Coordinated Voltage Control with Reactive Power of the Distributed Generators using Genetic Algorithm

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Abstract— This paper presents a genetic algorithm-based method to determine coordinated voltage control in the unbalanced distribution radial system distributed generators. The coordinated voltage control has been done with DGs reactive power control and OLTC operation. The result indicates that involving DGs reactive powers in the voltage control will result in a reduction of number of OLTC operations and the reduction of the voltage level in the distribution system. Further, the results also indicate that the from the coordinated voltage control, the losses can be decreased.

Index Terms— Distributed Generators, Distributed System, Genetic Algorithm, Reactive Power, Voltage Control, Voltage Regulator.

I. INTRODUCTION

Distributed Generator can be referred as small generating unit connected to the distribution network, which was not centrally planned and dispatched. Set of such generators can be called as Distributed generation (DG). The main reason for less generation by centrally located power plants is the time taken for installation of power plant. They include higher level of pollution as thermal power plants have large share in conventional power generating units. Benefits of distributed generation include power quality and reliability, transmission and distribution support, environmental performance, energy price risk management and some localized economic benefits [1].

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DG mainly tries to extract clean energy from natural resources which are renewable sources of energy. Photovoltaic and hydro generations are some examples of this kind. Often DG uses energy efficient and sustainable methods of power generation. Micro turbine and fuel cells comes into this category. There are more DG technologies like tidal energy, geothermal energy. These are not popular as of now because of difficulty in converting them to electrical power.

In a radial distribution feeder, voltage decreases towards the end of the feeder, as loads cause a voltage drop. However, it will be altered with the presence of DG. DG will increase the voltage at its connection point, which in turn will increase the voltage profile along the feeder [2]-[4]. This increase may exceed the maximum allowed voltage when the DG power is high. One way to mitigate this overvoltage is when DG absorbs reactive power from the grid. This method is effective for mitigation of overvoltage-caused DG in low voltage (LV) feeders where the mean of voltage control is obtained from an off-load tap changer. However, if DG absorbs reactive power, feeder losses will increase.

Voltage control is one of the important control scheme at a distribution substation, which conventionally involves regulation of voltage and reactive power at substation bus [5], [6]. The voltage control can be achieved by using voltage regulators. In this paper, it is analyzed the impacts of distributed generators on the voltage profiles of distribution systems. To regulate voltages, suggested to use OLTC & DGs reactive powers in distributed systems for controlling the voltage. In this effort Genetic algorithm is used for optimal setting of On load tap changing transformer(OLTC) and DGs reactive powers and it is simulated to verify on 3 phase 25 bus unbalanced radial distribution feeders.

2. GENETIC ALGORITHM

Genetic Algorithms (GAs) are adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. As such they represent an intelligent exploitation of a random search used to solve optimization problems. Although randomized, GAs are by no means random, instead they exploit historical information to direct the search into the region of better performance within the search space [9]. The basic techniques of the GAs are designed to simulate processes in natural systems necessary for evolution. In nature, competition among individuals for scanty resources results in the fittest individuals dominating over the weaker ones.

GAs do not require linearity, continuity, or differentiability of the objective function, nor do they need continuous variables. These two features make GAs particularly effective in dealing with discrete control devices such as tap changing transformers and with objectives such as minimal number of control actions. A considerable disadvantage of GAs is the amount of calculation time involved that increases exponentially with the number of independent variables. Several GA applications on the voltage-reactive power problem are known. Applications exist for planning and optimal allocation of reactive power sources, as well as for voltage security enhancement by preventive control

A simple Genetic Algorithm is an iterative procedure, which maintains a constant size population P of candidate solutions. During each iteration step (generation) three genetic operators (reproduction, crossover, and mutation) are performing to generate new populations (offspring), and the chromosomes of the new populations are evaluated via the value of the fitness witch is related to cost function. Based on these genetic operators and the evaluations, the better new populations of candidate solution are formed [10].

With the above description, a simple genetic algorithm is given as follow

1. Generate randomly a population of binary string
2. Calculate the fitness for each string in the population
3. Create offspring strings through reproduction, crossover and mutation operation.
4. Evaluate the new strings and calculate the fitness for each string (chromosome).
5. If the search goal is achieved, or an allowable generation is attained, return the best
Chromosome as the solution otherwise go to step 3.

3. RESULTS & DISCUSSIONS

3 phase 25 bus radial unbalanced systems is given in fig 1 ,the line and load data is taken from[11] ,the base MVA is 30 MVA, base kV is 4.16 kV and 5 DGs are connected with P=0.06 p.u & Q=0.027 p.u at 5th,12th,15^{th,} 18th & 22nd bus each. Only OLTC tap setting and DGs reactive powers are considered in this system genetic algorithm for the voltage control. The upper and lower voltage limits are 1.05 p.u & 0.95 p.u respectively and tap setting limits are ±10% are considered in this simulation. The Genetic Algorithm parameter is given in Table 1.The 100% & 70% load is considered for the simulation.

The objective function of GA used for the study is

$$\sum_{m=1}^{n} | V_{mref} - V_m |$$

V_{mref} is mth node voltage standard value

V_m is mth node voltage

Constraint conditions:

Node voltage: $V_{\min} < V_i < V_{\max}$

Reactive power of DG: $Q_{\min} < Q_i < Q_{\max}$

Tap position: $T_{\min} < T_i < T_{\max}$

TABLE 1

GENETIC ALGORITHM PARAMETERS

Generation	100
Population	20
Selection	Stochastic
Crossover	Scattered
Mutation	Adaptive feasible

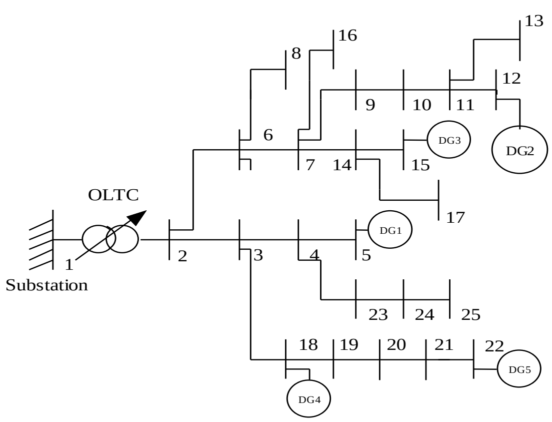

Fig. 1 3 Phase 25 bus unbalanced radial distribution system

3.1 Voltage control for 100% load:

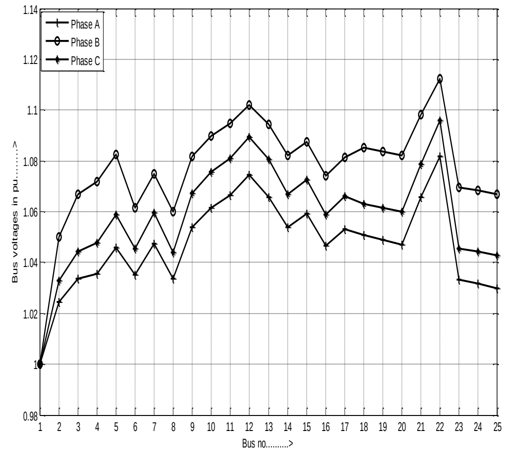

Fig.2. Voltage profile without voltage control

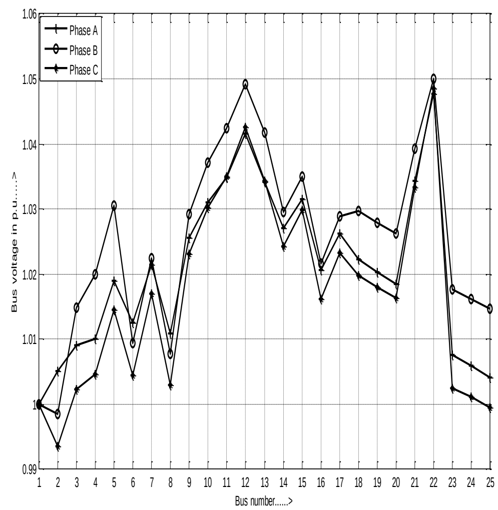

Fig. 3. Voltage profile with voltage control

Fig 2 shows that, the voltage profile for the 3 phase 25 bus unbalanced system with 100% load without voltage control, when 5 DGs are connected to the system. It can be seen that voltage profiles in all the phases crossed the upper limit 1.05 p.u, the peak voltage level can be seen at bus no 22nd, the peak voltage level at phase A is 1.0817 p.u, at phase B is 1.112 p.u & at phase C is 1.0957 p.u, it has been mitigated using the reactive powers of the DGs and the OLTC tap settings. The fig 3 shows that, the voltage profile for the system after voltage control, the system voltage has been reduced

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below upper limit. The optimal setting values of the OLTC, DGs reactive power is given in Table 2 and power loss of the system before and after the voltage control is given in Table 3

TABLE 2

OPTIMAL SETTING VALUES OF VOLTAGE CONTROLLING DEVICES AT 100% LOAD

Voltage Regulating devices	OLTC			Reactive power of DG		
	Phases			Phases		
	a	b	c	a	b	c
Setting values in p.u	0.99	0.95	0.97	0.019	0.015	0.011

Reactive power of DG_2			Reactive power of DG_3		
Phase a	Phase b	Phase c	Phase a	Phase b	Phase c
0.02	0.01	0.011	0.022	0.019	0.022

Reactive power of DG_4			Reactive power of DG_5		
Phase a	Phase b	Phase c	Phase a	Phase b	Phase c
0.010	0.014	0.014	0.008	0.011	0.01

Table 3

POWER LOSS AT 100% LOAD

Phases	Active power loss before voltage control in p.u	Active power loss after voltage control in p.u	Reactive power loss before voltage control in p.u	Reactive power loss after voltage control in p.u
Phase A	0.0035	0.0031	0.0048	0.0044
Phase B	0.0034	0.0030	0.0048	0.0044
Phase C	0.0034	0.0030	0.0048	0.044

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3.2. Voltage control for 70% load:

Voltage regulating devices	OLTC			Reactive power of DG_1		
	Phases			Phases		
	a	b	c	a	b	c
Setting values in pu	0.97	0.95	0.95	0.008	0.022	0.020

Reactive power of DG_2			Reactive power of DG_3		
Phase a	Phase b	Phase c	Phase a	Phase b	Phase c
0.008	0.012	0.017	0.008	0.018	0.016

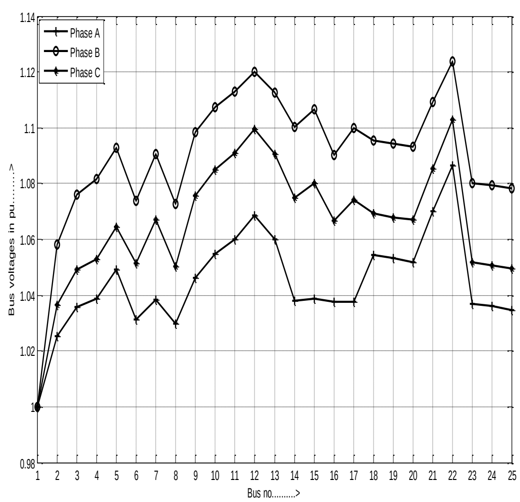

Fig. 4.Voltage profile without voltage control

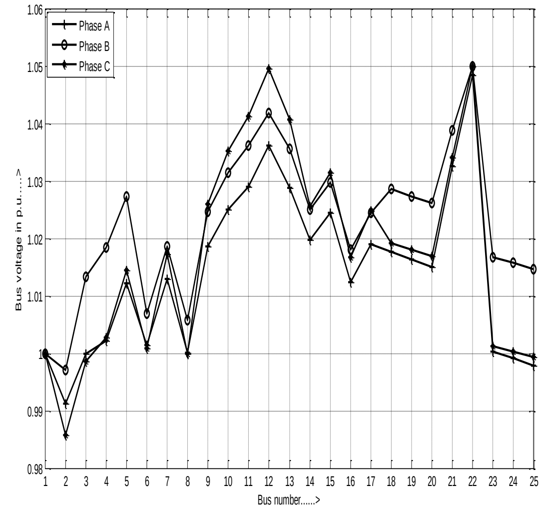

Fig. 5.Voltage profile with voltage control

Fig(s) 3 & 4 shows that, the voltage profile for the system with 70% load with and without voltage control respectively. It can be seen that from the figure 4, the voltage crossed the upper limit 1.05 p.u, after the DGs connected to the system. The peak voltage level is at 22nd bus, at phase A 1.086 p.u, at phase B 1.123 p.u, at phase C 1.102 p.u, It has been reduced using the reactive powers of the DGs and OLTC tap settings, the optimal setting values of the OLTC and DGs reactive powers are given in Table 4 and power losses before & after the voltage control is given in Table 5

TABLE 4

OPTIMAL SETTING VALUES OF VOLTAGE CONTROLLING DEVICES AT 70% LOAD

Reactive power of DG_4			Reactive power of DG_5		
Phase a	Phase b	Phase c	Phase a	Phase b	Phase c
0.0085	0.027	0.0085	0.0085	0.021	0.012

TABLE 5

POWER LOSS AT 70% LOAD

phases	Active power loss before voltage control in p.u	Active power loss after voltage control in p.u	Reactive power loss before voltage control in p.u	Reactive power loss after voltage control in p.u
Phase A	0.0031	0.0027	0.0041	0.0037
Phase B	0.0030	0.0026	0.0041	0.0037
Phase C	0.0030	0.0026	0.0041	0.037

4. CONCLUSION

The developed method for coordinated voltage control of distribution system interconnected with distributed generators. This method used genetic algorithm for optimization and backward forward sweep method for load flows. This methodology has been applied to 3 phase 25 bus unbalanced test systems with two various load conditions. The OLTC and DGs reactive powers are used for voltage control, it can be observed from the results obtained from simulation both voltage profile and losses were improved in each case considered and the no of operations of OLTC has been decreased with DGs reactive power participation in voltage control.

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