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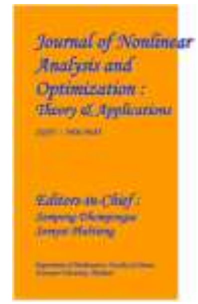

ANALYSIS OF A RADIAL DISTRIBUTION NETWORK AND MITIGATING LOSSES BYSTRATEGIC ALLOCATION OF DISTRIBUTED GENERATION

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ABSTRACT: Long-distance power transmission and distribution presents numerous challenges for power systems that rely on centralized network operations. Common practices rely primarily on fossil fuels, which pollute the air with carbon dioxide (CO2). In this work, we take a look at the issue of voltage drop and power loss in a radial IEEE system with 15 buses. Distributed generation (DG) is integrated into the network to strategically alter the system. The load flow algorithm and radial network model are implemented in MATLAB. Many scenarios are analyzed and simulated to determine how to maximize voltage and minimize power loss in the system.

Keywords: Distributed Generation (DG), Transmission System, Power System, Distribution Network.

1. INTRODUCTION

The distribution of electricity inside the power grid is managed by a centralized operating system network. Pakistan generates power at either 13.8 or 11 kilovolts (kV). In order to generate electricity, the country relies largely on fossil fuels, in particular thermal power plants, which are sometimes located in remote places.
In order to get electricity from places with higher potential to places with lower potential, conventional electrical power transmission networks have to use power converters, which cause power loss on the way to the consumer. Power generation and distribution are not synchronized because of losses in the transmission line.
The long-distance transmission network is just one of the many flaws in the current power system. Researchers today have a major concern about pollution. There have been major increases in carbon dioxide emissions and radioactive waste since Pakistan began relying heavily on fossil fuels as its primary source of energy generation. In addition to the environmental risks, the depletion of fossil fuels and the inability to expand the system's production capacity pose serious threats to the system's efficiency. This results in ineffectiveness, power outages, and safety issues. Since Pakistan's conventional transmission network is currently at capacity, further expansion risks causing voltage drops, power losses, and possibly blackouts. There is a worldwide movement to include renewable energy sources into the electricity grid. To do so, the current conventional energy system must be combined with alternative energy sources. The objective is to meet energy demand by supplying additional power through existing transmission infrastructure. There are substantial environmental, technological, and financial benefits to integrating DG because of DG's close proximity to the customer.

2. LITERATURE REVIEW

Researchers are curious about the optimal size and location of DG within the distribution network. Numerous academics have looked at various potential outcomes to determine the best way forward with this problem. **Mari et al (2018)**

The results of combining a PV generation framework with an 11kV radial distribution feeder were evaluated. Three different methods of SINCAL programming were used to incorporate the PV system into the feeder and evaluate its significance. The voltage increased noticeably, whereas the short circuit level rose just little, once the PV system was connected to the load. Losses at both low and high tension (LT and HT, respectively) have been improved.

Sahito et al (2017)

Power loss reduction analysis has been performed, and the selected strategic regions for integrating DG into the existing radial distribution network have been determined. The author analyzed three different cases and compared the power quality gains to the current distribution system. Simulations were executed in PSS Sincal. **Sahito et al (2015)**

Distributed generation's impact on power outages, voltages, and network short circuits was investigated in a recent study. Using PSS SINCAL, we examined how DG might affect the electrical grid. Depending on the devices' sizes and significance, there were significant power losses and voltage increases, as well as a moderate increase in short circuit levels within the authorized limits of devices..

Mahmud et al (2014)

created an analytical strategy for addressing voltage stability issues. Analytical methods are used to evaluate voltage swings, and a mathematical equation is used to establish a connection between swings in voltage and the available DG capacity.

Davda et al (2014)

Analyzed a real-world 3.9 MVA network and came up with a method for finding the best spots to put in embedded generators. Low voltage issue was fixed within the predicted range, as shown by the simulations. Reserve capacity increased when energy loss reduced.

Zhao et al (2014)

To pinpoint the weak points in the system, researchers turned to small-world network theory. It was proposed at that time that a genetic algorithm may be used to determine the optimal placement and size of grid-connected DG. Proof of concept and significant performance improvement were found when a flexible distribution network architecture was applied to an active distribution network.

Zulpo et al (2014)

The model's primary goal was to find the optimal size and placement of distributed generation (DG), which would result in less power and voltage fluctuations. In addition, it is a programming paradigm that defines a position with the help of non-linear derivatives, binary variables, and the standard optimization method. The advantages of Distributed Generation (DG) and how it can be included into the existing network have been demonstrated by numerous authors. However, this presents a significant challenge, as an autonomous system is required to determine the optimal scale and placement for DG. The 15-bus radial arrangement used by the IEEE is the subject of this research. Strategically incorporating Distributed Generators (DGs) into the network produces alterations to the system. Using MATLAB as a tool for simulating radial-based networks. We evaluate and simulate numerous scenarios to measure the voltage boost and power efficiency improvement of the system.

3.DISTRIBUTED GENERATION

Distributed generation (DG) is the process of producing electricity from renewable resources such as solar and wind near to the point of use. Two through five, or that range of numbers. The IEEE defines distributed generation (DG) as "the generation of electricity by multiple, independently operated generators that are linked together in a distributed network" . Microgrids are localized electrical networks that are linked to a wider system of power distribution. Connecting DG to low voltage transmission lines increases the reliability of power supply to the consumer end and decreases power loss while delivering clean energy. Using DG in close proximity has many advantages and is strongly recommended. By reducing power loss in the immediate area, it eliminates the need for a widespread network, resulting in significant savings.

4. PROBLEM FORMATION

There are benefits and cons to integrating Distributed Generation (DG) into existing distribution infrastructure. Distributed generation (DG) in a distribution system may display undesirable behavior if it is not properly located and sized. The vast distribution network and complex infrastructure of the electrical system make it crucial to identify nodes with low voltage levels.

The voltage at each bus and the power loss in each branch (the distance between two buses) must be determined before the radial distribution network can be evaluated.

Using the provided equation, you may find out what the voltage is like at the bus of your choosing.

$$V_b = V_a - I_i * (R_i + jX_i) = V_a - \left\{P_i - j\left(Q_i + \frac{V_k^2 + Yi}{2}\right)\right\} * \frac{R_i + jX_i}{V_k}$$

Va and Vb stand for the voltages at the transmitter and receiver, respectively. Pi represents active potential, whereas Qi represents reactive potential. The electrical resistance (Ri) and reactance (Xi) of a specific node are indicated. The active and reactive power losses can be calculated using the same formula.

$$P_{loss}(a,b) = \left(\frac{P_a^2+Q_a^2}{|V|^2}\right) * R_i$$

$$Q_{loss}(a,b) = \left(\frac{P_a^2+Q_a^2}{|V|^2}\right) * X_i$$

A branch from bus A to bus B in a two-bus network has active power equal to Ploss and reactive power equal to PQloss. The total branch loss can be calculated with the help of the equation that follows.

$$T_{loss} = \sum_{i=1}^{i=n-1} P_{i\ loss} + j\sum_{i=1}^{i=n-1} Q_{i\ loss}$$

5. SYSTEM DESCRIPTION

In this work, standard IEEE 15 Bus radial distribution system is studied to analyze the effect of integrating DG over the power loss and voltage drop. The illustration of IEEE 15 Bus system is shown below in (**Figure. 1**).

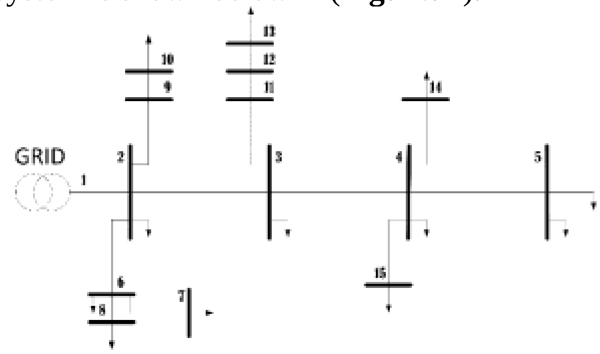

Fig. 1 One-Line Diagram

The DG system will be implemented in three different vehicles. In both examples, 1 MW of equivalent power is used. Distributed generation (DG) accounting for 30 percent of the demand is deliberately spread over three locations. Improvements in voltage drop and power loss are simulated for four different scenarios. Four distinct cases are shown in the table below.

Table.1: Cases under consideration

Case No.	Description
1	Basic network (without integration of DG)
2	Addition of 30% of Load as DG at Bus # 15
3	Addition of 30% of Load as DG at Bus # 05
4	Addition of 30% of Load as DG at Bus # 13

6. RESULTS AND DISCUSSION

We model the scenarios in Table 1 to determine the increase in voltage drop and power loss. Each node's load impedance in the aforementioned network is listed in Table 2. Improving the system's operational capability and power factor is impossible without distributed generation (DG). In all cases, the voltage profile was improved once Distributed Generation (DG) was introduced into the system, though to variable degrees depending on where the DG was installed. Incorporating DG can reduce voltage drop and power loss, leading to greater system efficiency, as demonstrated by the aforementioned four examples. The voltage profile of the network with distributed generation (DG) sources installed at three locations is shown in Figure 2 (a, b, and c). Table. 2: Load Impedance of all branches

Branches (Sender to Receiver)			Load
BranchNo.	Sending End	ReceivingEnd	R (Ω)
1	1	2	1.35309
2	2	3	1.17024
3	3	4	0.84111
4	4	5	1.52348
5	2	9	2.01317
6	9	10	1.68671
7	2	6	2.55727
8	6	7	1.0882
9	6	8	1.25143
10	3	11	1.79553
11	11	12	2.44845
12	12	13	2.01317
13	4	14	2.23081
14	4	15	1.19702

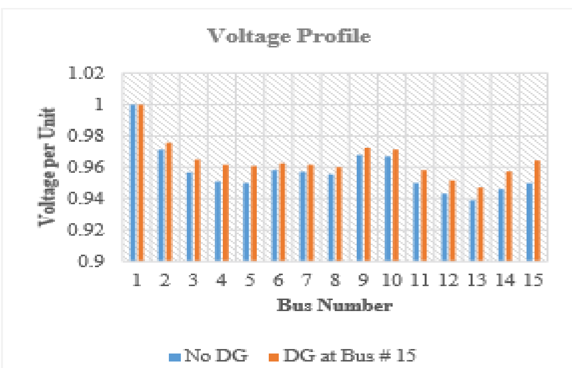

Fig. 2(a) Voltage Profile with DG at Bus # 15

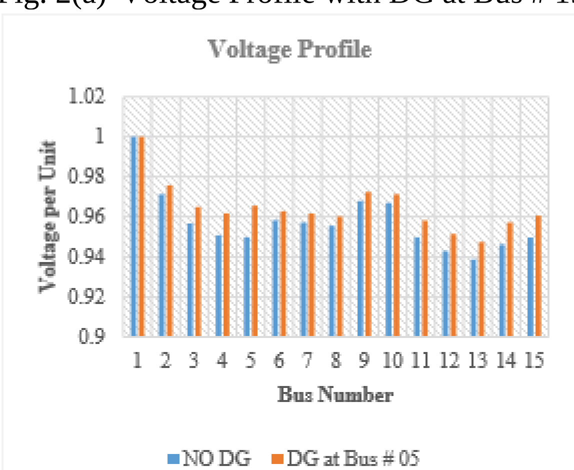

Fig. 2(b) Voltage Profile with DG at Bus # 05

Active power and reactive power are compared across all cases studied (including the baseline state before DG inclusion) in Table 3. To better understand how to prevent power loss, we measure the active and reactive power of each branch. If you want to see how much active and reactive power the system loses before it is reconfigured, "Case No. 1" is the simplest example to use. The most satisfying results in terms of overall power loss reduction may be found in Case No. 4, where the value goes from '0.0640 + 0.0588i' to 0.0492 + 0.0445i. Detailed information about each available bus is provided in the following table.

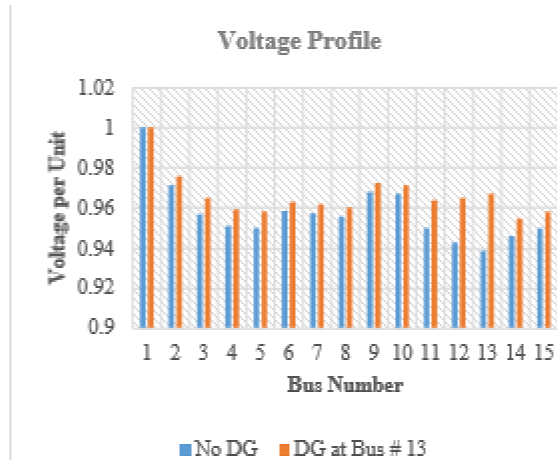

Fig. 2(c) Voltage Profile with DG at Bus # 13

Table. 3: Active and Reactive power before and after DG

7. CONCLUSION

To investigate voltage drop and power loss in an IEEE 15 bus network, this study applies network modeling. One particular radial distribution network is modeled in MATLAB. Distributed generation (DG) integration at key nodes resulted in a modified network, which is being compared to the original.

All three simulated scenarios were given the same amount of distributed generation (DG) integration for the same level of analysis. Active and reactive power losses were reduced with each of the three possible outcomes. The procedures outlined in this study can be used to upcoming circumstances concerning distribution network preparation.

Bus No.	Before DG		After DG					
	Active Power Loss (kW)	Reactive Power Loss (kvar)	Active Power Loss (KW)	Reactive Power Loss (kvar)	Active Power Loss (KW)	Reactive Power Loss (kvar)	Active Power Loss (KW)	Reactive Power Loss (kvar)
-----	Case No. 1		Case No. 2		Case No. 3		Case No. 4	
2	37.8001	36.9732	27.9751	27.3631	27.9965	27.3841	27.9821	27.37
3	11.3388	11.0908	6.9891	6.8362	6.9982	6.8451	6.9929	6.8399
4	2.4464	2.3929	1.2279	1.201	1.2302	1.2033	2.4043	2.3517
5	0.0554	0.0373	0.0541	0.0365	1.4431	0.9734	0.0544	0.0367
6	0.4721	0.3184	0.4678	0.3155	0.4678	0.3156	0.4678	0.3156
7	0.0592	0.0399	0.0586	0.0395	0.0586	0.0395	0.0586	0.0395
8	5.768	3.8906	5.7144	3.8544	5.7145	3.8545	5.7145	3.8545
9	0.0982	0.0662	0.0972	0.0656	0.0972	0.0656	0.0972	0.0656
10	0.4529	0.3055	0.4486	0.3026	0.4487	0.3026	0.4486	0.3026
11	2.1996	1.4837	2.1612	1.4578	2.1613	1.4578	1.2856	0.8672
12	1.5836	1.0681	1.5558	1.0494	1.5558	1.0494	1.4973	1.01
13	0.7546	0.509	0.7413	0.5	0.7413	0.5	1.2864	0.8677
14	0.8234	0.5554	0.8046	0.5427	0.8046	0.5427	0.8091	0.5458
15	0.1097	0.074	0.9982	0.6733	0.1072	0.0723	0.1078	0.0727

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