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Research paper



Mitigation of the greenhouse effect by solar cells penetration based on the genetic algorithm

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Abstract

Over the previous decade, global warming from greenhouse gas growth has become a significant science and political Over the previous decade, global warming from greenhouse gas growth has become a significant science and political problem. That infrared radiation is captured in a global atmosphere by greenhouse gasses, and that makes the CO2 levels have risen by about 25 percent since 1850 due to the combustion of fossil fuel in the ambient. Besides that, the concentrations of other trace greenhouse gasses such as methane and chlorofluorocarbons have risen even more. Global warming harms humanity and the planet together. Outcomes from the latest climate change researches showed there is increasing in the temperature during the next century by about 2° to 6°C. Sea levels are typically projected to rise from 0.5 to 1.5 meters for the next century, but there is little likelihood of significant or even harmful change. One of the great solutions to moderate global warming is by reduction the current consumed by the consumers from the generation power stations. The decline comes as a result of using nonconventional energy sources like the solar energy that installed in homes to participate in feeding the home's loads besides the current consumed from the secondary distribution transformers. The GA used in this paper to ensure all the PVs used in an efficient way that not causes any stability problem in the secondary distribution network.

Keywords: *CO2 Emission; Distribution Networks; Genetic Algorithm; Global Warming; Greenhouse Gases; Photovoltaic Cells; Solar Energy.*

1. Introduction

Electricity was the most versatile type of energy that can be readily regulated. It is loss-free and mainly non-polluting at the point of use. It can be generated clean by using carbon-free methods such as wind, water, and sunlight. Electricity is invisible, simpler to carry and distribute, and it is the most effective way of energy usage [1]. The problem here is the source of this clean energy, and it in most cases coming from transferring the chemical energy stored in the fossil fuel to electrical energy. For millennia, fossil fuels (FF) have been used to give energy, but their use has many drawbacks: FF seriously pollute the environment besides that the FF drilling can be regarded as a hazardous process [2]. FF needs to be burned, resulting in smoke and gas being pumped into the atmosphere to convey the chemical energy storied to electrical energy. Sad to say, burning FF releases damaging particles and greenhouse gasses into the atmosphere, leading to adverse effects on humans and the entire earth, for instance, firing coal reliefs into the atmosphere of toxic particles such as sulfur dioxide and heavy metals. These compounds offer many side effects that damage humans, such as acid rain and harm in breathing. The burning of FF can be regarded as a reason for illnesses such as cancer and asthma [3]. The problem of climate change comes as a result to the particles produced from burning fossil fuels that have adverse effects on our planet as a whole, and that effect probably comes from the particles placed into the atmosphere when coal burned. Substances such as carbon dioxide and methane enter the atmosphere and capture sun's heat, which since the early 1900s has led to a steady increase in global average temperatures. Climate changes can lead to anything from the destruction of natural environments to rising sea level [4]. In the use of solar energy, the solution to pollution and global warming problems appears, it is explicit that coal cannot be our only future energy source. Renewable technologies such as solar give many more benefits, ranging from reliability to reduced expenses to a smaller effect on the environment that keeps humanity moving towards more sustainable sources of energy. As a clean and competitive alternative to conventional power sources, renewable energy has experienced a significant increase in its deployment rate [5]. The integration of photovoltaic (PV) in the distribution networks (refer to Fig.1) lead in turn to many issues that reach to threaten the stability of the whole power system. This paper is devoted to addressing the issue of unfair association of PVs in distribution networks that have adverse impacts such as the unequal current flowing in distribution feeders that may urge the protective devices to made inaccurate tripping and lead to interruption of service and discomfort of the consumer. The genetic algorithm (GA) can use all accessible PVs smartly to reduce the CO_2 emission from the generation power plants [6], especially the thermal (coal or raw oil) power plant. The renewable energy sources in each area used optimally to reduce the current drawing from the distribution transformer and as a result for all the distribution areas reduction the overall current consumed from the generation station will be less, the coal burn will reduce, the CO_2 emission will decrease and that lead eventually for reducing the global warming to some extent.

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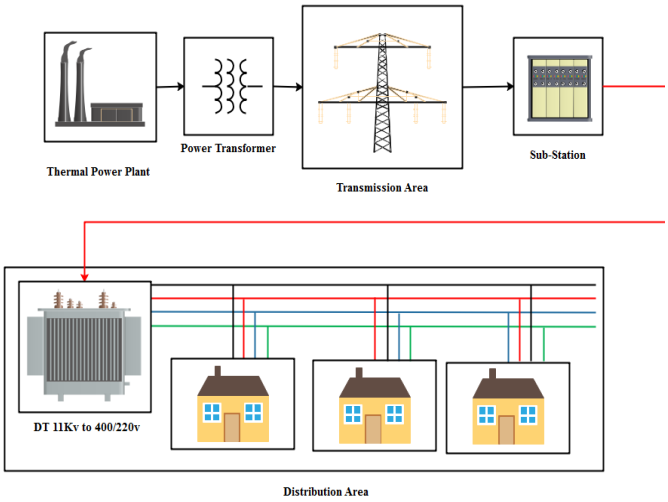


Fig. 1: The Distribution Region with Non-Conventional Energy Sources.

2. The problem description

The goal of this paper is the reduction of the current consumed by all the suburban homes in the distribution area under consideration that service by the distribution transformers (DT). The reduction would take place if some of the entire currents demanded by a distinct home divided into two parts, the first part fed from the solar energy available in-home and remaining demand consumed from the national grid. The windings of the DT usually a three-phase with Delta-star connection. The randomity in the current reduction can damage the DT because the case of unequally current drawn from each phase can increase the temperature of the windings [7] and that increasing the losses [8] and may damage the DT in the bad situations. The DT supplied by an additional smart controller that can process and compute the optimal connection of the PVs to the suitable phase in each home that ensures using all the available solar cells in a way not form an adverse effect on the DT that called by the processing unit (PU). The whole configuration to achieve the main goal is shown in Fig.2.

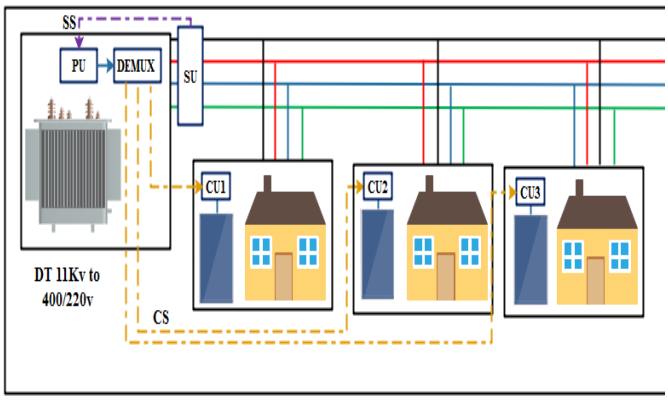


Fig. 2: The Mechanism for CO_2 Reduction Applied in Particular Smart Distribution Area.

The PU measure the current delivered by the DT to all the loads connected to the transformer through the sensing signal (SS) generated by the sensing unit (SU). In the same time, the PU control the PV connection in each home by the control unit (CU) that installed with the solar panel, and it can connect the PV to any with any phase in the home. The CU receiving control signal (CS) from the PU and according to that signal, the solar panel connected. The PU generate the control signal and send to the Demultiplexer (DEMUX) to transmit it to all the CUs units through the power line carrier (PLC) or by the short message service (SMS). The following assumptions take into consideration:

1) All the solar energy sources in the region is online PVs. The inverter in this type take a signal from the phase it will connect to and produce a synchronized signal similar to the signal coming from the national grid (same voltage and same power factor).
2) The power factor for all phases in all the dwellings considered has the same magnitude for simplicity.
3) Each PV can connect to one phase only at the end of PVs arrangement suggested by the GA.
4) The online PVs have current rate not exceed the 10A.

3. GA algorithm

Genetic algorithms are part of a broader algorithm family recognized as evolutionary algorithms. They apply ideas from the philosophy of biological evolution to search and optimize issues, such as natural selection, reproduction, genetic diversity and propagation, species competition/cooperation, and mutation. A genetic algorithm begins from the original population (original PVs from some random solution) that are represented by a binary number string. Crossover, mutation, and selection are applied to the population in each iteration to converge the best solution. GA can be used efficiently for solving the constrained and unconstrained optimization problems in the engineering field. It is each time enhance the solutions (population) by choosing in random way individuals to be the parents from the current iteration, and depending on them, the individuals of the next generation has been generated. After many iterations, the population tends toward the optimal solution.

3.1. Coding

In GA, a population has tested in the objective function as a set of solutions (chromosomes) for the optimal PVs distribution problem [9]. The variables are encoded in the population by using them as binary numbers [10]. For the issue of fairly PVs distribution on the residential home phases, 2 bits are regarded because 3 phases have to be represented. "00," "01," and "10," respectively, reflect phases 1, 2 and 3. After mutation or crossover, if produced, "11" will be altered to "00," "01" and "10" because this is prohibited option and the not define as a possible phase that the PV can be connected to and for that the "11" must be alternated to "00", "01" or "10". The population, in the beginning, imitated in randomly way and its size depending on the problem nature but in many times, it contains hundreds or thousands possible solution of the problem under consideration.

3.2. Objective function

The objective function represents the measurement for the fitting of each individual in the search space. The optimal individual (solution) is that one that satisfied the minimum objective function among all the others [11]. In this paper, the optimal PV distribution scheme is the scheme that can reduce the current consumption from the DT, and as a result, the generation power plants will produce fewer megawatts, and in the last, that can be reduced the pollution coming from the combustion of the fossil fuel. The proposed objective function any way ensure that the temperature of the windings will not increase after the using of the solar energy sources and is called by the winding temperate relief factor (WTRF). The WTRF can represent mathematically in equation (5),

$$O_1 = I_{PH1} - I_x \quad (1)$$

$$O_2 = I_{PH2} - I_x \quad (2)$$

$$O_3 = I_{PH3} - I_x \quad (3)$$

$$I_x = \frac{I_{PH1} + I_{PH2} + I_{PH3}}{3} \quad (4)$$

$$WTRF = \frac{\max(O_1, O_2, O_3)}{I_x} \quad (5)$$

Where I_{ph1}, I_{ph2}, and I_{ph3} represent the current drawn from each phase by all the loads connected to the DT, as shown in Fig.3. I_x represents the average value of the three-phase current. The 3% regarded an accepted ratio that the DT can work without any increase in the transformer's windings.

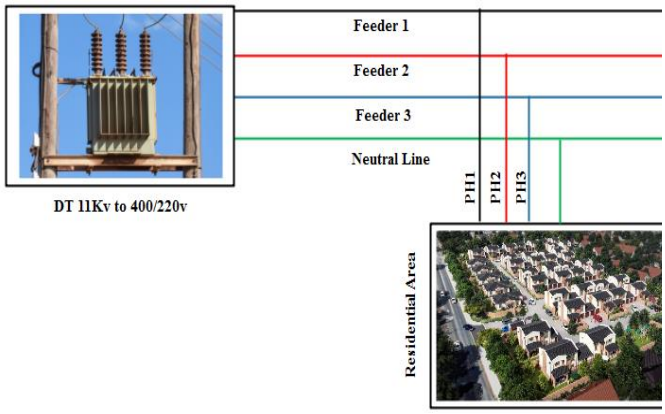


Fig. 3: Three-Phase Four-Wire Distribution Transformer Connected for Residential Area.

3.3. Crossover

In this step, the parents that choose in the current iteration combined to generate the new individuals called by the children that used in the next generation as individuals [12]. There are many types of the crossover mechanism like the single-point crossover, two-point and k-point crossover, uniform crossover [13]. In this paper, a 0.8 single- point crossover had been used.

3.4. Mutation

The critical problem in this optimization algorithms is their ability to fall in the local optima. It represents the optimal solution in the view of the algorithm but in the truth is one sub-optimal solution that the algorithm finds it and stay in it. This problem can be solved by the mutation that means applying not determined changed on the parents to ensure it continues to searching until finding the global optimum solution.

3.5. Selection

During the iterations, some of the individuals elected to generate the individuals for the next generation. The individuals choose carefully depending on their fitness function that represents the quality of the solution.

4. Result and discussion

The results and all the current consumed by all the residential homes are generated randomly by the MATLAB simulation environment to verify the GA performance. The algorithm attention to the following assumptions:

The area under study has 100 three- phase homes that can send and receive the information with the PU allocated in the DT.

1) The current consumed in any phase in the residential area (refer to Fig.3) not exceed 30A.
2) In the first scenario, there are 75 photovoltaic cells installed in 100 homes, and each one generates no more than 10A. The second scenario proposed that all the homes have PV with 8A.
3) The laptop specification is Intel® Mobile Core™ 2 Duo CPU T6400 @ 2.00GHz and the time consumed was according to these specifications.

The results for this paper can be divided into two parts according to the number of houses and number of PVs scenarios:

1) 100 homes, 75 PVs, 10A

The current consumed by each phase in the residential area had been generated randomly, as shown in Fig.4. It has shown that the homes connected to phase one drawn more current compared with the loads connected to phase two and three. The loads connected to phase two, in turn, seem large in magnitude compared to the loads in phase three and less from the loads connected to phase one.

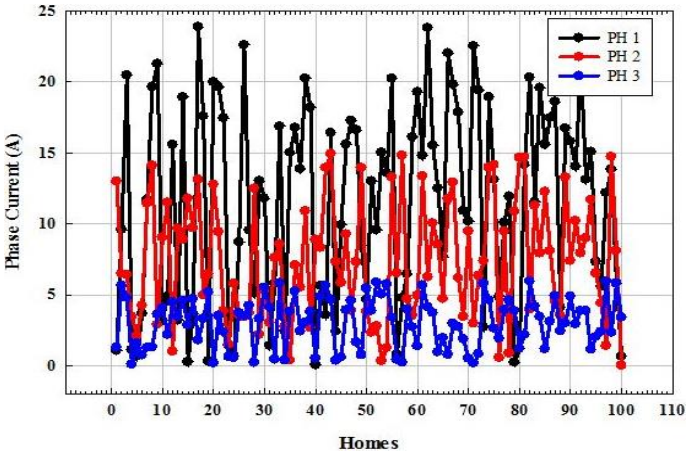


Fig. 4: The Three-Phase Consumed Current for 100 Homes in the Residential Area.

In this scenario, half of the homes in this area proposed to have non-conventional energy source already installed and ready to injecting current online to the homes. The Fig.5 shown the current generated by the 50 PVs and the other homes regarded as home have PV but with zero amperes. Note that the current in the proposed PVs not more than 10A.

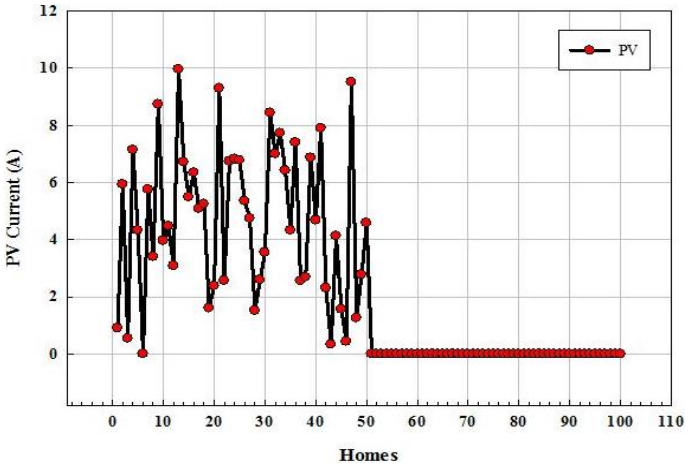


Fig. 5: The Current Generated by the 50 PVs Connected in 100 Residential Homes.

The SU and CU measure the current flowing to the transformer load that represents 100 residential homes and the current generated in all the homes with PVs and both of it sending the measurement to the PU available in the DT, as shown in Fig.2 and Fig.6.

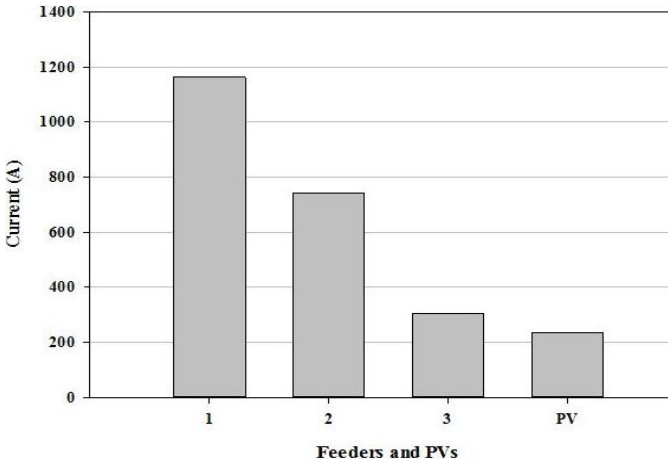


Fig. 6: Shown the Current Consumed by the Feeders and the Current Generated in All the PVs in the Residential Area.

One snapshot showing the DT loaded with 1163.54A on feeder1, 740.53A on feeder2 and 303.31 supplied by feeder3.The current generated in the PVs reach to around 234.05 A. The total current the DT must be fed to the destination is around 2210.4 A. The GA role is to distribute all the PVs in fair form on all the home phases in a way that not reduce the life span of the transformers due to the rising in the winding's temperature due to the more than 3% in WTRF. The Fig.7 shown the feeders situations after applying the GA.

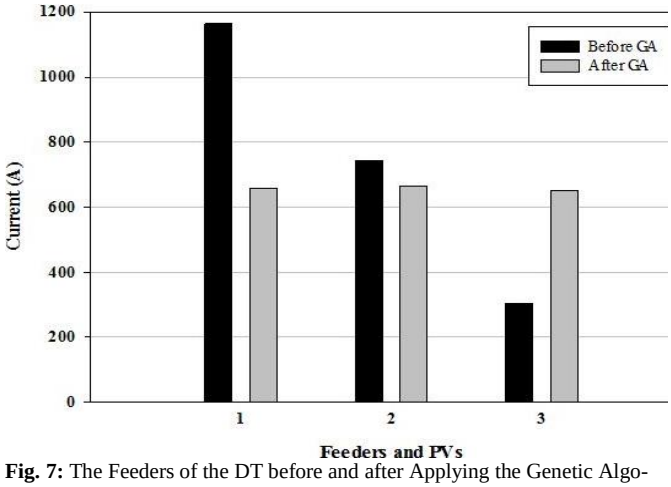


Fig. 7: The Feeders of the DT before and after Applying the Genetic Algorithm.

The current consumed from the national grid was 2210.4 A before using the solar energy and the after applying the GA the current consumed from the national gird decreased to 1976.3A. The region under study consumed current less by 10.5 % compared with the situation of not using any PV with a WTRF ratio of no more than 1%. If this technique used in all the distribution networks there will be a significant reduction in the power generated in the power stations and that lead to a noticeable reduction in the CO_2 emission and that represent a successful solution to some extent to the stubbing global warming problem.

2) 100 Homes, 100PVs, 8A

The Fig.8 represents the current consumed by each phase in all the 100 homes, and the current generated all the PVs in the same residential area but under the current assumption.

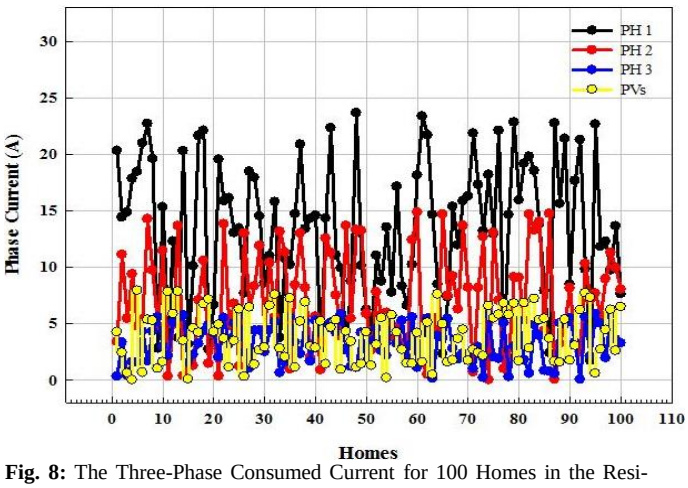


Fig. 8: The Three-Phase Consumed Current for 100 Homes in the Residential Area with 100 PV Installed in Each Home.

The current consumed form the DT and the generated in the residential area shown in Fig.9.

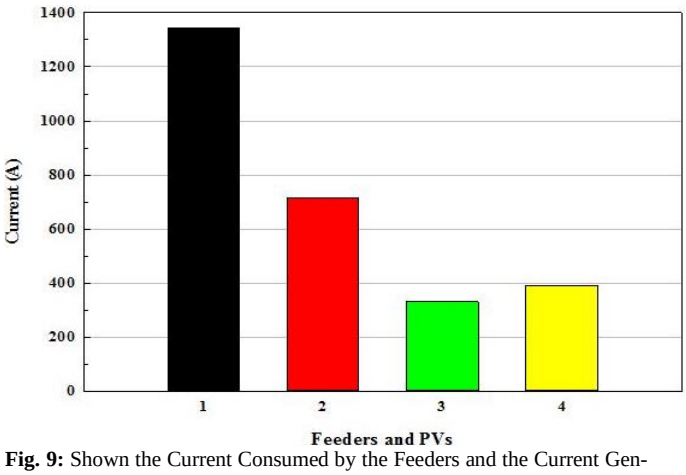


Fig. 9: Shown the Current Consumed by the Feeders and the Current Generated in All the PVs in the Residential Area.

The current consumed in this case from the feeder1 equal to 1342.73A, in feeder 2 equal to 716.60A and in feeder 3 consumed 330.64A. The current generated by the PVs equal to 389.79A. The GA added the PVs to the network, and the current consumed from the DT will be as shown in Fig.10.

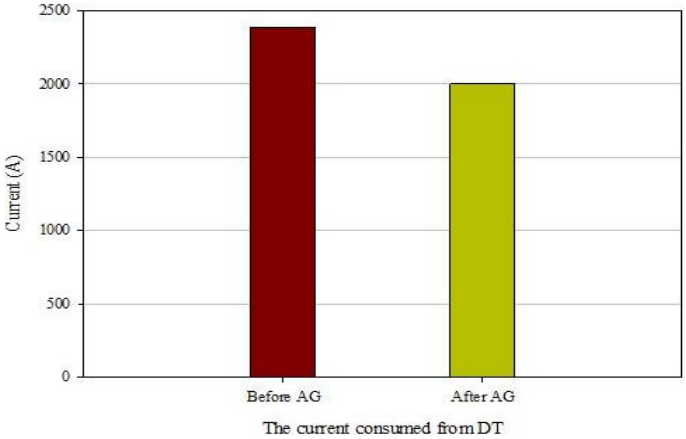


Fig. 10: The Total Feeders Current Delivered by the DT before and after Applying the GA to the Residential Region.

There are decreasing by 16.3% in the loading on the DT and the difference, and at the same time, the WTRF was not exceeding 1.2%. The current Flowing in the DT feeders before and after applying the GA appear in Fig.11.

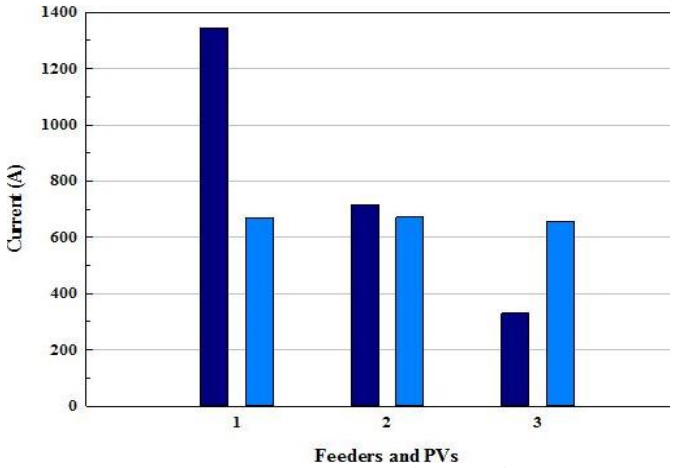


Fig. 11: The Current Delivered by the DT before and after Applying the GA.

5. Conclusion

The world is nowadays suffering from dangerous problems led to a catastrophe consequence on the humankind and the planet. One of the insisting and urgent issue that the earth and the creatures started to suffering from their damaging effects is the global warming problem. This paper can contribute to the mitigation of the problem by reducing the CO_2 producing from the combustion of fossil fuel in the generation power stations. The solution satisfied by replacing the conventional energy sources by the non-traditional sources like the photovoltaics used in this paper. The results showed a decrease in the current supplied to the residential area with 100 households maintaining the distribution transformers in a stable situation without any increase in the winding temperature resulting in shortening the life span of these transformers.

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