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The Influence of Voltage Regulation Devices Based Distributed Generation in Distribution Networks

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Research Article

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Abstract: Voltage levels may rise over permitted bounds as a result of distributed generation's (DG) extensive integration into distribution networks. As a result, the implementation of distributed generation has an impact on the design, deployment, and functioning of conventional voltage regulation equipment, including on-load tap changing transformers and capacitor banks. Investigating the best location, dimensions, and functionality of these voltage regulating devices in systems with DGs is thus necessary. This research uses an agenetic algorithm optimization approach to evaluate the effect of DGs on the performance of capacitor banks and on-load tap changing transformers (OLTC). The 16-bus generic distribution test system from the United Kingdom was the study system. The study's findings demonstrate that DGs in distribution networks have a beneficial effect on voltage regulating devices' ability to reduce loss and enhance voltage profiles. DGs could, however, raise the necessary shunt compensation.

Keywords Capacitor Bank, Distributed Generation, Genetic Algorithm, On-load Tap Changer, Power Loss, Voltage profile

Introduction

For voltage control, distribution networks are often outfitted with on-load tap changing transformers (OLTC) and capacitor banks (CAPs). This is done in order to lower power losses on the network and enhance the voltage profile across the network. For certain pieces of equipment to function well, their size and position are essential. As a result, a number of studies have used different optimization methodologies to examine the placement and dimensions of capacitor banks. By reducing power loss on a distribution network, particle swarm optimization (PSO) was used to determine the ideal capacitor sizes [1,2]. Additionally, a genetic algorithm was used in [3,4] to determine the best location for shunt capacitors. The impact of integrating dispersed energy sources on the effectiveness of the suggested methods was not taken into account in the works, nevertheless. Since distributed generators (DGs) cause voltage rise issues, their integration into distribution networks is expected to have an impact on capacitor bank dispatching and operation. Therefore, it is necessary to assess how

DGs affect voltage-regulating equipment such as capacitor banks and on-load tap-changing transformers. Because of this, several writers have expanded the optimization study to incorporate DGs by optimizing the size and placement of DGs and capacitor banks at the same time. In order to increase voltage stability, DGs and capacitors were sized simultaneously using the Amemetic Optimization Algorithm (MA) in [5,6]. In order to enhance the voltage profile and reduce power losses, DGs and capacitor banks were sized and positioned optimally using a combined PSO and GA technique in [7]. It has been shown that the best place for DGs depends on non-technical criteria such land availability in addition to technical ones like losses or voltage profile [8]. Additionally, the distribution system operator has little to no influence over where the DG's owner or customer chooses to connect to the grid. Therefore, it is necessary to investigate how DG location affects the best placement and dimensions of capacitor banks as well as OLTC settings.

This study used a genetic algorithm to examine the effects of different DG locations on the placement and dimensions of capacitor banks as well as OLTC settings. The United Kingdom generic 16-bus system used as the test system. The two goal functions taken into consideration in the research were voltage profile and loss reduction.

The impact of distributed generation, capacitor banks, and OLTC transformer voltage regulating devices on a distribution network is discussed in this study. the best in Section I. The issue formulation of the influence of different DG placement, capacitor bank size, and OLTC configurations utilizing the evolutionary algorithm. Section IV highlights a short explanation of the test system. The next sections go into great depth into several distribution network behavior scenarios that include different DG sizes and locations, capacitor banks, and OLTC transformers. The last meeting concludes the work completed.

1. ProblemFormulation

A heuristic optimization approach based on natural selection is the genetic algorithm. Its success rate in identifying the best solution for non-linear mathematical problems has led to its widespread usage as a power system optimization tool [7]. The following describes the system restrictions and objective functions that were used in this work:

ObjectiveFunctions

Voltage profile: The minimization of voltage profile index (Vp) is defined as shown in (1).

V_p=√(ΔV²+ ΔV²+ ⋯ΔV²) andΔV=(V− 1),(1)where $G_{ij}$and $B_{ij}$are the conductance and susceptance between buses i and j; $P_{Di}$and$Q_{Di}$are the active and reactiveloaddemandsatbus$i$.Equations(8)a nd(9)arethe power balance equations which ensure that the power generated at a bus is equal the load plus the losses.

2. TestSystemandSimulation

3. The 16-bus UKGDtestsystem is the distribution network used in this experiment. A 132kV supply network feeds into a 33kV distribution network. With the smallest and longest lengths being 2.055 km and 32.79 km, respectively, it blends long, medium, and short transmission lines. The base reactive power load is 7.74MVAR, and the overall system active power base load is 38.16MW. An autotransformer with tap changers was used to represent

the voltage regulator that runs between busses 8 and 9. Together with other pertinent information, the transformer and voltage regulator taps and voltage regulators for every distribution line were acquired from [9]. Figure 1 depicts the 16-bus distribution test system used in this study from the United Kingdom. There are two OLTCs in the system. The capacitor bank was positioned at buses 5, 11, and 16, respectively, after being evaluated via installation at buses 11, 7, and 10. Additionally, to enhance the voltage profile,

The flowchart for the GA used is shown in

Figure 2. The number of generations and population size for the GA was selected to be 100 and 20 respectively. Two sample simulation cases are presented.

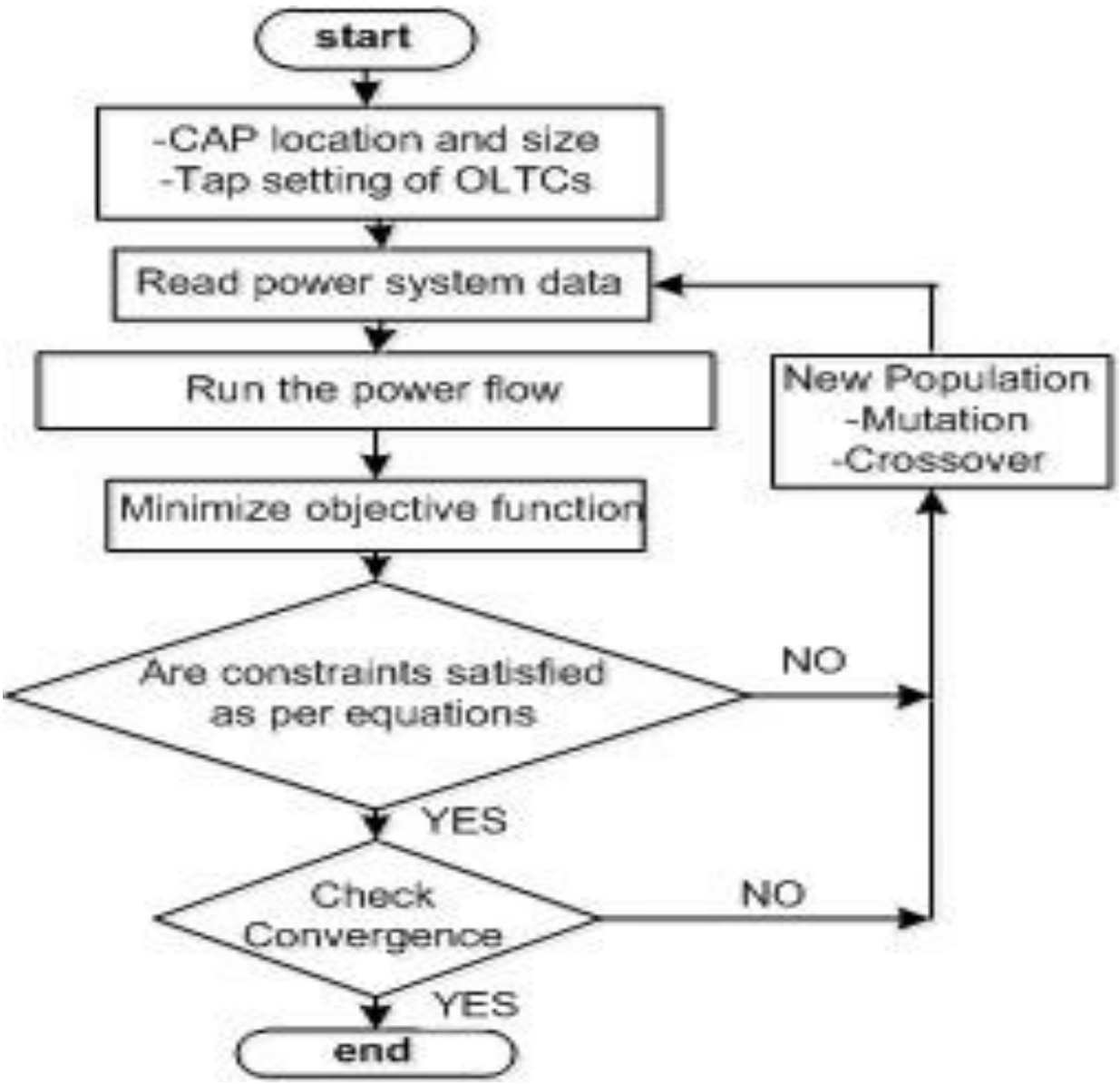


Figure2. Flowchartofusedgeneticalgorithm

Case2: Loss reduction, as a single goal subject to system restrictions, was the objective function in this instance. Because of the minimum amount of shunt compensation (1.4 MVar) that was recorded, the sub-cases in case 1 were also thought to be the most cost-effective locations for DGs. This was because the DGs were operating at unity power factor and the sub-cases were located at the load center (bus 5) and tail end of the feeder (bus 11). Additionally, compared to the scenarios while running at a unity power factor, the CAP location was unaffected when the DGs ran with reactive power capacity. However, in order to optimize the network's voltage profile, all of the DGs were running in inductive mode, which involves collecting reactive power from the grid. As a result, more shunt compensation was needed to reach its maximum value. Following this, the voltage profile improved overall in all three circumstances as compared to the times when the DG was running at unity power factor. Therefore, DGs running at reactive power capability will enhance the voltage profile at the expense of requiring more shunt adjustment. The findings also show that placing the DG at bus5 (the load center) produced the optimal voltage profile. With the DG atbus11, the worst voltage profile was recorded. Additionally, there was less movement in all instances for the OLTC setting at the substation (between buses 1 and 2) than there was in all analyses for the one between buses 8 and 9.

Case 2: Table 2 displays the outcomes for instance 2. When DGas was present, the network's losses were often lower than when the capacitor bank was present. The DG (with reactive power capabilities) being at bus 16 was the lone exception. Bus 10 was the ideal placement when only the capacitor bank was optimized. However, it was discovered that the best site for the capacitor bank was to beat buses 4,5 and 10, respectively, when DG was placed at buses 5, 11, and 16. In contrast to the unity power factor instance, the capacitor bank position altered when the DG ran with reactive power capability in order to minimize power loss. The DG being at bus 16 was the sole exception. The best capacitor bank was located at bus 10 in both situations. Therefore, the ideal placement of capacitor banks is not impacted by the DG mode of operation. Additionally, the optimal value for losses was obtained when the DG was placed at bus 5 with a reactive power capacity of 3.98 MVar and a unity power factor of 1.42 MVar.

Table1. Simulationresultsforcase1

Sub-cases		**OLTCsettings**		**CAP**		DGReactive Power	Voltage profile
		Bus1-2	Bus8-9	Location	Sizing (MVar)		
CAPsonly		1	0.95	10	6	0	0.1
CAPandDGat bus 5	DGatunityPF	1.02	0.96	11	1.4	0	0.07
	DGwithreactivepower	1.02	0.98	11	6	-5.8	0.06
CAPandDGat bus 11	DGatunityPF	1.02	1.05	7	1.4	0	0.13
	DGwithreactivepower	1	0.99	7	6	-3.5	0.09
CAPandDGat bus 16	DGatunityPF	1.01	0.95	10	6	0	0.12
	DGwithreactivepower	1	0.95	10	6	-1.3	0.11

Table2. Simulationresultsforcase2

Sub-cases		OLTCsettings		CAP			
		Bus1-2	Bus8-9	Location	Sizing (MVar)	ReactivePower fromDG	Powerloss(MVA)
CAPsonly		1.01	0.9	10	3	0	5.43
CAPandDGat bus 5	DGatunityPF	1.01	0.95	4	4	0	3.53
	DGwithreactivepower	1.01	0.95	10	1.8	5.5	1.42
CAPandDGat bus 11	DGatunityPF	1.02	1.05	5	1.4	0	3.97
	DGwithreactivepower	1.02	1.05	9	4.8	-1.5	3.87
CAPandDGat bus 16	DGatunityPF	1.0	0.9	10	2.8	0	5.21
	DGwithreactivepower	1.01	0.96	10	4.4	-1.3	5.58

4. Conclusions

This research used the 16-bus UKGD test system as a case study to investigate the impact of voltage regulating devices (such as capacitor banks and OLTC) on distribution networks with distributed generation. The effect of DGs on the best placement of capacitor banks was also examined, taking into account two goal functions: reducing power losses and improving voltage profiles. The findings show that the position of capacitor banks is unaffected by the DG mode of operation for voltage profile enhancement. Additionally, DGs with reactive power capabilities enhance the voltage profile across a network. The position of the capacitor bank is affected by the DG's mode of operation for loss reduction. When the DG is placed near the load center, the optimal outcome for loss reduction is obtained. Additionally, DG placement has less of an effect on substation OLTC settings than OLTC positioned along a distribution feeder. When DG is placed near the load center, voltage regulating devices work best in terms of losses and voltage profile improvement; when DG is placed at a remote location, performance is at its poorest
.

Nomenclature

Vp	voltage profile
V_n	voltageatthenthnode,n={1,2,3…}
$_{loss}P^2$	activepowerloss
$_{loss}Q^2$	reactivepowerloss
V_is	voltagemagnitudebus$i$
V^{min}	maximumvoltagemagnitudebus$i$
V^{max}	minimumvoltagemagnitudebus$i$
δ	voltagephaseangle atbus$i$
T	tapsettingofthe OLTC.
T^{min}	minimumtapsettingofOLTC
T^{max}	maximumtapsettingofOLTC
P_{Gi}	activepowergenerated atbus$i$
Q_{Gi}	reactivepowergenerated atbus$i$
P^{max}	maximumactivepowergenerated atbus$i$
P^{min}	minimumactivepowergeneratedatbus$i$
Q^{max}	maximumreactivepowergeneratedatbus$i$
Q^{min}	minimumreactivepowergeneratedatbus$i$
PF_{DG}	powerfactorofDG

PF^{max}	DGmaximumpowerfactor
PF^{min}	DGminimumpower factor
G_{ij}	conductancebetweenbuses$i$and$j$
B_{ij}	susceptancebetweenbuses$i$and$j$
P_{Di}	activeloaddemandsatbus$i$
Q_{Di}	eactiveloaddemandsatbusi
DG	
DG	

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