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A NEW STRATEGY FOR PHASE SWAPPING LOAD BALANCING RELYING ON A META-HEURISTIC MOGWO ALGORITHM

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Abstract

The significant spread of the single-phase loads in the consumer homes make the distribution network suffering from many dangerous problems like the load unbalancing. This problem comes because the single-phase devices continuously plugged in and out to different phases each time. This paper cared about this problem and solved it efficiently by the new meta-heuristic algorithm called GWO that applied for the first time to solve the load balancing issue. The algorithm has the ability based on the smart meter included swapping mechanism to disconnect the appropriate home phases from their initial connection to specific feeders and reconnected again to other feeders for satisfying the balancing in the secondary distribution network. The algorithm adapted to reaching the balancing with a minimal number of swaps and take care of the online PVs if the consumer likes to buy energy to the national utility. It distributed all the PVs in a manner that not cause a balancing problem or lead to a stability issue. The proposed method has been applied to some unbalanced areas with random data generated in MATLAB to confirm the efficacy of the proposed algorithm.

Keywords: Load balancing, Gray Wolf algorithm, phase swapping, solar energy, swapping factor, unbalanced feeders

I. Introduction

The power system can be divided into three main parts, generation, transmission and distribution. The distribution system in turn can be divided into two parts: primary and secondary distribution systems [XIII], [I]. The secondary distribution system in usually a three-phase, four-wire system [XVII] , [IV] that comes after the step-down distribution transformers rated 11Kv to 400/230v as in Fig.1.

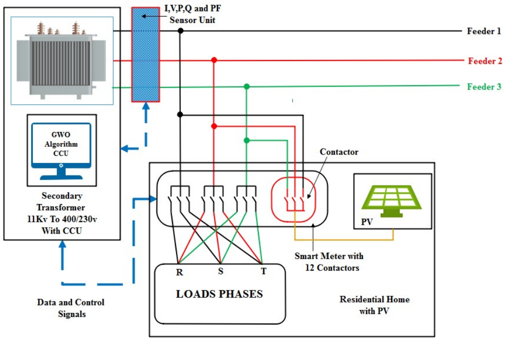

Fig. 1: The secondary distribution network in smart residential region

The load connected to the secondary distribution system (feeders) is either single or three phase loads[VI]. The verity of loads on distribution system make some phases of the feeder heavily loaded and the other phases have a light load[VIII], [XV]. This phenomenon leads to cause the unbalancing between the phases. Unbalancing occurred when the current in the secondary distribution feeders neither have the same magnitude nor the phase difference among them equal to 120, or one of them [III]. One of the highly essential issues that the electrical distribution network engineers thinking about is how to obtain the optimal connection of the home's phases among the three wires in the LV distribution network. The consequence of the optimality connections is the phase balancing. The unbalanced loads lead to false tripping of the protection devices such as the over-current relay [XI], unbalanced voltages, and more losses and finally the efficiency of the system components will be less [III]. The unequal current flowing in the feeders can cause also increasing in the neutral current that tripping the feeder service, the sensitive loads in the network will not operate normally, the security of the line will reduce for the labors and overloaded the equipment of the power system [XIV]. The problem can solved by the feeder's reconfiguration at the system level or phase swapping at the feeder [X].Phase swapping is used to realize the load balancing. It is a direct way that accomplishes the balancing load with minimum cost [III]. This method proposed to redistribute all the home's phases on the three feeders in away guarantee to make the current drawn from each one of them approximately equal in magnitude and in this case the *PUI%* factor will have a small value. Phase swapping can be divided into two types: nodal and lateral phase swapping. The searching space to obtain the correct and optimal or sub-optimal rephasing scheme that regarded as a solution for the balancing problem is enormous and exponentially proportional to the number of redistributed phases. The role of the professional technology is to select the best switches positions among a large number of solutions to satisfy the best balance case [XII]. The positions converted to a signal for the smart meter contactors to change their initial state to a new state that satisfied the optimal or sub-optimal balancing. The kinds of the swapping illustrated in Fig.2.

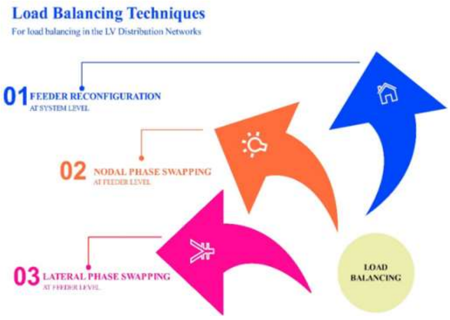

Fig. 2: The Load Balancing Swapping Techniques

In this paper, the AMI proposed to have the nodal swap ability depending on nine contactors. The optimal switches position for the phases of the homes computed in the CCU depending on the gray wolf optimization (GWO) Artificial intelligent (AI) algorithm in a manner that satisfied the minimum *PUI*%. The GWO used for the first time to achieve load balancing. GWO developed to be a multi-objective GWO (MOGWO) to accomplish the load balancing in a smaller number of swaps. Finally, the MOGWO adapted again to take care of the photovoltaic (PVs) that considered available in the consumers' homes to connect it all to the feeders in a manner that not made any problem in the stability of the distribution network.

II. Swapping Problem

There are many ways for load modeling, in this paper, the composite loads that connected to each phase in homes will be represented by their current magnitude drawn from the feeder that phase already connected to. The problem is how to redistribute the phases of the homes on the feeders to mitigate the unbalancing on these feeders. The technique used for rearranging the home phases (nodes) is called nodal phase swapping.The Phase swapping is a combinational optimization issue that it classified as a nondeterministic polynomial complete (NP-complete) problem [VII]. These types of problems do not have an optimal solution, but an excellent suboptimal solution is available. The search space of the swapping problem computed as (3^L) where L is the no. of phases in the network connected to the three secondary feeders. The complexity is increased exponentially with the increasing of the no. of phases, and that makes the amount of solutions reach to a very high number. For example, if there are 50 homes, and each home has 3 phases, there will be approximately equal to $3.699*10^{71}$ possible swap solutions to this problem. Here, looking for the optimal solution - less *PUI%* value by the try and error method is a tedious process that consumes a significant amount of time. The critical case here is the possibility of network topology changing during the searching process because of the inconstant nature for the network due to the plug-in and out of the single-phase loads on the home phases. In this case, the changing to some suboptimal solution may make the unbalancing worse. The proper solution to this problem is using the Meta-Heuristic algorithms that are searching on the solution with a quick procedure that reaches the appropriate swap scheme with reasonable time. The Gray Wolf Optimization (GWO) is one of the searching meta-heuristic algorithms that discovered recently and achieved a perfect result in the engineering field[XVI]. GWO can solve the balancing problem and reach to a great suboptimal swap scheme. The swap process means transferring the loads of homes among the three feeders. The changing of all the phases may be a costly process and harms some sensitive loads. To mitigate that, the GWO modified to be multi-objective GWO (MOGWO) that can achieve the balancing and at the same time in a minimum number of phase swapping. The photovoltaic (PVs) nowadays penetrated the residential distribution network, and the consumers installed it in homes to participate in decreasing the electricity bills. In this paper, the PVs assumed to be connected online to the feeders. MOGWO modified for the second time to take the online PVs in its consideration for load balancing without causing any hazards to the stability of the system. The PVs make the solution of the phase balancing more complicated computational process.

The balancing problem solved under the following assumptions:

- All the loads connected to the home phases are a single-phase load. The three-phase loads are balanced in nature and can connected directly to the feeders before the swap controller as in Fig.3.

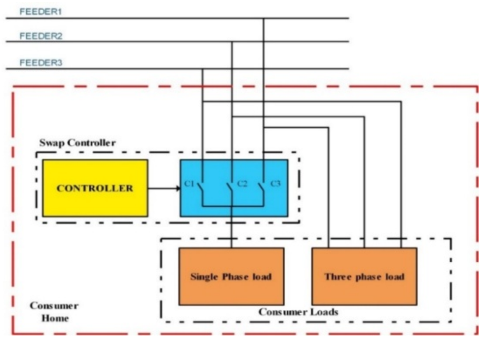

Fig. 3: The connection of single and three phases in consumers' homes

- The single-phase loads connected to the swapping controller is smart loads with inverter property.
- The phases of homes connected to the feeders have an equal power factor value. This assumption allows us to depending only on the current magnitude only in the balance problem. This assumption is permitted especially in the residential areas [II], [V], [VII],[XVIII], [IX].
- Each phase of each home can just connect to one feeder in specific time.
- The voltage drops between homes connected to the feeders assumed equal to zero.

In brief, the main objective of the study was:

- Minimize the unbalanced load in the three LV secondary feeders that come after the distribution transformers of the residential regions in the secondary distribution networks as it is shown in Fig.2.

III. Objective Function

The GWO meta-heuristic algorithm will exam many solutions that the algorithm electedcarefully depending on a random factor and the best one among them is that one achieves less objective function. There are many objective functions like the loss function or the cost objective function. In this paper, the objective functions will be the PUI% and the Swap Factor Index (SFI%). The load balancing situation is decided according to the PUI%. The feeders will be in a good balance state if the PUI% was less than six percent taking in the consideration achieving that by minimum number of phase swapping (minimum SFI%).

- **Phase Unbalance Index**

It defined as the ratio of the maximum difference between the feeder currents and the average to the average itself. Mathematically defined in equations (1) and (2).

$$PUI\% = \frac{\max(|I_{PH1} - I_{Avr}|, |I_{PH2} - I_{Avr}|, |I_{PH3} - I_{Avr}|)}{I_{Avr}} \quad (1)$$

$$I_{Avr} = \frac{(I_{PH1} + I_{PH2} + I_{PH3})}{3} \quad (2)$$

Here, I_{PH1}, I_{PH2} and I_{PH3} is the feeder currents magnitude on phases 1,2 and 3. $I_{avr}$is the average value of the three feeder currents.

- **Swap Factor Index**

It defines as the ratio between the phases swapped between the first and the final configuration of the network to the total number of the phases in the network under consideration. The mathematical form of the SFI% explained in equations (3) and (4).

$$SFI\% = \frac{\text{The total No. of swaps from the intial network configuration}}{\text{The Total No. of phases}} \quad (3)$$

$$SFI\% = \frac{C_{Swaped}}{C_{Total}} \times 100\% \quad (4)$$

Where the C_{Swaped} represent the overall number of phases transferred from feeder to feeder from the start to the final network configuration. C_{Total} is the total number of loads connected to the network.

V. Algorithm

The GWO algorithm is a meta- heuristic technique used in the optimization branch to solve the nonlinear complex problems like the load balancing in a radial secondary distribution network. The main steps that the algorithm follow to reach for a balanced distribution network through an optimal or suboptimal phase swapping shown in the Fig.4.

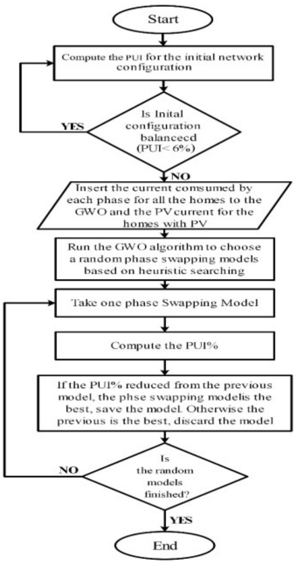

Fig. 4: The operation mechanism of GWO algorithm

- **GWO in Real World and in Power System**

The algorithm mimics the method of the gray wolves that called (Canis lupus) in hunting the prey. The same technique can be employed in the power system to solve the load balancing problem. The wolves here is the swapping schemes that classified according to its fitness values. In other words, the swapping models (schemes) tested individually, and the fitness value of each one is recorded and compared with the others. The scheme that achieved the fittest fitness value will be regarded as α. The β and δ have less value so they are the next dedicated solutions after α to solve the problem. The other schemes regarded as a ω. The omega is a bad scheme to achieve the load balancing because it has the smallest fitness value. The best fitness value will indicate the best scheme that represents a better solution to the balancing problem. The process of chasing, encircling and attacking the optimal solution (prey) is same here, but the wolves represent the contactors switches in the smart meters.

VI. Mathematical Model

The mathematical model can be described by the following items:

- **The Switching Process**

The contactor act as electrical switch to connect a single home phase to specific feeder. In the balancing issue, each single-phase load can connect to one feeder at a time. So, for the loads and PVs contactors it could be written as in equation (5):

$$\sum_{i=1}^{4} Ci = 1 \tag{5}$$

Where C_i represents a contactor (virtual electrical switch) that connect the home phases or the PV (nodes) to one of the three feeders depending on a signal from the controller. The fig.6 represent the method of swapping one node to any suitable feeder among the three distribution feeders. The other nodes can be connected in the same way illustrated in Fig.6.

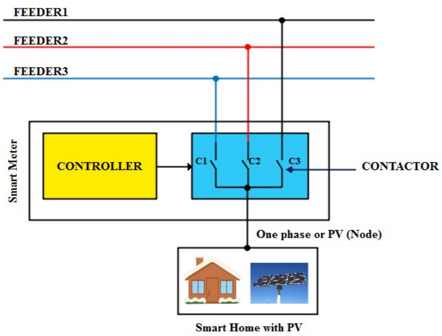

Fig. 6: The swapping mechanism for transfer the home phases or the PV on any one of the feeders.

- **The GWO Algorithm**

To simulate the wolf's hierarchy in power system engineering, the optimal balanced scheme among all the solutions will regarded as α. The best-balanced solutions after the α called β and δ respectively. The other candidates' schemes can be regarded asω. The first step in GWO algorithm is the encircling the optimal solution. The encircling represented mathematically in equation (6) and (7)[XVI].

$$\vec{D} = |\vec{C}.\vec{X}_p(t) - \vec{X}(t)| \tag{6}$$

$$\vec{X}(t+1) = \vec{X}(t) - \vec{A}.\vec{D} \tag{7}$$

Where t represents the iteration under the consideration now, $\vec{X}$ is a vector indicated to the gray wolf position. $\vec{A}$ and $\vec{C}$ are vector of coefficient. $\vec{X}_P$ is a position vector of the prey. The $\vec{A}$ and $\vec{C}$ vectors extracted from equation (8) and (9):

$$\vec{A} = 2\vec{a}.\vec{r}_1 - \vec{a} \tag{8}$$

$$\vec{C} = 2.\vec{r}_2 \tag{9}$$

Where $\vec{a}$ decreased linearly from 2 to 0 during the iterations and the r_1 and r_2 are random vectors with a value between 0 and 1. The second step in the algorithm is the hunting of the optimum scheme (prey). In the beginning, the prey location has not been known. The α guide the hunting and βandδ participate also infrequently in that. To represent the hunting in a mathematical manner, the α, β and δ have good knowledge about the possible location of the prey. The three best solutions obtained previously saved and the other wolves (ω) are forced to update their positions to match the position of the best three candidates according to equations (10) to (16):

$$\vec{D}_\alpha = |\vec{C}_1 . \vec{X}_\alpha - \vec{X}| \tag{10}$$

$$\vec{D}_\beta = |\vec{C}_2 . \vec{X}_\beta - \vec{X}| \tag{11}$$

$$\vec{D}_\delta = |\vec{C}_3 . \vec{X}_\delta - \vec{X}| \tag{12}$$

$$\vec{X}_1 = \vec{X}_\alpha - \vec{A}_1 . (\vec{D}_\alpha) \tag{13}$$

$$\vec{X}_2 = \vec{X}_\beta - \vec{A}_2 . (\vec{D}_\beta) \tag{14}$$

$$\vec{X}_3 = \vec{X}_\delta - \vec{A}_3 . (\vec{D}_\delta) \tag{15}$$

$$\vec{X}(t+1) = \frac{\vec{X}_1 + \vec{X}_2 + \vec{X}_3}{3} \tag{16}$$

The final positions of the ordinary wolves will be in random place around the circle of alpha, beta or delta agent as it shown in Fig.7.

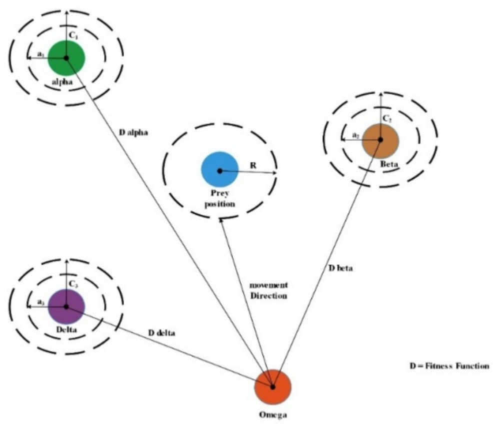

Fig. 7: Position updating in GWO

The final step of hunting is the attacking of the prey by decreasing the value of $\vec{a}$ vector from two to zero during the iterations. The changing in the $\vec{a}$ vector leads to variation in $\vec{A}$ vector. When $|\vec{A} < 1|$, the wolves oblige to attack toward the prey and when $|\vec{A} > 1|$ that forced the agents to spread away from the prey with hope to find better prey than the last one.In the power system, the GWO algorithm searching smartly about the optimal scheme (solution) for the contactors in the smart meter that swapping the home's phases and the PV if available from their original feeders to a new feeder in a way guarantees that the secondary distribution network will be in balancing case. The algorithm generates a specific number of schemes in each iteration depending on the number of individual agents defined by the user. The fitness for all the agents estimated by the objective function and the most favorable result obtained stored as the alpha wolf for the current iteration. At the end of all the iterations, the scheme produced the best fitness function can be regarded as the optimal position scheme that can perform the best balancing. During the iterations, the searching about the optimal solution submits to many random factors that can accelerate the searching process and obtaining the optimal solution as it explained in [XVI]. Optimal solution has been sending through the two-way communication to the contactors in the smart meter to alter its status that doing the load balancing among the secondary distribution network.

VII. Simulation Results

The GWO algorithm code is tested in MATLAB 2018b simulation environment to achieve the balancing among the three feeders according to three cases. The first case is dealing with the reaching to the balance without any caring for the number of swaps in phases of the homes. The second case satisfied the load balancing with a minimum number of exchanges in homes phases. The third case take in its consideration adding a renewable source (Photovoltaics) that available in homes to participate in load balancing. The laptop computer specifications used in simulation was (Intel® Mobile Core™ 2 Duo CPU T6400 @ 2.00GHz). The algorithm tested on random data generated in MATLAB and real data collected from the smart meters of Al-Rasikhcompany. In the random data, to ensure there are unbalancing in feeders we programmed the algorithm to let the currents drawn from each phase R in all the homes not exceed the 60A, from S phase 36A and T phase 24A as it is shown in Fig.9.

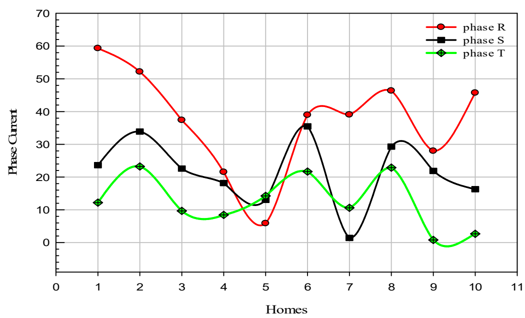

Fig. 9: The currents of the three phases for 10 homes. There are three non-symmetrical currents (Unbalance currents)

▪ GWO Algorithm to Achieve the Load Balancing

The main goal in this branch is achieving the balancing without any caring for the number of swaps that happened in the homes of the consumers. In the fact, the number of swaps must treat carefully to be less as much as possible because the phase swaps may damage the sensitive loads in the consumer homes. To avoid this problem the assumption no. 2 is adopted. The performance of the proposed algorithm is tested under three scenarios:

- **Middle Number of Homes (50 Homes)**

The last item proved the algorithm could solve the balancing problem for a few numbers of homes in a few seconds. Now, the algorithm will be encountered around 3.699*1071 schemes. The currents of the fifty homes three phases each is shown in Fig.12.

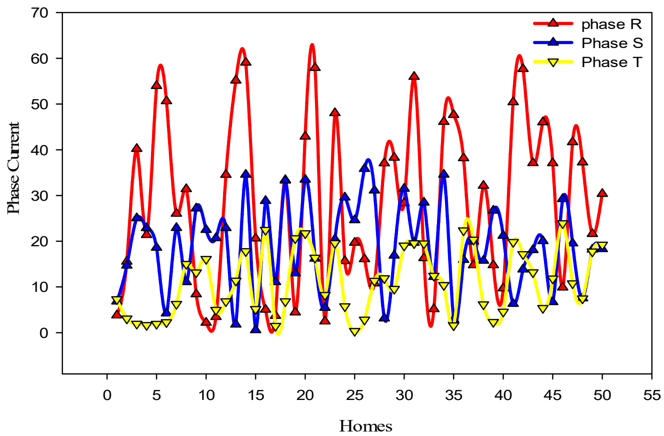

Fig. 12: Random test currents for 50 homes

Here the number of solutions is vast compared with the 50 homes. The algorithm with three different 5000 agents is tested and the results recorded in table 1. The swap factor computes according to the assumption that each phase connected to the symmetrical feeder in example, phase R connected to feeder 1 and so on. From the table 1, the first run was the best in case of 5000 agent in spite it takes around 29 seconds and the balancing in feeders better than others as shown in Fig. 13.

Table1: The results of applying GWO on 50 homes and 5000 agents

Agents	Runs	Time consumed	PUI	Swap Factor
Agents = 5000	First Run	28.724912 seconds	0.9625	67.3333
	Second Run	7.672928 seconds	7.5852	70
	Third Run	7.986910 seconds	10.0181	66

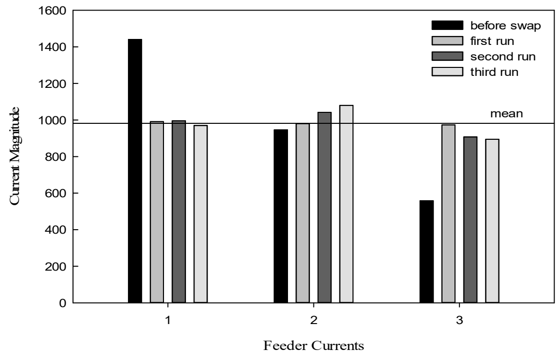

Fig. 13: Random test currents for 50 homes 5000 agents

Now, the algorithm tested on other three kind of random currents recorded to verify its validity under different situations. The current in feeders reach the balancing where the *PUI%* reached to less than one percentage in less than ten seconds as it clear from table 2. Figure 14 showed the three unbalanced feeders be balanced after applying the GWO algorithm.

Table2: The results of applying GWO on 50 homes and three different data

Agents	Runs	Time consumed	PUI	Swap Factor
Agents = 5000	First Data	7.818659 seconds	0.0580	70.6667
	Second Data	8.797096 seconds	0.3301	74.6667
	Third Data	8.856067 seconds	0.0326	68.6667

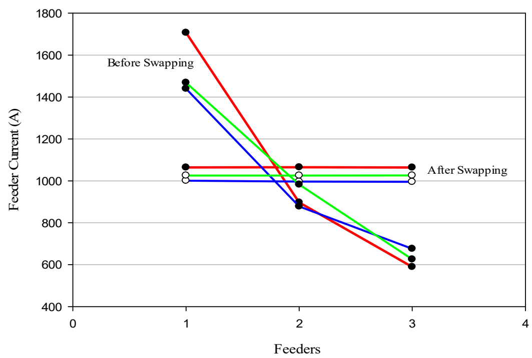

Fig. 14: Random test currents for 50 homes 10000 agents and the feeder currents after swapping process

- **Large Number of Homes (100 Homes)**

When the number of homes reach to 100 homes the algorithm will test a real challenge because now the number of solutions for this problem reach to $1.368*10^{143}$ possible solutions. The random data generated for 100 homes was as shown in Fig.15.

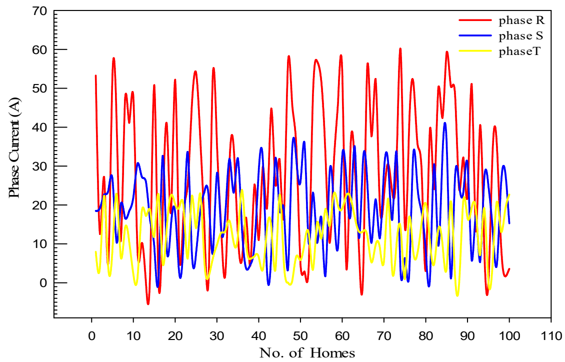

Fig. 15: Random test currents for three phase 100 homes

The current magnitude of the three phases of each home does not have equal value, and it is in a bad unbalancing state. The current of the feeders was as shown in Fig. 16 (the red curve). The algorithm takes around 12.654109 seconds to fix all that and return the feeders to the balancing condition (the blue curve). There were 50 iterations, and in each iteration, there were 100 agents, so there were just 5000 agents that give an excellent PUI value. The three-feeder current was around 2000A and this is true because the PUI value after swapping was 0.0012 with a swap factor equal to 66.3333.

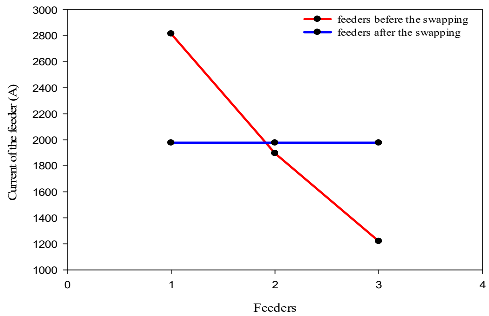

Fig. 16: The feeder currents before and after swapping process for 100 homes

The question here is from which iteration the algorithm reaches to the balancing value (PUI<6). The answer is in Fig. 17 that included the result of the objective function (OF) according to all the iterations that achieved in three separate current data. The figure showed that the feeders reach the balancing from the first iteration.

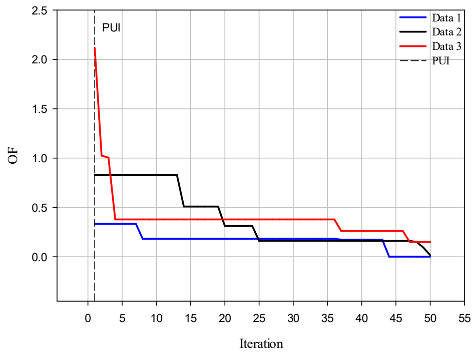

Fig. 17: The Objective function value with each iteration for three sets of current data

- **MOGWO Algorithm to Achieve the Load Balancing with Minimum Swaps**

Till now, the balancing achieved very well, but there is a factor the designer must take care about in spite we suppose the single-phase loads of the consumers is smart and with the inverter. The swap of the phases means switching the phases off and reconnect it to another feeder after a specific period. It has a terrible influence on the devices so the swap must be less as possible besides reaching to the main goal (balancing). The GWO algorithm modified to become multi-objective GWO by adding the weight to the GWO to take in the consideration the balancing and swapping as shown in equation (17):

$$\text{Objective Function} = W * \text{Balancing Value} + (1\text{-}W)\ \text{No. of Swaps} \quad (17)$$

The weight value is a problem must take care about and for test purpose the code tried on 50 homes with nine different weights to detect the suitable value. Figure 18 shown the effecting of weight changing on the balancing and swaps number

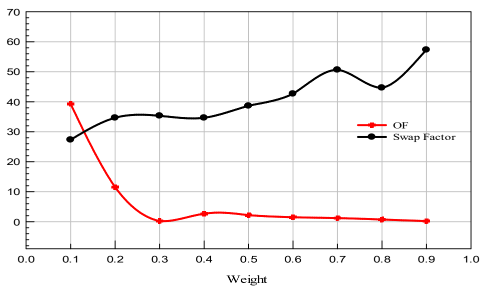

Fig. 18: The effect of weight on the OF and swap factor

With a careful looking to the Fig.18, the designer can know that the suitable weight can be chosen after a trade-off between the objective function value and the number of swaps to achieve it. The two curves tell us that the perfect value for this set of data is 0.3. For more detailed, the weight interval between [0.3 0.6] will plotted with increment 0.05 in each step for the same set of data as it showed in Fig.19.

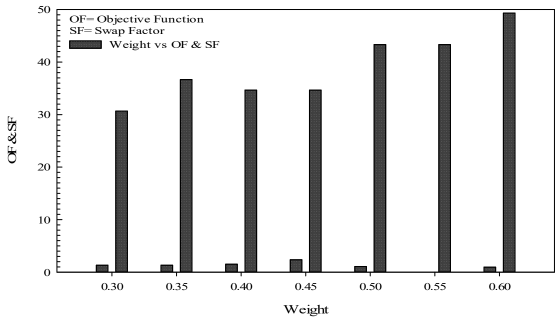

Fig. 19: The effect of weight on the OF and swap factor for the interval [0.3 0.6] from Fig.18

The (0.55) weight is the best that give the freedom to the algorithm to achieve a proper balancing (PUI% less than one) in less than 45 percent phase swapping so it will be constant from now so forth. The Fig. 20 showed the same curves of Fig. 18 in same weigh interval of Fig.19 for four sets of recorded homes currents. The 0.55 weight achieved 1 percent OF and the SF was in the range of 40% and that can be regarded as an accepted result.

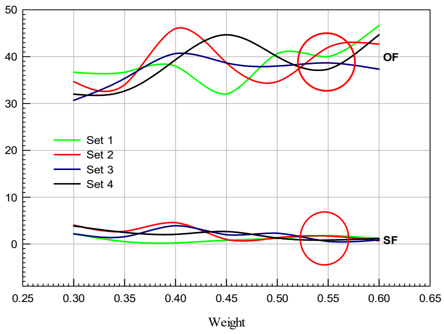

Fig. 20: The effect of weight on the OF and swap factor for the interval [0.3 0.6] from Fig.18

The important of using the MOGWO can be showed if we compare the performance against the ordinary GWO. The table 2 illustrated the result of using the MOGWO (0.55 weight) and the ordinary GWO on the same three sets of a random recorded data from 100 homes.

Table 2: The effect of weight on the balancing process

	GWO			MOGWO		
Current set	**PUI**	**Swap Factor**	**Time Consumed (s)**	**PUI**	**Swap Factor**	**Time Consumed (s)**
1	0.0911	66.3333	8.761794	1.9713	47	9.035040
2	0.0763	70	8.818328	1.4065	47.6667	9.263594
3	0.2204	69	9.034390	1.9054	48.6667	8.935511

From the table, the time consumed in the GWO less than the time required to reach the balancing in MOGWO. That is true because the second algorithm is more complicated than the first one. According to the PUI%, both of them reach an excellent feeder balancing (OF <2). The critical improvement is the noticeable decreasing in the swap factor in MOGWO that lower the probability of damaging the consumer sensitive devices. The MOGWO ability to reach the balancing case is not affected by the number of homes but the timed consumed to process the problem and find a suitable solution may increase to some extent. Fig. 21 explain the OF and SF values with the increase of homes to reach 150 homes stating from 10 homes and increasing ten homes in each step beside changing the iteration number of the algorithm for three times to test the influence of that on the objective function and the swapping factor.

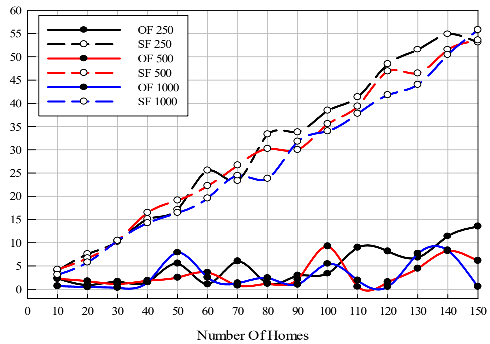

Fig. 21: The effect of changing the number iterations on the OF and SF

- **Balancing in Case of PVs Penetration**

The solar energy becomes a permissible choice nowadays. In destination areas, the consumers install the solar panels (PVs) in roofs of their homes to decrease the electricity bill as much as possible. The penetration of the PVs to the distribution network without any calculation can cause a stability problem. The PVs inject currents in the distribution network and the increased current in one feeder or all of it more than the thermal limits damage the feeder/s and put it out of the service. The fall down of one feeder make the system unstable and can harm the 3 phase motors as an example. The proposed model of the MOGWO algorithm rebuilt again to take in its consideration some homes have a PVs and solve the balancing problem according to that. The assumption here is all the PVs of the consumers connected online to the feeders. The current injected in the feeders can be computed and recorded by the smart meter, and the national utility can pay for that or reduces the cost of the electricity bill.

The PVs penetration will discuss on three separate scenarios small, middle and large penetration. The MOGWO algorithm can efficiently choose the suitable phase that the PV connected to in each home in the region under study without any effecting on the balancing of the secondary distribution network.

- **Small Penetration**

To test the algorithm in this case, we will suppose there are 100 homes with three phase each and just 20 of them already installed online PVs. The currents of PVs beside the phases current are generated randomly. Figure 22 shows the phase currents and the PVs for all the homes.

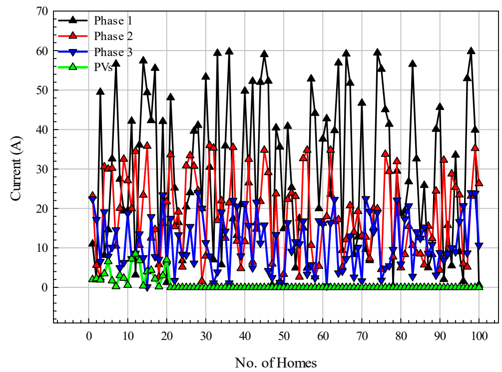

Fig. 22: The small PVs penetration

The current of the feeders before and after applying the modified MOGWO algorithm is illustrated in the Fig.23. The currents in the feeders after applying the MOGWO algorithm is near the average value. The feeder 1 may damage because it has a high current that may go behind the thermal capacity of the feeder in contrast with the non-efficient feeder 3. These problems solved and the current in all the feeders after the swapping process approximately near the average.

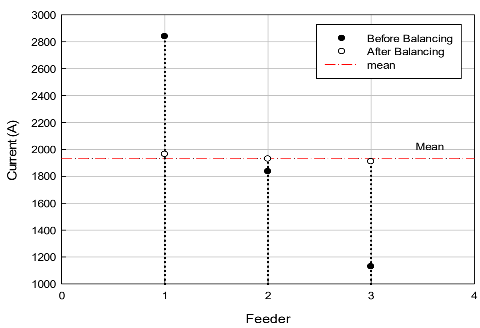

Fig. 23: The feeder currents before and after applying the MOGWO algorithm

- **Large Penetration**

In large penetration, let us suppose all the homes have PVs. All the current is randomly generated and dependent as a data to the algorithm to redistributed it among the feeders in a way that ensure at the end all the feeders in balancing situation as it shown in Fig.25.

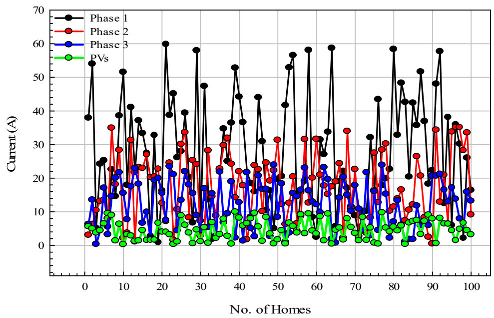

Fig. 25: The large PVs penetration

The table 4 shown a comparison between the middle and large penetration of PVs on the performance of the proposed algorithm to reach the balancing case for the same sets of data applied on both of them.

Table 4: The effect of adding 100 PVs on the performance of MOGWO

	MOGWO with 50 PVs				MOGWO with 100 PVs			
Current set	PUI	No. of swapped phases out of 400 phases	Swap Factor%	Time Consumed (s)	PUI	No. of swapped phases out of 400 phases	Swap Factor%	Time Consumed (s)
1	0.7242	152	38	69.758898	0.0506	142	35.5	17.678499
2	0.9247	151	37.75	26.615362	0.4010	149	37.25	17.749719
3	0.7306	140	35	42.836493	0.9774	155	38.75	9.295025

The result showed that the time consumed in the case of 100 PVs is less than the time algorithm demanded to achieve the balancing in the 50 PVs, and this is confused paradox. This speech appears not scientific and not rational because the search space now is much larger than search space when there are 50 PVs. The specialist in the AI algorithms tells that right if the algorithm was searching in all the search space, but it does not. The algorithm is jumping randomly in the search space and looking for the solution and when there are100 PVs that give more comfortability and freedom to an algorithm to find a suitable scheme that leads to the balancing situation in short time.

VIII. Conclusion

In this paper, the proposed algorithm solves the load balancing problem by nodal swapping technique. It achieved that efficiently in the minimum number of phase swapping to mitigate the effect of phase transfer on the sensitive loads. The GWO algorithm cares for the PVs available in the distribution network understudy in a manner that connected it to the feeders without any fear of balancing issue that may threaten the stability of the system. The GWO and the modification copy MOGWO reach to less than 1 percentPUI, which represents a perfect phase balancing situation in the distribution system. The result obtained assured the validity of the proposed algorithm in the field of the load balancing and power system engineering.

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