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Loss Reduction and Voltage Profile Improvement in a Rural Distribution Feeder using Solar Photovoltaic Generation and Rural Distribution Feeder Optimization using HOMER

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Abstract:

Rural Electricity is lagging in terms of service as well as penetration of power. Most of the rural householders do not have power supply, if at all they have high in voltage fluctuations and system losses. Due to this, the performance of distribution system becomes inefficient. Optimal placement and sizing of Distribution Generator (DG) in the distribution system will improve the performance of the distribution system. This paper analysis a practical rural feeder of 3.06 MW peak load in Mysuru, Karnataka, India. A methodology used for finding optimal placement and sizing of DG in the rural feeder. The practical rural feeder is simulated in Power World Simulator (PWS) and analyze the voltage magnitude and system losses. Simulation results shows that optimal placement and sizing of DG will improve the voltage profile within the acceptable limits and reduce the system losses. Hybrid Optimization of Multiple Electric Renewables (HOMER) optimization analysis designs best system model by considering different constraints and with Renewable Energy sources (RES) for the rural distribution feeder.

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Keywords: Distribution network, Distribution Generator (DG), HOMER, Optimization, Power World Simulator (PWS), Solar Photovoltaic (PV).

1. Introduction:

Electrical power system divided into Generation, Transmission and Distribution. Distribution system supplies power to the rural distribution consumers and load on the distribution network increasing day to day.

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The load meeting in the rural distribution network is a challenging issue while maintaining the all constraints of the distribution system [1]. Due to increased load demand in the distribution system, the load current drawn from the source would increases. This may lead to an increase in voltage drop and system losses [2]. The performance of distribution system becomes inefficient due to the reduction in voltage magnitude and increase in distribution losses.

Distribution Generation (DG) is a small scale of generation at the consumer end (that is, at the distribution system). Most of the Distribution Generation (DG) sources are renewable energy sources like wind, solar, fuel cells etc. These sources are environmental friendly and improve the performance of the distribution system. Optimal placement and sizing of DG in the distribution network will give the all benefits of DG like voltage profile improvement and reduce the system losses, improved power quality, relive T&D congestion, reduce reserve requirements and the associated costs etc. [3]. Various factors can be considered for deciding the optimal size and location of the DG like penetration levels of DG, its location uncertainty, and varying output from DG's [4].

Among all the renewable sources, solar Photovoltaic generation (PV) has been growing interest since it offers many advantages like solar PV's are environmental friendly, abundant in nature, operating and maintenance costs for PV panels are considered to be low, almost negligible and compared to costs of other renewable energy systems solar energy panels prices have seen a drastic reduction in the past years and are still falling, solar photovoltaic panels one of major renewable energy systems that are promoted by government through subsidy funding and residential solar panels are easy to install on rooftops or on the ground without any interference to residential life style.

The aim of this paper is to analyse a practical rural distribution feeder with peak load demand of 3.06 MW in Mysuru, Karnataka, India. The distribution feeder has the problems associated with high energy losses, voltage regulation problems, large number of interruptions and interrupted power supply, overloading in the sections. Optimal placement and sizing of DG will reduce the system losses, improve the voltage profile within the acceptable limits and increase the system reverse capacity etc. Hybrid Optimization of Multiple Electric Renewables (HOMER)based Optimization analysis designs the best system model by considering different constraints like life time of the plant, Net present cost (NPC), emission of pollutants and sensitivity values of renewable sources.

This paper organized as follows. In section II, formulate the practical rural distribution feeder and section III provides the information about simulation tools used in this paper. In section IV, explained about methodology used for finding optimal location, size of the DG and HOMER Optimization analysis procedure. In section V, discuss the simulation results and finally in section VI, the conclusions are presented.

2. Problem Formulation

This paper analyse a practical rural distribution feeder "Saraswathi feeder" located in Mysuru, Karnataka, India. The feeder has the peak load of 3.06 MW with 30 distribution transformers (DTC) and one HT line. The DTC details are shown in Table 1. In electrical terms, power is proportional to product of voltage and current. The power supply system has only control over voltage; it has no control over the currents drawn from the particular loads. Therefore, the power quality issue is related to maintain the supply voltage within the acceptable limits.

Table 1: DTC Load Details

DTC Rating (KVA)	Voltage ratio (in Volts)	No of DTC connected	Load connected to each DTC (KVA)	Total Load (KVA)
250	11000/433	5	249	1245
100	11000/433	22	99	2178
63	11000/433	2	62	124
25	11000/433	1	24	24
		Total		3571

Electric distribution system expand with time on the demand. Due to increased load demand, the system losses increases and voltage profile of the system in not within the acceptable limits so that the performance of distribution system is inefficient. Distribution Generation (DG) will improve the power quality where voltage support by the grid is difficult. In this paper analysis the major problems faced by the rural distribution consumers is poor supply voltage and high system losses. The voltage profile of the existing rural distribution feeder “Saraswathi feeder" as shown in Fig.1.

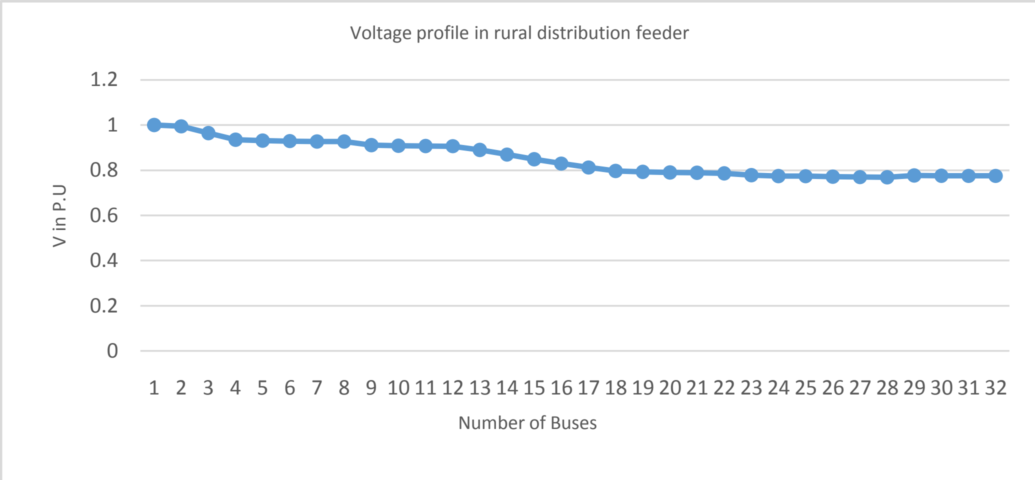

Fig.1 Voltage profile of rural distribution feeder

3.Simulation Tools

3.1 Power World Simulator

It is a power system Visualization, simulation and analysis tool. This simulator tool can do all power system calculations like optimal power flow (OPF), Security constrained OPF (SCOPF), OPF reserves, available transfer capacity (ATC), PV and QV curves etc. It is an interactive power system simulation package designed to simulate high voltage. The software contains a highly effective power flow analysis package capable of efficiently solving systems for large number of buses. Powerful visualization techniques are used on an interactive basis, resulting in an extremely intuitive and easy to use graphical user interface (GUI). Power world simulator package aids the power engineer’s planning and operational stages of power system.

3.2 Homer

HOMER (Hybrid Optimization of Multiple Electric Renewables), the micro- power optimization model, simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. HOMER is the design of micro power systems for the efficient evaluation of various RE power generation Technologies. It compares a wide range of equipment with different constraints and sensitivities to optimize the system design. The planning and decision making in rural electrification projects, HOMER can be of significant due to designing of the system flexibility. Its analysis is based on the technical properties and the life cycle costing (LCC) of the system. The LCC is comprised of the initial capital cost, cost of installation and operation costs over the system’s life span. HOMER has advantages over the usual statistical models, since its high processing speed allows it to run and evaluate an hourly simulation of thousands of possible system configurations Simulations modelled by HOMER are thus more accurate.

4. Methodology

The purpose of this project is to find the best location and size of a DG unit in order to decrease the power losses in the system. When we speak about the best location and size, it means that the most optimum location and the best size of a DG unit in a distribution system to minimize the losses. In a system, there may be some optimum locations and sizes for a DG unit but one of them is the best location and size between them. The proposed algorithm for finding the optimal size and placement of a DG unit in a distribution system is based on “iterative approach”. The iterative approach is explained given below in steps.

Step 1: Model the network for peak loading conditions.

Step 2: Perform the load flow analysis.

Step 3: Check the system losses and voltage profile at each bus.

Step 4: Identify the minimum voltage profile buses.

Step 5: Consider the active power limits of a DG unit at each bus using the equation

% DG penetration=P_{DG}/P_{Load} *100

Step 6: At each DG unit, observe the voltage profile and system losses.

Step 7: Repeat the above two steps for all the minimum voltage profile buses.

Step 8: Compare the losses at each bus and find the minimum loss in the distribution feeder.

Step 9: Compare the Voltage profile improvement in each bus at different DG size’s.

Step 10: Select the best size of DG for minimum losses and voltage profile improvement in their location.

5. Simulation Results

5.1 System Loss Reduction and Voltage profile Improvement Results:

The practical rural distribution feeder “Saraswathi feeder” is simulated in power world simulator (PWS) and analyzed the voltage profile and system losses before and after placement of DG. The Saraswathi feeder is designed in PWS as per the single line diagram of Saraswathi feeder. After design run the simulation, get the voltage profile and system losses with and without DG. The simulation diagram of Saraswathi feeder in PWS as shown in Fig. 2.

Using the Proposed Methodology, find the optimal placement and size of DG. The optimal placement and size of the DG at 16th bus with 70% of DG penetration. At this, the system losses reduced to 83.33% and voltage profiles are within the acceptable limits (that is $0.95<Vi<1.05$). Fig.3 shows the voltage profile of Saraswathi feeder and Fig.4 shows the active and reactive power loss of Saraswathi feeder before and after placement of DG.

5.2 HOMER Optimization Results:

The HOMER Schematic diagram for Saraswathi feeder as shown in Fig.5. Based on giving inputs for each Component (cost input, sensitivity variables, size of the each component), HOMER simulates all possible combinations and give the optimal designs. From fig.6, for rural feeder load balancing, power given from the diesel generator and solar photovoltaic (PV), converter converts DC power to AC and for efficient use of system, batteries are used and it act as autonomy when power is not supplied through diesel generator and solar photovoltaics (PV).Table 2 shows the optimization results of Saraswathi feeder.

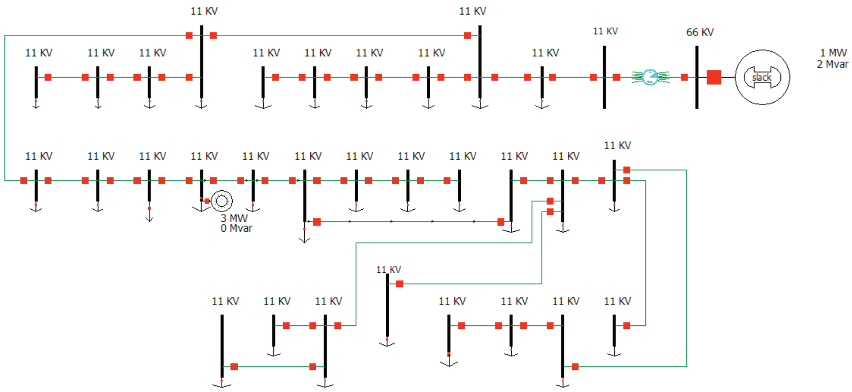

Fig. 2 SLD of Saraswathi feeder in PWS with Optimal placement and size of DG

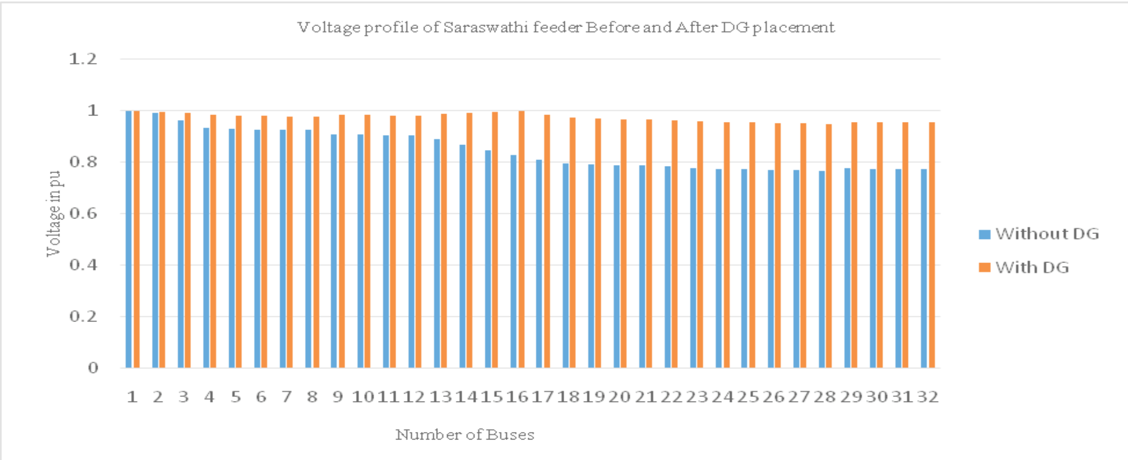

Fig. 3 Voltage Profile of Saraswathi feeder before and after placement of DG

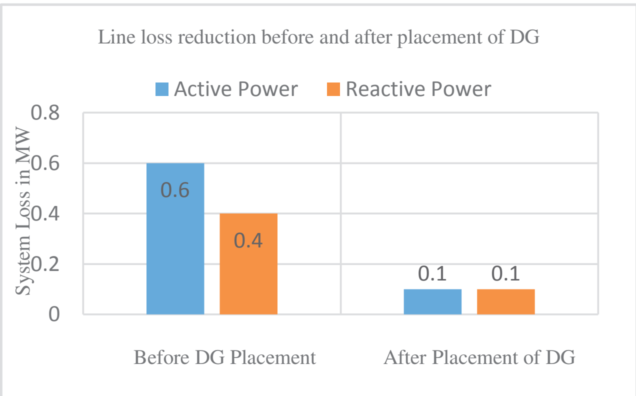

Fig. 4 Active and Reactive power loss before and afterPlacement of DG

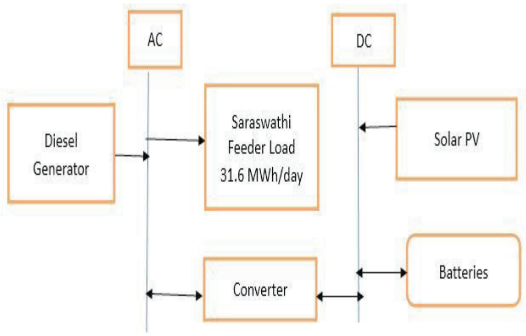

Fig. 5 HOMER Schematic diagram for Saraswathifeeder

Table 2: HOMER Optimization results

Architecture	Cost	
	COE (RS)	NPC(RS)
Diesel Generator (3 MW)	5.022	74,87,91,900
Diesel(3MW)+Solar(0.4 MW)+Converter (3MW)	5.664	84,44,66,000
Diesel(3MW)+ Battery(80 numbers)+Converter(3MW)	5.668	84,50,84,800
Solar(0.4MW)+Diesel(3MW)+Battery(80 numbers)+Converter(3MW)	5.687	84,79,14,100

In the above table, COE: Cost of Energy, NPC: Net Present Cost. The cost is represented in Rupees.

For designing good system, HOMER consider all possible configurations and constraints. Table 2 shows Optimal configurations based on Net Present Cost (NPC) of the system. Using HOMER simulation, the best system with Renewable Energy sources can be designed and the system can be utilized in the optimal way.

6. Conclusion

This paper analysis a practical rural distribution feeder "Saraswathi feeder" with peak load of 3.06 MW located in Mysuru, Karnataka, India. The rural feeder has the problems associated with high energy losses, voltage regulation problems, large number of interruptions and interrupted power supply, overloading in the sections. Optimal placement and sizing of DG in the rural distribution feeder will overcome the all above problems faced by rural distribution network. A methodology is used for optimal placement and sizing of DG in the rural distribution feeder. Simulation results shows that, after placement of DG at optimal location with optimal sizing reduce the system losses and improve the voltage profile within the acceptable limits. HOMER Optimization analysis designs best system by considering all system constraints and with renewable energy sources.

Appendix

Table 3 shows Climatic, Metrological conditions of Mysuru and Fig 6 shows solar radiation details of Mysuru [6,7,8,9].

Table 3: Climatic, Metrological condition of Mysuru

	Unit	Climate data location
Latitude	^{o}N	22
Longitude	^{o}E	77
Elevation	M	445
Heating design temperature	^{o}C	13.65
Cooling design temperature	^{o}C	37.78
Earth temperature amplitude	^{0}C	20.56

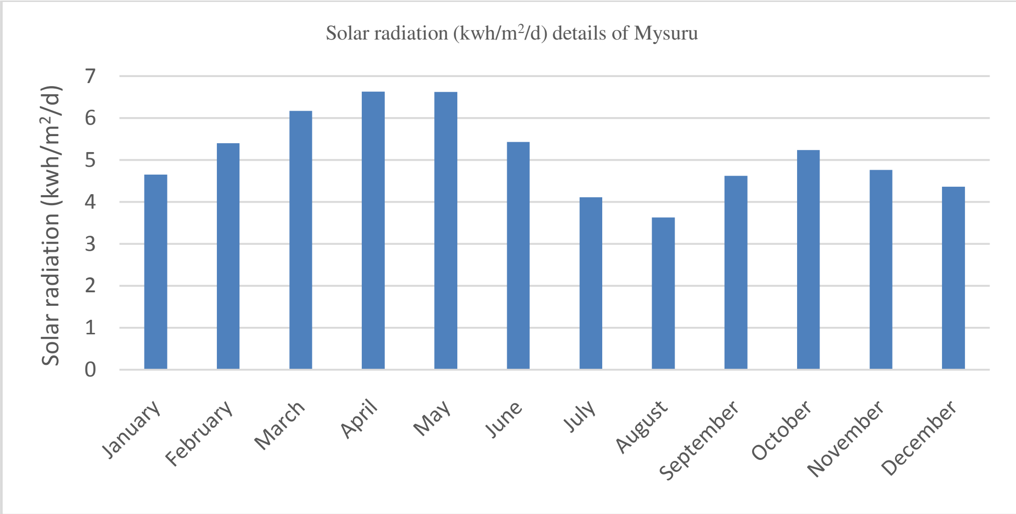

Fig. 6 Monthly Solar radiation details of Mysuru

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