent and reactive power loss by 5.8 percent for the base case. When the optimization is employed for when the reactive power is increased by 20 percent, it can be observed that there is no increase in losses and on the other hand the active power reduces by 5.5 percent and the reactive power by 2.5 percent.

6. Results and Main Block diagrams

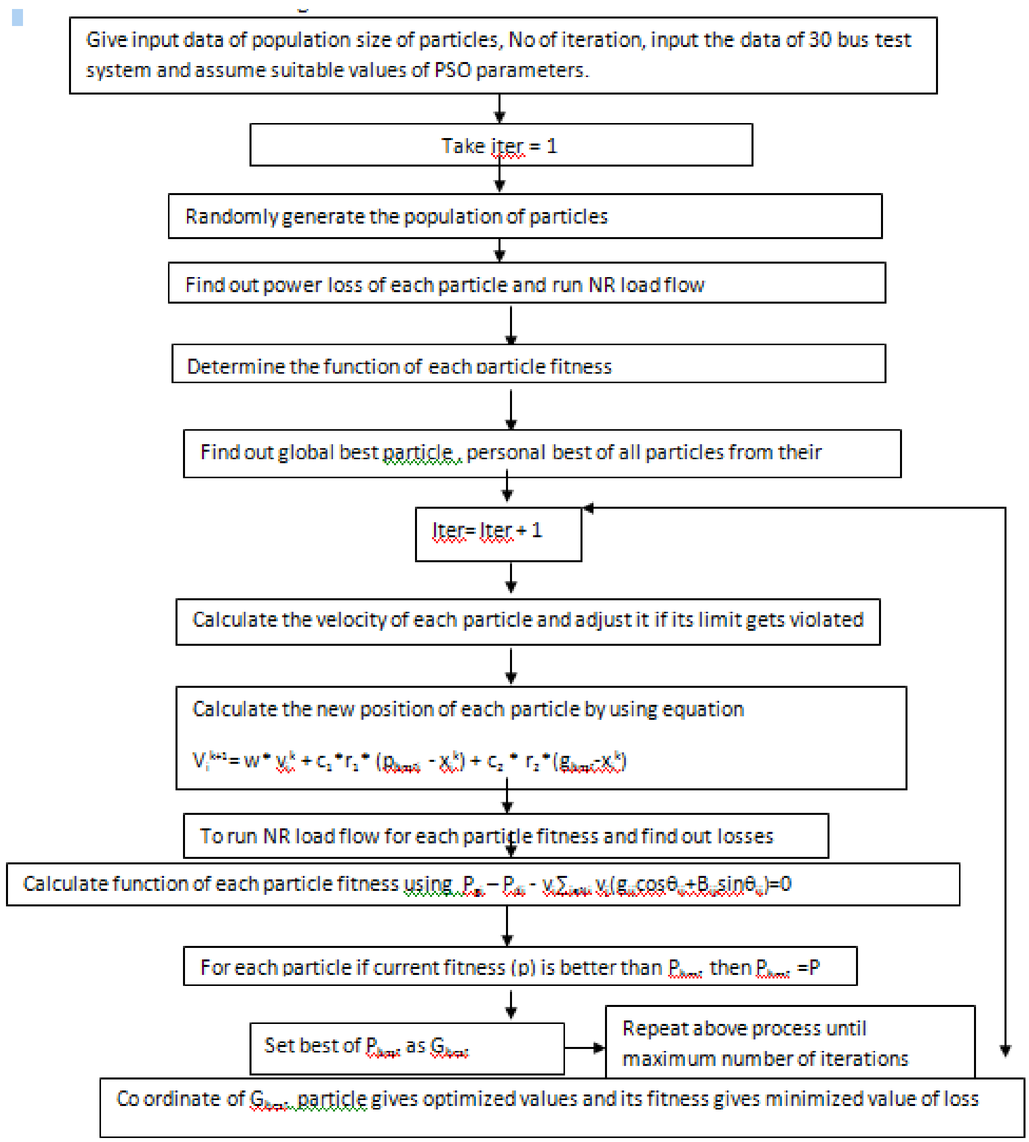

Figure 1. Flow chart for implementation of PSO.

6.1 Base Case

The results of the base case before optimization are given below:

Table 1. Results of base case before optimization

Voltage Magnitude Minimum	Voltage Magnitude Maximum	Voltage Angle Minimum	Voltage Angle Maximum	Maxi-mum Power Losses(MW)	Maximum Q Losses (MW)
0.980 p.u@ bus 30	1.000 p.u@ bus 11	-17.81 deg@ bus 30	0.00 deg @ bus 1	5.23MW @ line 1-2	15.66 MVAR@line 1-2

6.2 Before Molecule Swarm Enhancement Case

Table 2. Bus data, active and reactive power of one bus injection to another bus injection and active and reactive power losses under such load increment before improvement

Branch Data								
Branch	From	To	From Bus Injection		To Bus Injection		Loss(I^2Z)	
#	Bus	Bus	P(MW)	Q(MVAR)	P(MW)	Q(MVAR)	P(MW)	Q(MVAR)
1	1	2	162.92	-41.33	-162.01	13.97	0.915	2.74
2	1	3	83.93	-15.71	-83.37	-5.45	0.558	2.04
3	2	4	41.83	-1.66	-41.64	-18.56	0.183	0.56
4	3	4	80.97	34.28	-80.79	-38.48	0.184	0.53
5	2	5	79.68	-8.06	-79.15	-13.30	0.528	2.22
6	2	6	58.8	-1.89	-58.44	-18.09	0.361	1.10
7	4	6	75.26	0.01	-75.14	-4.63	0.12	0.42
8	5	7	-15.05	6.94	15.08	-18.27	0.032	0.08
9	6	7	37.95	-14.46	-37.88	5.19	0.073	0.23
10	6	8	29.99	-38.47	-29.94	33.59	0.047	0.16
11	6	9	29.87	114.92	-29.87	-105.71	0.00	9.21
12	6	10	15.27	-22.21	-15.27	23.87	0.00	1.66
13	9	11	0.00	87.65	-0.00	-81.78	0.00	5.86
14	9	10	29.87	18.06	-29.87	-17.57	0.00	0.49
15	4	12	39.57	55.11	-39.57	-51.14	0.00	3.97
16	12	13	-0.00	34.48	0.00	-33.86	0.00	0.62
17	12	14	7.14	1.75	-7.12	-1.70	0.025	0.05
18	12	15	15.85	3.35	-15.79	-3.23	0.065	0.13
19	12	16	5.38	2.56	-5.36	-2.53	0.012	0.03
20	14	15	0.92	-0.22	-0.92	0.22	0.001	0.00
21	16	17	1.86	0.37	-1.86	-0.37	0.001	0.00
22	15	18	4.98	1.98	-4.97	-1.96	0.012	0.02
23	18	19	1.77	0.88	-1.76	-0.87	0.001	0.00
24	19	20	-7.74	-3.21	7.74	3.22	0.009	0.02
25	10	20	9.99	4.16	-9.94	-4.06	0.041	0.09
26	10	17	7.15	6.62	-7.14	-6.59	0.011	0.03
27	10	21	15.07	5.45	-15.03	-5.38	0.033	0.07
28	10	22	7.13	1.30	-7.12	-1.27	0.014	0.03
29	21	22	-2.47	-8.06	2.47	8.07	0.003	0.01
30	15	23	3.53	-1.98	-3.52	1.99	0.006	0.01
31	22	24	4.65	-6.80	-4.62	6.85	0.029	0.05
32	23	24	0.32	-3.91	-0.32	3.93	0.008	0.02
33	24	25	-3.76	1.44	3.77	-1.42	0.011	0.02
34	25	26	3.52	2.79	-3.50	-2.76	0.019	0.03
35	25	27	-7.29	-1.37	7.32	1.41	0.022	0.04
36	28	27	20.42	5.62	-20.42	-4.97	0.000	0.65
37	27	29	6.11	1.81	-6.08	-1.74	0.033	0.06
38	27	30	6.99	1.76	-6.93	-1.64	0.061	0.12
39	29	30	3.68	0.66	-3.67	-0.64	0.013	0.02
40	8	28	-0.06	-8.51	0.06	-15.47	0.001	0.00
41	6	28	20.50	-17.06	-20.49	9.85	0.018	0.06
						Total	3.452	33.43

6.3 Load Increment after Particle Swarm Optimization

Table 3. Details of bus data, active and reactive power of one bus injection to another bus infusion and the active and reactive power losses under such load increment after particle swarm optimization

Branch Data								
Branch	From	To	From Bus Injection		To Bus Injection		Loss(I^2Z)	
#	Bus	Bus	P(MW)	Q(MVAR)	P(MW)	Q(MVAR)	P(MW)	Q(MVAR)
1	1	2	162.92	-41.33	-162.01	13.97	0.915	2.74
2	1	3	83.93	-15.71	-83.37	-5.45	0.558	2.04
3	2	4	41.83	-1.66	-41.64	-18.56	0.183	0.56
4	3	4	80.97	34.28	-80.79	-38.48	0.184	0.53
5	2	5	79.68	-8.06	-79.15	-13.30	0.528	2.22
6	2	6	58.8	-1.89	-58.44	-18.09	0.361	1.10
7	4	6	75.26	0.01	-75.14	-4.63	0.12	0.42
8	5	7	-15.05	6.94	15.08	-18.27	0.032	0.08
9	6	7	37.95	-14.46	-37.88	5.19	0.073	0.23
10	6	8	29.99	-38.47	-29.94	33.59	0.047	0.16
11	6	9	29.87	114.92	-29.87	-105.71	0.00	9.21
12	6	10	15.27	-22.21	-15.27	23.87	0.00	1.66
13	9	11	0.00	87.65	-0.00	-81.78	0.00	5.86
14	9	10	29.87	18.06	-29.87	-17.57	0.00	0.49
15	4	12	39.57	55.11	-39.57	-51.14	0.00	3.97
16	12	13	-0.00	34.48	0.00	-33.86	0.00	0.62
17	12	14	7.14	1.75	-7.12	-1.70	0.025	0.05
18	12	15	15.85	3.35	-15.79	-3.23	0.065	0.13
19	12	16	5.38	2.56	-5.36	-2.53	0.012	0.03
20	14	15	0.92	-0.22	-0.92	0.22	0.001	0.00
21	16	17	1.86	0.37	-1.86	-0.37	0.001	0.00
22	15	18	4.98	1.98	-4.97	-1.96	0.012	0.02
23	18	19	1.77	0.88	-1.76	-0.87	0.001	0.00
24	19	20	-7.74	-3.21	7.74	3.22	0.009	0.02
25	10	20	9.99	4.16	-9.94	-4.06	0.041	0.09
26	10	17	7.15	6.62	-7.14	-6.59	0.011	0.03
27	10	21	15.07	5.45	-15.03	-5.38	0.033	0.07
28	10	22	7.13	1.30	-7.12	-1.27	0.014	0.03
29	21	22	-2.47	-8.06	2.47	8.07	0.003	0.01
30	15	23	3.53	-1.98	-3.52	1.99	0.006	0.01
31	22	24	4.65	-6.80	-4.62	6.85	0.029	0.05
32	23	24	0.32	-3.91	-0.32	3.93	0.008	0.02
33	24	25	-3.76	1.44	3.77	-1.42	0.011	0.02
34	25	26	3.52	2.79	-3.50	-2.76	0.019	0.03
35	25	27	-7.29	-1.37	7.32	1.41	0.022	0.04
36	28	27	20.42	5.62	-20.42	-4.97	0.000	0.65
37	27	29	6.11	1.81	-6.08	-1.74	0.033	0.06
38	27	30	6.99	1.76	-6.93	-1.64	0.061	0.12
39	29	30	3.68	0.66	-3.67	-0.64	0.013	0.02
40	8	28	-0.06	-8.51	0.06	-15.47	0.001	0.00
41	6	28	20.50	-17.06	-20.49	9.85	0.018	0.06
						Total	3.452	33.43

6.4 The Optimized Results with Three Shunt Capacitors in Buses 3, 10 and 24 with Values

Table 4. Results of optimization algorithm has placed three shunt capacitors in buses 3, 10 and 24 with values

BUS	Capacitor Value
3	5.35
10	14.885
24	5.9549

6.5 The Total Active and Reactive Power Losses

Table 5. Results of active and reactive power losses after implement the optimization algorithm

Total Active power loss(MW)	3.452MW
Total Reactive power loss(MVAR)	33.43

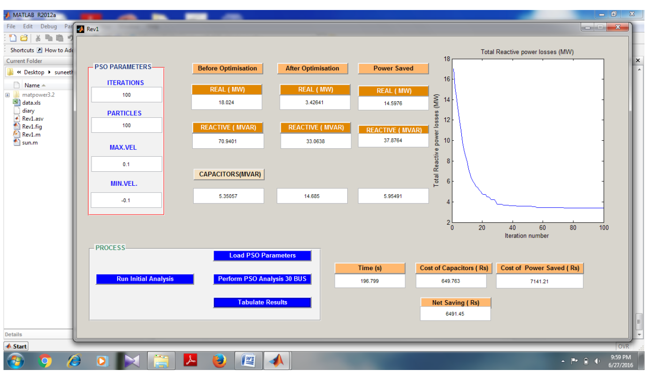

Figure 2. Screen shot of the post optimization indicating and tabulation the results of the proposed enhancement approach.

6.6 After Execution of Enhancement Algorithm

Table 6 Results of cost of capacitors, expense of force spared, net saving after execute the enhancement algorithm

Cost of Capacitors	Rs. 649.763
Cost of power saved	Rs. 7141.21
Net Saving	Rs. 6491.45

7. Conclusion

A scheme for decreasing the active power loss by optimizing the value of the capacitor is proposed and implemented using particle swarm streamlining approach. A controlled fitness function is used to define the optimization problem. It can be seen from the outcomes thought that the enhancement approach reduces the reactive and active power losses considerably. There is reduction in loss notwithstanding when there is an expansion in the reactive load segment there by accepting the appropriateness of the proposed technique for various situations. The simulations results point to the way that the losses can be diminished by the appropriate area and estimating of the shunt devices.

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