Webology (ISSN: 1735-188X)
Volume 18, Number 6, 2021

Optimal Allocation Of Different Type Of Distributed Generation In Order To Improve Performance Of Power System Networks Using Jaya Algorithm

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Abstract – The Optimal use of Distributed Generation (DG) is crucial for future need of electrical energy. The optimal allocation of DG is essential for proper functioning of electrical power system networks. To reduce the active power losses and improve the overall voltage profile, these are main concerns for safe operation of power system networks. In this paper, we have compared four different types of DG with different characteristics namely active power & reactive power. A new algorithmic-specific parameter-less advanced optimization algorithmic namely Jaya algorithm is used for optimal use of DG in order to improve the performance of power system networks. In IEEE-14 bus system, the optimum losses for DG type-1 is 3.4772MW, type-2 is 4.5760MW, type-3 is 6.7239MW and type-4 is 4.5761MW. The Type-1 DG is more effective in order to reduce power losses in power system networks as compared to other types of DG_s. In IEEE-30 bus system, the optimum losses for DG type-1 is 1.5848MW, type-2 is 1.4092MW, type-3 is 2.1590MW and DG type-4 is 1.9563MW. The active power losses are reduced and at the same time overall voltage profile is improved using Jaya algorithm.

Keyword – Distributed Generation (DG), Optimal Location of DG, Optimal Size of DG, Jaya Algorithm

I. INTRODUCTION

Distributed Generation (DG) is a small generator spotted throughout a power system network, providing the electricity locally to load customers [1]. DG can be an alternative for industrial, commercial and residential applications. DG makes use of the latest modern technology which is efficient, reliable, and simple enough so that it can compete with traditional large generators in some areas [2-3].

In recent years, the power industry has experienced significant changes on the distribution power system primarily due to the implementation of smart-grid technology and the incremental implementation of distributed generation. Distributed Generation (DG) is simply defined as the decentralization of power plants by placing smaller generating units closer to the point of consumption, traditionally ten mega-watts or smaller. While DG is not a new concept, DG is gaining widespread interest primarily for the following reasons, increase in customer demand, advancements in technology, economics, deregulation, environmental and national security concerns.

The distribution system is conventionally radial and operates without installed generation units. The electrical energy is supplied to the distribution network through transmission at the grid supply point. Therefore, power flows in one direction from transmission to distribution. At present, there is increasing number of the generation connected to the distribution system which is generally called Distributed Generation. The location and amount of power supplied from DG into the distribution system have influence on the operation of the system. They can either increase or decrease the efficiency and stability of the system. The large power supplied from the DG can even reverse the direction of power flow. Therefore, the suitable location and sizing of the DG is preferred. In [4-5], the optimal location of a specific sizing DG is determined using JAYA algorithm. The objective is to reduce active power losses and improve overall voltage profile of the power system networks. Nowadays, the technological evolution, environmental policies, and also the expansion of the finance and electrical markets, are promoting new conditions in the sector of the electricity generation and the DG play important role to fulfill the necessity of future electrical energy [6-7].

JAYA ALGORITHM:

The word “Jaya” is a word taken from “Sanskrit” an Ancient language of India. This means victory. The name of the algorithm itself shows the characteristics of the Jaya algorithm. The Jaya algorithm tries to become victorious by finding near an global optimal solution and dominating the worst solution. The jaya algorithm was proposed by Rao (2016). The algorithm was initially developed for solving constrained and unconstrained benchmark problems. Further, the application of the Jaya algorithm was extended to the various field of engineering optimization i.e. heat exchanger design, mechanical component design, manufacturing processes optimization etc. The working of the Jaya algorithm is defined as follows.

Assume any objective which is to be optimized and it id denoted by f(x). Let objective function is having DV design variable (j= 1,2…..DV), Let NP is the size of initial solutions (k=1…….NP)

Firstly, generate NP Initial solutions based on this given boundary conditions. Now, at any iteration i, if the best solution obtained in the entire solution is $f(x)_{best}$ and the worst solution obtained is $f(x)_{worst}$, then solution during the i^{th} iteration then the parameters will be modified as per the following equation.

$$Xi'j,k = Xij,k + rand1\,(- \,|Xij,k) - rand2\,(Xij,worst - |Xij,k|)$$

Here, $X^{i}_{j,k}$ is the value of the j^{th} variable for the k^{th} candidate during, $X^{i}_{j,best}$ is the value of design variable j^{th} variable corresponding to the best solution. Similarly, $X^{i}_{j,worst}$ is the value of design variable of j^{th} variable corresponding to the worst solution. The $rand_1$ and $rand_2$ are two random numbers between 0 and 1. Above $X^{i'}_{j,k}$ is accepted if and only if the corresponding function value is better than the previous value else $X^{i}_{j,k}$ is kept as it is. All the accepted values of parameters based on the acceptance of modified solution are kept and these works as the input to the next iteration. Furthermore, above process is repeated till the termination criterion is not reached.

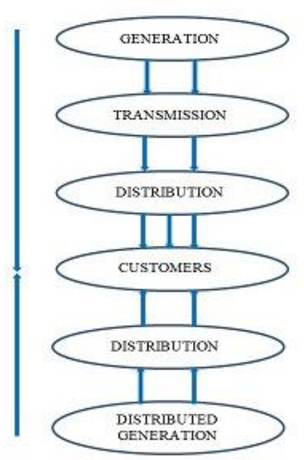


Fig.1 New industrial conception of the electrical energy supply

New technologies allow the electricity to be generated in small sized plants. Moreover, the increasing use of renewable sources in order to reduce the environmental impact of power generation leads to the development and application of new electrical energy supply schemes [8]. Some of the energy- demand is supplied by the centralized generation and another part is produced by distributed generation. The electricity is going to be produced closer to the customers.

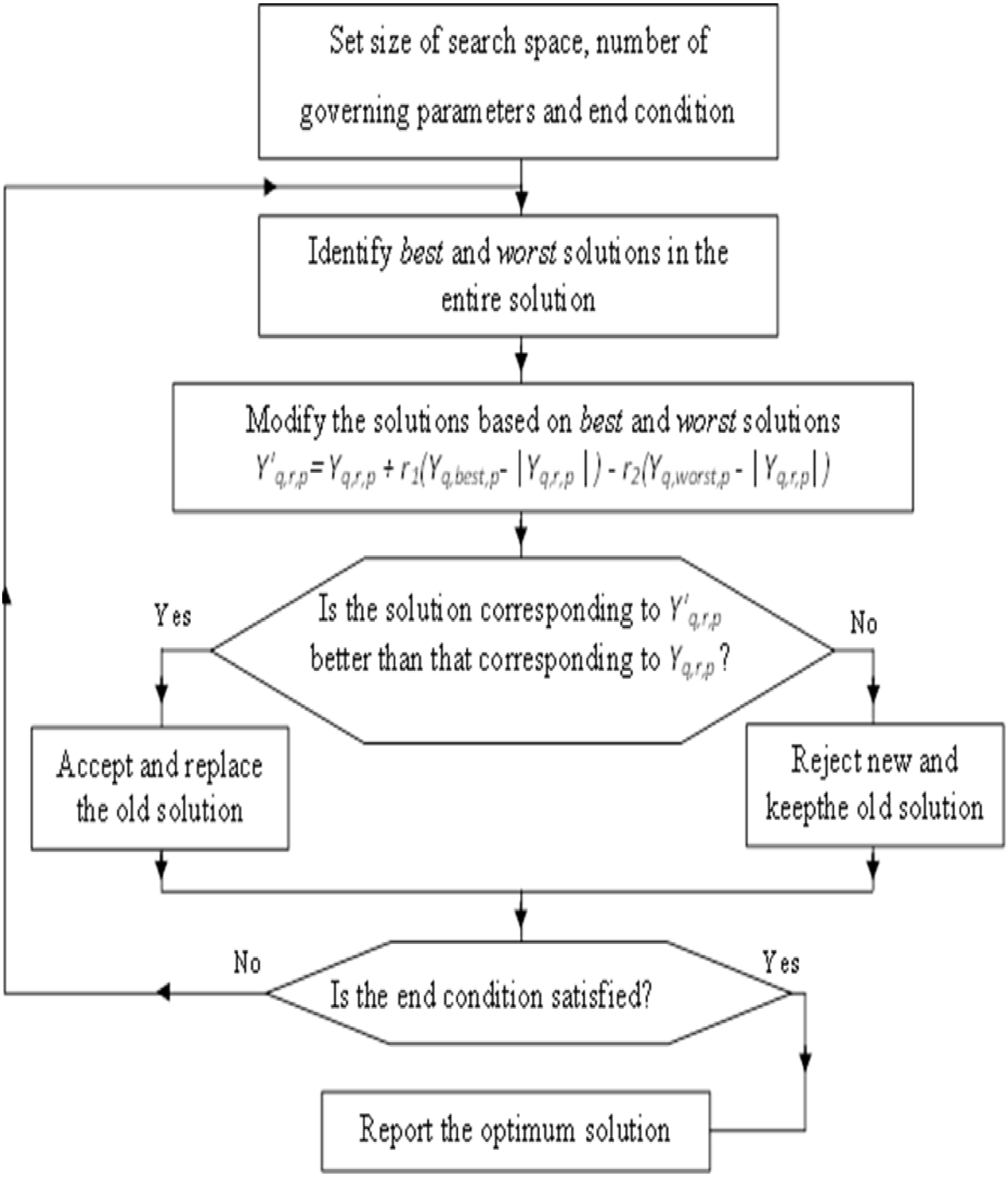
In other words, the electrical system between the substation fed by the transmission system and the consumer's meter is known as the distribution system. The basic elements of a distribution system are feeders, distributors and the service mains. Figure 1 depicts the single line diagram of a typical low tension distribution system [9-10].

The framework of Jaya algorithm applied to solve OPF problems, Initialize the population size (values DGs in MVA) 'P', number of dimension (buses) 'D', termination criterion i.e. maximum number of iteration 'N'. Initialize the value for power factor i.e. 1 for leading & -1 for lagging and 1 for unity power Generate the initial solutions equals to population size 'P' i.e. values DGs in MVA in the form of array x.

```
For j= 1:D
For i= 1: P
Evaluate optimal power flow solution for given values of DG for bus j  i.e ftij (x).
End For
Identify minimum & maximum loss corresponding to solutions of DG for bus j i.e. $ft_{best},j(x)$ & $ft_{worst},j(x)$.
For k= 1:N
$x_{i,j}$ t+1 → modified values of $X_{i,j}$ t based on equations (1) & (2).
```

```
For i = 1:P
Evaluate optimal power flow solution for given values of DG for bus j  i.e $ft+1(x)i,j$ .
Identify minimum loss corresponding to solutions of DG for bus j i.e. $f^{t+1}(x)_{best,}. j$.
    If $f^{t+1}(x)best, j < ft(x)best, j$
$Pt(x)_{best} = f^{t+1}(x)_{best}, j$ ;
else
$Pt(x)_{best} = ft(x)_{best}, j$
    End If
End For

End For
Forward updated solutions as input to next iteration.
End For
```


Set size of search space, number of governing parameters and end condition
Identify *best* and *worst* solutions in the entire solution
Modify the solutions based on *best* and *worst* solutions
$Y'_{q,r,p} = Y_{q,r,p} + r_1(Y_{q,best,p} - |Y_{q,r,p}|) - r_2(Y_{q,worst,p} - |Y_{q,r,p}|)$
Is the solution corresponding to $Y'_{q,r,p}$ better than that corresponding to $Y_{q,r,p}$?
Yes
No
Accept and replace the old solution
Reject new and keepthe old solution
No
Yes
Is the end condition satisfied?
Report the optimum solution

II. DISTRIBUTED GENERATION

As a result of deregulation in the electric power sector a new identify appeared in electric system map known as “distributed generation” (DG). Distributed generation (DG) is not entirely new concept but it is emerging approach for rendering electric power in the heart of power system. It mainly depends upon the installation of a portfolio of small size, compact, and clean electric power generation units at or near the load (customer).

According to new technology, the electric power generation trend uses distributed generation units sized from kW to MW at load sites instead of using traditional centralized generation units sized from 100 MW to several GW and located for from the loads where the natural resources are available [11]. Small scale power generating technologies, such as gas turbines, small hydro-turbines, photovoltaic, wind turbines and fuel cells, are bit by bit replacing conventional generating technologies in various applications, in the electric power system [12]. These distributed technologies have many benefits, such as high fuel efficiency, short contribute to their growing popularity. Considering the manner in which the very earliest power utilities were operating to produce and delivering electricity. Utilities have their own assigned territory, producing and delivering electricity topically. The national grids or regional grids then came along to from large interconnected system that made power systems more economic and reliable [13-14].

Various Distributed generation (DG) devices can be strategically placed in power system for grid, reducing power losses, improving voltage profile and load factors, doing away with for system upgrades and improving system integrity, reliability and efficiency . In this paper JAYA algorithm technique has been used to obtain the optimal size and the location of DG for which the power loss of the system is minimum, voltage regulation at each bus is maintained and the frequency of the system in stable. The type-1 DG is capable of delivering only active power such as photovoltaic, micro turbines, fuel cells, which are integrated to the main grid with the help of converters/inverters. However, according to current situation and grid codes the photovoltaic can and in sometimes are required to provide reactive power as well. Type-2 DG capable of delivering both active and reactive power. DG units based on synchronous machines (cogeneration, gas turbine, etc.) come under this type. Type-3 DG capable of delivering only reactive power. Synchronous compensators such as gas turbines are the example of this type and operate at zero power factors. Type-4 DG capable of delivering active power but consuming reactive power. Mainly induction generators, which are used in wind farms, come under this category [18-19].

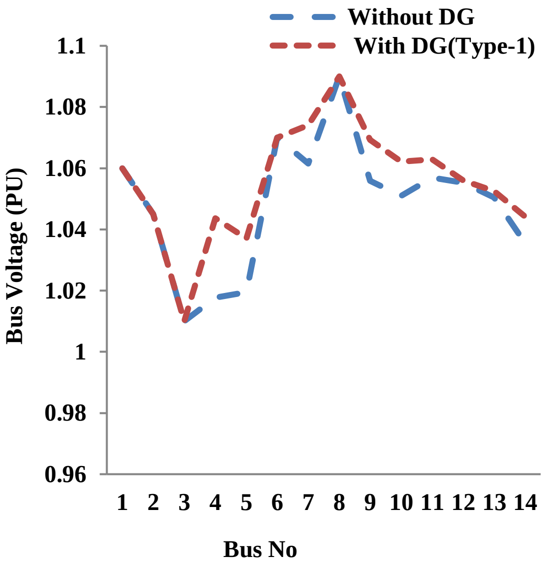
IV. RESULTS & DISCUSSION

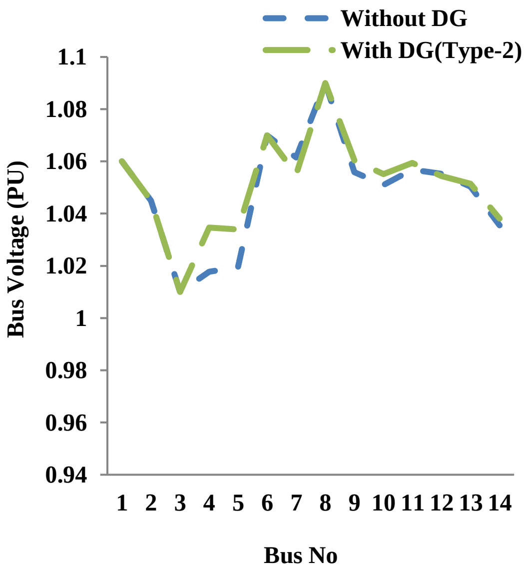
A. Results for IEEE-14 bus system:

After installation of different types of DG in power system networks, the comparative study of voltage profiles which are shown in figure2. In the case of DG type-1 is more appreciable as compared to DG type-3, type-2, type-4 and without use of DG. The optimum losses for DG type-1 is 3.4772MW, type-2 is 4.5760MW, type-3 is 6.7239MW and type-4 is 4.5761MW and without use of DG which is 4.5760MW. The use of type-1 DG is more effective for improvement of voltage profile point of view but it is more effective in case of overall active power loss in power system networks.

Table no-1 IEEE-14 Bus Systems for Bus Voltage

Bus No	Bus voltage Without DG	Bus voltage With DG (Type-1)	Bus voltage With DG (Type-2)	Bus voltage With DG (Type-3)	Bus voltage With DG (Type-4)
1	1.0600	1.0600	1.0600	1.0600	1.0600
2	1.0450	1.0450	1.0450	1.0450	1.0450
3	1.0100	1.0100	1.0100	1.0100	1.0100
4	1.0177	1.0436	1.0347	0.9462	1.0348
5	1.0195	1.0371	1.0339	0.9870	1.0340
6	1.0700	1.0700	1.0700	1.0700	1.0700
7	1.0615	1.0741	1.055	1.0403	1.0534
8	1.0900	1.0900	1.0900	1.0900	1.0900
9	1.0559	1.0693	1.0604	1.0401	1.0595
10	1.051	1.0622	1.0551	1.0391	1.0543
11	1.0569	1.0629	1.0594	1.0516	1.0590
12	1.0552	1.056	1.0544	1.0539	1.0543
13	1.0504	1.0525	1.0515	1.0488	1.0514
14	1.0355	1.0442	1.0381	1.0273	1.0374





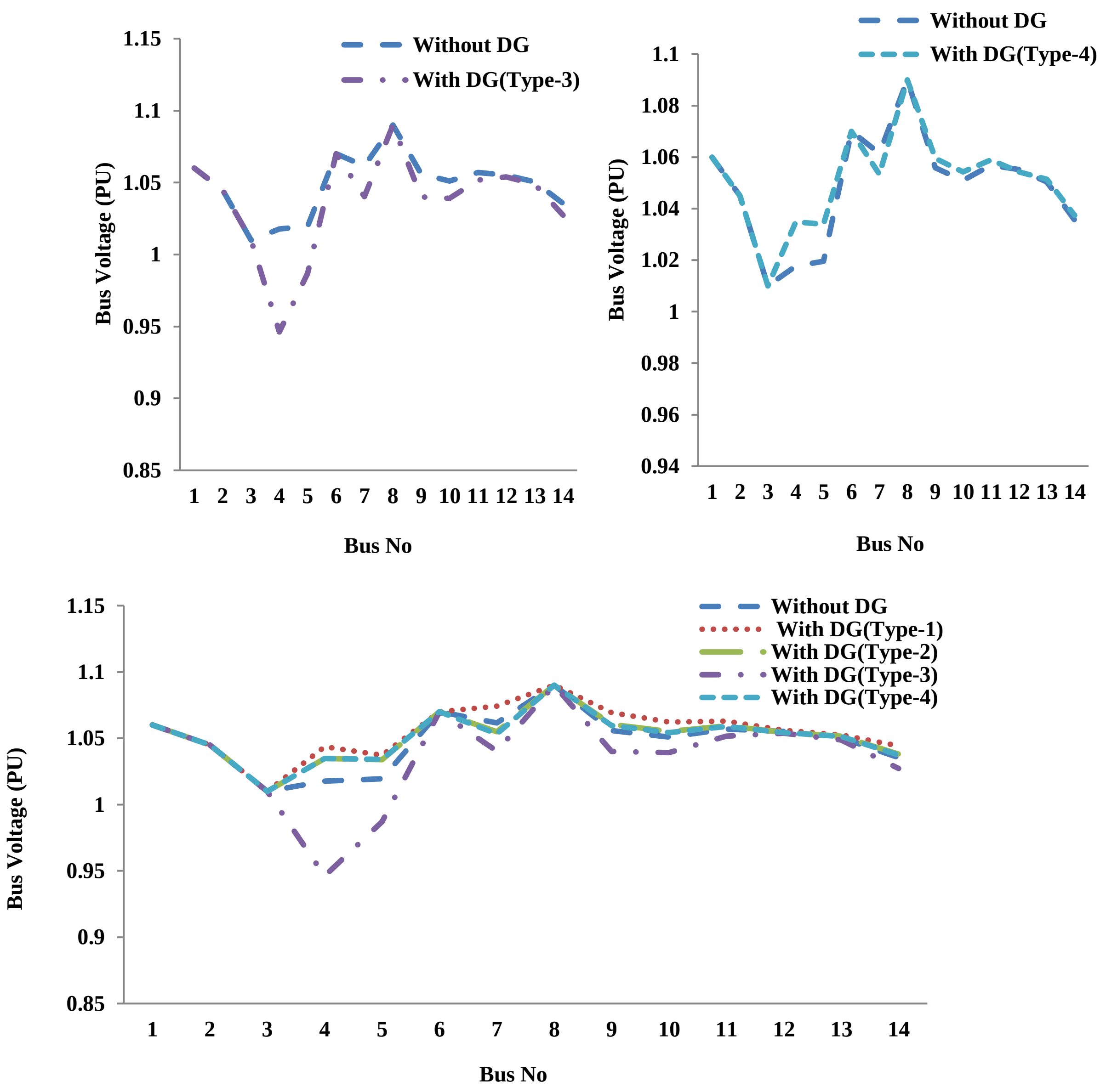
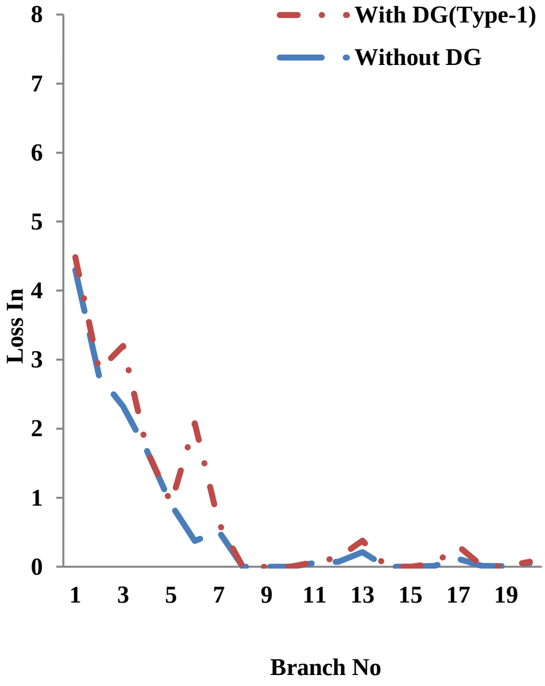


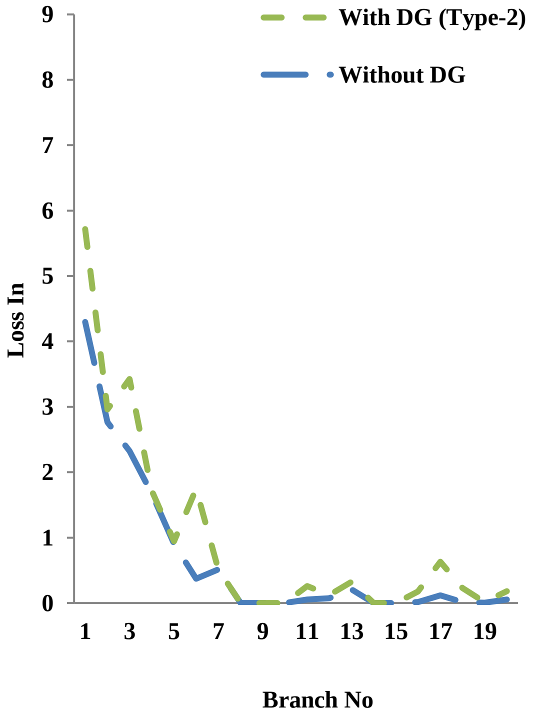
Fig.2 IEEE-14 Bus voltage profile with and without installation of DG

Table no-2 IEEE 14 Bus System Power Loss without and with DG

BRANCH			Without DG	With DG (Type 1)	With DG (Type 2)	With DG (Type 3)	With DG (Type 4)
Branch No	From	To					
1	1	2	4.2976	0.1872	0.4197	0.3033	0.3611
2	1	5	2.7629	0.0866	0.196	0.5634	0.1630
3	2	3	2.3233	0.8786	1.1015	0.5449	1.0658
4	2	4	1.6767	0.0062	0.0438	1.6705	0.0313
5	2	5	0.9038	0.0161	0.0391	0.5773	0.0313

6	3	4	0.3734	1.7076	1.3754	1.2192	1.4277
7	4	5	0.5144	0.1193	0.0032	1.3415	0.0010
8	4	7	0	0	0	0.0000	-0.0000
9	4	9	0	0	0	0.0000	0
10	5	6	0	0	0	-0.0000	0.0000
11	6	11	0.0554	0.0139	0.204	0.0728	0.2275
12	6	12	0.0718	0.0624	0.0496	0.0658	0.0494
13	6	13	0.2121	0.1667	0.1096	0.1789	0.1101
14	7	8	0	0	0	0	0.0000
15	7	9	0	0	0	0	0
16	9	10	0.0129	0.0314	0.1655	0.0035	0.1765
17	9	14	0.1162	0.1814	0.5142	0.0903	0.5375
18	10	11	0.0126	0.0001	0.2166	0.0323	0.2391
19	12	13	0.0063	0.0032	0.0097	0.0070	0.0106
20	13	14	0.0541	0.0165	0.1282	0.0531	0.1441





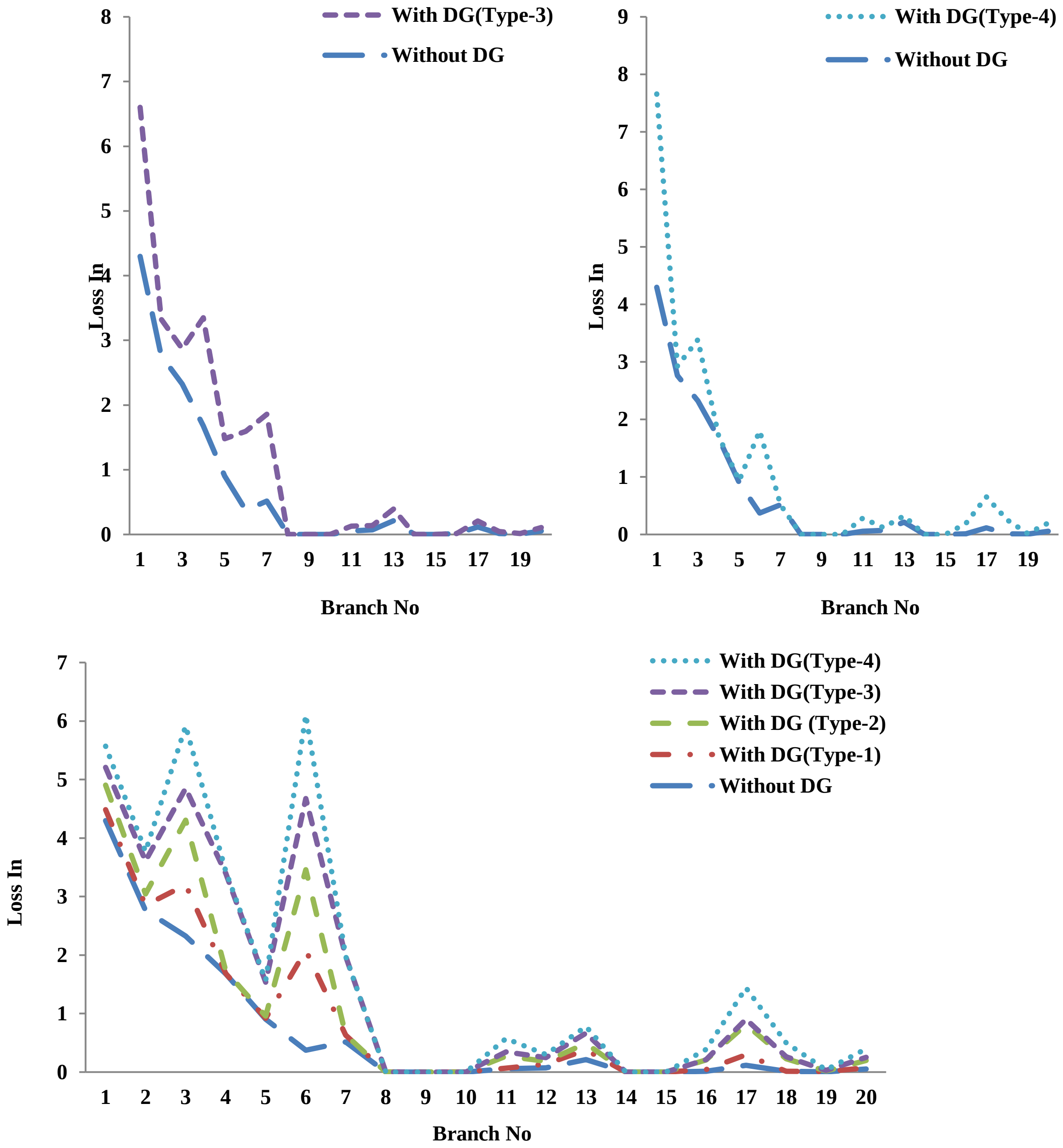


Fig.3 IEEE-14 system network losses with and without installation of DG

Table. 3 Comparison of different type of DG's at various specifications

S. N.	Description of DG	Without DG	DG Type-1	DG Type-2	DG Type-3	DG Type-4
1	Optimum Location		4	8	4	8

2	Optimum Loss	4.5760	3.472	4.5760	6.7239	4.5727
3	Optimum Size		184.4140	196.5155	-724.3406	200.5279
4	Real Power(MW)		184.4140	157.2124	$-4.4353e^{-14}$	160.4223
5	Reactive Power (MVAR)		0	117.9093	-724.3406	-120.3167

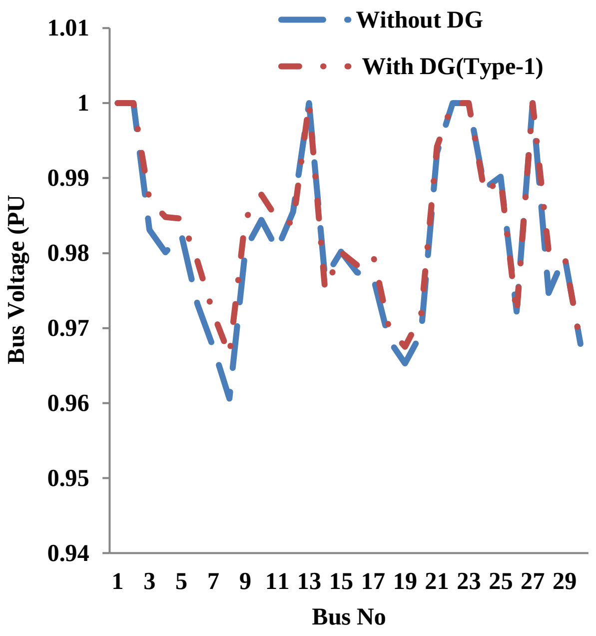
B. Results of Voltage Profile for 30-Bus and Branch System:

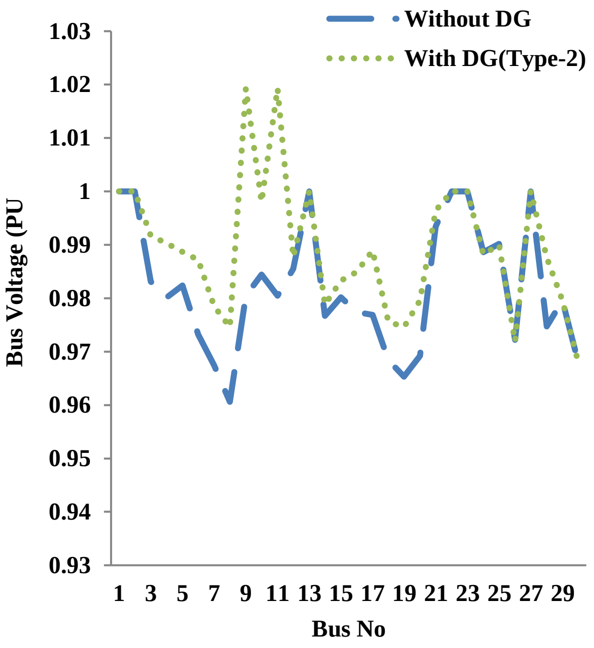
After installation of different types of DG in power system networks, the comparative study of voltage profiles which are shown in figure 4. In the case of DG type-2 is more appreciable as compared to DG type-1, type-3, type-4 and without use of DG. The overall power loss after installation of different types of DG such as for type-1 is 1.5848MW, type-2 is 1.4092MW, type-3 is 2.1590MW and DG type-4 is 1.9563MW and without use of DG is 48.3588MW. The use of type-2 DG is more effective for improvement of voltage profile point of view and it is additional operative in case of overall active power loss in power system networks.

Table: 4 IEEE-30 Bus Systems for Bus Voltage

Bus No	Bus voltage Without DG	Bus voltage With DG (Type-1)	Bus voltage With DG (Type-2)	Bus voltage With DG (Type-3)	Bus voltage With DG (Type-4)
1	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000	1.0000
3	0.9831	0.9871	0.9917	0.9924	0.9850
4	0.9801	0.9848	0.9903	0.9914	0.9823
5	0.9824	0.9846	0.9887	0.9910	0.9833
6	0.9732	0.9789	0.9872	0.9903	0.9757
7	0.9674	0.9719	0.9785	0.9812	0.9693
8	0.9606	0.9664	0.9746	0.9911	0.9632
9	0.9805	0.9846	1.0193	0.9888	0.9797
10	0.9844	0.9878	0.9980	0.9880	0.9818
11	0.9805	0.9846	1.0193	0.9888	0.9797
12	0.9855	0.9839	0.9877	0.9887	0.9835
13	1.0000	1.0000	1.0000	1.0000	1.0000
14	0.9767	0.9751	0.9788	0.9795	0.9746
15	0.9802	0.9801	0.9833	0.9825	0.9790
16	0.9774	0.9784	0.9849	0.9808	0.9754
17	0.9769	0.9798	0.9889	0.9804	0.9745

18	0.9684	0.9700	0.9756	0.9712	0.9669
19	0.9653	0.9675	0.9746	0.9684	0.9634
20	0.9692	0.9716	0.9796	0.9724	0.9671
21	0.9934	0.9942	0.9964	0.9942	0.9926
22	1.0000	1.0000	1.0000	1.0000	1.0000
23	1.0000	1.0000	1.0000	1.0000	1.0000
24	0.9886	0.9880	0.9882	0.9886	0.9880
25	0.9902	0.9899	0.9900	0.9902	0.9899
26	0.9722	0.9718	0.9719	0.9722	0.9719
27	1.0000	1.0000	1.0000	1.0000	1.0000
28	0.9747	0.9803	0.9876	0.9929	0.9774
29	0.9796	0.9796	0.9796	0.9796	0.9796
30	0.9679	0.9679	0.9679	0.9679	0.9679





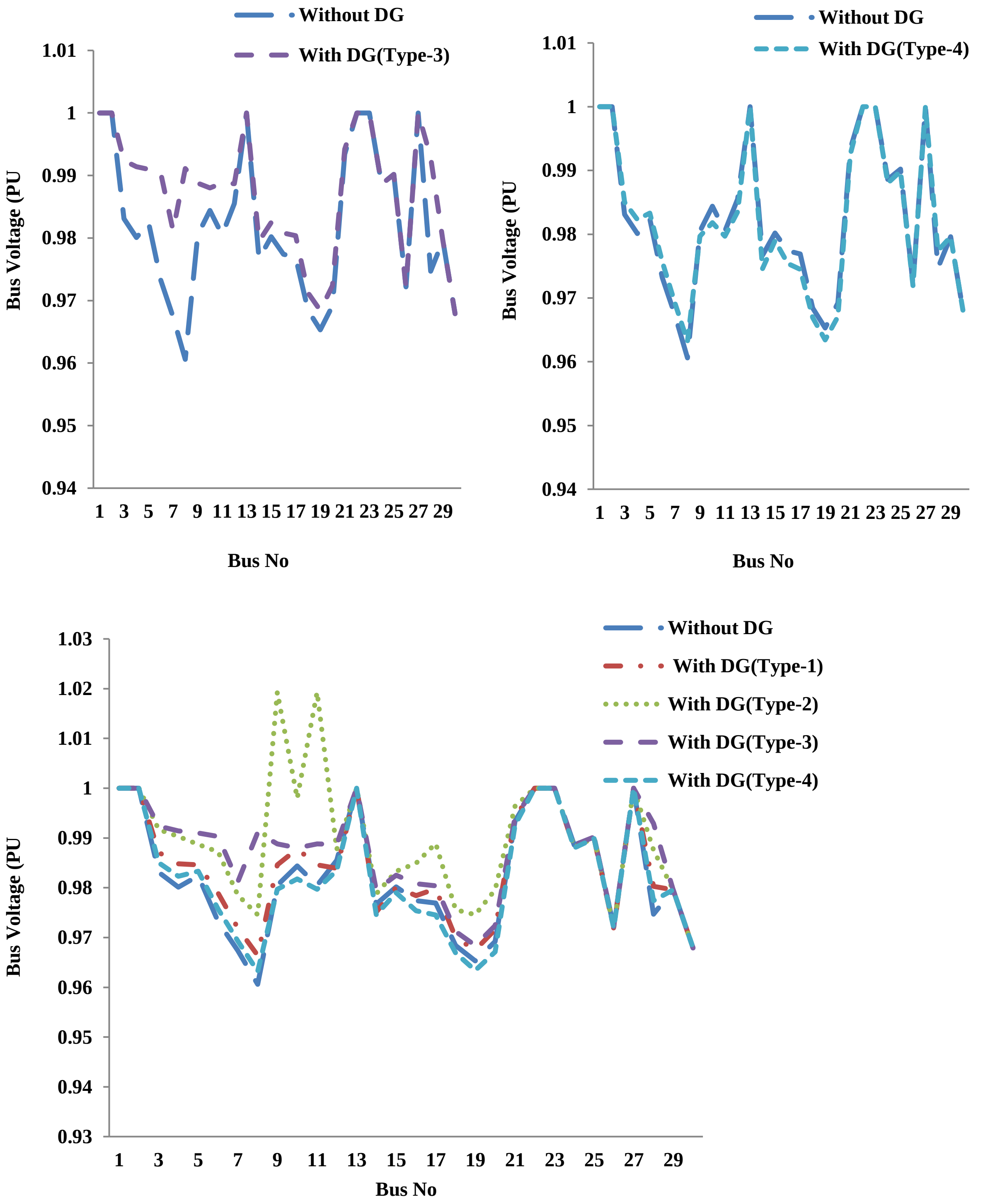


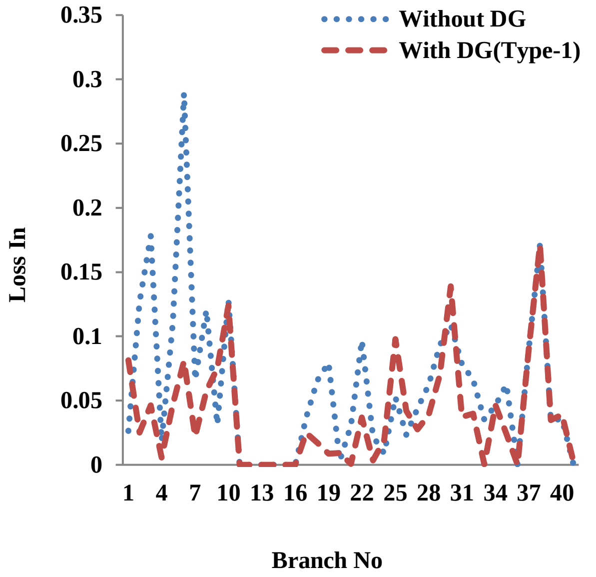
Fig.4 IEEE-30 Bus voltage profile with and without installation of DG

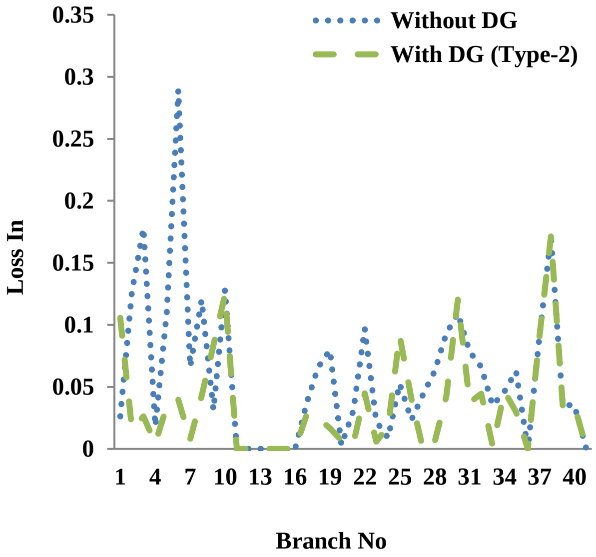
BRANCH	Without DG	With DG (Type-1)	With DG (Type 2)	With DG (Type 3)	With DG (Type 4)

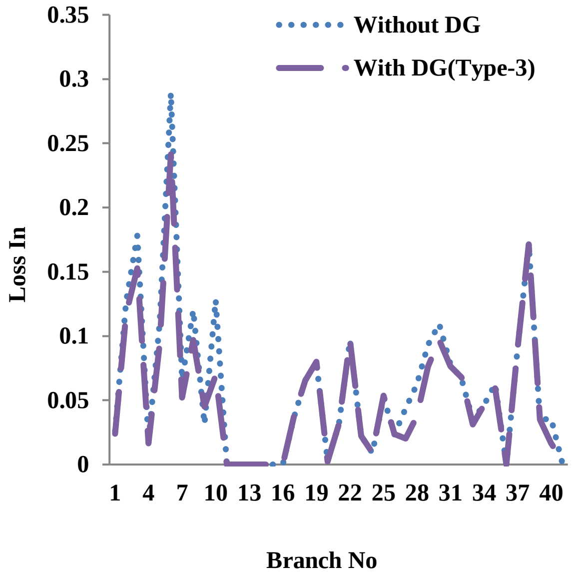
Branch No	**From**	**To**					
1	1	2	0.0263	0.0700	0.1033	0.0239	0.0094
2	1	3	0.1267	0.0237	0.0137	0.1171	0.0367
3	2	3	0.1780	0.0492	0.0239	0.1526	0.0878
4	3	4	0.0183	0.0052	0.0041	0.0166	0.0048
5	2	4	0.1103	0.0489	0.0333	0.0939	0.0705
6	2	5	0.2892	0.0851	0.0354	0.2415	0.1477
7	4	6	0.0662	0.0232	0.0063	0.0522	0.0374
8	5	6	0.1202	0.0596	0.0410	0.0968	0.0813
9	6	7	0.0314	0.0727	0.0840	0.0453	0.0536
10	6	7	0.1281	0.1240	0.1244	0.0698	0.1250
11	6	8	0	-0.0000	0	0	-0.0000
12	6	9	-0.0000	0	-0.0000	0	-0.0000
`13	9	10	0	0	0	0	0
14	9	11	0	0.0000	0	0	-0.0000
15	4	10	0	0	0.0000	0	0.0000
16	12	12	0	0	0.0000	-0.0000	0
17	12	13	0.0368	0.0254	0.0274	0.0376	0.0284
18	12	14	0.0656	0.0187	0.0251	0.0653	0.0284
19	12	15	0.0795	0.0100	0.0170	0.0800	0.0355
20	14	16	0.0031	0.0086	0.0069	0.0024	0.0064
21	16	15	0.0307	0.0004	0.0050	0.0313	0.0056
22	15	17	0.0968	0.0389	0.0445	0.0965	0.0686
23	18	18	0.0221	0.0038	0.0059	0.0223	0.0120
24	19	19	0.0089	0.0188	0.0186	0.0093	0.0114
25	10	20	0.0524	0.0952	0.0930	0.0536	0.0652

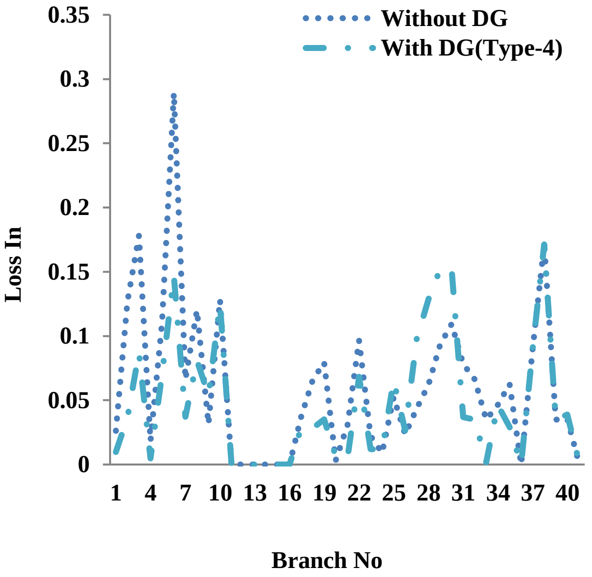
26	10	20	0.0234	0.0406	0.0414	0.0236	0.0263
27	10	17	0.0437	0.0278	0.0013	0.0200	0.0967
28	10	21	0.0622	0.0395	0.0034	0.0371	0.1276
29	21	22	0.0931	0.0708	0.0384	0.0760	0.1511
30	15	22	0.1094	0.1373	0.1185	0.0968	0.1516
31	22	23	0.0783	0.0368	0.0374	0.0764	0.0368
32	23	24	0.0663	0.0407	0.0447	0.0680	0.0351
33	24	24	0.0350	0.0004	0.0021	0.0312	0.0020
34	25	25	0.0464	0.0464	0.0464	0.0464	0.0464
35	25	26	0.0626	0.0249	0.0297	0.0593	0.0295
36	28	27	0.0000	-0.0000	0	0	0
37	27	27	0.0901	0.0901	0.0901	0.0901	0.0901
38	27	29	0.1713	0.1713	0.1713	0.1713	0.1713
39	29	30	0.0349	0.0349	0.0349	0.0349	0.0349
40	8	30	0.0356	0.0388	0.0350	0.0165	0.0388
41	6	28	0.0012	0.0031	0.0019	0.0032	0.0026

Table: 5 IEEE-30 Bus Systems for Branch Loss


Without DG
With DG(Type-1)
Loss In
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40
Branch No


Without DG
With DG (Type-2)
Loss In
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40
Branch No


Without DG
With DG(Type-3)
Loss In
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40
Branch No


Without DG
With DG(Type-4)
Loss In
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40
Branch No

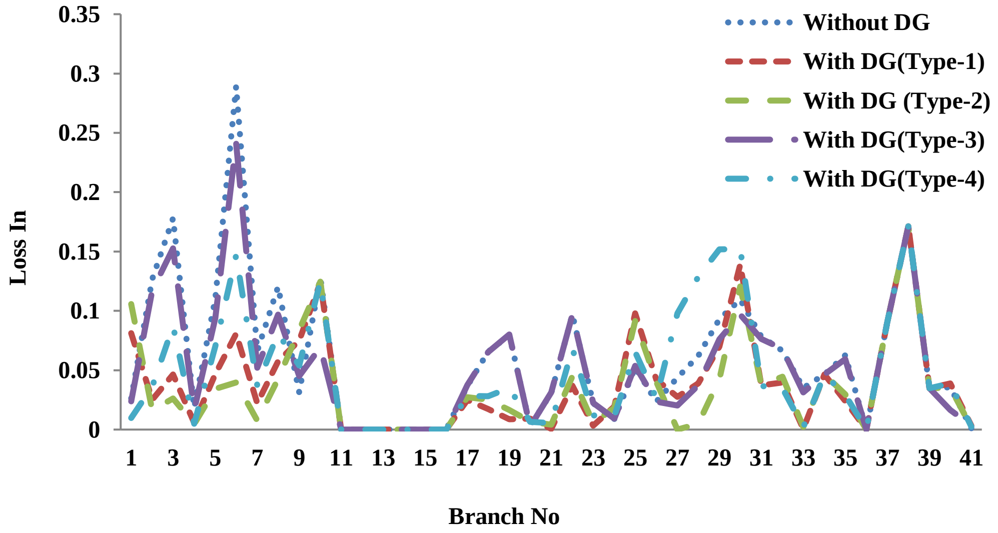

Without DG
With DG(Type-1)
With DG (Type-2)
With DG(Type-3)
With DG(Type-4)
Loss In
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41
Branch No

Fig:5 IEEE-30 system network losses with and without installation of DG

Table. 6 Comparison of different type of DG's at various specifications

S. N.	Description of DG	Without DG	DG Type-1	DG Type-2	DG Type-3	DG Type-4
1	Optimum Location		10	9	8	22
2	Optimum Loss	2.440	1.58 48	1.4092	2.1590	1.9563
3	Optimum Size		43.1782	60.4485	37.9231	32.8524
4	Real Power (MW)		43.1782	48.3588	$2.3252e^{-15}$	26.2819
5	Reactive Power (MVAR)		0	36.2691	37.9731	-19.7114

V. CONCLUSION:

A new algorithmic-specific parameter-less advanced optimization Jaya algorithm is used in this paper for optimal procedure of DG which provide better performance of power system networks. There are four types of DG are used with different active and reactive power characteristics. The optimal allocation of DG at optimal place is essential for proper functioning of electrical power system networks. To reduce the active power losses and improve the overall voltage profile, are main concerns for safe operation of power system networks. The optimal allocation of different types of DG at optimal location are done using Jaya algorithm which provided enhance performance as compared to other type of optimization techniques. In IEEE-14 bus system, the optimum losses for DG type-1 is 3.4772MW, type-2 is 4.5760MW, type-3 is 6.7239MW and type-4 is 4.5761MW. In IEEE-30 bus system, the optimum losses for DG type-1 is 1.5848MW, type-2 is 1.4092MW, type-3 is 2.1590MW and DG type-4 is 1.9563MW. In IEEE-14 bus system the type-1 is more effective in case of overall active power loss in power system networks similarly in IEEE-30 bus system the type-2 is also more effective in case of overall active power loss in power system networks and at the same time the overall voltage profile is also improved as compared to other type of DG in IEEE-14 and IEEE-30 bus system.

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