MARMARA UNIVERSITY
FACULTY OF ENGINEERING

Optimizing The Unbalance Factor in Distribution Systems Using GWO

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Optimizing The Unbalance Factor in Distribution Systems Using GWO

by

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ABSTRACT

Electrical vehicles will be highly used soon. The power demand for electrical vehicles will have an effect on the distribution systems. One of the major challenges that utilities need to examine is the increase in the unbalance factor. Phase unbalancing can damage distribution system components. However, there are different ways to overcome this problem. Phase switching and making use of the reactive power of pVs are two of the ways. Thus, in this work, these algorithms are used with GWO which gives us the optimal configurations. Simulations are carried out in the IEEE 123-Bus system predefined on OpenDSS that enables us to add loads, and renewable energy sources externally. Results show us the improvement in the unbalance factor and compliance with engineering standards.

LIST OF SYMBOLS

V_{avg} = Average Phase Voltages of the nodes in per unit.

n_p = The number of phases of a bus

V_{diff} = The maximum voltage magnitude difference between the average voltage of a bus and node voltages in p.u.

V_1: The node voltage of phase A in p.u.

V_2: The node voltage of phase B in p.u.

V_3: The node voltage of phase C in p.u.

UF_i (%): Percentage of the unbalance factor of a bus.

n_b = The number of UF calculatable buses.

N_b = The number of buses.

ABBREVIATIONS

ANSI: The American National Standards Institute

IEEE: The Institute of Electrical and Electronics Engineers

OpenDSS: The Open Distribution System Simulator

EV: Electric Vehicles

PV: Photovoltaic Panels

P.u.: Per unit

S = The apparent power of photovoltaic Panels

P = The real power of photovoltaic Panels

Q = The reactive power of photovoltaic Panels

GWO = Grey Wolf Optimization

PSO = Particle Swarm Optimization

HSA = Harmony Search Algorithm

GA = Genetic Algorithm

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1. INTRODUCTION

The main responsibility of the distribution utilities is voltage regulation [1]. Especially, the electricity demand is increasing day by day. And it will continue to increase too. Because the population is increasing, and technology is developing. New technologic devices need electricity. And especially, a new trend is electric vehicles. Electric vehicles are joining our life rapidly and in near future, their number will become much more than it is today [2]. Distribution networks should be prepared for this demand before any dangerous situation happen. As written before, voltage regulation should be satisfied in these networks. The voltage magnitude of each phase should become in the interval of 0.95 and 1.05 p.u. according to the ANSI standard [3].

In three-phase unbalanced distribution networks, three distribution wires enter the homes. Sometimes voltage magnitude of these wires becomes different, or they violate the ANSI standard. In such a case, voltage magnitudes drop, or frequency fluctuations occur. These events damage home appliances, and sometimes they can be dangerous in terms of health. Three-phase should be balanced in distribution networks. The phase unbalancing can be caused by various factors, such as unevenly distributed single-phase loads or uneven impedances in the distribution system. Phase unbalancing brings about many problems. It may cause power loss, or it may speed up the aging process of the distribution network components. There are many ways to analyze the phase unbalancing and to define the unbalance factor. All these ways reach the same definition. Researchers have stated that the unbalance factor is an indicator of how unbalanced the system is. The unbalance factor should be decreased to maintain the quality of the electricity. To decrease the unbalance factor, researchers have used optimization algorithms. Meta-heuristic algorithms are easily implemented for this kind of purpose. After choosing the right optimization algorithm, it is significant to know by using which techniques the unbalance factor is decreased. There are lots of methods to use when it comes to decreasing the unbalance factor.

In this paper, we mainly focus on the cause of unevenly distributed single-phase loads. To create this scenario, we work on a predefined IEEE 123-Bus system provided by OpenDSS which has voltage drop problems and is one of the accepted test systems [4]. To create a big amount of single-phase loads, we make use of the characteristics of EVs. OpenDSS enables researchers to interfere with the system externally. Therefore, we add electrical vehicles to the bus system. Furthermore, since we focus on decreasing the unbalance factor by using different techniques, we also need to add PVs to the bus system as their reactive power amount helps us decrease the unbalance factor. After setting up what we need, we go with choosing the right optimization algorithm. Grey Wolf Optimization (GWO) is easily implemented on MATLAB enabling us to interfere with the code to make it work for our cases. After optimizing the unbalance factor, we see that some cases do not comply with the ANSI standard. We use regulators to comply with the standards with the help of GWO. To make this project more realistic, different cases are considered. All the cases are deeply analyzed in the result and discussion part and all conclusions show the improvement in the unbalance factor.

1.1. Thesis Content

In the introduction part, we explain the increase in unbalance factor caused by unevenly distributed single-phase loads, the importance of this problem, how this problem affects the distribution systems and components, and finally how we approach the problem and solve it.

In the research objective part, we explain what we expect to accomplish in this project and how different approaches help us overcome this problem.

One of the necessary things to do when developing some solutions to common problems is to look through what other researchers and experts have done to solve the problem. Reading articles and taking some notes of what other people have done helps us deal with the problem and gives us an opportunity to find new approaches that have never been used before.

The design part is where we explain our constraints, cost of design, and engineering standards that we have to abide by. We also talk about the tools we have used in this report. After reading this part, readers have the basic information they need to understand our work.

In the method part, we explain the logic behind our approaches and how they help us.

In the result and discussion part, we provide readers with plots to show how our approaches solve the problem and how effective they are. We explain the plots in detail.

We conclude our report in the conclusion part by summing up our approaches to the problem.

2. RESEARCH OBJECTIVE

There are many reasons to increase the unbalance factor such as unequal impedances in the distribution system, unequal transformer taps settings, etc. However, in this report, we put our concerns into the single-phase loads that are unevenly distributed. Our main objective is to decrease the unbalance factor that causes excessive power loss, motor failures, etc.

In this project, we work with the IEEE 123-Bus system which is an unbalanced system and has voltage drop problems [4] and is provided by OpenDSS. Since it is inevitable that electrical vehicles and renewable energy resources will be highly used soon, problems that may arise because of them should be solved. How we create an environment where the unbalance factor is above the usual levels is that we externally add electrical vehicles that act like loads to only one phase of the system.

After creating an environment where we have voltage drop problems and most importantly the unbalance factor problem, now it is time to solve the problems and make sure that everything will be working perfectly with EVs in the distribution system. When it comes to decreasing the unbalance factor, different approaches greet us. In this Project, we use phase switching and find the optimal reactive power of PVs with the help of Grey Wolf Optimizer (GWO). Not only does GWO help us decrease the unbalance factor but also it helps us find the best tap positions of regulators to meet the engineering standards in the end.

3. RELATED LITERATURE

In [5], the authors implemented the Greedy Randomized Adaptive Search algorithm, an iterative meta-heuristic algorithm, to solve the unbalancing between three phases in a 29-bus distribution system. And they used the VNS algorithm for local searching. They changed the loads between the phases in each node. Before the implementation of these algorithms, they calculated the unbalancing factor by using the voltages of each phase. Their aim is that the unbalance factor should be as minimum as possible. But it should not be greater than 2%. If unbalance factor is above 2%, utilities and consumers can be damaged.

In [6], the authors focused on the village-based distribution network (8-bus, 35 households), but unbalance of this network is huge. They tried to set up PV to this network. They used Grey Wolf Algorithm (GWO) to localize the optimum place of these PVs. And, they used the Backward- Forward Load Flow Algorithm to calculate total power losses in the system. They considered three different seasons in this paper, Winter Summer, and Spring because PV generation and load demand will be different in each season. The results indicate that if more PVs are added to the network, it will reduce the losses. And as a result, if unbalance factor in the load decreases, also total losses will be decreased, and the voltage profile will be more satisfied.

Article [7] deals with a phase load balancing method for low voltage electricity distribution networks. In this paper authors make a 24-time interval with real data from northern Romania. the authors implemented two different Meta-Heuristic Algorithms, the first one is the Genetic Algorithm (GA), and the second one is Particle Swarm Optimization (PSO). Also in this paper, the authors calculate the unbalanced factor as in [5]. And this unbalance factor will be an objective function. They try to decrease it. But in this paper, they use current values to calculate the unbalance factor, in [5] authors use voltage values between phases to calculate it.

In [8], the authors focused on phase swapping in the IEEE123-Bus system and IEEE34-Bus system. They think that unbalanced loading causes an unbalanced feeder. An unbalanced feeder means that we will have more power loss and surging the power quality. They worked for minimizing the power loss by swapping the minimum number of phases. They calculated the unbalanced factor as in [5] and [7], but in this paper, the authors calculated both the current unbalanced factor and voltage unbalance factor. And determined for which phase they implement this algorithm reduced the computational effort and searching space. In the end, power loss decreased, and the system index improved.

In [9], to reduce the unbalanced 3 phase, Y connected and Delta Connected static reactive power compensation devices are used for the optimization. And they aim to minimize the power loss in Distribution Network systems. The authors consider the current unbalanced of the transformer and voltage unbalance of 3 phase nodes. And in this paper, the IEEE123-bus test system and IEEE34-bus test system are used. Also, linearization methods are used for the optimization this provides the acceleration for the solving speed.

In [10], the authors try to solve the problem by using three different cases by using the IEEE13-bus test system. They consider the first case, as the only voltage regulator to control the system, the second case is only Distributed Energy Resources controlled system, and the last case is just a combination of the first two cases. As a general formula $S^2 = P^2 + Q^2$, if there is a small change in active power (P), it causes a wide range in reactive power(Q). And in this paper, Harmony Search Algorithm is used to control the voltage level.

In this work, a meta-heuristic algorithm, Gray Wolf Optimization (GWO) is applied to the IEEE123-bus test system. Before implementation of GWO, electric Vehicles are added to the test system as loads. Then, GWO is implemented for three different cases. Case 1 is GWO implementation for phase switching, Case 2 is GWO implementation for adjustment of Reactive Power of PVs. After the implementation of first two cases, Daily simulation is implemented in this system by using both Case 1, and Case 2 to have a more realistic simulation. And the last case is GWO implementation for the Regulator Tap numbers to adjust the voltage profile between 0.95 and 1.05 p.u. according to ANSI standard [3]. The last case includes all the situations (Phase switching, PVs Reactive power adjustment, and Daily simulation).

4. DESIGN

4.1. Realistic constraints and conditions

$$V_{avg} = \frac{1}{n_p} \times \sum_{i=1}^{n_p} V_i \tag{1}$$

$$n_p \geq 2 \tag{2}$$

$$V_{diff} = \max[|\left(V_1 - V_{avg}\right)|, \left|\left(V_2 - V_{avg}\right)\right|, \left|\left(V_3 - V_{avg}\right)\right|] \tag{3}$$

$$n_b \leq N_b \tag{4}$$

$$UF_i(\%) = \frac{V_{diff}}{V_{avg}} \times 100 \tag{5}$$

$$UF_i(\%) \ \leq \%\, 2 \tag{6}$$

$$For\ PV\colon\ \ S^2 = P^2 + Q^2 \tag{7}$$

$$For\ Regulator\ :\ -16 \leq Regulator\ Tap\ Position \leq 16 \tag{8}$$

4.2. Cost of the design

As we mentioned in the previous parts, our project is a simulation of one of the distribution networks which is well known IEEE123 Bus Test System. Since this is only a simulation, both programs are free for students. MATLAB needs a license to be used but the university provides us a license for this program. Because of that reason, there is no need to pay money. But if we try to implement this in the real world, of course, we will need some money.

4.3. Engineering Standards

IEEE 1547 standard is designed by the Electrical and Electronics Engineers Institute. It contains some criteria about the connection of the distributed energy sources to the grid [11].

According to ANSI standard, the service voltages should be within ±5% of their nominal voltage level which translates to 0.95 to 1.05 p.u. voltage. When a service voltage goes below 0.95 p.u., it is considered an undervoltage violation and if the service voltage exceeds 1.05 pu, then it is an overvoltage violation [3]

4.4. Details of the design

IEEE123 Bus System

IEEE 123 Bus Test System is predefined on OpenDSS like other test systems (13-Bus,34 Bus, 123 Bus). It operates at 4.16 kV. And it is a more complex system according to others. This system has 132 buses and 7 regulators. The system has 99, 84, and 95 nodes in phase A, phase B, and phase C respectively [12].

OPENDSS

The electrical Distribution system has various pieces of equipment. For instance, transformers, distribution lines, and substations. All these types of equipment have numerous parameters that affect the properties of devices. Small changes in these parameters can have a big effect the whole system. Software programs help us at this point. Because solving the effect of these parameters is hard manually. Software programs provide us with more confident solutions. Errors of these solutions are less compared with solving manually. For this reason, computer programs are preferred while doing power system solutions. And it is easy to simulate these programs. They enable us to predict the effect of adding new equipment or changing the parameters of available pieces of equipment to distribution systems.

One of these software programs is OpenDSS which was developed in 1997 by EPRI (Electric Power Research Institute). OpenDSS helps us to solve complex equations in a power system. Unbalanced, multi-phase power flow, linear and non-linear analyses, and fault analyses can be done easily by using OpenDSS. OpenDSS has pre-defined test cases like IEEE-13 Bus Test System, IEEE123 Bus Test System, etc. These test systems are common test systems that are known all around the world.

Traditional distribution system types of equipment are available in OpenDSS such as transformers, lines, etc, and different distributed energy resources are available in OpenDSS like PV systems, and storage devices. We can easily change the parameters of these assets, or we can add new assets to distribution systems by using OpenDSS.

OpenDSS has an object-oriented language. Although there are uncountable advantages of OpenDSS, its interface is not good, and plotting the graphs is much more complex. At this point, the COM interface helps us while using OpenDSS with different modern programming languages like MATLAB or Python. The effect of any change in distribution systems can be done and visualized by using MATLAB easily [13].

PV

Photovoltaic cells use sunlight and turn it into electricity [14]. When PV panels are added to distribution networks, they help us provide more energy which results in an increase in the voltage magnitudes of nodes. We make use of the characteristics of PV a lot. The amount of reactive power supplied by PVs helps us decrease the unbalance factor. They are also preferred in real-world applications as they are less harmful to the environment. However, one of the disadvantages of using PVs is that they do not contribute to the production of electricity all the time as they need sunlight to produce it. Therefore, they are effective at noon times.

Electric Vehicles

Most cars are working with internal combustion motors recently. This type of car damage the environment and human health. Recently, electrical vehicles which are less harmful to the environment have become popular [15]. The popularity will continuously be increasing. Soon, there will be many more electric vehicles with the improvements in charging. They will put an end to old combustion engine vehicles. Some car brands have already started to produce electric vehicles. Before we move into the era of electric vehicles, we should simulate the future expansion of our test system caused by extra electric vehicles.

Addition of Electric Vehicles

In this project, as mentioned in previous parts, IEEE 123 Bus Test system was used. Electric vehicles are inserted into the system externally. We inserted Electric vehicles into 6 different buses randomly. To obtain more unbalanced phases, we inserted EVs in the first phase of each bus. EVs were defined as Load in OpenDSS. And they have a load shape throughout the day. Load shape assumption is done that EVs will be charged when the people come their home from work up to they go back to their work. They need electricity when they are in a charging situation. We assume that each EV needs a 10kW average. And in each bus, we have 10 EVs. The topology of the IEEE123-Bus Test system with EV is shown in Figure 4.4.1

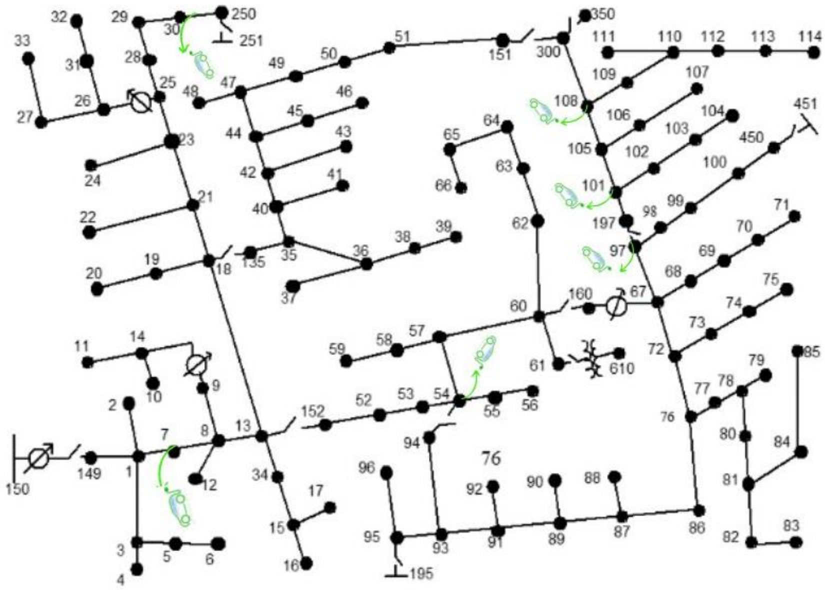

Figure 4.4.1 Topology of IEEE 123 Bus System with EVs

Addition of PVs

In this project, we made profit from PVs. PVs generate electricity when they are exposed to sunlights. That means we can not use PVs every hour. We can easily create a PV on OpenDSS. It has already existed library for the PV. PVs have a load shape like EVs. PV load shape can not be determined by us. As we mentioned in previous sentences, PVs need the sun to generate electricity. That means we can use PVs at noon hours with maximum efficiency. PVs daily load shape as you predict it supplies energy at noon hours. Six different PVs are inserted to test the system. Their maximum power magnitudes are 100kW and they have real and reactive power that can be generated. The topology of IEEE123-Bus Test system with PV is shown in Figure 4.4.2

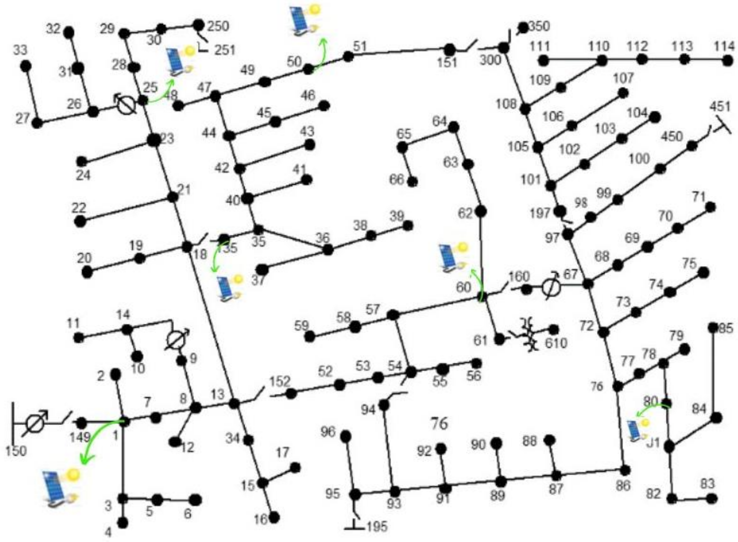

Figure 4.4.2 Topology of IEEE 123 Bus System with PVs

Finally, Topology of IEEE 123-Bus system after adding PV and EV shown in Figure 4.4.3 as a final topology

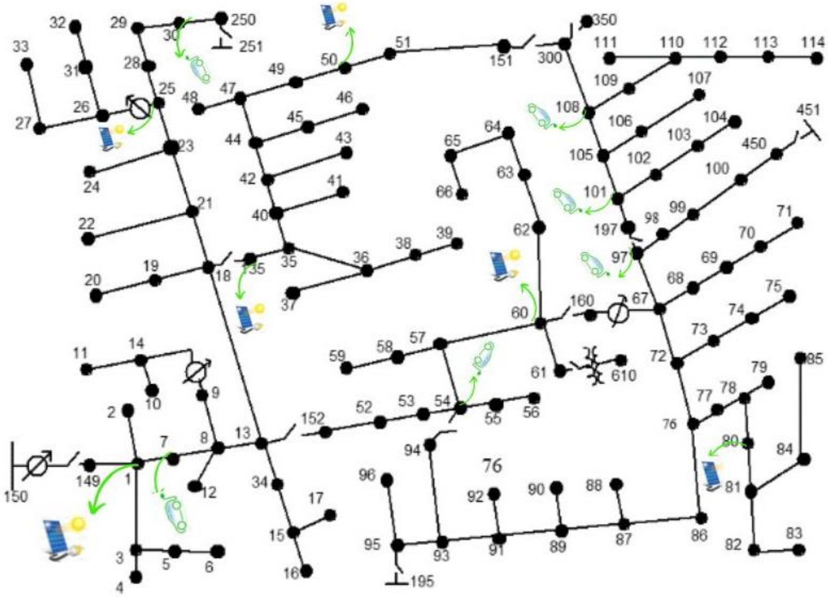

Figure 4.4.3 Topology of IEEE 123 Bus System with PVs and EVs

5. METHODS

As we have explained before, our main objective is to decrease the unbalance factor that is increased by unwanted situations like a big amount of loads connected to only one phase of the buses. We have read many ways to decrease the unbalance factor so that everything works perfectly and no appliance and distribution system components get damaged. In this paper, two ways are introduced to decrease the unbalance factor. One of them is so effective that the unbalance factor gets almost 16 times less. It is called phase switching. Phase switching basically tells us to change the phase of the loads at the same bus. Let's think of a scenario where we externally define a big amount of load to phase A of the 30th bus. It is also shown as 30.1 on OpenDSS. Then we solve the power flow with the help of OpenDSS engine and see that the unbalance factor is above the limits [5]. Then we change the location of this load to 30.2 which is phase B of the same bus and solve the power flow again. Luckily, we see a decrease in the total unbalance factor. The phase switching method is based on this algorithm.

Another way that we use to decrease the unbalance factor is to change the reactive power of the PVs in our distribution system. We define PVs externally in our system and make use of their characteristics. Adjusting the reactive power of the PVs by GWO helps us decrease the unbalance factor but the effect of this method is not that high compared to phase switching.

In this paper, we create 4 cases where we make use of these methods, and change the simulation type (snapshot and daily simulation). After applying these methods we see that we also need to change the regulator tap positions as they help us regulate the voltage level to comply with the ANSI standards stated in this paper [3].

We have seen what our aim is so far but the real question is how we can apply these methods, and how we can make sure the optimal tap position of the regulators. Actually, all the methods mentioned above require us to use optimization. Optimization helps us solve minimization or maximization problems when an objective function and lower and upper bounds are provided. Since we use Matlab and OpenDSS to do the simulations, we need an optimization code that we can play with to meet our requirements and GWO helps us in this way. we download the source code and change the algorithm in our way. We first define the objective function which depends on the operation we do and integrate the algorithm so that we can use the optimal values that it produces.

Implementation of the algorithm is given below.

• Step 1: Start the OpenDSS engine, set the parameters, compile the test case, and fix the tap positions.

• Step 2: Add EVs and PVs to the system externally. EVs should be added to only one phase of the system which is chosen to be phase A.

• Step 3: Solve power flow with the help of OpenDSS engine and keep load and bus information to further process them.

• Step 4: Prepare GWO parameters. Set the objective function to be used by GWO, and set lower and upper bounds. These bounds depend on the operation. Set the dimension. The dimension also depends on the operation. Set other GWO parameters like SearchAgent number and max iteration.

• Step 5: Start the GWO and find the best values until the final iteration is done. For phase switching, GWO uses the sum of all the unbalance factors of buses as the objective function and tries to decrease this sum as much as possible and gives the best load location in terms of phase-type. For adjusting the reactive power of PVs, it again uses the sum of all the unbalance factors of buses as the objective function and gives the optimal amounts of reactive power of PVs. As for the tap position of regulators, it uses the sum of the absolute values calculated by subtracting 1 p.u. from node voltages and gives the nominal positions.

• Step 6: Using the optimal values found by GWO, solve the power flow again and keep all load and bus information.

• Step 7: Compare the load and bus information to see the effect of GWO on the power flow in terms of the unbalance factor improvement and compliance with ANSI standards

6. RESULTS AND DISCUSSION

In this paper we simulated 4 different cases in IEEE 123- Bus Test System. Implemented cases are shown in Table 1.

Table 1 Cases

CASES	OPERATION	SIMULATION MODE
CASE 1	Phase Switching	Snapshot
CASE 2	Adjusting Q output of PV	Snapshot
CASE 3	CASE 1+ CASE 2	Daily Simulation
CASE 4	CASE 3 + Regulator Tap Position	Daily Simulation

I. CASE 1

In this case, we implemented a phase switching algorithm by using GWO, to implement this algorithm, there should be at least 2 phases at that bus. In Figure 6.1.1 you can simply understand graphs of before and after phase switching. In ' Before Phase Switch Graph 'There are some nodes that violate the ANSI standard at Phase A and Phase B. However, after implementing the phase switching algorithm There is no node that violate the ANSI standard. Furthermore, after applying the algorithm, voltages of nodes of three phases come closer to each other gathering around 1 p.u. which shows that the unbalance factor is decreased a lot.

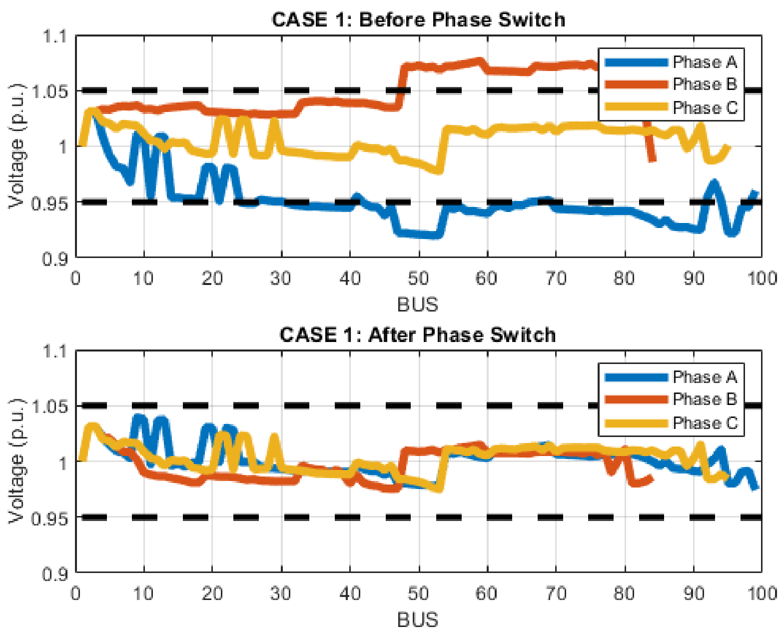

Figure 6.1.1 Simulation of IEEE 123 Bus System with Phase Switching

You can see old and new load positions after implementing this algorithm of some loads in Table 2.

Table 2 Location of Changed Loads

LOAD NAME	OLD LOCATION	NEW LOCATION
S7A	7.1	7.3
S29A	29.1	29.3
…	…	…
EV2	30.1	30.2
EV5	101.1	101.2

II. CASE 2

In this case, we adjust the reactive power of PVs according to the general formula S^2= P^2+Q^2. It provides us voltage regulation if PV is active. Because as we said before, PV can not work all hours in a day. PV needs sunlight to generate electricity. The graph is shown in

Figure 6.2.1, it is observed that in some buses there are clear changes in voltage. (Especially between 10-20 on the x-axis)

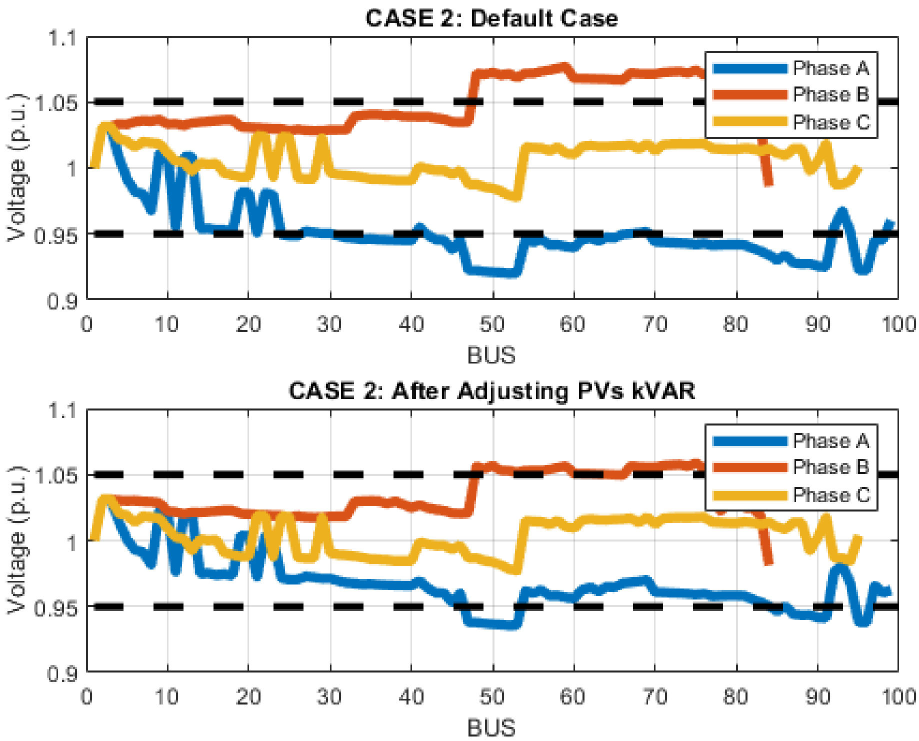

Figure 6.2.1 Simulation of IEEE 123 Bus System with Reactive Power Adjustment

In following Table 3, you can see the adjusted Q values before and after the implementation of the algorithm.

Table 3 Before and After Reactive Power Adjustment

PV NAMES	**PV1**	**PV2**	**PV3**	**PV4**	**PV5**	**PV6**
OLD Q in KVAR	60	60	60	60	60	60
NEW Q in KVAR	-104.02	150	70.68	29.12	150	-150

III. CASE 3

In this case, we implement both Case 1 and Case 2. We implement Case 1 when the sun is not enough to generate electricity from PVs. If sunlight is enough to generate electricity that means at noon hours, we use adjusting PV's reactive power algorithm. There is a difference compared to Case 1 and Case 2. The difference is the simulation mode. In Case 1 and Case 2, we simulate our system in snapshot mode. However, in this case we simulate our system in daily mode. That provides us with more realistic results.

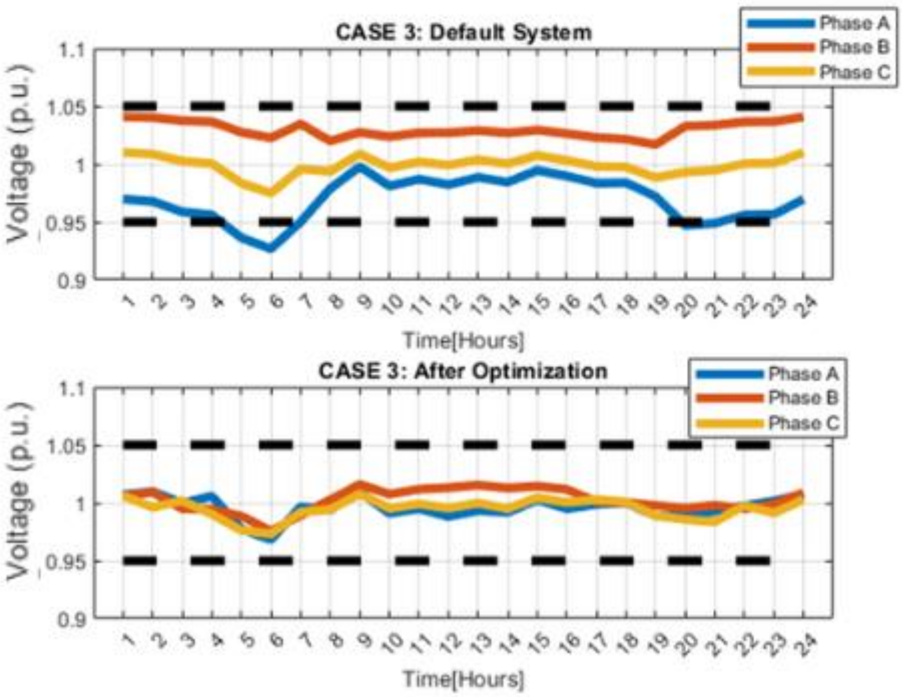

Figure 6.3.1 Simulation of IEEE 123 Bus System with Phase Switching and Reactive Power Adjustment at 23rd Bus

In figure 6.3.1**,** we get the plot of only 23rd bus in our system to observe more visibility. And all the time intervals, our voltage values are in the allowable interval. But for the other buses, there are some time intervals that violates the ANSI standard. To prevent that we implement Case 4.

IV. Case 4

In this case, we implement changing regulator tap position algorithm in addition to Case 3. In IEEE 123 Bus test system we have 7 regulators. We find the optimum tap positions for each regulator. After implementing this algorithm, as you can see in Figure 6.4.1, voltages of all buses are provided in the desired interval for the whole day compared to default graphs.

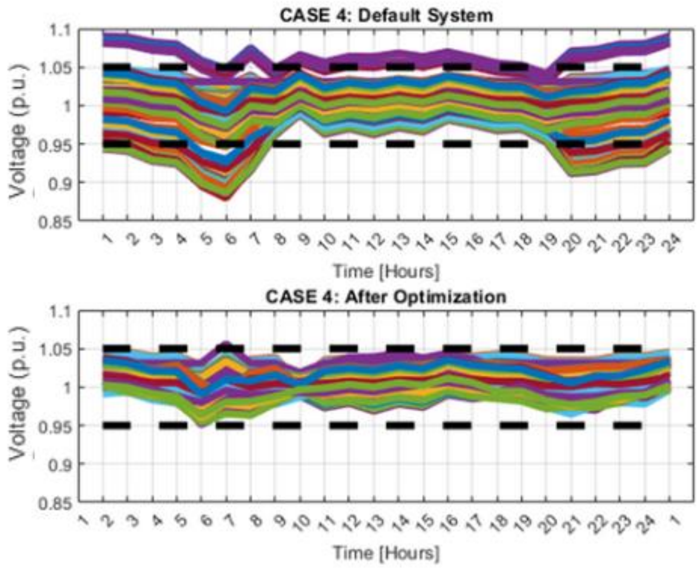

Figure 6.4.1 Simulation of IEEE 123 Bus System with Phase Switching and reactive power adjustment at all buses

You can see old and new regulator tap positions after implementing this algorithm to regulators in Table 4.

Table 4 Before and After Regulator Tap Positions of each Regulator

Regulator Name	**Regulator 1**	**Regulator 2**	**Regulator 3**	**Regulator 4**	**Regulator 5**	**Regulator 6**	**Regulator 7**
Old Tap Positions	5	5	5	5	5	5	5
New Tap Positions	9	-1	-1	0	6	5	5

In Table 5, it is shown that which type of algorithm is implemented each time interval through a day.

Table 5 General Information of The Implementation in Case 4

Time	Old UF	New UF	Operation	RegTap UF
0 – 1	337. 92	17	P. C	-
1 – 2	344.53	18.08	P.C	-
2 – 3	372.17	23.05	P.C	-
3 – 4	379.04	28.38	P. C	-
4 – 5	419.58	28.86	P.C	-
5 – 6	435.33	34.79	P.C	28.52
6 – 7	396.87	28.85	P. C	-
7 – 8	160	24.08	P.C	-
8 – 9	115.4	23.72	P.C	20.62
9 – 10	172.01	76.45	PV kVAR	-
10 – 11	164.31	80.05	PV kVAR	-
11 – 12	187.00	111.59	PV kVAR	-
12 – 13	169.04	94.46	PV kVAR	-
13 – 14	176.55	94.48	PV kVAR	-
14 – 15	142.48	58.77	PV kVAR	-
15 – 16	147.68	57.18	PV kVAR	-
16 – 17	155.79	13.39	P. C	-
17 – 18	145.59	21.61	P.C	-
18 – 19	174.93	23.18	P.C	-
19 – 20	398.65	29.23	P. C	-
20 – 21	394.63	32.11	P.C	-
21 – 22	379.23	21.99	P.C	-
22 – 23	377.74	29.62	P. C	-
23 – 0	337.91	18.44	P.C	-

7. CONCLUSION

In this work, one of the most important problems about distribution systems that utilities need to analyze before the new era comes where many people charge their vehicles, renewable energy sources play a big role in producing the electricity is considered. As the population increases, electricity quality should be maintained. The unbalance factor has a negative impact on the quality of the electricity which may be detrimental to any device that is connected to the electricity. Two ways to decrease the unbalance factor are deeply analyzed and their effects are compared in the result and discussion part. It is no doubt that the phase switching is so effective that the unbalance factor gets less almost 16 times. As for the reactive power of pVs, it depends on the apparent power. After these methods, GWO is used one more time to find the optimal tap positions of the regulators to regulate the voltage so that engineering standards are complied with. Simulations are done with snapshot and daily simulation modes to better analyze the system. The unbalance factor decreased to the allowable levels and all engineering standards are observed.

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APPENDICES