VOLTAGE PROFILE AND RELIABILITY IMPROVEMENT OF A RADIAL DISTRIBUTION FEEDER WITH DISTRIBUTED GENERATION

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Abstract: Now a days there is a tremendous pressure on utilities to supply reliable and adequate power supply. To meet this demand the utilities have to evolve new technologies namely inserting the DGs at the appropriate place in an feeder. Placing a DG at the appropriate place in an feeder helps to improve reliability, improve voltage regulation and also it is cost effective. This analysis done on vastare rural 11kV feeder originating from chikkamagaluru MUSS. The data collected from chikkamagaluru MUSS for the year 2016 and calculated various reliability indices, voltage regulation, payback period and shown improvement of reliability, voltage regulation after placing DGs.

Index Terms: **Reliability, Distributed Generator, voltage Regulation, availability**.

I. INTRODUCTION

Power system mainly comprise of generation, transmission and distribution. Out of these three components of power system the most affected component is the distribution. Compared to Generation and Transmission less emphasis is given on Distribution though it plays an important role in delivering power supply to consumers. Every utility should plan for some reliability improvement techniques based on the requirement of their own. The reliability level is closely related to its cost function meaning a good reliable system insists heavy investment and in turn poor reliable system forces more downtime cost to consumer. One of the reliability improvement techniques may be inserting DG in the existing feeder at appropriate place. The Distributed Generation in general is any type of electrical generator or static inverter that produces alternating current (AC). The DG has the capability of parallel operation with the electric utility distribution system or it is designed to operate independently from the electric utility system and it can also feed a load that is already connected by electric utility distribution system. Sometimes Distributed Generator is also called as simply Generator. DGs are classified based on capacity from micro to large and based on technology Renewable, modular and CHP(Combined Heat and power).

In this paper, the reliability indices and voltage regulation are calculated for the existing vastare 11kV feeder using various formulas for the daily load data collected from chikkamagaluru MUSS for the year 2016. The various reliability indices such as SAIDI, SAIFI, CAIDI, ASAI and ASUI and voltage regulation are recalculated after placing the DGs at the appropriate place in vastare 11kV feeder. The payback period of DGs for the utility is also calculated and tabulated to shown placing of DGs is also cost effective. Also since the DGs taken for study in this paper are renewable it is environmental friendly and reduces the green house effect.

II. METHODOLOGY

The main objective of this work is to improve the reliability indices and to improve the voltage regulation of vastare 11kV distribution feeder. The Reliability indices are calculated based on the daily log data collected from chikkamagaluru MUSS for the existing feeder. Then the DGs are placed in the appropriate place in the vastare feeder and the placing of DGs is suggested by MATLAB software programme after running a load flow analysis. The reliability indices and voltage regulation calculated based on the formulas 1 to 6 listed below.

1) System Average Interruption Duration Index:

$$\text{SAIDI} = \frac{\text{Total Duration in Hours}}{\text{Number of customers supplied}} \quad (1)$$

2) System Average Interruption Frequency Index:

$$\text{SAIFI} = \frac{\text{Frequency ofOutage}}{\text{Number of customers supplied}} \quad (2)$$

3) Customer Average Interruption Duration Index:

$$CAIDI = SAIDI/SAIFI \quad (3)$$

4) Average Service Unavailability Index:

$$ASUI = \frac{SAIDI}{Total\ Hrs} \quad (4)$$

5) Average Service Availability Index:

$$ASAI = (1 - ASUI) \quad (5)$$

The Reliability indices are again calculated after placing the DGs and are tabulated. The voltage regulation of the vastare feeder is calculated using the below formula.

$$\text{Voltage Regulation} = \frac{(\text{Voltage on No Load} - \text{Voltage on Full Load})}{\text{Voltage on No Load}} \quad (6)$$

The results are tabulated from Table 1 to 6.

III. RESULTS AND DISCUSSIONS

The frequency and duration of outages for the year 2016 of the vastare 11kV distribution feeder are tabulated in Table 1. The total outages which include forced and scheduled outages are 2626:16 Hrs and the total frequency of outages are 1104 which include both forced and scheduled.

Table 1 Total Outages for VASTARE Feeder for the year 2016 (Chikkamagaluru MUSS)

Months	Scheduled Outage		Forced Outage		Total outage	
	Freq	Duration(Hr)	freq	Duration(Hr)	freq	Duration(Hr)
Jan	63	248:33	22	3:37	85	252:10
Feb	68	258:07	18	12:26	86	270:33
Mar	91	285:28	23	5:25	114	290:53
Apr	75	269:35	23	8:23	98	277:58
May	67	217:28	55	49:23	122	266:51
Jun	68	173:56	70	50:17	138	224:13
Jul	29	18:56	34	34:29	63	53:25
Aug	32	55:09	17	15:43	49	70:52
Sep	43	169:00	12	1:38	55	170:38
Oct	58	176:32	21	5:52	79	182:24
Nov	68	257:38	26	19:09	94	276:47
Dec	84	266:50	37	22:42	121	289:32
TOTAL	**746**	**2397:12:00**	**358**	**229:04:00**	**1104**	**2626:16**

The reliability indices SAIDI, SAIFI, CAIDI, ASAI and ASUI are calculated based on the data collected in the Table 1. The results are tabulated in the Table 2 tabulated below.

Table 2 Customer oriented reliability indices for the vastare distribution feeder from Jan to Dec for the year 2016

MONTHS	INTERRUPTIONS	Outage(HOURS)	TOTAL HOURS	TOTAL CUSTOMERS	SAIFI	SAIDI	CAIDI	ASAI	ASUI
Jan	85	252.17	744	2170	85.00	252.17	2.97	0.6611	0.3389
Feb	86	270.55	672	2170	86.00	270.55	3.15	0.5974	0.4026
Mar	114	290.88	744	2170	114.00	290.88	2.55	0.6090	0.3910
Apr	98	277.97	720	2170	98.00	277.97	2.84	0.6139	0.3861
May	122	266.85	744	2170	122.00	266.85	2.19	0.6413	0.3587
Jun	138	224.22	720	2170	138.00	224.22	1.62	0.6886	0.3114
Jul	63	53.42	744	2170	63.00	53.42	0.85	0.9282	0.0718
Aug	49	70.87	744	2170	49.00	70.87	1.45	0.9047	0.0953
Sep	55	170.63	720	2170	55.00	170.63	3.10	0.7630	0.2370
Oct	79	182.4	744	2170	79.00	182.40	2.31	0.7548	0.2452
Nov	94	276.78	720	2170	94.00	276.78	2.94	0.6156	0.3844
Dec	121	289.53	744	2170	121.00	289.53	2.39	0.6108	0.3892
TOTAL	**1104**	**2626.27**	**8760**	**26040**	**1104.00**	**2626.27**	**2.36**	**0.699047**	**0.300953**

The customer oriented reliability indices are calculated and tabulated as shown in the above Table 2. The minimum SAIFI is reported in the month of August and maximum SAIFI is reported in the month of June. The maximum SAIDI is reported in the month of March and minimum SAIDI is reported in the month of July.

The load flow analysis done for the vastare feeder using MATLAB software programme and the result is tabulated in the Table 3. After load flow analysis the DGs are placed at the bus numbers suggested by the MATLAB programme.

Table 3 Load flow analysis with Six Distributed Generators

DG Size(kW)	600, 500,300,200,200,200
Location(Bus Number)	32, 108,73,113,99,54
Active Power loss(kW)	198.2935
Reactive Power loss(kVAr)	153.2053
Bus with highest LSF	80
Optimal DG Size(kW)	140.9407

The reliability indices are calculated after placing the DGs and are tabulated in Table 4.

Table 4 Summary of customer oriented reliability indices after Placing DG1, DG2, DG3, DG4, DG5 and DG6

SAIDI	SAIFI	CAIDI	ASAI	ASUI
790.30	**332.217**	**2.3629572**	**0.909437**	**0.090563**

The single line diagram of Vastare Distribution feeder after insertion of DG1, DG2, DG3, DG4, DG5 and DG6 is shown in figure 1.

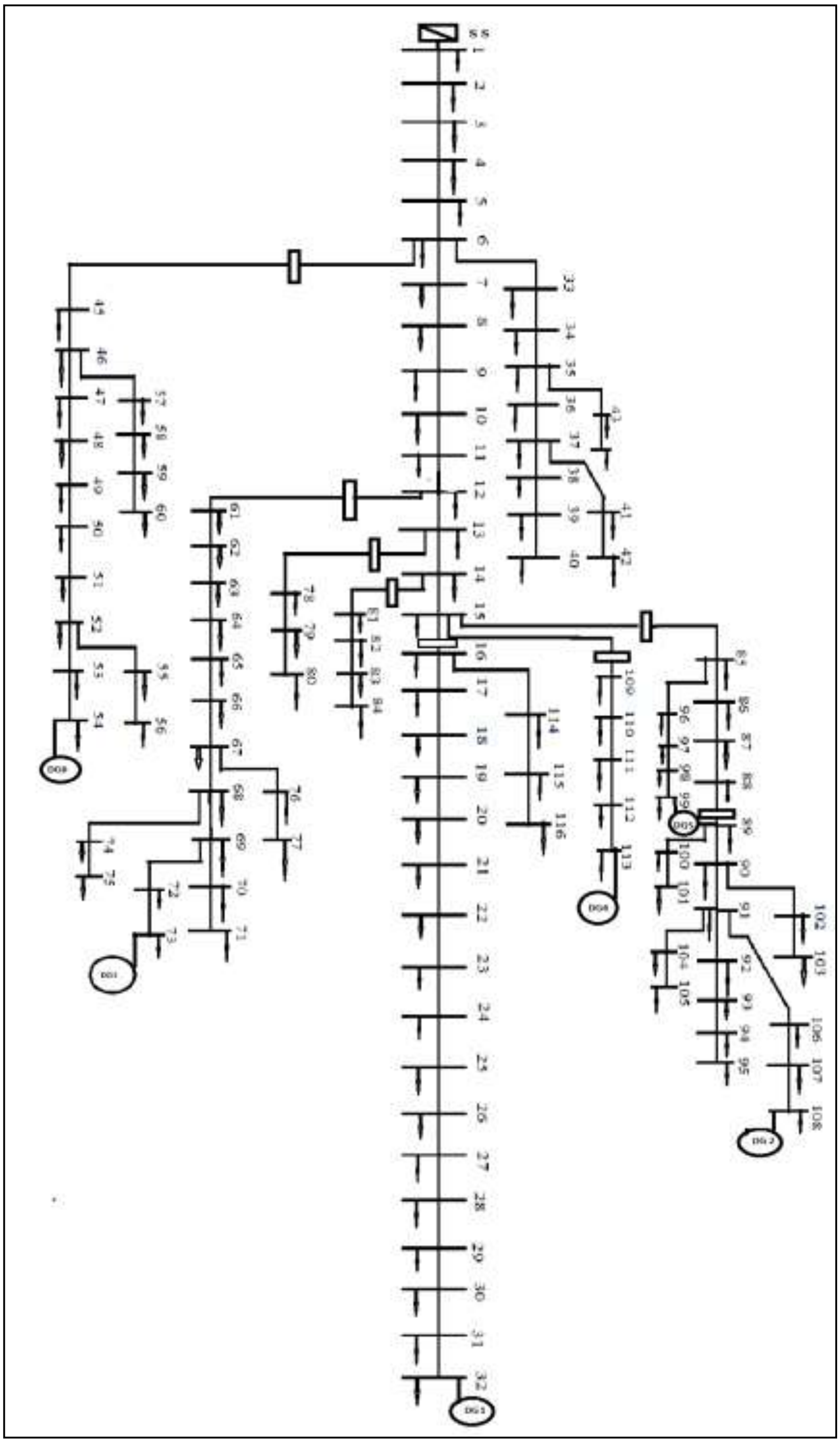

Fig 1 Rearrangement of vastare feeder after placing DG1 to DG6

The graphical representation of various indices is plotted from figures 2 to 5.

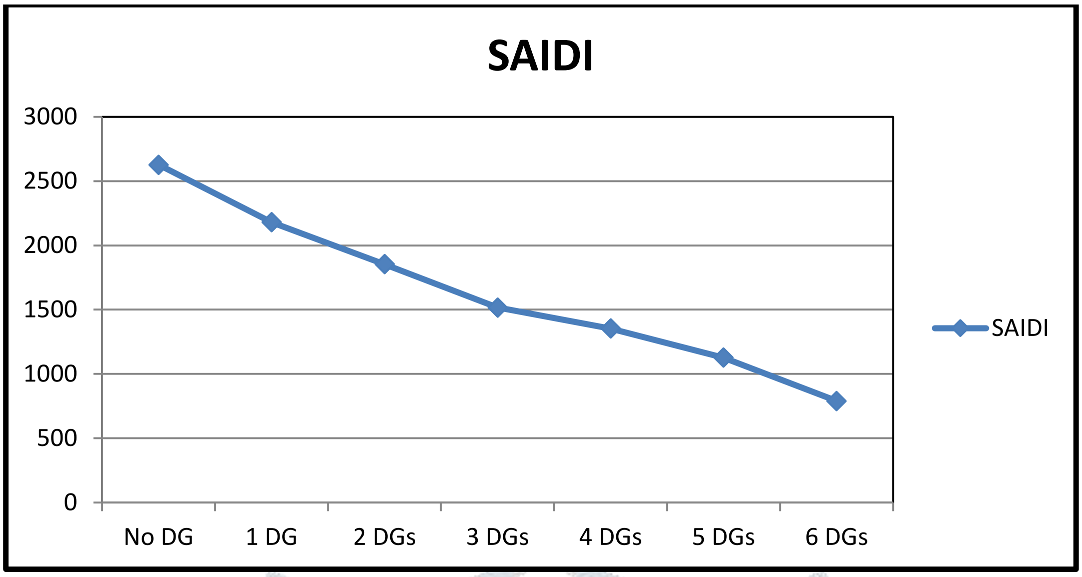

Figure 2 Improvement of SAIDI on DG Placement

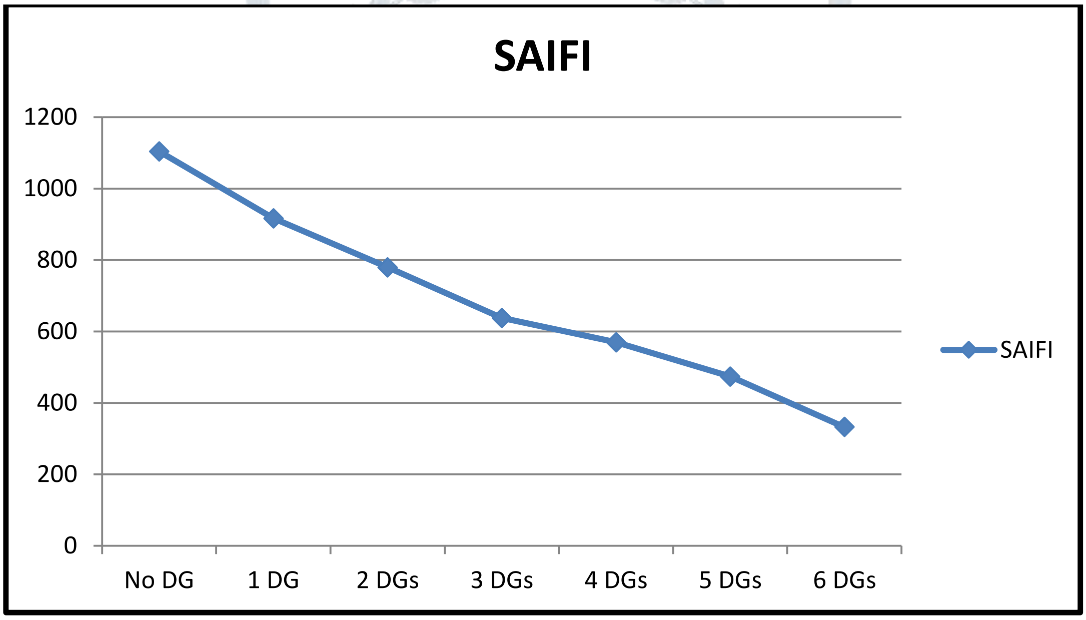

Figure 3 Improvement of SAIFI on DG Placement

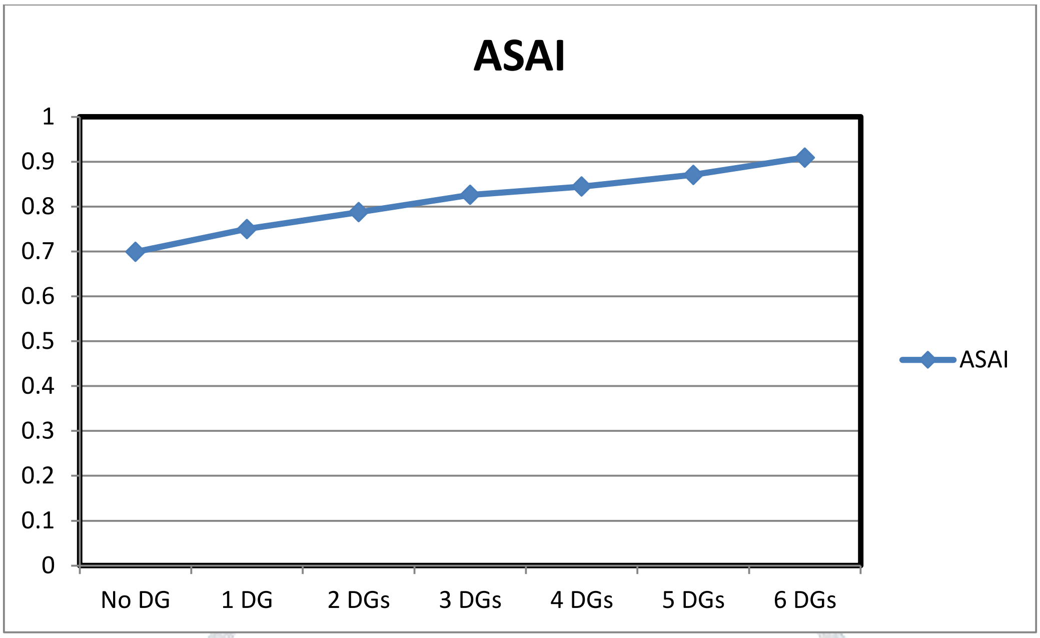

Figure 4 Improvement of ASAI on placement of DG.

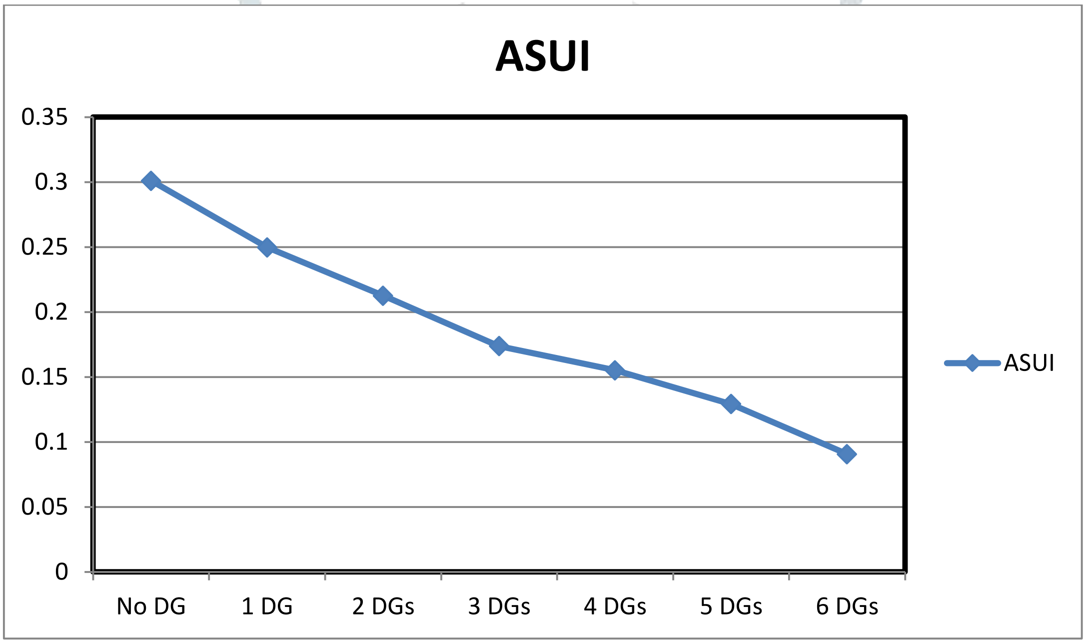

Figure 5 Improvement of ASUI on placement of DG.

Cost Analysis of DG installation:

The reliability improvement using DG is shown in the above section. Also the installation of DG is economical to electric utility companies. In this section the cost analysis and payback period to electric utility company is carried out. The cost of solar power system is Rs 1.2 Crore for 200kW capacity and the cost includes solar panels, structure to install panel, inverter and installation charges.

The detailed cost analysis carried out for the 6 DG's excluding the cost of land and maintenance is tabulated in the Table 5.

Table 5 Cost Analysis of six DGs

NO OF DG	DG Capacity(kW)	Customers connected	Connected Load(kW)	Average load(kW)	Outage Hours	Units(kWH)	Loss to utility(Rs)	DG Cost(Rs)	Payback Period(Years)
DG1	600	369	583	466	2626	1223842	6119210	36000000	6
DG2	500	269	342	274	2626	719598	3597990	30000000	8.5
DG3	300	279	268	214	2626	562022	2810110	18000000	6.5
DG4	200	134	152	122	2626	320405	1602025	12000000	7.5
DG5	200	188	177	142	2626	372930	1864650	12000000	6.5
DG6	200	278	348	278	2626	730103	3650515	12000000	3.5
TOTAL							19644500	120000000	6.10

The total cost of the six DG installation is Rs 120000000=00 and the total loss to utility is 19644500=00. The average pay back period for the utility is around six years.

Voltage regulation of vastare feeder:

The voltage regulation of vastare 11kV distribution feeder is calculated for all the 116 Buses, The results are tabulated below in Table 6 and shown for some of the Bus numbers.

Table 6 Voltage Regulation of vastare feeder

Bus Number	Voltage Regulation before DG Insertion	Voltage Regulation after DG Insertion
02	0.0163	0.0044
54	0.0867	0.0285
73	0.2506	0.0152
99	0.2576	0.0080
116	0.2617	0.0154

IV. CONCLUSION

The reliability indices calculated for the existing vastare 11kV distribution feeder are SAIDI is 2626.27, SAIFI is 1104.00, CAIDI is 2.36, ASAI is 0.69 and ASUI is 0.30. The reliability indices calculated after placing six DGs on the vastare feeder are SAIDI is 790.30, SAIFI is 332.217, CAIDI is 2.36, ASAI is 0.90 and ASUI is 0.09. This shows that the outage duration on vastare feeder is decreased and also frequency of interruptions is reduced. Also the availability of the feeder is increased from 0.69 to 0.90. The voltage regulation of the feeder is also improved. The payback period for the utility is around six years. So by using DG technology the construction of new lines can be avoided as the DGs are installed near customer load points. Also DGs are environmental friendly which reduces co_2 emission and easy to install.

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