Penetration effects of various kinds of distributed generation systems on the distribution system

Amandeep Gill, Surendra Kumar Yadav, Pushpendra Singh

Abstract**:** ***Distributed generation system penetration in the existing distribution system is done for minimizing the losses and improving the voltage profile. There are total five types of distributed generation systems exist based on their power delivery like distributed generation system injecting real and reactive power, supplying real power only, supplying reactive power only, absorbing reactive power only , supplying real power and absorbing reactive power. All these five types of distributed generation systems have different penetration effects on the radial distribution system. We get different voltage profiles and power losses for different types of distributed generation systems. The testing of these five types of distributed generation systems will be done on IEEE 33 bus radial distribution system. For computing, the line parameters and power losses of the above testing system the forward-backward sweep load flow method will be applied.***

Index Terms**:** ***Distributed generation systems (DGs), radial distribution system (RDS), per unit (pu) Power Factor (PF).***

I. INTRODUCTION

The electric energy is the main factor in enhancing the social as well as economic living problems. This enhancement makes a massive need for electric energy. The electrical system has actually become the most important facilities which make it possible for all other facilities. The power demand is increasing rapidly and for this reason, there is a need for intending the future power system, which needs a great quantity of the schedule of power from various resources. As a result, the idea of delivering power only via traditional power systems to remote clients has not been possible [1]. This intends on increasing the makeover of power delivery infrastructure into the smart grid. To solve these problems, the idea of decentralized power generation has actually shown up as a brand-new choice. A traditional grid generally replies to demand increase by including new generation abilities and updating the existing power system infrastructure. It consists of the advancement of brand-new substations together with the new distribution setup. This method involves a big expense, as a result of the investments required for setup, building etc [2]. To get rid of this issue, a standard change in electrical power technology, called distributed generation system (DGs) based decentralized generation or dispersed generation is occurring in the existing distribution system. Distributed generation allows for creating as well as integrating little power abilities, and also hence achieves economic savings by delaying the construction cost of brand-new facilities. The DGs are normally placed near the load centre [3]. The DGs supplies reliable and reputable power to the customers without including transmission problems. DGs have minimized the transmission losses and protection costs. DGs appropriate for a procedure with renewable sources. So, DGs give adaptability in providing electric power to the consumers with environmental advantages. The DGs play a crucial duty in utilizing non-renewable as well as renewable energy sources causing a decrease in air pollution greenhouse gases. The renewable based DGs can additionally help in reducing the operating expense, increasing efficiency, reducing the sound and emissions [4]. The non-renewable based DGs are working on gas turbines, reciprocating engines, combustion turbines and micro-turbines. The renewable based DGs are working on the wind, biomass, solar, hydro, geothermal, tidal sources of energy. DGs are facing challenges like commercial, environmental, regulatory and technical. The technical challenges are like power quality, protection, voltage regulation and stability. With the introduction of DGs, the power flows in conventional power systems became bi-directional from unidirectional, which affects the working of relays. Distribution systems are also facing the disadvantages of system islanding. Power Supply of renewable-based DGs is not continuous [5]. Irrespective of all the challenges and problems discussed above DGs is a great boon to the existing distribution system. Penetration of DGs has improved the voltage profile of the existing system and it had minimized the power losses. In this paper, we will discuss the effect of penetration of various kinds of DGs penetration on the existing radial distribution system (RDS). There are five types of DGs like DG I (supplying real and reactive power), DG II (supplying real and absorbing reactive power), DG III (supplying real power only), DG IV (absorbing only reactive power) and DG V (supplying only reactive power). DG I will be working on lagging power factor (PF) and its example is a synchronous generator like cogeneration. DG II will be working on leading PF and its example is induction generators used on the wind farm. DG III will be working on unity PF and its examples are fuel cells, photovoltaic (PV), micro-turbines. DG IV will be working on zero PF and its example is synchronous compensators. DG V will be working on zero PF and its example is a synchronous condenser [6]. Power expressions for various kinds of DGs are shown in table 1.

Revised Manuscript Received on July 05, 2019

Amandeep, Assistant Professor at JECRC University, Jaipur, Rajasthan. India.

Dr. Surendra Kumar Yadav, Professor of Computer Science and Engineering in JECRC. Jaipur, Rajasthan. India.

Dr. Pushpendra Singh, Associate Professor, department of Electrical Engineering, JK Lakshmipat University, Jaipur, Rajasthan, India.

Table 1. Power expressions for different types of DGs

S.no.	DGs Type	Power expression
1	DG I	P+jQ
2	DG II	P-jQ
3	DG III	P
4	DG IV	-jQ
5	DG V	jQ

These DGs will be tested in IEEE 33 bus radial distribution system. The forward-backward load flow method will be used for computing the parameters of this RDS.

II. METHODOLOGY FOR DIFFERENT TYPES OF DGS PENETRATION

For applying the forward-backward load flow method for calculating line parameters and power losses of the IEEE 33 bus RDS basic equation for load flow has to be derived for a sample two bus system connected with DGs as shown in fig. 1.

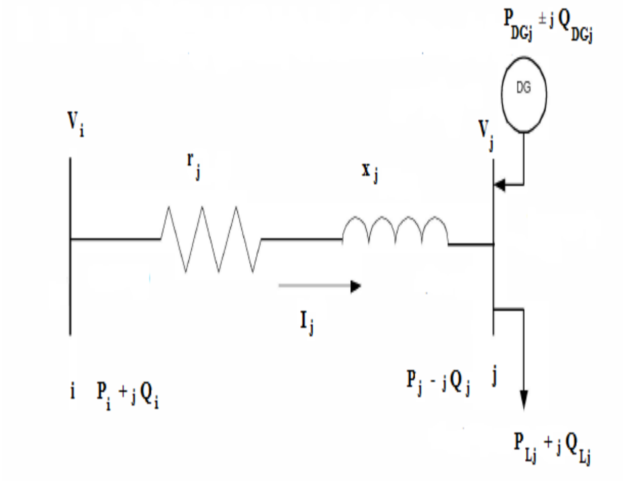

Figure 1. A Sample two bus system

The current I_j flowing through the branch between i and j is shown by (1).

$$I_j = \frac{V_i - V_j}{r_j + jx_i} \quad (1)$$

Where V_i is the voltage at bus i, V_j is the voltage at bus j, r_j is the resistance and x_j is the reactance of the branch between i and j.

Power at the receiving end j is shown by (2)

$$P_j - jQ_j = (V_j I_j)^* \quad (2)$$

Where P_j is the real power and Q_j is the reactive power at the receiving end j. (3) shows the total power at the receiving end j.

$$P_j = P_{Lj} + P_{Loss,i} - P_{DGj} \quad (3)$$

Where, P_{Lj} is the real power absorbed by the load at receiving end j, $P_{Loss,\ i}$ is the power loss through downstream bus i, P_{DGj} is the DG power injected by DGs at bus j. DGs is considered as negative load and the negative sign shows reactive power fed by DG.

$$Q_j = Q_{Lj} + Q_{Loss,i} \pm Q_{DGj} \quad (4)$$

Where, Q_{Lj} is the reactive power absorbed by the load at bus j, $Q_{Loss,\ i}$ is the downstream loss of the bus i, Q_{DGj} is the reactive power absorbed or injected by the DGs at bus j [7]. (5) and (6) shows the expression for power losses.

$$P_{Loss,j} = \frac{r_j\left[P_j^2 + Q_j^2\right]}{|V_j|^2} \quad (5)$$

$$Q_{Loss,j} = \frac{x_j\left[P_j^2 + Q_j^2\right]}{|V_j|^2} \quad (6)$$

Restraints for DGs are as follows:

A. Voltage limitation

The inequality restraints are the system's voltage restrictions, that is, +5% or - 5% of the nominal voltage value.

$$V_{jmin} \leq V_j \leq V_{jmax} \quad (7)$$

Where V_{jmin} and V_{jmax} are the minima and maxima voltage limits at bus k.

B. DG system size limitation

The boundary or discrete inequality restraints are the DG-unit's size in kVA.

$$S_{DGmax} \geq S_{DGk} \geq S_{DGmin} \quad (8)$$

Where S_{DGmax} and S_{DGmin} are the maximum and minimum apparent power limitation of the DG system.

C. DG system power factor limitation

The boundary or distinct inequality constraints are the DGs power factor

$$PF_{DG(max)} \geq PF_{DGk} \geq PF_{DG(min)} \quad (9)$$

D. Thermal Limitations

$$I_j \leq I_{j(max)} \quad (10)$$

Where $I_{j\ (max)}$ is the maximum branch current restriction of line section between buses i and j [8].

If all the restraints are satisfied after that only the resultant service is approved or else it should be rejected. DGs placement area and size selection are shown in the flowchart of the algorithm on DGs penetration in RDS figure 2.

Retrieval Number:H7431068819/19©BEIESP
DOI:10.35940/ijitee.H7431.078919

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

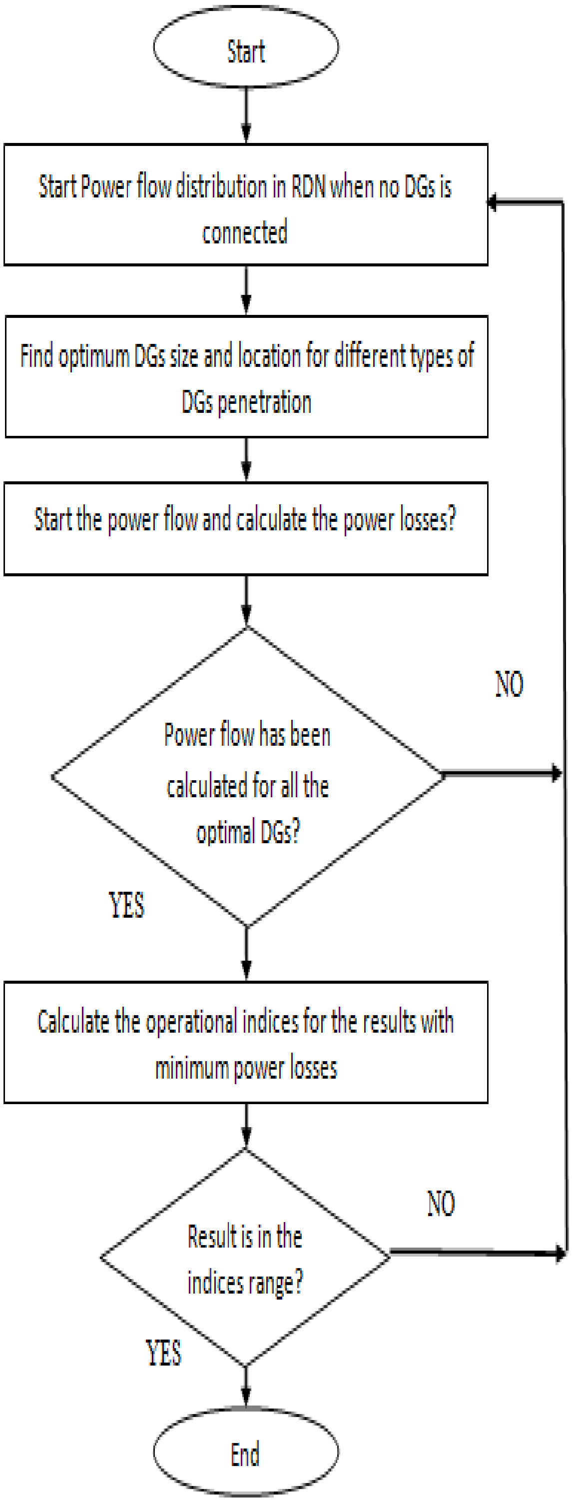

Figure 2. Flowchart of algorithm on DGs penetration in RDS

III. RESULTS

The single line diagram of 12.66 kV IEEE 33 bus RDS showed in figure 3 is the test system for different types of DGs penetration. The forward-backward load flow analysis had been applied for computing the line parameters and losses of the system. The data for this system is acquired from [9]. The total real power load demand of the test system is 3714 kW and reactive power load demand is 2316 kVAR.

Different types of DGs are placed in the test system and the results are compared with the system having no DGs (Base case). DGs penetration in this RDS has an effect on voltage profile and power losses of the RDS.

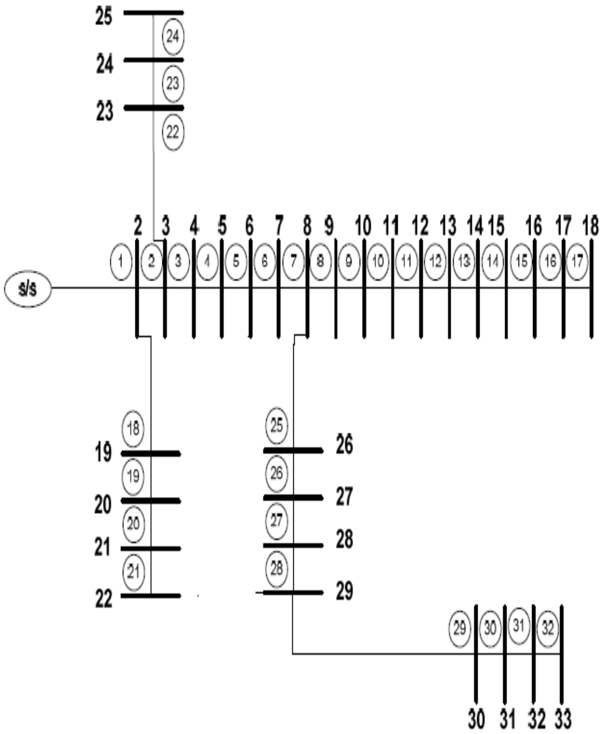

Figure 3. IEEE 33 bus RDS

Table 2. Optimal results of Different types of DGs

DG Type	Optimal Voltage profile (pu)	Optimal Power loss reduction (kW)
Base case	0.964	0
DG I	0.983	54.43
DG II	0.972	-10.36
DG III	0.975	49.82
DG IV	0.960	-11.81
DG V	0.966	47.63

Optimal results of various kinds of DGs effect on RDS are shown in table 1. The voltage profile of DG I is improved to 0.983 pu compared to the 0.975 pu of DG III, 0.972 pu of DG II, 0.966 of DG V and 0.964 pu of the base case. DG IV has a lower voltage profile than the base case. So, DG I, DG III and DG II, DG V are good for voltage profile improvement. The voltage profile comparisons are shown in figure 4.DGs are most effective for power loss minimization. DG I have done the maximum power loss reduction of 54.43 kW as compared to 49.82 kW for DG III, 47.63 kW for DG V. DG II and DG IV had the worst impact on RDS as they had increased the power losses more than the base case i.e. they had a negative power loss reduction. DG I, DG III and DG V had reduced the power losses with a decent amount. The power loss reduction comparison is shown in figure 5. Hence DG I, DG III and DG V are well suited for penetration in the RDS.

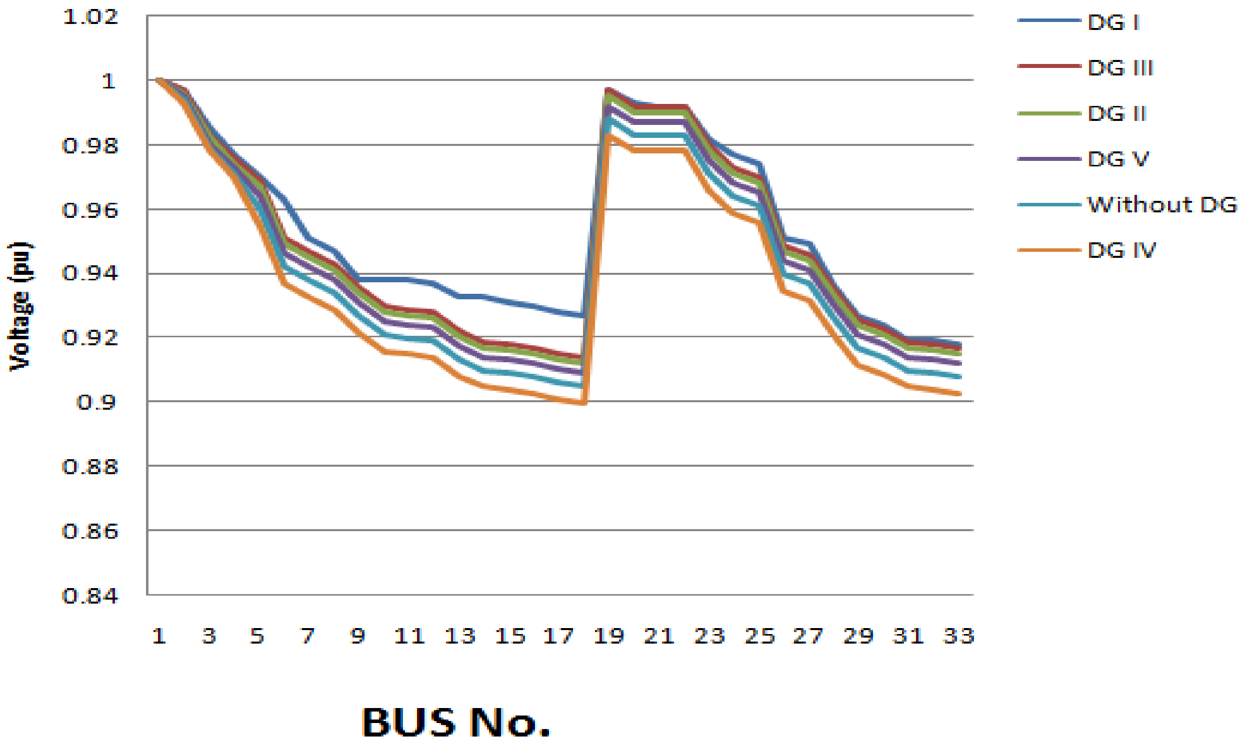

Figure 4. Voltage profile comparison

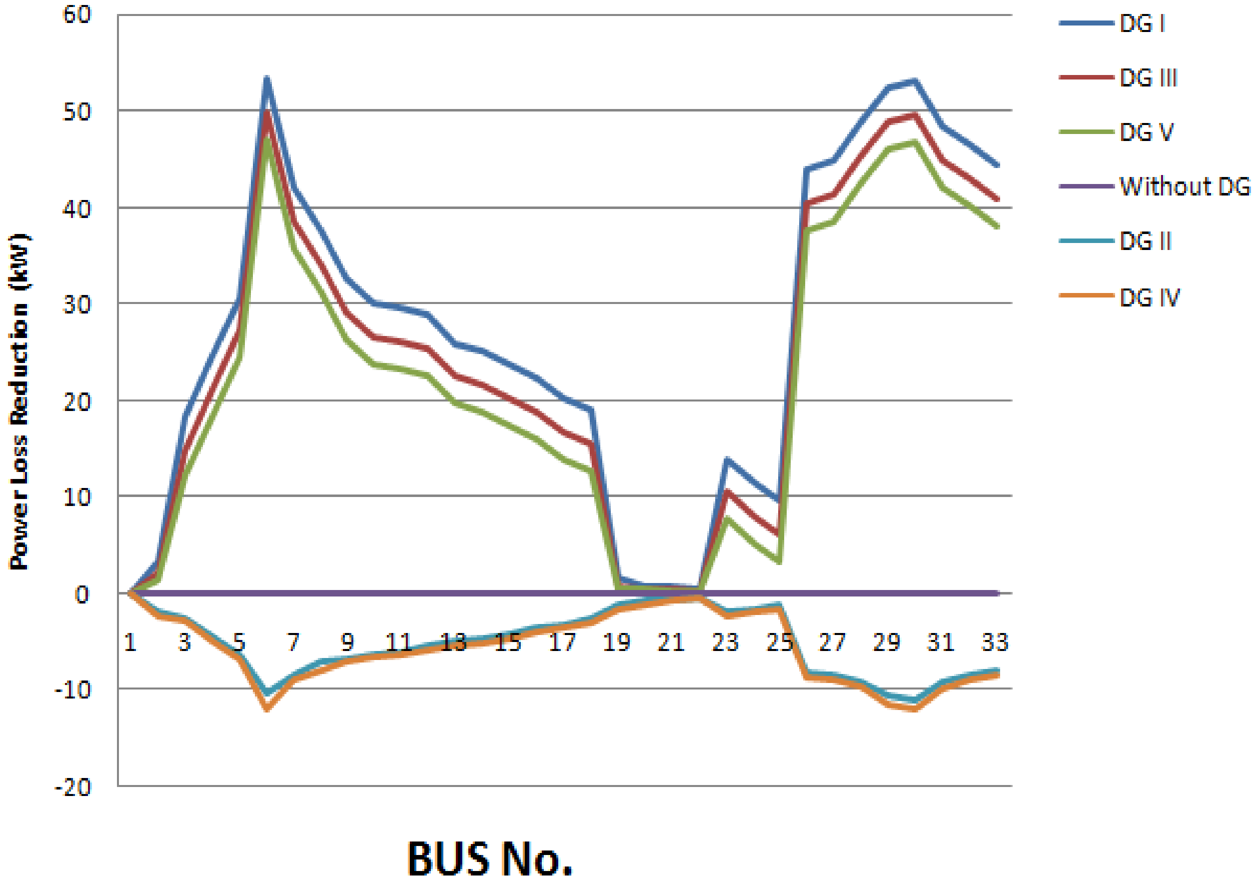

Figure 5. Power loss reduction comparison

IV. CONCLUSION

The penetration effect of various kinds of DGs on the radial distribution system is showed in this paper. For testing of these different DGs IEEE 33 bus, RDS has successfully designed in Matlab software. For penetration five types of DGs have successfully tested on RDS. These five DGs have different effects on the voltage profile and power loss minimization of RDS. DG I have the best results in improving the voltage profile and reducing the power losses. Based on the results DG I, DG III and DG V are the best types for DGs penetration. DG IV and DG II are not suitable for DGs penetration.

REFERENCES

1. N. C. Sahoo and K. Prasad, "A fuzzy genetic approach for system reconfiguration to enhance voltage stability in radial distribution systems", *Energy Conversion and Management*, Vol.47, pp.3288–3306, 2006.
2. K. Premkumar and B. V. Manikandan, "Speed control of Brushless DC motor using bat algorithm optimized Adaptive Neuro-Fuzzy Inference System", *An International Journal of Applied Soft Computing*, Vol.32, pp.403-419, 2015.
3. K. M. Jagtap and D. K. Kathod, "Impact of different types of distributed generation on radial distribution system", *International conference on Reliability, Optimization and Information technology,Delhi, pp.473-476, 2014.*
4. S. A. A. Shahriari, A. Y. Varjani and M. R. Haghifam, "Cost reduction of distribution system protection in presence of distributed generation using optimized fault current limiter allocation", *An International* Journal of Electrical Power and Energy Systems, Vol.43, pp.1453–1459, 2012
5. R. Pandi, H. H. Zeineldin and W. Xiao, "Determining Optimal Location and Size of Distributed Generation Resources Considering Harmonic and Protection Coordination Limits," IEEE Transactions on Power Systems, Vol.28, No.2, pp.1245-1254, 2013.
6. K. Vijeta and D. V. S. S. S. Sarma, "Protection of distributed generation connected distribution system," *In Proceedings of Advances in Power Conversion and Energy Technologies (APCET), Mylavaram,* pp.1-6, 2012.
7. D. R. Prabha and T. Jayabarathi, "Optimal placement and sizing of multiple distributed generating units in distribution systems by invasive weed optimization algorithm", *Ain Shams Engineering Journal,* Vol.7, No.2, PP.683-694, 2016.
8. F. Abbasi and S. M. Hosseini, "Optimal DG allocation and sizing in presence of storage systems considering system configuration effects in *distribution systems," IET Transaction on Generation, Transmission and Distribution, Vol.10, No.3, pp.617-624, 2016*
9. *S. Bouhouras, K. I. Sgouras, P. A. Gkaidatzis and D. P. Labridis, "Optimal active and reactive nodal power requirements towards loss minimization under reverse power flow constraint defining DG type", An International Journal of Electrical Power and Energy Systems, Vol.78, pp.445–454, 2016.*

AUTHORS PROFILE

Amandeep Gill received his B.E. from University of Rajasthan, Jaipur and M.E from Thapar University of Patiala, Punjab. He is pursuing his Ph.D from JECRC University, Jaipur, Rajasthan. He is working as Assistant Professor at JECRC University, Jaipur, Rajasthan. His research fields are Distributed Generated systems, Power Systems, Artificial Intelligence etc

Dr. Surendra Kumar Yadav is presently working as Professor of Computer Science and Engineering in JECRC. He did M.Tech. in Computer Science, MBA in Human Resource management and Bachelors in law. He was awarded his Ph.D. in field of Search Techniques in Artificial Intelligence. His special focus areas are, Search Techniques in Artificial Intelligence, Data Mining and Warehousing, Distributed Computing and Principle of programming. He has published papers in various international and national journals.

Dr. Pushpendra Singh received the M.Tech. in Power System and Ph.D. in Electrical Engineering from Malviya National Institute of Technology (MNIT) Jaipur, Rajasthan, India. He is currently working as Associate Professor, department of Electrical Engineering, JK Lakshmipat University, Jaipur, Rajasthan, India. He is the member of The Institute of Engineers, India (IEI). His research experience includes power system restructuring, power quality, integration of DERs, demand side management, power system stability, smart grid, distributed generators, climate change mitigation etc.