

Fair and Balance Demand Response application in Distribution Networks

Ibrahim H. Al-Kharsan ^{*1,2}, Ali.F. Marhoon¹, Jawad Radhi Mahmood¹

¹Electrical Engineering department, University of Basrah, Basrah, Iraq

²Computer Technical Engineering Department, College of Technical Engineering, The Islamic University, Najaf, Iraq

Correspondence

* Ibrahim H. Al-Kharsan
Electrical Engineering department,
University of Basrah, Basrah, Iraq
Email: smrtg809@gmail.com

Abstract

The unprogrammed penetration for the loads in the distribution networks make it work in an unbalancing situation that leads to unstable operation for those networks. the instability coming from the imbalance can cause many serious problems like the inefficient use of the feeders and the heat increased in the distribution transformers. The demands response can be regarded as a modern solution for the problem by offering a program to decreasing the consumption behavior for the program's participators in exchange for financial incentives in specific studied duration according to a direct order from the utility. The paper uses a new suggested algorithm to satisfy the direct load control demand response strategy that can be used in solving the unbalancing problem in distribution networks. The algorithm procedure has been simulated in MATLAB 2018 to real data collected from the smart meters that have been installed recently in Baghdad. The simulation results of applying the proposed algorithm on different cases of unbalancing showed that it is efficient in curing the unbalancing issue based on using the demand response strategy.

KEYWORDS: Algorithm, Demand Response, Direct load control, Distribution Networks, Unbalance Loads.

I. INTRODUCTION

The modern technologies entered the electrical power system make it more flexible and provide a method to achieve better control. In the same time, it created a series problem like that related to the reliability, the efficiency, the high losses in the energy, the pollution results from the gases emission to the atmosphere, the high cost of power generation and the high ratio of peak to average in the consumption. The high energy consumption was seen as an urgent matter because the solution calls for more money to be spent and professional experts available. The high demand issue results from the fixed tariff of electricity that makes the consumers not take the amount of consumption in their consideration, and that leads to a high peak to average ratio (PAR) [1]–[3]. In spite of the high demand not continuous for extended periods (may few hours in one day) but there is a high investment to overcome the problem if the problem solves by increasing the generation. The adding of new generation plants requests an overall reconsideration for the transmission and distribution infrastructures. The smart grid in this century has an essential role in changing the philosophy of electrical power engineering. In the past, the power generation should be equivalent to the consumed power, but with the advent of

the non-conventional grids, everything has been changed, and users can consume energy in the same quantity as already generated from the units by using of the DR strategy. DR can alter the consumption pattern of the consumers based on some motivations beside it represent an effective solution for all the issues mentioned above[4]. The DR can lead to a low consumption curve instead of the sharp one that leads to additional

costs coming increasing the generation plants to cover the peak periods in the load curve, and that represents a non-economic solution. DR idiom means “changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized” [3], [5], [6]. The DLC regarded one of the popular programs that applied to convert the consumption behaviors when the load on the generation stations becomes more and more, and that threatens the stability of the system if the problem stays without a solution [7]–[9]. In the DLC program, specific consumers or appliances have been recorded, and the utility can operate with full freedom to shut down or scheduling the operation of them in the events to need for that like in the hours of peak



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demand. The participating in this program received an incentive for allowance to the utility to control their loads [10].

II. THE PROPOSED ALGORITHM

The implementation of the Direct Load Control Program (DLC) in the Secondary Distribution Networks (SDN) is has a paramount importance as there are many loads consumed large amount of energy and it has a vital role to play in generating the circumstances that could place the network in a position that could threaten its stability. Fair Demand Response with Direct Load Control Mechanism (FDR-DLCM) is the proposed algorithm to achieve the DLC program in the SDN that spread in the residential areas. The paper discussed in this section applying for the DLC program on the AL-Qahera sector in Baghdad, and we suppose it has 48 homes. The utility success in contracting with all the owners of the homes to participate in this program. The utility is responsible for paying a financial incentive in exchange for the full control of the registered phases ($R_{Phs-DLC}$). It has the right to switch off or to schedule the $R_{Phs-DLC}$ as necessary for reducing the power consumption in the peak demand hours. The participators can dedicate some deferrable loads (the not essential loads that can work at any time in the day or night like the washing machine) to the program and let the critical loads out the authority of the utility. The novelty for the suggested mechanism is the fairness, which means justice in switching the $R_{Phs-DLC}$. The loads participated in the program ready to shut down at any time without any alert to the consumers, but it is a good matter if the algorithm satisfied the equality in switching off that loads.

The general framework for the DLC DR procedure that done starting from the utility to the last stage in the system (the consumers) clarified in twelve steps below:

1. The utility checks the generated and consumed energy, and if there is dispatching, nothing, in this case, should do, but if the consumed energy started to be more than the produced here, some loads should be shedding.
2. MCC (Main Control Computer) is sending a signal to the control units (CUs) that installed in the secondary transformers of the SDN to measure the consumption of the $R_{Phs-DLC}$ (see Fig. 1).
3. The CUs sending signals to the SMs to measure the consumption of the targeted nodes.
4. The aggregated amount of consumption that measured by all the CUs in the region sending back to the MCC in the utility.
5. Depending on the received data, the MCC divided the reduction requested to achieve the optimal power dispatching on the regions.
6. MCC Determine the reduction in consumption for each region and sending that to the CUs.
7. The CU receives the data and memorize it and readiness to achieve the DLC on the registered loads.

8. The algorithm avoids any load that used in the previous event and trying to use all those loads not participated in any event, or its participation is low.
9. The proposed algorithm performing an accumulative summing for all the choices loads and check if it equal to the amount that the MCC asked to shed.
10. If it is enough, stop the algorithm and leave.
11. If the algorithm needs switching OFF additional loads, it looking again for the fewer loads that participated in the previous event reach the demanded current consumption.

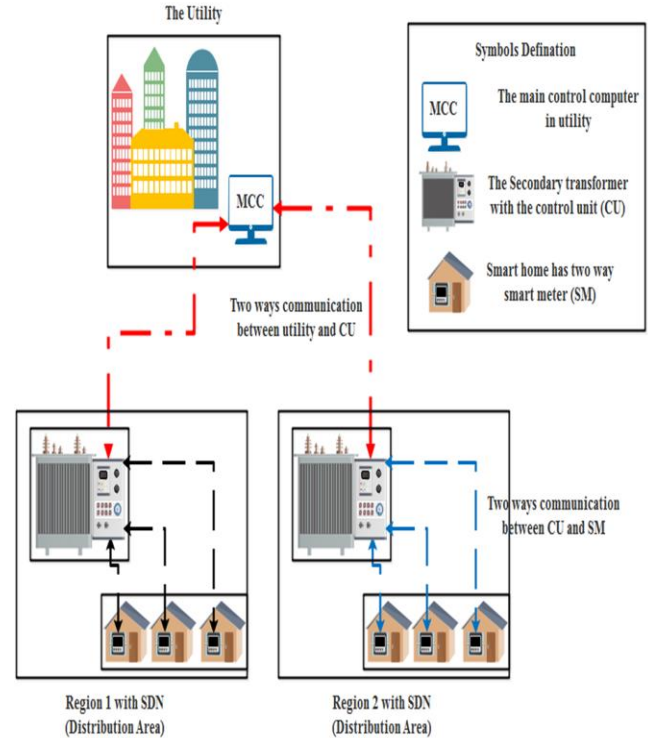


Fig. 1: The communicate mechanism between MCC, CUs and SMs to achieve the DLC program.

The previous steps that explain the procedure followed by the utility to satisfying the DLC program in the critical events illustrated in Fig.2. The proposed algorithm has been designed to give the participators in the DLC program the right to give the loads registered in the DLC program a particular priority, and this regarded the second novelty. In other words, we suppose the algorithm care about the following load indications:

- High priority (HP): the consumer announced not shut down this load if there any alternative solution.
- Moderate priority (MP): it means the consumer can abandon the load in spite he needs it.
- Low priority (LP): the consumer declares the load is permissible for shutting down in any event.

The proposed algorithm measured all the load consumption and the priority of each load and, depending on the data collected, and it was able to decide what the loads that should remain in operation and the loads should be stopped to

overcome the event under consideration. The proposed algorithm operation illustrated in the flowchart in Fig.2.

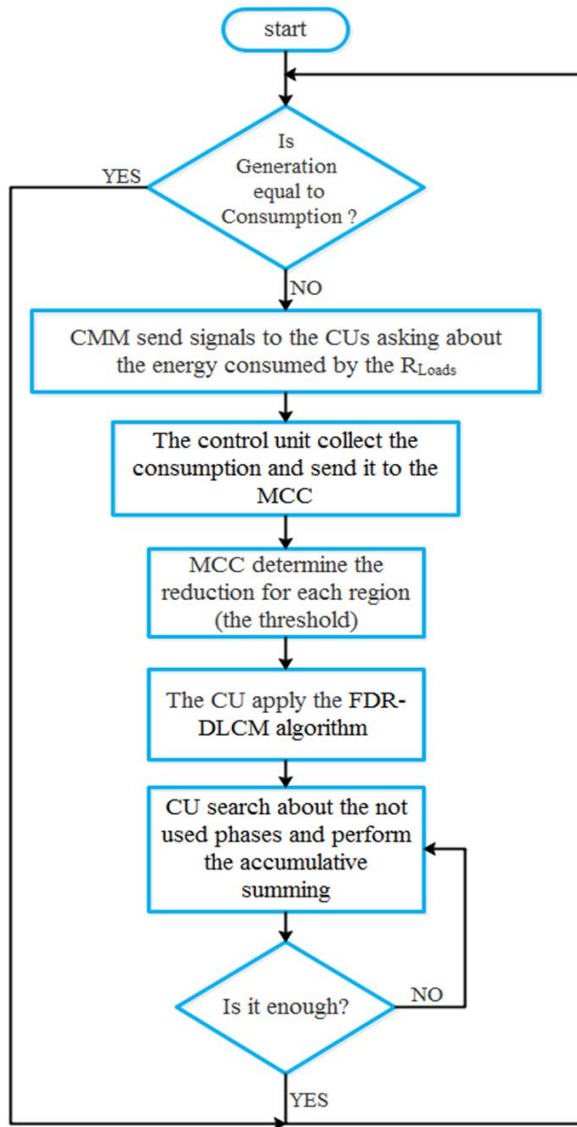


Fig. 2: The flowchart of the main steps for achieving the online DLC program.

According to the instruction signal from the MCC, the FDR-DLCM algorithm installed in the CUs pursue the following steps to achieve the DLC program on the $R_{Phs-DLC}$ to reduce the power consumption:

1. CU is sending a signal to the SMs in the region under its responsibility, ordering it to measure the consumption of all the $R_{Phs-DLC}$ and return measured data to it. The CU saves the coming information in the (PhaseCurrent) matrix.
2. The CU sending another signal to the SMs requesting the desired priorities by the participants. The priorities saved in the memory of the CU in the (Priority) matrix.
3. The CU Recall the saved (TimeStep) matrix in the CU memory. It showed the times every phase shut down according to the events that happened in the past.

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6. The CU has four cases to handle the DR program:

CASE1: If the (**total consumption** < **TransCurrent**) does not do anything and let all the phases on its previous state.

 - a. CASE1: If the (total consumption < TransCurrent) does not do anything and let all the phases on its previous state.
 - b. CASE2: if ((ColCurrent2 + ColCurrent3) < TransCurrent) the limited consumption in this situation enough to operate all the phases with MP and HP. The algorithm computes first the remaining amount of consumption (RestCurrent) and determine how many phases with LP enough to energize and switch OFF the others.
 - c. CASE3: if (RestCurrent = TransCurrent - (ColCurrent3)) The algorithm, in this case, switching OFF all the low priority loads and chooses some of the $R_{Phs-DLC}$ with a moderate priority. The high priority phases stay in ON state because of the limitation of the utility enough for that.
 - d. CASE4: if (RestCurrent = TransCurrent) The limitation, in this case not enough to cover all the $R_{Phs-DLC}$ with HP. The important event is hard, and the algorithm forced to switch OFF the request phases until if it has the most significant priority. Axiomatically, all the phases with low and moderate priority are switched OFF.
7. In all the four cases, when there is a new event that happened, the algorithm chooses a new phase to switch off and avoided the phases switched off in the previous event except in the cases that the algorithm compiles to that action in the massive emergency to achieve the fairness principle.

The flow chart that shown in Fig. 3 illustrate the trajectory that the proposed algorithm sticks to reach the desired reduction in the consumption by using the direct load control program. The following steps achieved in the CU that installed in the secondary transformer in each region.

CU represents the aggregator of data for all the consumers in a specific region because the utility does not directly deal with the final consumers because the CU collects all the demanded data requested by the MCC from the consumers. The CU represent an advance microcontroller that can programing to achieve the targeted tasks that it designs for.

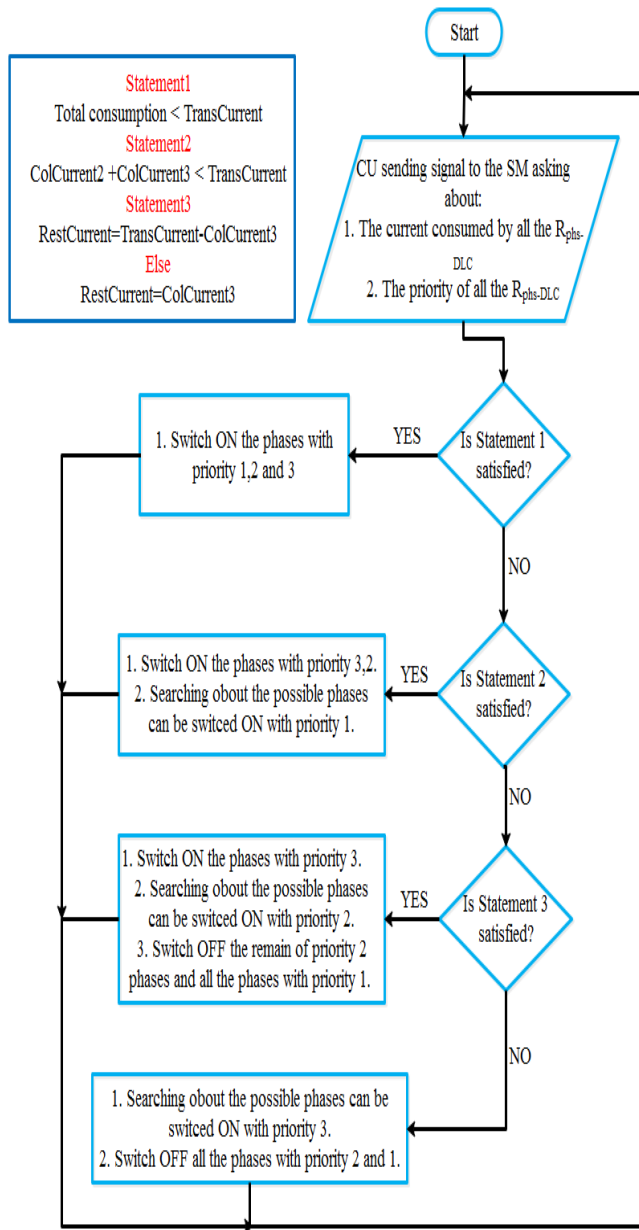


Fig. 3: The flowchart of the online algorithm that installed in the CU.

III. THE RESULTS

The simulation results obtained in this paper have been satisfied by using MATLAB2018b on a real and row data obtained from the 50 SMs that installed in the AL-Qahera sector in Baghdad by Al-Rasikh company. We regarded it has 48 residential homes, and the utility reach a contract with all of them. The utility registered the phases of the contracted homes as a supported load used in case there is an important event. The utility agreed to pay a specific amount of money as an incentive, in any event, to take place in the power system. The utility has full control over all the loads in the contract and can apply for the DLC program at any time without prior permission from the homeowners. The results divided into two parts; the first part discussed all the possible four cases that may cause the algorithm encounter in the real environment. The second part is for affirmation of the

fairness principle that the proposed algorithm should achieve in case many events happened in the system.

1. Demonstration the Algorithm Performance

In order to testing the algorithm performance, all the home phases in Al-Qahera regarded as a $R_{phs-DLC}$. The real measured current in the mentioned area showed in Fig. 4. The total current consumption is equal to 459.06A according for that

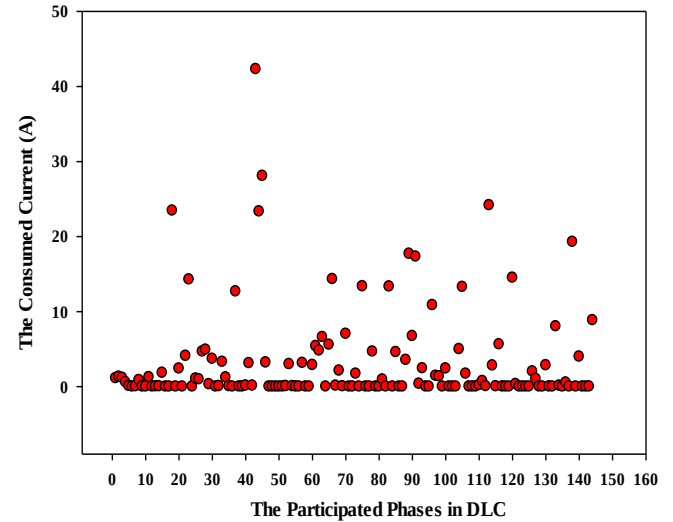


Fig. 4: The Al-Qahera current consumption that used in testing the performance of the proposed algorithm. The priority of the consumers generated virtually in a MATLAB environment randomly because the DR is not applied yet in Iraq, as shown in Fig. 5.

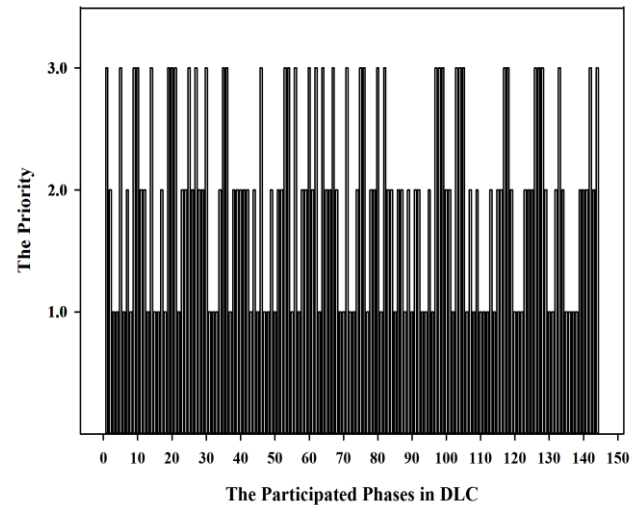


Fig. 5: The proposed priority for the Al-Qahera registered consumers in DLC program.

The consumers give a low priority for most of the phases. Some of the consumers prefer the moderate priority due to the moderate importance of these phases by their opinion. The fewer chooses the high priority for a specific reason like the connection of necessary tools or machines that achieve particular tasks during the period take the measurements taking into consideration they may lose the incentive paid by the utility if during this time there is an event that has been occurred as that depicted in Fig. 5 above.

The consumed data and the priority not have constant configuration and not take fix style, but it changed continuously between day and night or between different seasons in the year. The four cases of the instructions that may reach to the CU from the MCC has been studied depending on the data and priority has been shown in Fig. 4 and Fig. 5.

• **The Overall Consumption < The MCC Limitation**

The first case that may encounter the CU in a specific region is that when the MCC ordered it not to take any action because the reduction of the consumption in the other sectors was enough to pass the event safely. Table I shown detailed information about the consumption due to each priority and what the overall consumption of AL-Qahera under the recoded data and the new consumption limit that the area must consume less than it.

TABLE I
THE CASE1 PARAMETERS

ColCurrent1	ColCurrent2	ColCurrent3	Overall Consumed current	The permissible consumed current (The MCC limitation)
209.2 A	168.34 A	81.52 A	459.06A	500A

From the table, we notice that the MCC limitation (500A) can cover all the region consumption (459.06A), so the algorithm not switching OFF any phase with any priority and the consumption before and after applying the algorithm is same as shown in Fig. 6. The first bar explains the total consumption of all the houses that registered in the program, and the second one showed the consumption after applying the algorithm. Usage still the same due to the working in case1 that performs nothing and all the phases in ON state. Initially, suppose the following:

- ✓ The CUs have two ways of communication with all the SMs of the registered homes in the DLC program in the region.
- ✓ The SMs have the ability to perform the phase swapping technique depending on 9 CRs installed in the SMs.
- ✓ The phases are connected to the same SFs. For example, phase1 in all the homes has been connected to the first SF and phases 2 and 3 connected to the second and third SF, respectively.
- ✓ When the CU send (1) that activated the CR to be in ON state and connected the registered phase to the SF and vice versa.

In Case1, the CU switched ON all the phases by sending an operating signal - High signal or (1) - to trigger ON CRs in the SMs.

The balancing of the SFs is a critical issue and the question arising here about the effecting of the DLC program on the state of the SFs after applying for the DLC DR program.

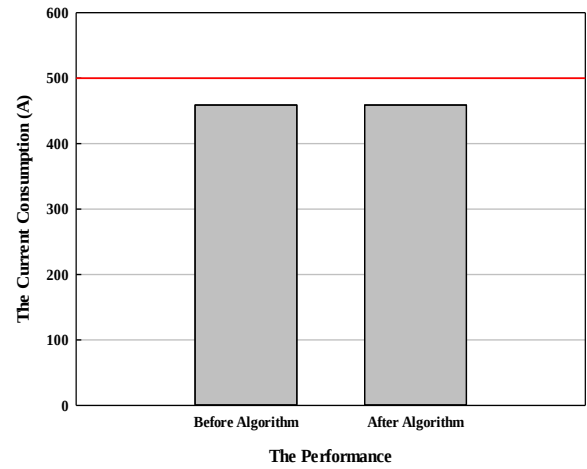


Fig. 6: The result of CASE1.

Fig. 7 shown the current consumed after the operation of the proposed algorithm.

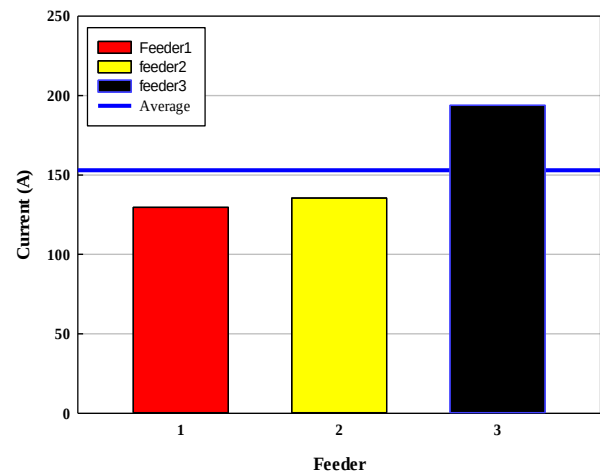


Fig. 7: The SFs after applying the DLC program.

There is clear unbalance that may lead to not desired results in the view of the secondary transformers if the temperature of the coil increased, and that leads to inefficient operation for the transformers.

• **CASE2: (ColCurrent2 + ColCurrent3) < TransCurrent**

In this case, there is an amount of reduction that must be happening to the phases with LP. The other two priorities not be impressed by the reduction, and the CU lowering the consumption based on the SMs of targeted phases. From Table I the phases with priority 2 and 3 consume 249.86A and if we suppose the message that reaches to the CU from the MCC was “Decrease the consumption to 270A”, that mean the algorithm switching ON a specific number of the LP phases that consume around 20.14A (**RestCurrent** that is over the current consumed by the MP and HP Rphs-DLC) as shown in Fig. 8.

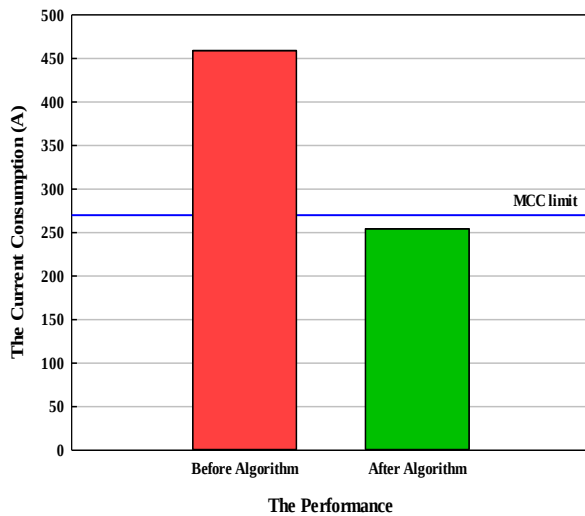


Fig. 8: The old and new consumption in CASE2.

MCC ordered the algorithm for decreasing the consumption to 270A, but when the algorithm checks the accumulative sum for $R_{phs-DLC}$, it found the last load can be switched ON make the consumption equal to 254.38A and in case adding any new load the consumption exceeded the limit of the utility. The CU sending signal to the SMs that reduced the consumption due energizing 70.9% of the overall phases in Al-Qahera, as shown in Fig. 9.

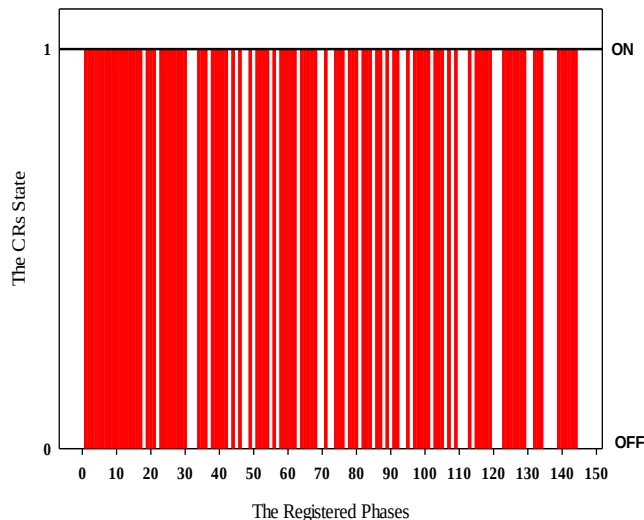


Fig. 9: The CRs state in CASE2.

The last portion wondering about the effect of the proposed algorithm on the balancing situation and to what extent it is good or bad. Fig. 10 illustrated the current after applying the DLC and comparing with the average value, and it showed the following:

- ✓ The current consumption after applying the algorithm is less in all the feeders comparing with the consumption before applied the DLC program (refer Fig. 8).
- ✓ The CUI reach to (59.4819%) and that indicate to serious unbalance.

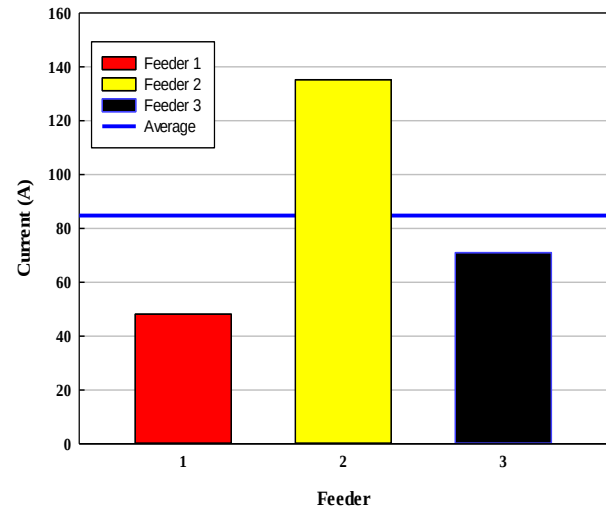


Fig. 10: The SFs when CASE2 applied by algorithm.

• CASE3: $RestCurrent = TransCurrent - ColCurrent3$

The third case happened when there is urgent hard event, and the MCC ordered the CU to reduce the region consumption to an amount enough just to the loads with HP and some loads with MP as an example if $TransCurrent = 150A$. The algorithm searching smartly about the suitable phases with MP that can be operated in the remaining current that allowed to be consumed above the consumption of the phases with HP. The remaining current for the MP phases equal to 68.48A. The total phases energized in this case, to achieve the threshold of consumption are 64 phases that represent 44% of the total phases of the Al-Qahera sector as that clear in Fig. 11.

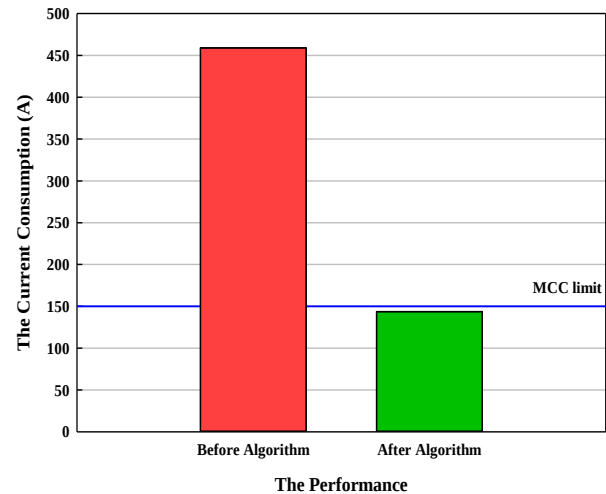


Fig. 11: The reduction in consumption due CASE3.

The operation signal generated by the CU and sent to the SMs illustrated in Fig. 12, where the HIGH signal energized the load and vice versa. The consumption after applying the algorithm reach 143.61A, as illustrated in Fig. 11, with the current consumed before the urgent cases in the power system. The SFs situation is illustrated in Fig. 13 that highlighted the amount of current consumed by each one among the SFs and appear the following facts:

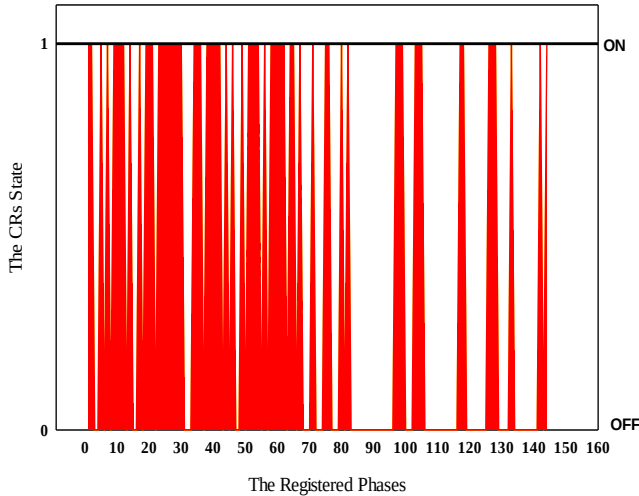


Fig. 12: The CRs situation due to the CASE3.

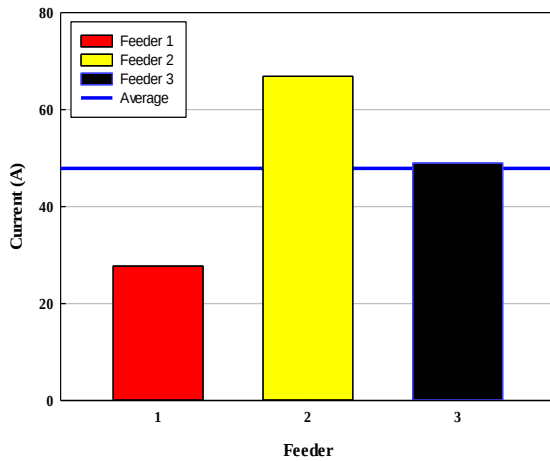


Fig. 13: The SFs after applying the CASE3.

- ✓ The consumption under the determined threshold has been satisfied.
- ✓ The reduction creates a bad unbalance in the SDN where in this case, the CUI reaches 42.0305% compare with 26 before applying the algorithm and this problem should be solved.

• CASE4: RestCurrent=TransCurrent

This case regarded the hardest case because there is a significant event that makes the MCC shut down all the LP and MP phases and allows for specific HP loads to still energized. To test the algorithm, the MCC supposed to send a message with the following content to the CU “Reducing the consumption to 50A “. The algorithm should search for the HP phases that can consume 50A only. The algorithm reaches to operate the suitable phase that consumed 48.33A and shut down all the others. Fig. 14 illuminated the SFs situation before and after applying the proposed algorithm. There are 31 HP phases still energized that represent 21.5% form the total phases in Al-Qahera, as showing in Fig. 15. The CUI% recorded after applying the algorithm was 56.9212%, and that means the SFs in an unbalancing situation. The imbalance happens in this case worse than the unbalance before applying the proposed algorithm 26%, and

this case also needs to solve the unbalancing to avoid the harmful effects in the future. The SFs after applying the algorithm has been illustrated in Fig. 16.

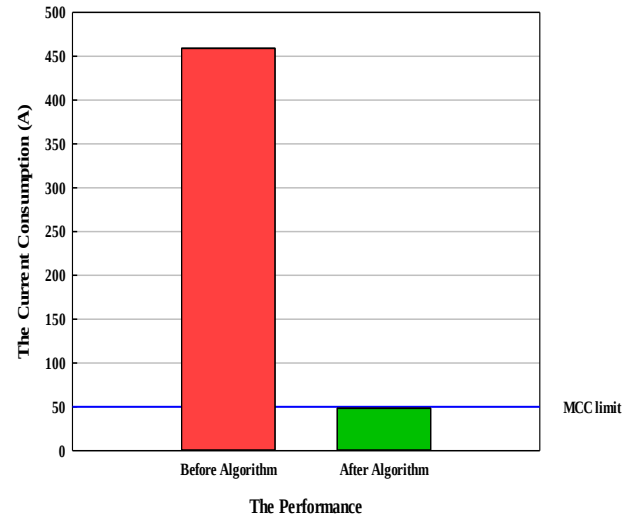


Fig. 14: The Consumption before and after specific event.

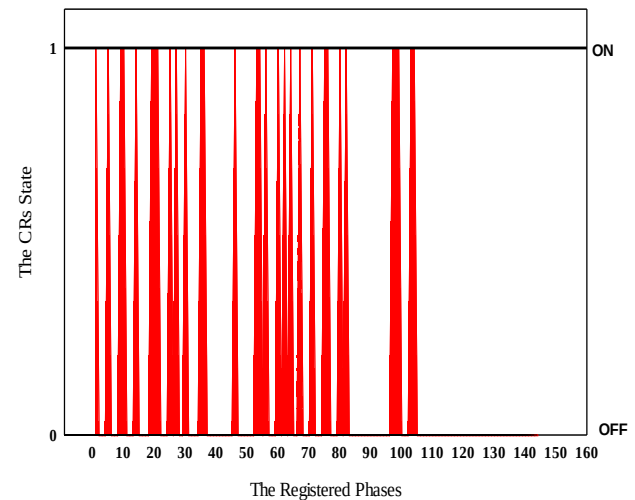


Fig. 15: The signals that reach the CRs in CASE4.

2. Proving the Fairness Principle

The fairness used by the suggested FDR-DLCM algorithm that can contribute effectively in changing the behavior of the last consumer means the justice and balancing in choosing the phases that shut down when there is an event required that. To full clearance, the MATLAB simulation environment used to prove the fairness principle by supposing the utility contract with 3ph 6 homes in the Al-Qahere sector in Baghdad and the DLC DR program has been applied on during 100 events. The total consumption of specific homes is 65.92A. The algorithm should choose different phases in each event and not stick to specific ones because that represents a comfort factor to the consumers who participated in the program. The fairness for the CASE2, CASE3, and CASE4 proved and neglected the CASE1 because the algorithm does not act any action in CASE1.

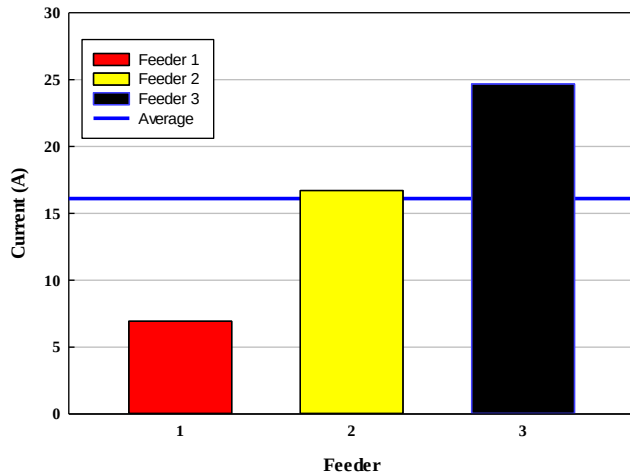
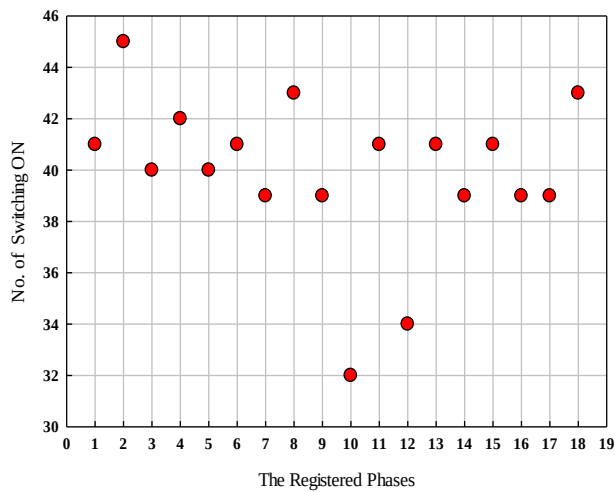


Fig. 16: the SFs after applying the CASE4.

• CASE2: The threshold =40A

The Fig. 17 illustrates the situation of the Rphs-DLC if there are 100 tests performed during four hours to maintain the consumption under 40A. In each test, the algorithm supposes the consumers changed the load priorities due to some reasons and that called the variable priority test (VPT)

Fig. 17: The Shutdown times for the R_{phs-DLC} if there are repeated events

The registered loads in the DLC program used in an unbiased manner, and there is no load, not shut down, and some loads still ON during all the events. Within all the 100 events, the algorithm satisfied the threshold demanded by the MCC. The threshold was not let the six homes consuming more than 40A by measuring the consumption of the phases and choosing the suitable candidates among it to energized and switching off all the others. The Fig. 18 showed the consumed current amount during the four hours with 100-times testing. The algorithm efficiently gives a satisfying result along the experimental time. In the previous part, we supposed the consumers are changing the priority of the phases with all tests. In this part, the algorithm has been tested under the assumption “the phases priority is fixed in

all events in the test period” and that called by the fixed priority test (FPT)

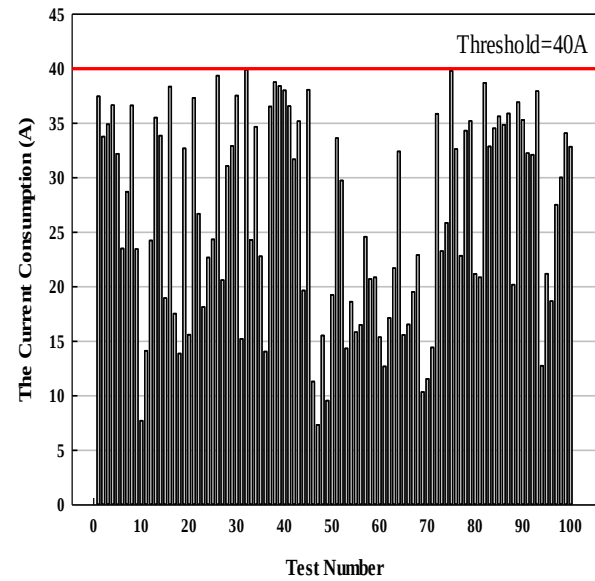


Fig. 18: The current consumption during the experiment period.

The Fig. 19 illustrated the FPT result if the algorithm encountered the CASE2, and it means the threshold cover the HP and MP phases and some of the LP phases. The outcome showed that the LP phases switched off throughout the test and the remain phases used fairly manner during the test. Depending on the data in Table II the algorithm performance under the FPT scenario has been tested. It used to prove the algorithm validity for the two next cases (CASE3 and CASE4).

During the FPT, the algorithm reaches to the demanded consumption in addition to the fair using of the phases, as denicied in Fig. 20

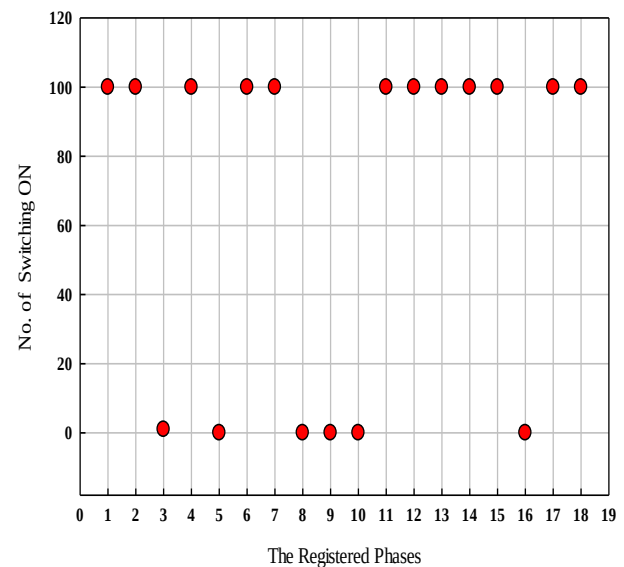


Fig. 19: The Registered loads under the similar priority test.

TABLE II
THE FPT PARAMETERS

Parameter	Value
Phases current (A)	[1.12,1.32,1.17,3.55,17.71,6.73,0.04,0.04,1.84,1.06,0.96,4.66,4.91,0.31,3.7,5.4,4.8,6.6]
Priority	[2,3,1,3,1,3,3,1,1,1,3,3,2,3,3,1,2,2]
The total Consumption	65.92A
The consumption by LP phases	27.22A
The consumption by MP phases	17.43A
The consumption by HP phases	21.27A
The Threshold of CASE2	40A
The Threshold of CASE3	25A
The Threshold of CASE4	17A

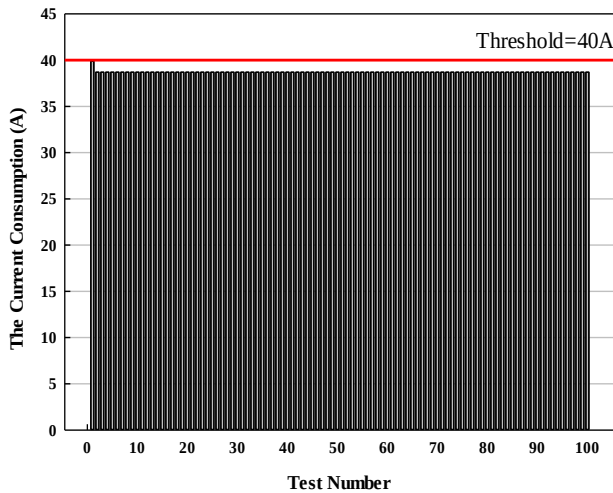


Fig. 20: The consumption not exceed the threshold in CASE2 FPT.

- **CASE3: The Threshold= 25A**
 - **VPT**

Fig. 21 and Fig. 22 illustrate the success in applying the fairness principle and the reduction in current consumption. In Fig. 22, we notice there is a high reduction in some of tests like the test number 13,47 and 65 and that coming because one the fairness principle forced the algorithm to energize the HP or MP phases that not used before (to satisfy the fairness principle), and in chance, all the candidate phases were consuming low current, so the final consumption will be low but under the utility threshold.

- **FPT**

Fig. 23 and Fig. 24 illustrate the success in applying the fairness principle and the reduction in current consumption in the FPT. Eight phases that have HP as recorded in Table 4.2, and it consume an amount of current reach to the threshold, and for that, there is no enough current to operate any other loads with MP or LP as it is shown in Fig. 23

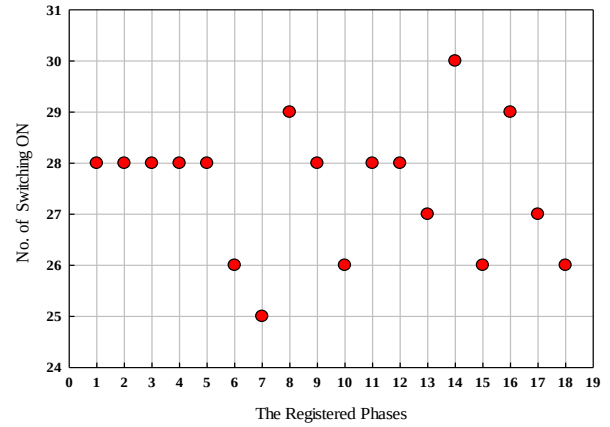


Fig. 21: The fairness principle in CASE3 VPT.

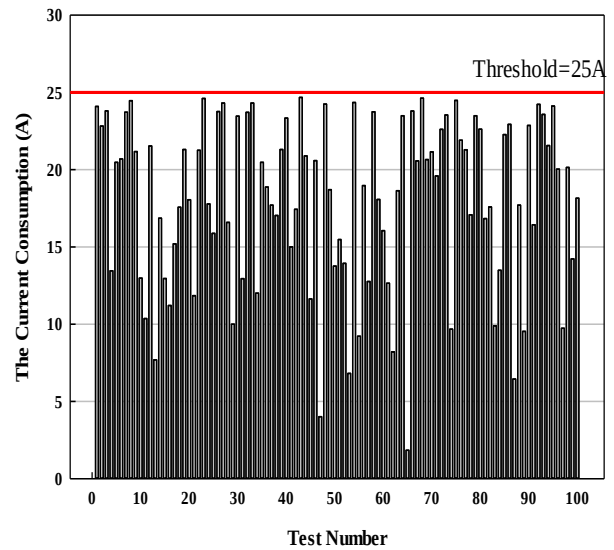


Fig. 22: The current consumption reduction below the threshold level.

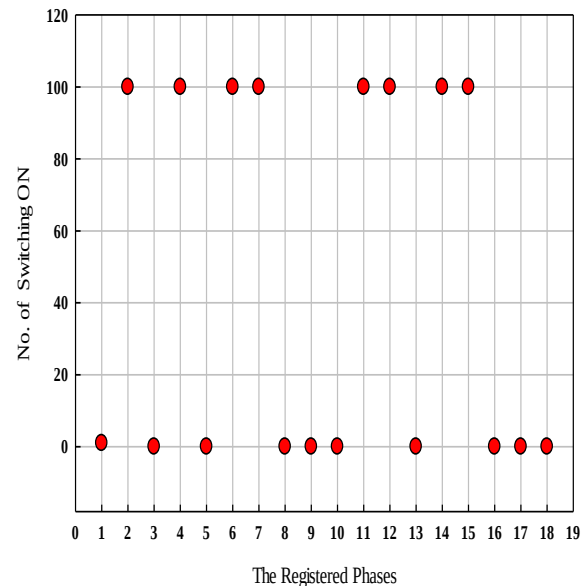


Fig. 23: The fairness principle in CASE3 FPT.

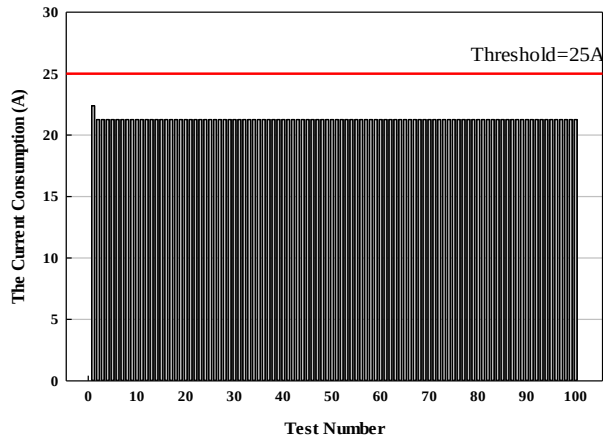


Fig. 24: The consumption reduction below the threshold level in FPT.

• **CASE4: The Threshold= 15A**

The current, in this case not enough to energize all the phases with HP, so the algorithm chooses wisely the candidate loads that satisfied the threshold demanded by the utility and caring to the fairness in the phase electing.

○ VPT

The fairness principle and amount of consumption are satisfied in Fig. 25 and Fig. 26.

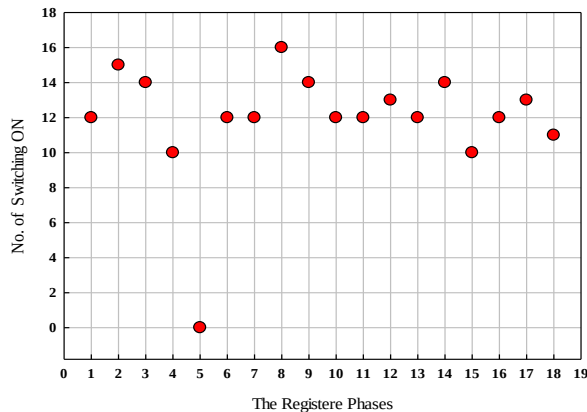


Fig. 25: The fairness principle in CASE4 VPT.

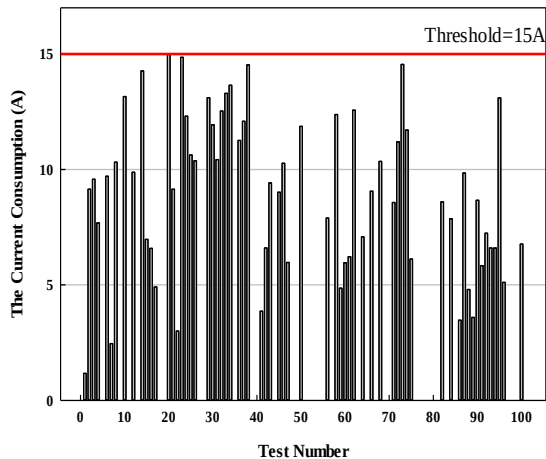


Fig. 26: The consumption reduction below the threshold level in VPT.

○ FPT

The fairness validation and the consumption that is under the MCC threshold level are depicted in Fig. 27 and Fig. 28.

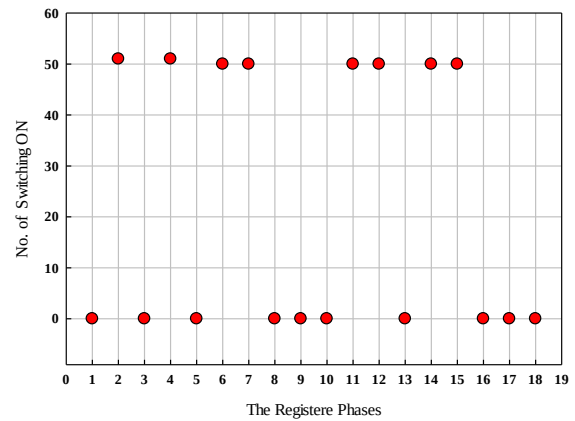


Fig. 27: The fairness principle in CASE4 FPT.

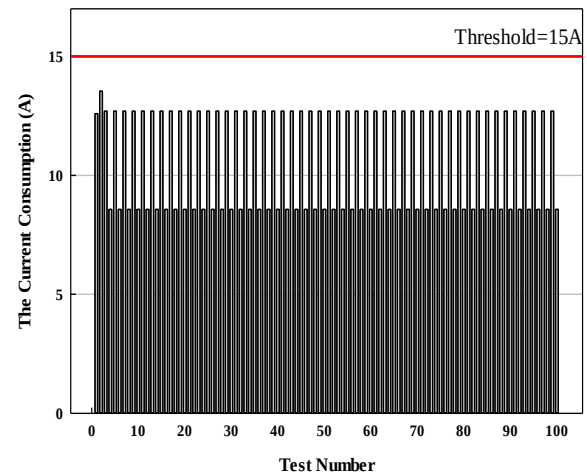


Fig. 28: The consumption reduction of CASE4 FPT.

3. The Treatment of the Load Balancing Problem

The proposed algorithm achieves the main target that it designs for with additional important feature that called the fairness. The reduction in consumption and altering the final behavior of the consumers in the distribution area is demanded to achieve the optimal power dispatching with reasonable costs. The algorithm treats the essential events that result from there is a sudden peak demand that may be a critical factor from the stability point of view. The shedding loads treatment created from another viewpoint a severe problem in the SDN. The current reduced in all the SFs but not in a regular rate that leads to sharp unbalancing cases, as it showed so far. The proposed algorithm adapted to balance the SFs by using the phase swapping technique to change the position of the choose phases by the DR algorithm. The MOGWO algorithm is merged with the FDR-DLCM to create a new hybrid algorithm that can perform the balanced DLC DR program. The SMs installed in all the 48 homes in the Al-Qahera sector supposed to have a swapping mechanism that represents attached 9CRs with the SMs. The flowchart that explains the hybrid algorithm is illustrated in

Fig. 29. The four cases have been studied in section 4.4.1, severing from sharp unbalancing that results from a reduction of the consumption or switching OFF some phases on specific feeders and let the others ON. The balancing of the SDN leads to an efficient investment of the available equipment and lowering the probability of discomforting the consumer's relief by sudden events like damaging the secondary transformers.

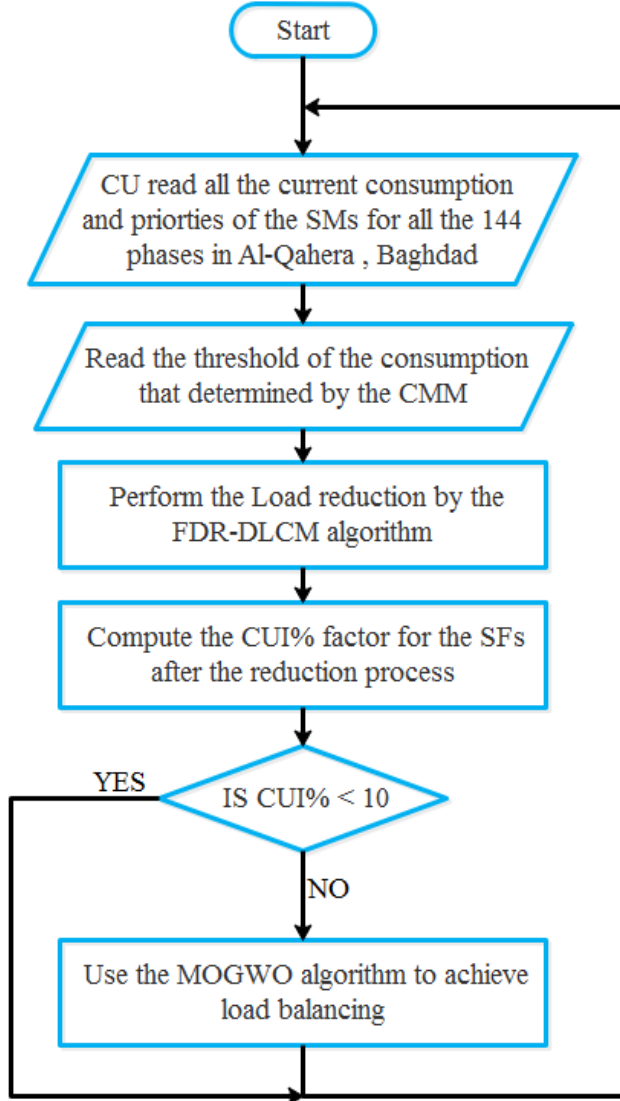


Fig. 29: The online hybrid algorithm to perform balanced reduction in current consumption during the peak demand events.

• **Case1:**

In case 1, the result of applying the FDR-DLCM on the RPhs-DLC in Al-Qahera showed it not alter anything, and the consumption stays itself (refer to Fig. 6) because of the threshold, in this case, can cover all consumption of the LP, MP and HP phases. The CUI% for the SFs reach 26%, and that means there are unbalancing that need for a solution (refer to Fig. 7). Outcomes of applying the hybrid algorithm showed in Table III that illustrated the consumption before and after DR and the CUI% that indicate to the unbalancing ratio in the SFs.

TABLE III
THE HYBRID ALGORITHM CASE1 RESULTS

The consumption before DR	The consumption after DR	CUI% for the SFs
459.06A	459.06A	0.5163

The CUI% achieved by the hybrid algorithm is less than one percent, and it is in the accepted level of unbalancing. The consumption of SFs is illustrated in Fig. 30.

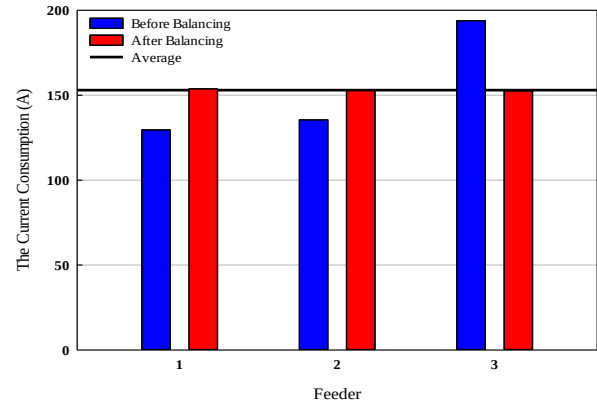


Fig. 30: The SFs after and before using the hybrid algorithm (CASE1).

• **Case2:**

In this case, the proposed FDR-DLCM algorithm has succeeded in altering the consumption pattern and make it under the threshold of the utility, as illustrated in Fig. 8. The problem that appears after reducing the phases consumed energy form the SFs is the hard unbalancing where the CUI% equal to 59.481 (refer to Fig. 10). The balancing situation is worse compared to the CUI% before applying for the DR program. The hybrid algorithm solved the problem and satisfied the threshold in consumption, as illustrated in Table IV and in additional for that in Fig. 31.

TABLE IV
HYBRID ALGORITHM OUTCOMES OF CASE2

The consumption before DR	The consumption after DR	CUI% for the SFs
459.06A	254.38A	0.3459

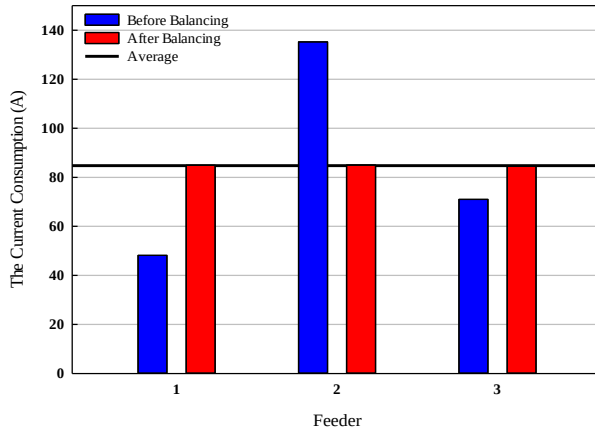


Fig. 31: The SFs after and before using the hybrid algorithm (CASE2).

• **Case3:**

As in the CASE2, the FDR-DLCM algorithm achieved the demanded reduction (refer to Fig. 11) but with a not proper balancing where the CUI% equal to 42.0305 and that still out the range of the accepted ratio (less than 10%) and the state of the SFs was better before applying the reduction (refer to Fig. 13). The applying of the hybrid algorithm gives a satisfactory result depicted and tabulated in Fig. 32 and Table V respectively.

TABLE V
THE HYBRID ALGORITHM CASE3 RESULTS

The consumption before DR	The consumption after DR	CUI% for the SFs
459.06A	143.61A	0.1253

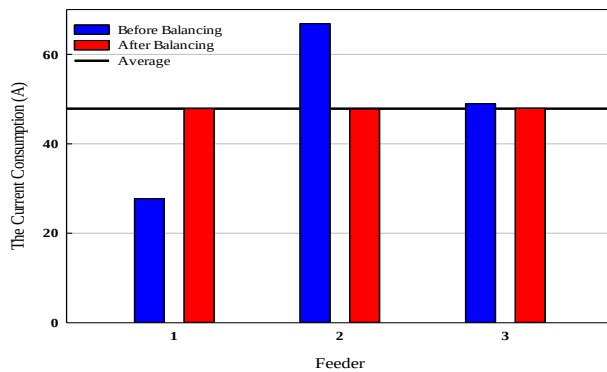


Fig. 32: The SFs after and before using the hybrid algorithm (CASE3).

• **Case4:**

As in the two cases before, the consumption is reduced according to the threshold determined by the MCC of the utility, as that appears in Fig. 14. The CUI% for this case was 56.92%, and it is rejected because of it much higher than the accepted ration for balancing in the SDN that results in severe unbalancing in the SFs, as that clear in Fig. 16. The hybrid algorithm exceeded the balancing problem and reduced the consumption to the desired level of the utility, as it clear in Fig. 33 and tabulated in Table VI.

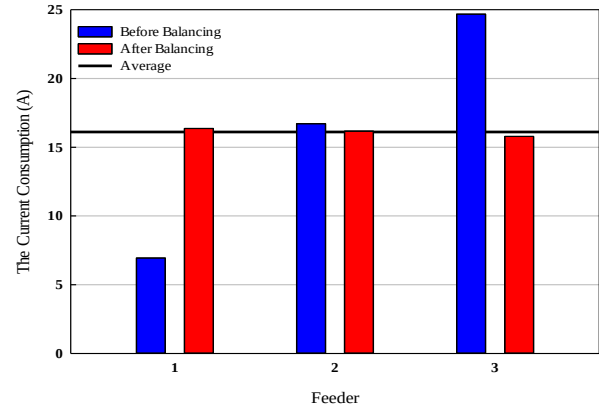


Fig. 33: The SFs after and before using the hybrid algorithm (CASE4).

TABLE VI
HYBRID ALGORITHM RESULT OF CASE4

The consumption before DR	The consumption after DR	CUI% for the SFs
459.06A	48.33A	1.9863

IV. CONCLUSIONS

This chapter discusses the mechanism for achieving the demand response in the Al-Qahera sector in Baghdad. There are many programs under the DR, but the choice program in this thesis was the direct load control program that gives the utility the full authority on the phases that registered under the program as an exchange to the monetary incentives that paid to the participators in the program. The result achieved can be summarized in the following points:

1. In the beginning, the proposed algorithm (FDR-DLCM) has been succeed in altering the consumption behavior for the consumers in the peak load periods and reduced the consumption to the determined level by the utility. The algorithm applied on four different scenarios allowed to test the performance under all the expected events from the viewpo int of the hardness of the event that it may encounter when it applied.
2. The FDR-DLCM has been succeed in all the different four cases, but it causes serious balancing problems that caused as an effect of the unsymmetrical choosing of the phases that must be switching OFF. The random phases electing make some SFs heavily loaded and the others with low load. The CUI% indicated in all the four cases to the possibility of damaging the secondary transformers by increasing the temperature in its coils or it leads to the inefficient investment of the equipment of the SDN like the feeders.
3. The balancing problem leads to changing the FDR-DLCM algorithm to a new algorithm that is a hybrid algorithm that it represents a smart mixture between the FDR-DLCM and the MOGWO algorithm.

4. The hybrid algorithm attains an efficient outcome due to its ability to reach the requested level of reduction as the FDR-DLCM algorithm and, at the same time, have the ability to balance like the MOGWO algorithm [11], [12]. The hybrid algorithm tested again on the four operation cases, and it proves itself in the consumption reduction and the load balancing.

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