Multi objective function based Power Quality study on large penetration of Renewable energy sources

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Abstract : ***Integration of Distributed Generations (DGs) to power system offers several advantages such as reduced transmission and distribution system resources, increased reliability, stability, better power quality. . And these depend on the system configuration, type and capacity of DG, location of integration and management of DG, The optimal allocation of DG is needed for increasing the benefits in power system. Power quality is a major issue to be considered for the analysis in power system when distributed generators are integrated. Operation of Renewable distributed generators (RDG) will increases the rate of power quality issues, hence extra care has to be considered when RGD 's are integrated. Here analysis is carried out on variation of voltage profiles, varying load, stochastic wind power and power losses. The analysis is carried out to compare the results before and after optimal integration of DGs. Optimal integration is done based on the weighted sum of multi objective function based on Voltage Deviation, power losses and . This paper presents the results of simulations for standard Ieee33 bus Distribution systems.***

IndexTerms – **Renewable distributed generation, large penetration, optimal location, voltage profiles.**

I. Introduction

The term "distributed generation" (DG) refers to the production of electricity near the load center at the distribution level. The distributed generation resources are renewable energies and cogeneration (simultaneous production of heat and electricity). Distributed Energy Resources (DER) had changed many features of distribution system operation, design and Execution. With increase in number of decentralized systems with smaller generating units connecting directly to the distribution networks near load center, the distribution companies reduce loss in their networks.

The position and capacity of the DG must be optimized to increase the benefits and minimize their negative impacts on the power system [6]. The technical parameters are voltage profile, system protection, reactive power, power loss, power quality, power control and conditioning, reliability and stability.

Improper placement of DG will leads to the increment in system losses which includes both active and reactive power losses, operating cost and network capital cost. it also lead to injection of harmonics, possibility of reverse power flow, risking the safety issues and complex controlling scheme . In view of these, proper allocation of distributed generation could enhance the network potential in terms of better voltage profile and lower the system power losses, while improving the quality of power supply.

With the above considerations the optimal allocation and sizing of DG is necessary to improve the overall efficiency of the system by reducing the losses and improving voltage profiles and performance of the power system.

Optimal allocation and capacity of DG

Optimal placement of DG is subjected to an electrical network (power system) operating constraint, investment constraint and DG operating constraint. The multi objective functions are chosen based on Pareto concept, to Minimize the system's total power losses, cost and voltage deviations and to Maximize the DG capacity, benefit/cost ratio, voltage limit load ability subjected to Power flow equality constraints, Voltage violation limit (bus voltage),DG penetration limit, DG with constant power factor, Maximum number of DGs, Power generation limits and Total harmonic distortion limit constraints.

Power Quality

The integration DGs in to power network faces problem with power quality issues in a number of ways such as voltage sags or voltage dips, voltage variations, voltage swells, voltage imbalance, harmonic distortion, harmonic resonance, noise, voltage spikes, critical load and voltage flicker. Which leads to negative impacts like, increment in system losses which includes both active and reactive power losses, operating cost and network capital cost it also lead to injection of harmonics, possibility of reverse power flow, risking the safety issues and complex controlling scheme.

II. PROBLEM FORMULATION

Power quality

a. Penetration level

The penetration level of DG is chosen based on the following equation. .

$$PLDG\% = \frac{Size\ of\ DG}{Total\ demand} * 100 \ \ \ldots\ldots\ldots\ldots 2.1$$

Where, PLDG% is penetration Level of DG

b. Multi objective function

2.1.1 Power loss calculation

The equation of the real power losses in the system can be given in terms of exact loss formula as state below, The power loss is given by

$$P_L = \sum_{i=1,j=1}^{n} [\alpha_{ij}(P_iP_j + Q_iQ_j) + \beta_{ij}(Q_iP_j - P_iQ_j)] \ldots\ldots\ldots 2.2$$

Where $\alpha_{ij} = \frac{r_{ij}}{V_iV_j} Cos(\partial_i - \partial_j)$ and $\beta_{ij} = \frac{r_{ij}}{V_iV_j} Sin(\partial_i - \partial_j)$

2.1.2 Voltage profile index (VPI) is given by

$$VPI = \sum_{i=1}^{Nbus}(V_i - V_{i,ref}) \ldots\ldots\ldots 2.3$$

where,Vi is the Magnitude of voltage of bus Viref. is the Magnitude of voltage of bus slack for VP provides an opportunity to quantify and aggregate the importance, amounts, and the voltage levels at which loads are being supplied at the various load busses in the system. This expression should be used only after making sure that the voltages at all the load busses are within allowable minimum and maximum limits, typically between 0.95 p.u. and 1.05p.u. In this case all the load buses are given equal importance. In reality, DG can be installed almost anywhere in the system. Therefore, VPII can be used to select the best location for DG.

Voltage Profile Improvement Index The inclusion of DG results in improved voltage profile at various buses. The Voltage Profile Improvement Index (VPII) quantifies the improvement in the voltage profile (VP) with the inclusion of DG. It is expressed as,

$$\text{VPII} = \frac{\text{VP w/DG}}{\text{VP wo/DG}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .2.4$$

Based on this definition, the following attributes are:

VPII < 1, DG has improved the voltage profile of the system,

VPII = 1, DG has no impact on the system voltage profile,

VPII > 1 DG has not beneficial. Where, VP W/DG, VP Wo/DG are the measures of the voltage profile of the system with DG and without DG respectively. The general expression for VP is given as,

2.1.3. Logarithmic voltage deviation index (LVDI)

$$\text{LVDI} = 10 * \log\frac{(\text{Vref})}{(\text{V})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.5$$

Where vref is the reference node voltage and V is the value of the voltage at different busses after the load flow.

Waited sum of Multi objective function = (w1*VPII +w2*LVDI)

The summation of w1 and w2 is made equal to unity.

2.1.4. DG Modelled as PV Type

The DG as a PV node is commonly Constant voltage model. The specified values of this DG model are the real power output and bus voltage magnitude. For maintain constant voltage the, change in voltage ΔVi should maintain zero by injecting required reactive power.

2.14.5. Modelling of WIND and SOLAR DGs

The Photovoltaic systems convert Solar Energy into Electrical energy. Their output is DC power and is converted into AC power via an inverter to be compatible with AC grid. The power output of a solar photovoltaic (PV) panel depends on the area (A) of the PV panel, solar irradiance μ(t) and efficiency of the PV panel β.

$$P_{PV}(t) = A\beta\mu(t)$$

The Wind turbine power output[18] is proportional to the kinetic energy, air density, etc. Other parameters of Wind turbine include cut- in wind speed, cut-out wind speed and rated wind speed, and typical values of them are 3.5 m/s, 25 m/s, and 14 m/s respectively. Precise values can be obtained from manufacturer's data sheet for the respective limits.

$$P_{wind}(t) = 0.5\alpha\rho(t)A\upsilon(t)^3$$

Where α is the Albert Betz constant, ρ(t) is air density, A is area swept by turbine rotor, and ν(t) is wind speed.

III. RESULTS AND DISCUSSIONS

This method is applied to the standard IEEE 33 bus system operated at 12.66kV level of voltage and consists of 33 busses, 32 branches, with 3715kW and 2300kVar of power respectively as shown in Figure.3.1. The base case load flow is obtained where the power losses without the connection of the DG's are 202.68kW and 143.22kVAr respectively.

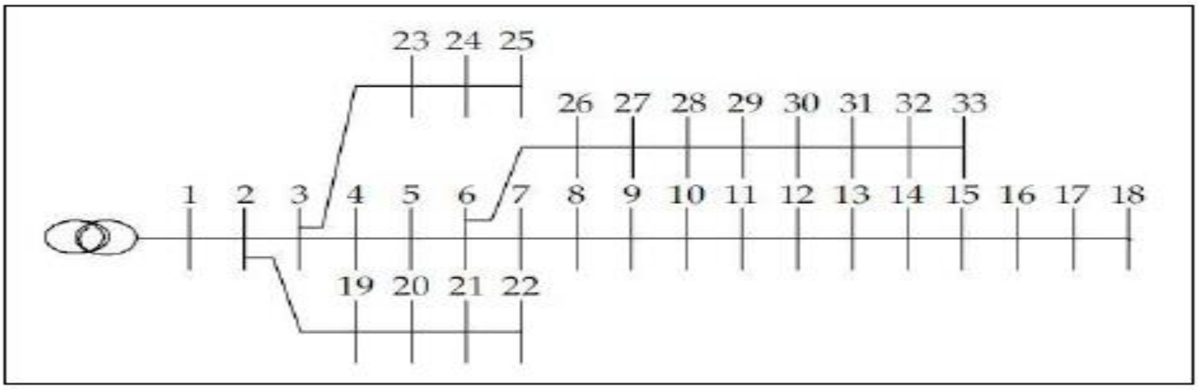

Fig.3.1: Single diagram of IEEE 33 bus test system

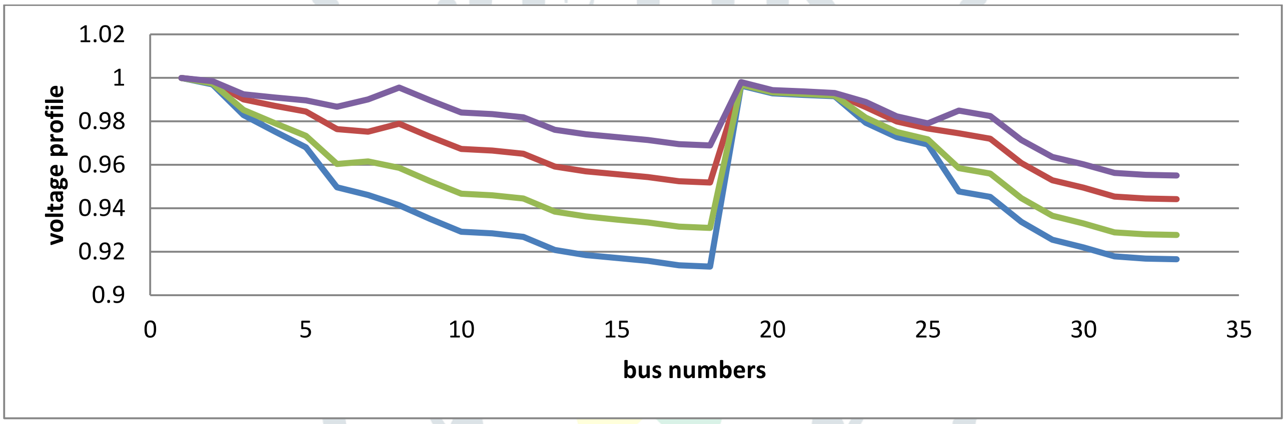

Figure .3.2: voltage profiles of the system when different types of DGs are installed at 50% penetration

Table 3.1 . Showing base voltage , power loses, Voltage profile improvement index and WMOFI

Sl No	Vbase	Ploss	VPII	WMOFI
1	1	0	**1**	0
2	0.997	12.2404	1	0.700391
3	0.9829	51.7912	0.994186	0.698177
4	0.9755	19.9005	0.991903	0.697564
5	0.9681	18.6989	0.993769	0.699863
6	0.9497	38.2486	0.99211	0.701201
7	0.9462	1.9145	0.99262	0.702039
8	0.9413	4.838	0.865782	**0.613929**
9	0.9351	4.1805	0.874663	0.621007
10	0.9292	3.5609	0.883895	0.628294
11	0.9284	0.5537	0.885043	0.62921
12	0.9269	0.8811	0.886061	0.630133
13	0.9208	2.6662	0.892897	0.635779
14	0.9185	0.7292	0.89659	0.638689
15	0.9171	0.357	0.898158	0.639986
16	0.9157	0.2815	0.89968	0.64125
17	0.9137	0.2516	0.900835	0.642343
18	0.9131	0.0531	0.901452	0.642861
19	0.9965	0.161	1	0.700457
20	0.9929	0.8322	1	0.700928

21	0.9922	0.1008	1	0.70102
22	0.9916	0.0436	0.988235	0.692864
23	0.9794	3.1816	0.990385	0.695981
24	0.9727	5.1437	0.992727	0.698515
25	0.9694	1.2875	0.993506	0.699504
26	0.9477	2.6009	0.994297	0.703006
27	0.9452	3.329	0.994555	0.703532
28	0.9337	11.3009	0.995495	0.705785
29	0.9255	7.8333	0.99466	0.706349
30	0.922	3.8957	0.994898	0.707009
31	0.9178	1.5936	0.995157	0.707786
32	0.9169	0.2132	0.994019	0.707117
33	0.9166	0.0132	0.995227	**0.708005**

Table 3.2: Summary of voltages and losses for 33 bus system

DG Penetration Level	Optimal Location	DG type	Active power Losses			Minimum Voltage in p.u	
			Without DG(kw)	With DG(kw)	%PLR	Without DG(p.u)	With DG(p.u)
15 %	07	Solar	202.68	159.63	21.24	0.91309(18)	0.94318
	29	Wind		169.90	16.17		0.92466
	29 06	Solar + wind		145.62	28.15		0.95182
30%	06	Solar	202.68	101.36	35.33	0.91309(18)	0.95401
	30	Wind		141.54	26.24		0.93415
	30 06	Solar + wind		61.148	45.46		0.96989
50 %	07	Solar	202.68	110.66	45.40	0.91309(18)	0.94318
	30	Wind		123.71	38.96		0.92466
	29 07	Solar + wind		65.142	67.85		0.95182

Table 3.1 Shows base voltage , power loses, Voltage profile improvement index and waited sum of objective function of standard IEEE 33bus system, the voltage profile index and improvement index are calculated by integrating DG with the mentioned penetration level and then the waited sum of multi objective function . Table 3.2 shows the summary of different penetration levels at 15%, 30% and 50% respectively, of solar, wind and hybrid solar with wind distributed generators. The losses are reduced the maximum value with solar and wind power combination for the same penetration level. The losses with solar distributed generation are obtained to be less compared to wind distributed generators.

IV. CONCLUSION

In this paper, the allocation of DG with optimal size and location is done using a nature-inspired algorithm called modified shuffled frog leap algorithm. This is a newly developed intelligent technique which gives better results. Here, optimal placement of DG is done based on the moment of frogs in search of food. The analysis is carried out on the IEEE 33bus test system for different scenarios by considering the renewable distributed generators. It is evident that the percentage losses in the system are reduced and minimum voltage at the bus is increased with the hybrid generation of both solar and wind. During heavy load, the DG will compensate the entire additional load by nullifying voltage sag at the affected nodes.

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