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Research paper



Optimal Sitting and Sizing of PV Generation Connected to the Radial Distribution Feeders

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Abstract

Electricity is a basic need for the daily life of everyone, and it serves as the main driver for the economic growth in any country. Coal-fired Electricity generation forms the major share of energy resources in the world. In India, Coal-fired electricity generation represents about 78% of the total power generation in the country. Coal reserve is fast depleting in the world. This situation has necessitated many countries in the world to opt for Distributed Generation (DG), using renewable sources of energy, to meet, the growing demand for electricity and to meet the depleting situation of Coal. In the past, some studies have been carried out by the Researchers using different types of DG systems. This study considers installation of PV systems, making use of the abundant availability of Solar Energy Resources. Appropriate sitting and sizing of DGs could lead to many positive effects for the distribution systems concerned. However, at the same time, inappropriate sitting and sizing of DGs could lead to many negative effects on the distribution systems concerned, such as the voltage profiles, beyond permissible limits and increased network losses. Therefore, it becomes necessary to allocate DGs at optimal locations with optimal sizing. This paper presents the results of the study carried out in a 400 V distribution system as well as in an 11-kV feeder in the Kanchipuram Distribution System in Tamil Nadu, India. This paper also presents the economic impact of the system with PVCs regarding Internal Rate of Return (IRR)for the investment made.

Keywords:*Distribution system; Photovoltaic Generation (PVG); Distributed Generation(DG); Optimal sizing and sitting; Internal Rate of Return .*

1. Introduction

This Electricity is an essential commodity for the daily life of everyone and that one cannot think of living without it. Energy demand serves as a primary driver for economic development in any country. The energy sector constitutes a relatively modest share of (GDP) Gross Domestic Product in most of the countries. Traditional fossil fuels, such as coal, petroleum and natural gas, are major forms of energy. Coal-fired Electricity generation forms the dominant share of energy resources in the world. Coal-fired electricity generation represents about 78% of the installed capacity in India. However, as per the Greenpeace report, the extractable coal reserve of 18.2 billion tons of Coal India Limited (CIL) would exhaust in about 17 years, while the demand for electricity is increasing at an annual growth rate of 7.3% in India, as per the Bridge to India report. Also, according to official figures, nearly one-third of villages (5665) out of the total of 18452 villages in India are waiting for electrification. As a result, there is a heavy demand for the electricity needs. In addition to the fast depletion of the Coal reserve and increased T&D losses, the air quality and human health have severely degraded because of high particulates and sulfur dioxide (SO2) and carbon dioxide (CO2) emissions strongly affecting the world's climate.

The above situation has compelled many countries in the world for the adoption of Distributed Generation (DG). The increasing penetration of distributed generation (DG) in power distribution systems presents technical and economic benefits as well as integration challenges to the utility engineers. Inappropriate sitting and sizing of DGs could lead to many negative effects on the distribution systems concerned, such as voltage profiles going beyond permissible limits, and increased network losses. Therefore, it is becoming increasingly important to decide on sitting and sizing of the DGs optimally in active distribution networks while planning. This work aims to develop optimal planning strategies and methods to decide on the optimal sitting and sizing of PVGs exploiting the abundant Solar energy resources available at low cost. In the past, some studies have been carried out by the Researchers for optimal sitting and sizing of different types of DG systems, using sophisticated computing methods and tools, but not easily accessible to the practising field engineers.

Vijaysimha et al. present a Genetic Algorithm based optimisation Technique determining DG systems in multi-location, varying from one to five locations. They have tested a 37-bus 23 kV. System. The authors have used multi-objective optimisation approach for size-location planning of distributed generation in distribution systems. The test system considered is a 23 kV system while the loads are LT loads. The presentation of results lacks clarity. [1]. Athira et al. present a Particle Swarm Optimization technique to place Fuel Cell DG and Solar cell DG optimally in the radial distribution feeders, solving a single objective optimisation function of loss minimisation. They have tested their method on theIEEE-14 bus system. They have not considered the benefit of capacity release in the system due to DG installation [2]. Chandrasekhar et al. have presented an approach for optimal placement and size of the DGs considering system technical issues such as active and reactive power losses, the voltage profile and the line loading of

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the system. The solar and wind systems are modelled as constant power factor model and variable reactive power model respectively. The renewable energy DGs placement is limited to some busses with the consideration of environmental constraints. A genetic algorithm based optimisation technique is used to find the placement of DGs. Four different types of DG systems, namely, Solar, Wind, Fuel cell, microturbines are used in a 38 Bus Distribution system. Multi-objective optimisation has been formed taken into account on all the indices, like Real and Reactive power losses, line loading and voltage profile with appropriate weights [3]. Suresh et al. have presented a Bat algorithm based solution procedure for the optimal allocation of solar systems in the distribution system minimising the power loss. The IEEE 33 bus test system is tested in this paper. The Bat algorithm is compared with the PSO and GA. Among the three methods, the authors have established that the Bat algorithm gives better results with higher penetration level. This research decides optimal locations but does not optimise the size of the DG. Also, the objective function does not include the benefits derived from the capacity release due to DG installation [4]. Mohd et al. have tested a 12 BUS radial distribution system. For finding the optimal location of DG, they have placed the DG at each load bus one at a time and determined power loss in each case by conducting the load flow study. By comparing the results of each case, they have determined the optimal location for DG. The optimal sizing and the economic benefit of the DG are not considered in this work [5]. Zhipeng et al. have studied the uncertainties of wind generators due to the stochastic wind speed and that of a solar generating source due to the stochastic illumination intensity. They have presented a new method to handle these uncertainties in the optimal siting and sizing of DGs. The objective function included all costs including the investment cost, operating cost, maintenance cost, network power loss cost and network adequacy cost. This work has not worked out the economic return on investment [6]. Prem et al. present the fundamentals of DG and DG technologies and review the classical and heuristic approaches for optimal sizing and placement of DG units in distribution networks and study their impacts on utilities and customers. The study attempts also attempt to compare the classical and meta-heuristic techniques for optimal sizing and siting of DG in distribution networks [7]. Mahmoud et al. in their paper demonstrate the improvement in network parameters which could be achieved by using single and multiple Distributed Generation units in three selected standard networks. A reliable multivariable method is used for finding optimal installation point and size of distributed generation units [8]. Qingwu et al. used the expected load interruption cost as the assessment of operational risk in distribution systems, which is assessed by the point estimate method (PEM). A novel mathematical model of chance-constrained programming (CCP) framework for optimal sitting and sizing of DGs in distribution systems is proposed considering the uncertainties of DGs. And then, a hybrid genetic algorithm (HGA), which combines the GA with traditional optimisation methods, is employed to solve the proposed CCP model. In this work, the capacity release cost is not considered to while minimising the cost of the system [9-11].

As could be seen in the literature review discussed above the past works have not considered the cost of capacity release due to DG installation, and the economic return on investment is not estimated. Further, most of the works have presented sophisticated methods and tools to determine the optimal location and sizing of the DG. The optimal sitting of DGs in the radial distribution system could be determined using load flow studies sizing by varying the size and determining the benefits by a method of local variation and load flow studies. This work considers these issues and presents a method for determining the Internal Rate of Return (IRR) on the investment.

Thus, this paper presents a simple method and approach to deciding upon the optimal location and sizing of PV Systems in Radial distribution feeders, both LT and 11 kV feeders that could be easily adopted and practised by the practising field engineers [10-14].

2.Methodology

The problem is to develop a simple, user-friendly method to determine the optimal location and the optimal size of the PV Systems for installation in the Radial distribution feeders. The method proposed is easy for the practising distribution field engineers to adoption

2.1. Method for the Determination of the Optimal Location

Optimum location is that node of a radial distribution feeder which results in a maximum saving of energy losses where a PV System is installed. In a radial distribution feeder, the power loss due to a load at a node is directly proportional to the product of the moment of that load about the substation and the load concerned, as in (1), defined in [10].

Power loss,

$$Power\ loss, PL = \frac{(0.001r)\ (LDF)}{(kV)2(PLDF)} MP \quad (1)$$

Where r is the resistance of a conductor used in the
feeder in Ohms
kV is the average circuit voltage in kiloVolts.
LDF is the Load Distribution Factor of the Feeder, defined as

$$LDF = \frac{PL}{M} \quad (2)$$

M is the Moment in km-kVA of the Load Pin kVA at that node and
PLDF is the Loss Load Distribution Factor of the Feeder, defined as

$$PLDF = \frac{P^2 L}{sum\ of\ w_i{}^2 l_i), i=1\ to\ n} \quad (3)$$

Where, wi is kVA flow in feeder section, i and li is the length of feeder section li in km, r, kV, LDF and PLDF being constant for any given feeder, we can write (1) as

PL is proportional to M.P. (4)

Using (4) the potential nodes for the installed PV systems in a feeder are identified first. A potential node is that node which causes maximum power loss with the load connected to the node in the feeder. When the PV system is connected to that node, to feed the loads in the feeder will result in a maximum saving of the power and energy losses in the feeder. Then the actual power loss, voltage profile and the current in the feeder sections the feeder with and without PV system connected to the identified nodes in the feeders concerned are computed using a Radial Load flow program, developed for this purpose. Comparing the Power and Energy loss savings with PV at different potential nodes, the optimum location is identified as that node which results in a maximum saving of power losses, PL saving.

Thus the objective function for maximization is given as, Max [[PLsaving]i] i = 1 to n (5)

2.2. Determination of the Optimal Size of PVS

The optimal size of the PV system connected at the Optimum location is determined by varying the size of the PV system incrementally from the capacity, considered for determining the optimal location, using the method of local variation. The size of PV System that gives the maximum saving in power and energy losses is the optimal size of the PV System.

Thus, the objective function is stated as

Max [Pi Psaving], [PVS] i = 1 to n (6)

Determination of IRR for the optimal cases
The Cash inflow and the cash outflow for the optimal cases are computed which constitute the following components:
Cash Outflow is the sum of the following:
The initial investment to install the PV system during year 1.
The present worth of O & M charges spent every year during the life cycle of the PVS.
Cash Inflows the sum of the present worth of:The cost of Saving of Energy losses in the feeder and in the Transformer, every year.
The cost of release in capacity in the feeder and Transformer capacity to meet the load growth in the system without augmentation of the feeder or the Transformer capacity.
The Cost of Energy supplied by the PV System every year during the life cycle of the PV System.
The economics of the investment is computed using the Discounted CashFlow Technique. The formula used for computing the present worth Pwof a future value (FV) is given by (3).

P_w=FV/〖(1+i)〗^n (7)

where 'I' is the rate of interest, and 'n' is the year of future value.
The Internal Rate of Return (IRR) is that rate of interest at which Net Cash flow is zero.adopt.

3. Test System Studied

3.1 400v Radial Distribution Feeders

Fig 1 shows a 400V the radial distribution Feeders 1 and 2 in the Kanchipuram district distribution system, in Tamil Nadu. The load Data of the Test System is given in Table-1. The resistance and reactance of the feeder are given in Table-2.

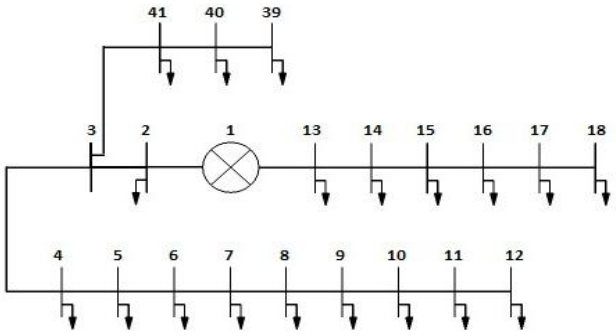


Fig. 1: single-line diagram of the 400V radialDistribution Feeders 1&2

Table 1: Load Data of the Test System

BUS	2	3	4	5	6
P[kW]	2.238	-	12.628	0.520	3.73
Q[kVAR]	1.678	-	9.471	0.39	2.797
BUS	7	8	9	10	11
P[kW]	3.73	4.476	2.238	2.238	3.730
Q[kVAR]	2.797	3.357	1.678	1.678	2.797
BUS	12	13	14	15	16
P[kW]	2.238	4.370	0.080	17.278	13.37
Q[kVAR]	1.678	3.357	0.06	12.958	10.02
BUS	17	18	41	40	39
P[kW]	2.238	2.238	2.238	2.238	11.19
Q[kVAR]	1.678	1.678	1.678	1.678	

Table 2: Resistance and Reactance values of theTest System

LINE	1-2	2-3	3-4	4-5
Resistance(Ω)	0.0194	0.0235	0.1170	0.0306
Reactance(Ω)	0.01387	0.0167	0.0835	0.0219
LINE	5-6	6-7	7-8	8-9
Resistance(Ω)	0.03066	0.0996	0.2646	0.2044
Reactance(Ω)	0.0219	0.07117	0.3968	0.3066
LINE	9-10	10-11	11-12	13-14
Resistance(Ω)	0.165	0.644	0.1064	0.152
Reactance(Ω)	0.252	0.966	0.1596	0.378
LINE	14-15	15-16	16-17	17-18
Resistance(Ω)	0.152	0.13832	0.1383	0.1938
Reactance(Ω)	0.1722	0.304	0.304	0.426
LINE	3-41	41-40	40-39	
Resistance(Ω)	0.4718	0.1848	0.084	
Reactance(Ω)	0.7077	0.2772	0.126	

3.2 11 kV Radial Distribution Feeder

The 11kV feeder studied is shown in fig 2. The load Data of the Test System is given in Table-3. The resistance and reactance of the feeder are given in Table-4.

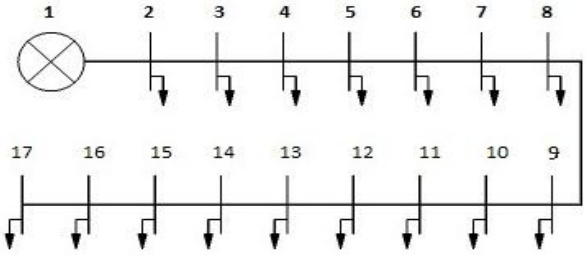


Fig:2: 11kV Distribution Feeder

Table 3: Load Data of the Test System

BUS	2	3	4	5	6
P[kW]	80	80	120	140	80
Q[kVAR]	60	60	90	105	60
BUS	7	8	9	10	11
P[kW]	50.4	160	80	190.4	151.2
Q[kVAR]	37.8	120	60	142.8	113.4
BUS	12	13	14	15	16
P[kW]	160	110.4	80	40	80
Q[kVAR]	120	82.8	60	30	60
BUS	17				
P[kW]	50.4				
Q[kVAR]	37.8				

Table 4: Resistance and Reactance values of the Test System

LINE	1-2	2-3	3-4	4-5
Resistance(Ω)	0.22	0.43	0.19	0.68
Reactance(Ω)	0.0823	0.1608	0.0710	0.2544
LINE	5-6	6-7	7-8	8-9
Resistance(Ω)	1.30	0.62	0.25	0.43
Reactance(Ω)	0.486	0.231	0.0935	0.1608
LINE	9-10	10-11	11-12	12-13
Resistance(Ω)	1.24	0.74	1.05	0.37
Reactance(Ω)	0.4639	0.276	0.392	0.138
LINE	13-14	14-15	15-16	16-17
Resistance(Ω)	1.04	0.74	0.37	0.81
Reactance(Ω)	0.389	0.276	0.1384	0.3030

4. Discussion of Results

4.1. Results of the 400 V Feeders Studied

The nodes 12, 39 and 16 in the feeders 1 & 2 were selected based on the Moment Study, discussed in section II above.

Case - 1:A20 kW PVS is connected at node 12.

The lowest level of the voltage obtained at node No. 12 without and with PV installed, is 0.656 p.u. and 0.915 p.u. respectively. Power loss in the feeder without PV is 10991W.Power loss in the feeder with PV is 8198W.Saving in power loss with PV is 2793W.The Energy loss in the feeder without PV is 28884.348 units. Energy loss in the feeder with PV is 21544.344 units. Saving in Energy loss every year with PV is 7340.004units. Addition-

al energy that could be fed due to capacity release in the feeder and Transformer is 99864 units.

Revenue Assessment:

Cash outflow during the life of the PV system includes, The Capital investment ofRs.1679000 in the first year + O& M charges ofRs.4000 every year.
Cash inflow in the year, i, includes, The Cost of annual saving in Energy losses of 7340.004 Units+ cost of energy supplied by PV in the years (as given in Table 5+ Revenue realisable per year due to the sale of the additional energy of 99864 units.
The IRR of the investment considering the additional sale of energy due to capacity release is 40.5%.

Case 2:A 20 kW PVS is connected at the node 39.

The lowest level of the voltage obtained at the far end node12 without and with PV installed at the node No.39 is 0.656 p. u. and 0.667 respectively. Power loss in the feeder without PV is 10991W.Power loss in the feeder with PV is 8514W.Saving in power loss with PV is 2477 W. Energy loss in the feeder without PV is 288884.348 units. Energy loss in the feeder with PV is 22374.792 units. Saving in Energy loss every year with PV is 6509.556 units. Additional energy that could be fed due to capacity release in the feeder and Transformer is 98462.4units.

Revenue Assessment:

Cash outflow during the life of the PV system includes, The Capital investment ofRs.1679000 in the first year + O& M charges Rs.4000 every year.
Cash inflow in the year, i, includes, Cost of annual saving Energy losses of6509.556 Units + cost of energy supplied by PV in the years (as given in Table 5+Revenue realisable per year due to the sale of the additional energy of 98462.4units.
The IRR of the investment considering the additional sale of energy due to capacity release is39.8%.

Case 3: A 20 Kw PVS is Connected at Node No. 16.

The lowest level of the voltage obtained at node No. 18 without and with PV installed at node 16, is 0.598 p.u. and 0.756 p.u. respectively. Power loss in the feeder without PV is 11942W.Power loss in the feeder with PV is 4267W.Saving in power loss with PV is 7675W.The Energy loss in the feeder without PV is 31383.576 units. Energy loss in the feeder with PV is11213.676Units. Saving in Energy loss every year with PV is 20169.9Units. Additional energy that could be fed due to capacity release in the feeder and Transformer is 121194.6 units.

Revenue Assessment:

Cash outflow during the life of the PV system includes, The Capital investment ofRs.1679000 in the first year+ O& M charges Rs.4000 every year.
Cash inflow in the year, i, includes, The Cost of annual Energy loss saving of20169.9Units+ cost of energy supplied by PV in the years (as given in Table 5) + Revenue realisable per year due to the sale of the additional energy of 121194.6 units.
The IRR of the investment considering the additional sale of energy due to capacity release is 50.7 %.

Table 5: Energy supplied by the 20 kW PV System

Year	Energy supplied by PV System (Units)	Year	Energy supplied by PV System (Units)
1	29700	14	26062
2	29404	15	25802
3	29108	16	25544
4	28818	17	25288
5	28530	18	25036
6	28244	19	24786
7	27962	20	24538
8	27682	21	24292
9	27406	22	24048
10	27132	23	23808
11	26860	24	23570
12	26592	25	23334
13	26326		

4.1.1Optimal Location for the Installation of PVS in the 400V Feeder

As could be seen from the above results, the minimum power loss in the feeder occurs when the PVS is connected to node 16 as shown in Fig.3 Thus the optimum location is the node 16.

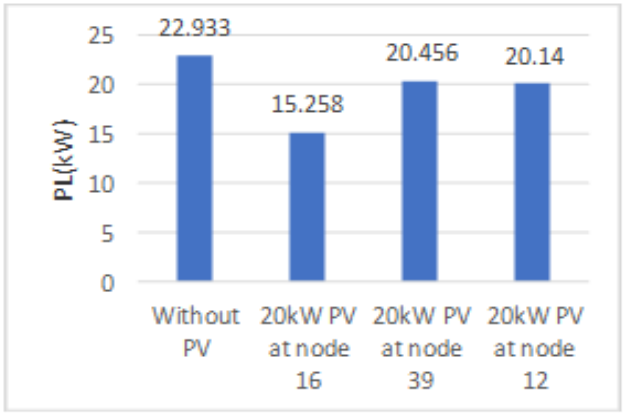


Fig 3. The power loss in the Distribution system

4.1.2Optimal Sizing of PVS in the 400V Feeder

The optimal sizing of PVS is decided based on the lowest loss in the feeder with the selected sizes of the PVS at the optimal node 16. The optimal location was fixed by connecting 20 kW PVS at node 16. To determine the optimal size in this node; the capacity of PVS was varied from 15 kW PVS to 35 kW PVS. The lowest power loss was noted for the capacity of 32 kW PVS. As shown in Fig.4, the 32 kW PVS at node 16 has the lowest power loss of 14.52 kW. Therefore, the optimal size of PVS for node No. 16 is 32 kW PVS.

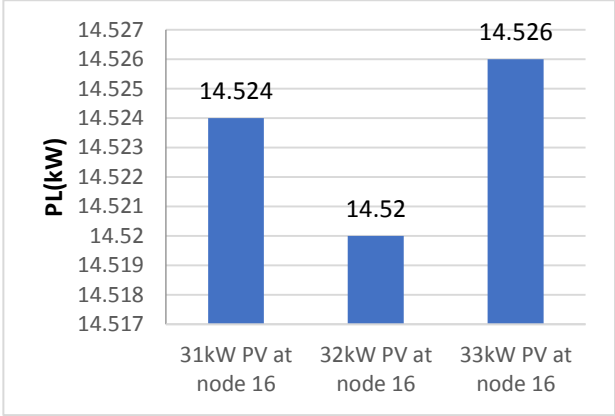


Fig 4 The power loss in the feeder for different sizes of PVS

4.2. Results of the 11 kV Feeder Studied

The nodes 5, 10 and 17 in the feeder, shown in Fig.2 were selected based on the Moment Study, discussed in section II above. The power loses obtained in these locations are shown in Fig. 5.

Case 1: the 500kW PVS is Connected at the Node 5.

The lowest level of the voltage obtained at node No. 17without PV installed is 0.908 p.u. The lowest level of the voltage obtained at node 17 with PVS installed at node 5, is 0.915 p.u. The Power loss in the feeder without PVS is 128.388kW. Power loss in the feeder with PVS is 109.399 kW. Saving in power loss with PVS is 18.989 kW. Energy loss in the feeder without PVS is 336403.664 units. Energy loss in the feeder with PV is 287500.572 units. Saving in Energy loss every year with PVS at Node 5 is 49903.092 units. Additional energy that could be fed due to capacity release in the feeder and Transformer is 2433659.4 units.

Revenue Assessment:

Cash outflow during the life of the PV system which includes the capital investment ofRs.46620750 in the first year and the O& M charges Rs.68000 every year.

Cash inflow is equal to the cost of annual Energy loss saving of 49903.092Units + cost of energy supplied by PV in the years as given in Table 6 + Revenue realizable per year due to the sale of the additional energy of 2433659.4 units.

The IRR of the investment considering the additional sale of energy due to capacity release is 32.6 %.

Case2: the 500kW PVS is Connected at the Node 10.

The lowest level of the voltage obtained at node No.17 without PVS installed, is 0.908 p.u. The lowest level of the voltage obtained at node 17 with PV installed at node 10, is 0.934 p.u. Power loss in the feeder without PVS is 128.388 kW. Power loss in the feeder with PVS is 76.851 kW. Saving in power loss with PVS is 51.537 kW. Energy loss in the feeder without PVS is 336403.664 units. Energy loss in the feeder with PVS is 201964.428units. Saving in Energy loss every year with PVS is 134439.236units. Additional energy that could be fed due to capacity release in the feeder and Transformer is 2415745.2units.

Revenue Assessment:

Cash outflow during the life of the PV system which includes the capital investment ofRs.46620750 in the first year and the O& M charges Rs.68000 every year.

Cash inflow is the sum of the cost of annual Energy loss saving of 134439.236 units + cost of energy supplied by PV in the years as given in Table 6 + Revenue realizable per year due to the sale of the additional energy of 2415745.2units.

The IRR of the investment considering the additional sale of energy due to capacity release is 35.04%

Case3: the 500kW PV is Connected at the Node 17.

The lowest level of the voltage obtained at node No. 17 without PVS installed, is 0.908 p.u. The lowest level of the voltage obtained at node 13with PVS installed at node 17, is 0.949 p.u. Power loss in the feeder without PVS is 128.388 kW. Power loss in the feeder with PVS is 72.757kW. Saving in power loss with PVS is 55.631 kW. Energy loss in the feeder without PVS is 337403.664 units. Energy loss in the feeder with PVS is 191205.396Units. Saving in energy loss every year with PVS at node 17 is 146198.268 units. Additional energy that could be fed due to capacity release in the feeder and Transformer is 2433659.4units.

Revenue Assessment:

Cash outflow during the life of the PVS system which includes the capital investment ofRs.46620750 in the first year and the O& M charges Rs.68000 every year.

Cash inflow is the sum of the cost of annual Energy loss saving of 146198.268 units + cost of energy supplied by PVS in the years as given in Table 6 + Revenue realizable per year due to the sale of the additional energy of 2433659.4 units.

The IRR of the investment considering the additional sale of energy due to capacity release is 35.4%.

Table 6: Energy supplied by the 500kW PV System

Year	Energy supplied by PV System (Units)	Year	Energy Supplied by PV System (Units)
1	742520	14	651584
2	735087	15	645051
3	727753	16	638617
4	720526	17	632217
5	713253	18	625917
6	706119	19	619650
7	699052	20	613450
8	692085	21	607316
9	685152	22	601249
10	678318	23	595216
11	671518	24	589282
12	664818	25	583382
13	658151		

4.2.1Optimal Location for the Installation of PVS in the 11kV Feeder

As could be seen from the above results, the minimum power loss in the feeder occurs when the PVS is connected to node 17 as shown in Fig.5 Thus the optimal location is the node 17.

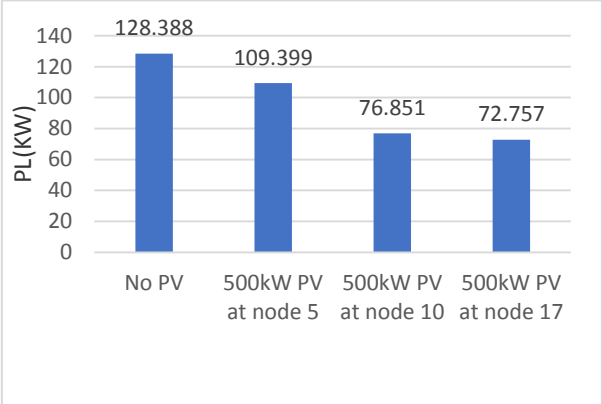


Fig: 5: Power loss in the 11kV feeder locations

4.2.2Optimal Sizing of PVS in the 11 kV Feeder

The optimal sizing of PVS is decided based on the lowest loss in the feeder with the selected sizes of the PVS at the optimal node 17. The optimal location was fixed by connecting 500 kW PVS at the selected nodes. To determine the optimal size of PVS at the optimal location (node 17), the capacity of PVS was varied from 600 kW PVS to 800 kW PVS. The lowest power loss was noted for the capacity of 793 kW PVS. As shown in Fig.6, the 793 kW PVS at node 17 has the lowest power loss of 64907.83 kW. Therefore, the optimal size of PVS for node No. 17 is 793 kW PVS.

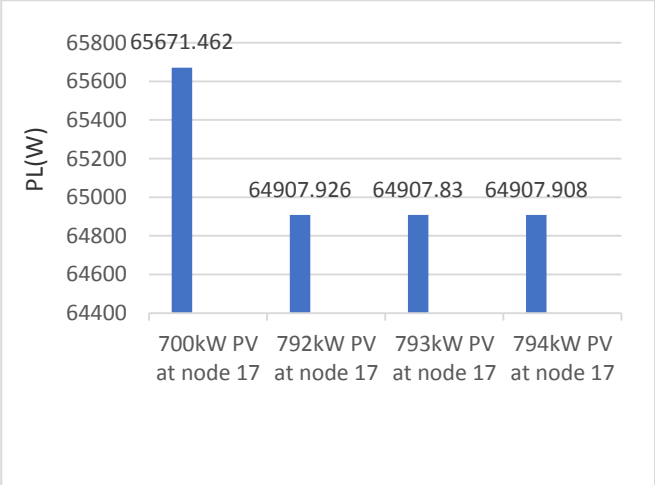


Fig 6. The power loss with different sizes of PVS at node 17

5. Conclusion

In view of the depleting situation of Coal reserves in the world, the need for going for promoting Distributed Generation in the Electrical Utilities was discussed. This study has considered the use of Photovoltaic Generating systems (PVS) as Distributed Generation both at 400 V level and at 11 kV level. Practical 400 V Radial Distribution feeders and an 11kV Radial feeders were studied as Case studies. A Simple Moment method and a Radial load flow technique to compute the feeder losses and the optimal location of PVS in the Feeders studied. The Method of Local Variation was used to determine the optimal size of the PVS at the optimal locations. The approach and method presented could be easily adopted and practised by the practising field engineers. The Discounted Cash Flow technique used for the financial analysis of the cases studied were presented.

The study clearly shows that use of PVS to meet the growing demand for electricity at different levels in the Power system, like Consumer load points, at the optimal locations in the LT feeders and at the optimal load centers in the Primary Distribution feeders like 11 kV, 22kV or 33kV feeders will result in power quality and economic benefits. The study brings out the advantages of the use of PVS over Coal-fired Power Generating systems. The same study can be extended with the implementation of SMART Grid itself.

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