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Implementing a Load Shedding Using the Golden Eagle Optimization through the Internet of Things-Based Smart Power Sockets

تنفيذ تخفيف الأحمال باستخدام تحسين النسر الذهبي من خلال مقابس الطاقة الذكية المعتمدة على إنترنت الأشياء

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Abstract: In the event of a power system tripping or overloading, a load-shedding scheme is activated to shed a portion of the load buses and restore the frequency to a stable level. However, this method makes many houses blackout for a long time. This paper presents an approach for implementing a load-shedding scheme at the household level to distribute the total load curtailments among all consumers. The integration between the IoT-based smart sockets and Golden Eagle Optimization (GEO) shows an efficient load-shedding method for preventing a full blackout at the consumer level. The results show an efficient control of load appliance at end user by control room in utility grid to implement a load shedding scheme with optimum total load curtailment.

Keywords: Load shedding, Smart power socket, Internet of Things (IoT), Golden Eagle Optimization

المستخلص: في حالة حدوث تعطل في نظام الطاقة أو زيادة في التحميل، يتم تفعيل مخطط لتخفيف الأحمال للتخلص من جزء من حافلات التحميل واستعادة التردد إلى مستوى مستقر. ومع ذلك، فإن هذه الطريقة تتسبب في انقطاع الكهرباء عن العديد من المنازل لفترة طويلة. يقدم هذا البحث نهجًا لتنفيذ مخطط لتخفيف الأحمال على مستوى المنازل لتوزيع إجمالي تقليص الأحمال بين جميع المستهلكين. يظهر التكامل بين المقابس الذكية المعتمدة على إنترنت الأشياء وتحسين النسر الذهبي (GEO) طريقة فعالة لتخفيف الأحمال لمنع انقطاع الكهرباء الكامل على مستوى المستهلك. وتظهر النتائج سيطرة فعالة على أحمال الأجهزة في نهاية المستخدم بواسطة غرفة التحكم في شبكة المرافق لتنفيذ مخطط تخفيف الأحمال مع تقليص إجمالي أمثل للأحمال.

الكلمات المفتاحية: تخفيف الأحمال، مقبس الطاقة الذكي، إنترنت الأشياء (IoT)، تحسين النسر الذهبي.

1 INTRODUCTION

One of the primary challenges faced by the energy sector in Palestine is the insufficient supply of electricity. Palestine has a complex energy sector that differs from other Middle East countries because it is considered a developing country under occupation. The supply of electrical energy to Palestinian areas is limited and consumption is closely monitored. If the amount of energy consumed exceeds this limit,

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the power supply to the entire area is disconnected. In order to comply with the limited power set by the Israeli occupation, municipalities in Palestinian territories have implemented the load-shedding technique on specific buses of the distribution network. Consequently, numerous Palestinian households encounter prolonged power outages as a measure to prevent a total electricity blackout throughout the entire area.

The load-shedding technique is considered the final solution to prevent a blackout in the electrical network. This technique carries out a curtailment of loads to rebalance the available produced power and total connected loads in a distribution network (Jallad et al., 2018). There are two primary categories of load-shedding schemes: conventional and adaptive. Power utilities typically use the conventional load-shedding scheme as their primary load-shedding approach. This method involves curtailing a predetermined quantity of loads at specified frequency thresholds without taking into account factors such as voltage dip, frequency decline, or disturbance location (Skrjanc et al., 2023). However, this approach is not capable of accurately shedding the exact amount of power deficit. As a result, implementing the conventional load-shedding scheme may result in removing excess or insufficient load quantities, leading to an overshot or undershot in system frequency, respectively. The adaptive load shedding method, which was suggested for islanding distribution networks, shed less load compared to the conventional approach. Nonetheless, this technique revealed a drawback where an unoptimized amount of load shedding led to a frequency overshoot. Currently, researchers are exploring the use of artificial intelligence techniques in load-shedding methods such as ANN (Sundarajoo & Soomro, 2023) and fuzzy Logic (Saboune et al., 2021). However, Fuzzy logic and artificial neural networks (ANNs) exhibit drawbacks including high computational training costs, susceptibility to data noise, and challenges in generalizing to new data. The load shedding method introduced by (Laghari et al., 2014) incorporates a certain degree of adaptability in load prioritization, enabling the shedding of loads while minimizing potential errors. The proposed load shedding technique possesses the ability to effectively restore the system frequency to its intended level within an isolated distribution network without experiencing excessive deviations. Nevertheless, this approach is characterized by a drawback in the form of prolonged computational time due to the necessity of analyzing all conceivable load permutations. To address this issue, the authors opted to focus solely on a set of six randomly chosen priority loads.

The researcher aims to implement a load-shedding strategy that effectively avoids blackouts at both the household and distribution network levels. Due to the absence of effective communication between utility providers and consumers, the traditional power grid exhibits inefficient performance in managing both demand and supply issues. For this problem, the researcher needs to find interactive communication and control between the power supplier and the end-user loads by exploiting smart grid and smart home technologies. In the smart grid, the smart meter is deemed essential as it is capable of measuring a range of electrical parameters such as voltage levels, current, power, power factor, and energy consumption. This data is transmitted to the energy supplier for billing purposes and to the consumer to manage the energy consumption. On the other hand, there has been a growing interest in smart home technologies for the purpose of conserving energy in households worldwide. A smart home is a house equipped with various electronic devices (sensors) and appliances connected to the internet, enabling them to be controlled remotely via a smartphone or other internet-connected device. With a smart home, homeowners can control and automate many aspects of their home, including temperature, lighting, security, and entertainment.

The evolution of IoT/Machine applications in heterogeneous wireless networks has driven the advancement of smart home applications, extending from individual rooms to entire buildings and smart cities. Previous research in this domain is reviewed. (Basnayake et al., 2015) introduced an Artificial Intelligence-Based Smart Building Automation Controller, offering adaptive energy efficiency, user comfort, and security through intelligent user identification, decision-making, and observation subsystems. (Xia & Song, 2018) present an adaptable ZigBee-based smart building system for offices, with Java and Android integration. However, ZigBee's limitations in range and speed are acknowledged. (Badabaji & Nagaraju, 2018) provide monitor home appliances via IoT, alerting users of gas leaks and fires through text messages and sirens, but faces limitations in Wi-Fi data rate and GSM expenses. (Marhoon et al., 2018) proposes a home prototype system with Wi-Fi, Bluetooth, and RFID for control and monitoring, though the implemented applications are basic. (Jabbar et al., 2019) and (Liao et al., 2019) introduce IoT-based smart home systems utilizing Node-MCU and Arduino Yun, respectively. While (Jabbar et al., 2019) focuses on portable monitoring and control, (Liao et al., 2019) emphasizes multifunctionality and Android connectivity. (Floris et al., 2021) implement a Raspberry Pi-based system to manage indoor environments, including light neural networks for occupancy estimation. (Omran et al., 2022) offer an affordable Wi-Fi-based smart home system for remote monitoring, employing Raspberry Pi and Arduino Mega. However, delays and inaccuracies in the Blynk app are noted. (Maltezos et al., 2022) introduce a fire and gas leakage alert system named SB112, incorporating ESP32 and Raspberry Pi, but other essential systems like energy consumption are overlooked. These studies contribute to the development of smart building technologies, but challenges like communication reliability and system integration remain.

This paper focuses on implementing a load-shedding method based on the Golden Eagle Optimization (GEO) to identify the loads that should be shed to achieve optimal load curtailment with a minimum number of iterations in the adaptive load shedding scheme. Thus, the proposed method prevents the blackouts on all consumers which the power deficit is distributed among all consumers. In addition, this paper develops a smart power socket to control in connection of home appliances. Finally, the control room in the utility sends a mount of loads that should be shed for each consumer using smart power socket via IoT platform.

2 Methodology of the PROPOSED METHOD

The proposed method for islanded Electrical distribution network consists of four steps: (1) The centre of inertia frequency calculation, (2) detecting and calculating imbalance power in the distribution network, (3) distributing the amount of power deficit between the whole consumers, and (4) shedding the loads for each consumer based on the smart sockets via IoT technology and Golden Eagle Optimization.

2.1 The Centre of Inertia Frequency Calculation

The calculation of the center of inertia frequency (f_{COI}) depends on the operating mode of the distribution network, which functions in two distinct modes. In grid-connected mode, the Centre of Inertia Frequency Calculation module utilizes the grid frequency whereas in islanded mode, the FCU calculates the value of f_{COI} using equation (1).

$$f_{COI} = \sum_{i=1}^{N} H_i f_i \Big/ \sum_{i=1}^{N} H_i \qquad (1)$$

where N is the number of connected generators; H_i is the inertia constant of each generator in seconds; f_i is the frequency of each generator in Hertz. In this study, system frequency is limited to values between 47.5 Hz and 52.5 Hz. It is important to note that protection devices are triggered immediately to disconnect all Distributed Generators (DGs) if the system frequency drops below 47.5 Hz or rises above 52.5 Hz, leading to a blackout. Figure (1) shows the flow chart of the centre of inertia frequency calculation.

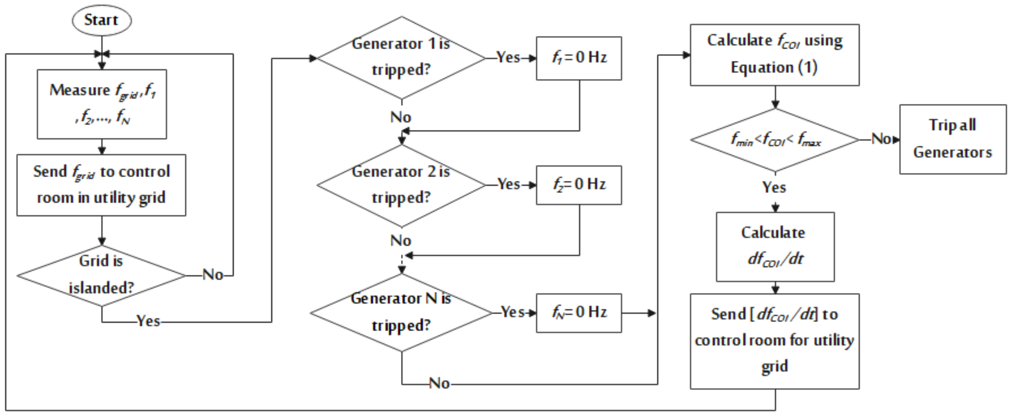

Figure (1). Flowchart of centre of inertia frequency calculation.

2.2 Detecting and Calculating Imbalance Power in The Distribution Network

The load-shedding controller detects any imbalance between the generated and demanded active power in the system during the islanding mode. Load shedding is initiated when the f_{COI} drops below 49.8 Hz and the rate of change of frequency (ROCOF) is negative. This process utilizes Phasor Measurement Units (PMUs) for real-time monitoring of the status of DG breakers within the network, as well as the output power from distributed generators, whether generated by renewable energy sources or diesel generators. When the load shedding controller detects an imbalance between the generated and demanded active power in the system during islanding mode, it calculates the power deficit using two approaches. The first is the event-based approach, which is initiated when one or more generators, such as renewable energy sources (RES), are disconnected from the distribution network or when there is a reduction in the output power from RESs, such as wind turbines and photovoltaic systems. The second is the response-based approach, which is activated when there is a sudden increase in load within the islanded distribution network. In the first approach, the power deficit is estimated by identifying the status of the generator breaker and recording the last power output before the outage, as shown in Equation (2).

$$P_{deficit} = \sum_{j=1}^{M} P_{disconnected\ Source} \qquad (2)$$

where: $P_{deficit}$ represents the power imbalance during islanding mode (including power loss) in per-unit, $\sum_{j=1}^{M} P_{disconnected\ Source}$ is the total output power of the tripped generators in per-unit, and M is the number of tripped generators. From this equation, it is evident that the estimated power deficit resulting from generator tripping equals the total loss of generated power in the system. To determine the power deficit for renewable energy sources (RESs), Equation (3) can be applied.

$$P_{deficit} = P_{RES,0} - P_{RES} \quad (3)$$

where $P_{RES,0}$ is the total output power generated by RESs at the moment of the RES event (such as changes in wind speed or solar radiation), and P_{RES} is the total output power generated by RESs after the event. The second approach is the Response-based strategy is also used calculate the power deficit in the system. This approach comes into play when there is a sudden increase in load within the islanded distribution network. The load-shedding controller calculates the power deficit using an appropriate response mechanism. This strategy relies on the derivative of the rate of change of island frequency (df_{COI}/dt). When a load increment event occurs, resulting in a change in the frequency rate, the power deficit can be determined using the power swing equation as shown in Equation (4).

$$P_{deficit} = \frac{2 \times \frac{df_{COI}}{dt} \times \sum_{i=1}^{N} H_i}{f_n} \quad (4)$$

Where: H_i the inertia constant of *ith* connected generator; N is the number of connected generators; f_n is the rated value of frequency, Hz. To reduce the amount of load that needs to be shed, the system's spinning reserve can be utilized. It is important to note that the spinning reserve depends on the capacity of the generators. The total spinning reserve (TSR) of the system can be calculated using Equation (5).

$$\mathrm{TSR} = \sum_{i=1}^{N} \mathrm{MGC_i} - \sum_{i=1}^{N} \mathrm{AGP_i} \quad (5)$$

where N is the number of connected generators; MGCi is the maximum generation capacity of ith generator; AGPi is the actual generated power of ith generator. To improve the system's frequency response and restore it to the reference value, the appropriate amount of load to shed can be determined using the following Equation:

$$\mathrm{TLSA} = P_{deficit} - TSR \quad (6)$$

where TLSA is the total load shed amount from electrical distribution network. The amount of loads that should be curtailed from the electrical distribution network is distributed between all consumers. Thus, the Load that should be Shed for each Consumer (*LSC*) is calculated according to Equation (7).

$$LSC = \frac{TLC}{TLN} \times TLSA \quad (7)$$

Where: *TLC* is the total load power for each consumer and *TLN* is the total power load in the electrical network. Figure 2 shows the flowchart of the proposed load shedding process, based on the cause that led to the electrical power deficit.

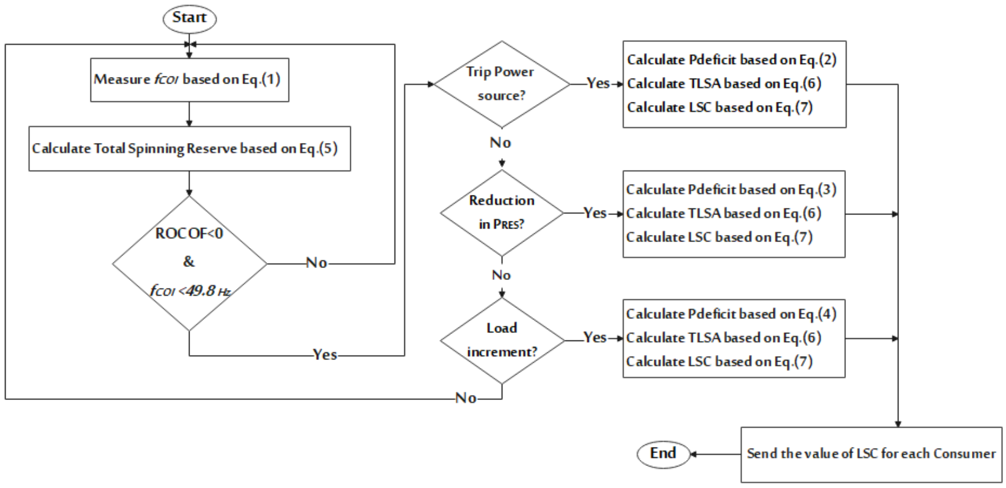

Figure (2). Flowchart of proposed load shedding at control room in Distribution network.

2.3 Load Shedding Scheme Based on the Golden Eagle Optimization

The consumer-level controller continuously categorizes electrical load sockets into two groups. The first group consists of sockets consuming less than 0.01 watts of electrical power, while the second group includes sockets consuming more than 0.01 watts. Additionally, the controller instantly records the total load consumption. When the signal shedding, TLSA and TLN values are received from the distribution network control room, the controller immediately calculates LSC based on Equation (7) and disconnects the first group of sockets from the main power to prevent any electrical consumption during and after the load shedding process. Then, the second group is selected the best combination of them to carry out the load-shedding scheme using the Golden Eagle Optimization (GEO) algorithm. The fitness function is designed to identify the optimal combination of sockets from the second group. The fitness function which is used in the GEO is shown in equation (8).

$$Minimum\ (F) = \left|LSC - \sum P_{selected\ sockets}\right| \qquad (8)$$

Where $\sum P_{selected\ sockets}$ is the total power of selected sockets from the second group. This fitness function aims for maximizing the amount of loads still connected after shedding.

The Golden Eagle Optimization (GEO) is a metaheuristic algorithm that draws inspiration from the hunting actions of golden eagles. These eagles have a remarkable ability to scan a broad region for prey and swiftly pounce on suitable targets. This algorithm was designed by (Mohammadi-Balani et al., 2021). The GEO algorithm replicates this behavior by initially creating a population of solutions, similar to "eagles," in a random manner. These "eagles" then explore the search area, seeking solutions superior to their own. Whenever an "eagle" discovers an improved solution, it communicates this knowledge to the rest of the population, aiding in the convergence towards the global optimal solution. The objective of the algorithm is to find a middle ground between exploration (venturing into new territories) and exploitation (concentrating on areas with potential outcomes). The provided diagram in Figure 3 illustrates the suggested load-shedding approach influenced by GEO.

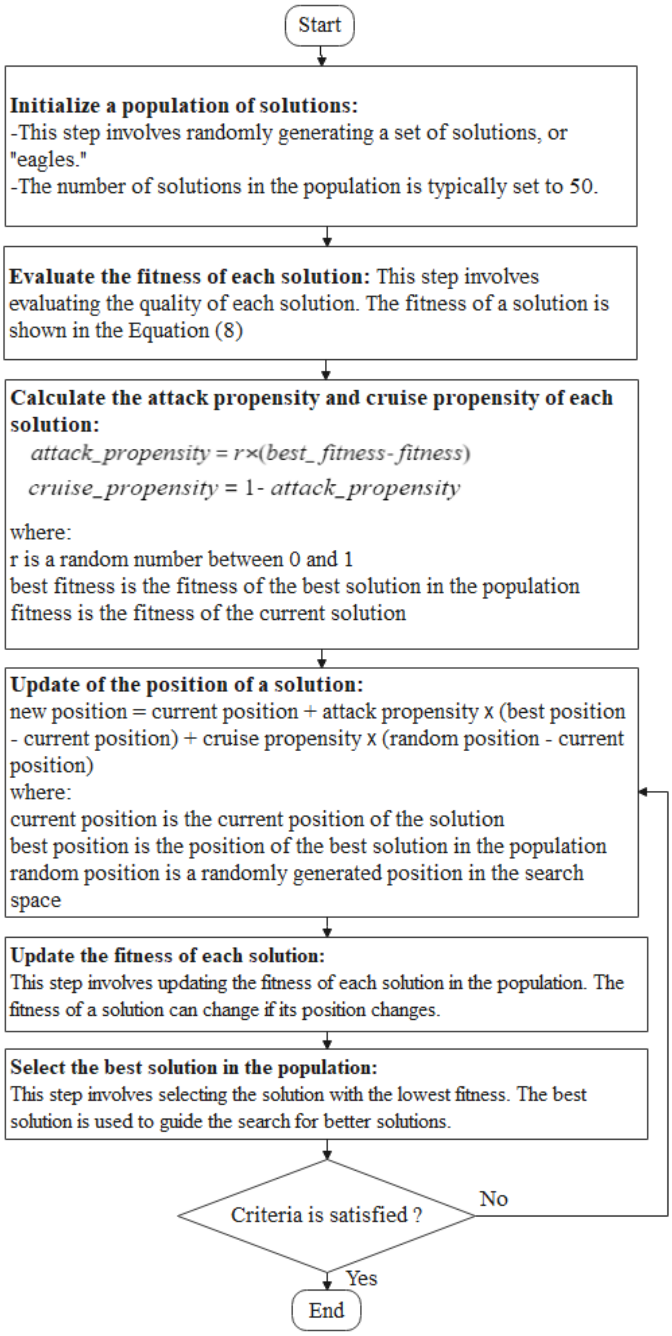

Figure (3). Flowchart of proposed load shedding using GEO algorithm.

It's worth mentioning that the stopping criterion could take the form of a maximum iteration count, a maximum alteration in solution fitness, or a specific level of precision.

The concept of socket-based load priority plays a crucial role in enhancing the efficiency of the algorithm. Electrical socket connected to loads consuming power are prioritized, while electrical sockets that are either not connected to a load or consuming less than 0.1 watt are excluded from the selection. By focusing on the electrical socket connected to loads which consuming power, the algorithm significantly reduces the number of possibilities and narrows down the search space for load shedding.

2.4 System Architecture Design

The proposed architectural design for an IoT-based load-shedding scheme within Wi-Fi networks employs the Blynk cloud, Raspberry Pi hardware (computer) and ESP32 Microcontroller. According to Equation (1), the control room in the utility grid determines the power deficit in the electrical network and then calculates the value of loads that should be shed for each consumer based on Equation (2). This value is uploaded into the Blynk cloud for a computer (Raspberry Pi hardware) to start the process of optimization load-shedding using GEO to disconnect the optimal load of home appliances. The home appliance sockets are structured and implemented to enable remote control and power consumption monitoring through the Blynk App via Wi-Fi connectivity. The proposed system boasts energy efficiency and cost-effectiveness, making it suitable for a range of buildings, including hospitals, hotels, universities, and businesses. Refer to Figure 4 for a visual representation of the proposed architectural design.

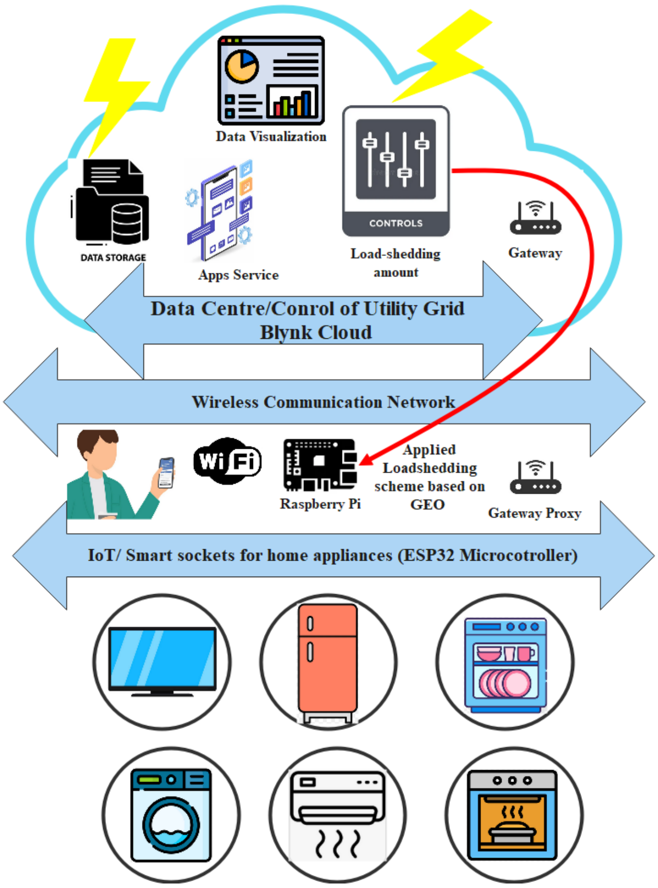

Figure (4). System overall architecture.

2.5 Design a Smart Socket Module

The designed smart socket module consists of an ESP32 microcontroller, PZEM-004T and dual solid-state relay, as shown in Figure 5. The PZEM-004T module is intended for indoor use and comes with an integrated voltage sensor and current sensor (CT). The PZEM-004T module functions as an electronic device for measuring voltage, current, active power, frequency, and power consumption (measured in watt-hours) in electrical networks found in homes. The PZEM-004T sensor can communicate with ESP32 microcontroller boards since it outputs measurements through serial communication (UART TX/RX protocol). The smart socket module connects to the internet using ESP32, allowing data to be transformed into values that can be understood by humans. Then, via Wi-Fi internet services, these processed values are transferred to a database to be stored. The solid-state relay is employed to disconnect the load whenever necessary, either by the user or the grid network operator.

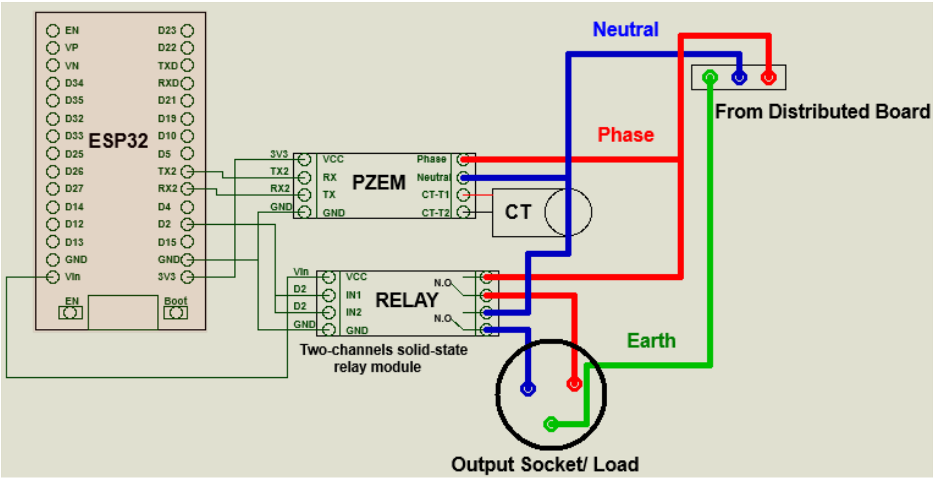

Figure (5). Smart circuit socket connections.

In order to remote control of the ESP32 microcontroller, display sensor data, store data, visualize, and others, the Blynk platform was used. Blynk is the internet platform with a mobile application available for iOS and Android operating systems that enables remote control of devices like ESP32 microcontroller, and similar hardware via the Wi-Fi and Internet (MQTT protocol). Figure 6 shows the block diagram of the link between the smart socket and the Blynk platform.

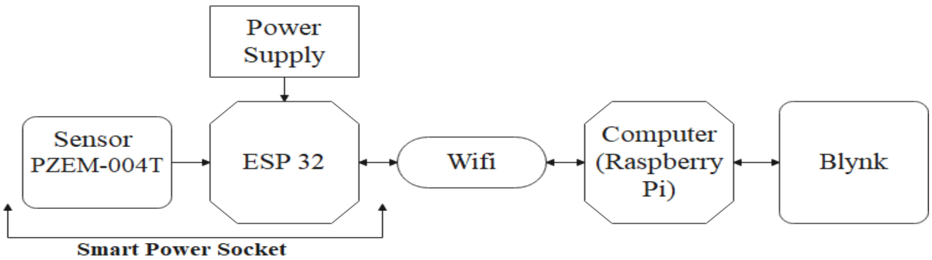

Figure (6). The block diagram of the designed system in consumer.

3 RESULTS AND PRACTICAL SCENARIO

The findings within this paper are structured into two main segments: The initial part includes the selecting the loads for disconnecting from the power grid using GEO. The subsequent section revolves around the implemented technique of disconnecting the electrical load by utilizing the suggested smart power sockets.

3.1 Applied Load-shedding Based on Golden Eagle Optimization

To verify the proposed strategy for implementing consumer-level load shedding, it is executed on the loads enumerated in Table 1 using MATLAB software. It can be noticed, the absent from this table are lighting loads like LED lamps. Furthermore, users have the option to designate load priorities that should remain unaffected by shedding, marking them as critical loads such as emergency lights, router, computer etc. This prioritization not only increases the speed of the algorithm in identifying which loads should be disconnected from the network, but it also ensures that essential and critical loads remain connected under all circumstances. By defining the priority of loads, the algorithm can safeguard vital loads, ensuring they are not removed from the network, thus maintaining the integrity of the system while optimizing performance. In Table (1), the chances of all these loads running at the same time are actually quite low. However, this assumption was introduced to broaden the research scope and help identify the optimal combination of consumed loads that most closely aligns with the required load to be disconnected from the grid.

Table (1). The Power Consumption of Household Appliances Operating Prior to Start of the Load Shedding Process

Load Number	Devices	Power (kW)
L1	Refrigerator	0.25
L2	HVAC	3
L3	TV	0.2
L4	Lights	0.25
L5	Washing machine	1. 5
L6	Oven	1.15
L7	Clothes dryer	1.23
L8	Dishwasher	1.45
L9	PC	0.3
L10	Water heater	1.5
L11	Geyser	3.5
L12	Water pump	1
L13	Vacuum cleaner	3
L14	Refrigerator	0.25

Table 2 presents the loads that should be removed from the grid when implementing GEO within the load-shedding scheme for four different values of LSC. It can be noticed that the total power of optimally selected loads is very close to LSC for all values. As a result, the amount of remaining loads during operation will remain maximized within the limits that prevent the collapse of the power grid frequency, thereby ensuring the continued operation of the electrical grid. According to Table 1, the total combined loads operating simultaneously before implementing the load shedding scheme equals 18.58 kW.

Hence, by distributing the power deficit among all consumers in accordance with Equation 7, complete blackouts within the distribution network and among consumers are averted concurrently. This objective underscores the core purpose of this investigation.

Table (2). The Optimal selected load for shedding to maximize the remaining loads in operation mode after implementing load shedding scheme

LSC (kW)	The selected loads for shedding	The total load shedding amount (kW)	Error= LSC - total curtailed loads	The total remaining load in operation after load shedding process (kW)
3.82	L1, L3, L6, L7, L12	**3.83**	-0.01	**14.75**

3.45	L3, L8, L9, L10	**3.45**	0	**15.13**
2.8	L9, L10, L12	**2.8**	0	**15.78**
1.38	L1, L6	**1.4**	-0.02	**17.18**

3.2 The Development Smart Socket

Figure 7 shows the hardware of the designed smart power socket. The ESP 32 reads the power consumption load, voltage, current, power factor and frequency via the PZEM sensor. In addition, the ESP 32 continuously sends these values to the MATLAB software to select the loads that should be shed. After that, the MATLAB software send back a signal to ESP 32 for disconnecting these loads immediately.

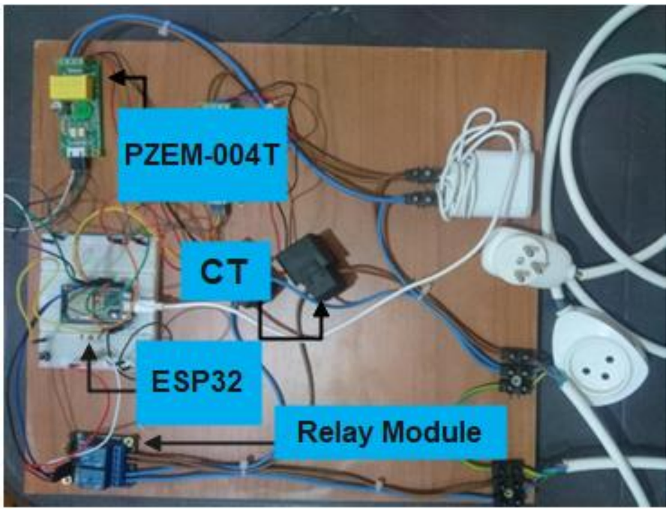

Figure (7). The prototype hardware of the designed smart power socket.

Figure 8 depicts the measurements, including power and voltage, taken from the fan device linked to the suggested smart socket. The socket's state indicates the fan is currently connected to AC power. Following the load-shedding selection, a signal is sent through the Blynk app from the computer to disconnect the designated loads using the smart power socket, as illustrated in Figure 9.

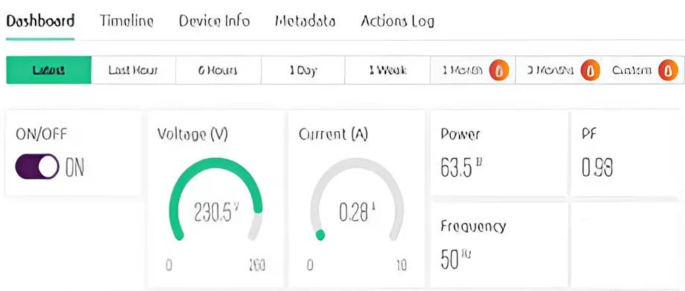

Figure (8). The Blynk dashboard for designed smart socket when the load is connected

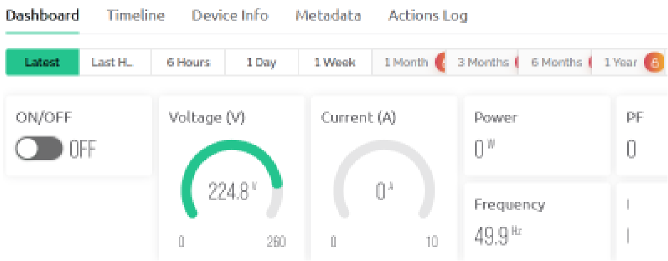

Figure (9). The Blynk dashboard for designed smart socket when the load is disconnected.

In this system, the proposed sockets are designed to measure the power consumption of each load and transmit the data to a computer. The computer then determines which sockets should undergo load shedding. In addition, the computer calculates the total load consumption at the consumer level. When the control room in the distribution network sends a load-shedding signal, the computer immediately uses the GEO algorithm to disconnect the optimal combination of load sockets by sending a signal to the ESP32, which activates the relay module to switch from a closed to an open state. The total load of this optimal combination should be as close as possible to the calculated LSC.

3.3 Interaction the Propose Loadshedding Scheme with Electrical Distribution Network

The test system examined in this research is a small distribution network to study the network frequency after imbalance power occurs, as depicted in Figure 10. It includes two types of distributed generators (DGs), the first type is a mini hydro DG which having a capacity of 2.5 MVA and a maximum power output of 2.17 MW with 2.5 seconds inertia constat. The second type is a solar PV generation unit generate 1.913 MW. The total load demand of the network is 6.179 MW included the losses in the network. The distribution network and its DGs are modeled using PSCAD/EMTDC software, and islanding operation is simulated by opening the main circuit breaker of the grid (BRKG). This system discusses the impact of using renewable energy based on inverters in islanded distribution network and the determination of the TLSA before send to each consumer and the effect on the systems' frequency after applied the load shedding scheme at the whole consumers.

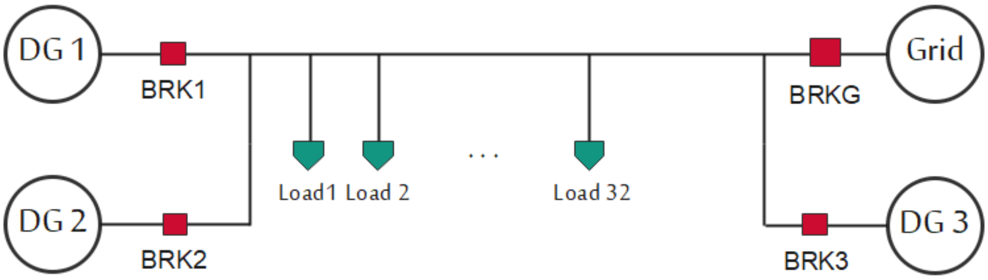

Figure (10). The electrical distribution network.

To demonstrate the impact of using renewable energy based on inverters to supply loads in the electrical network, two scenarios are developed for intentional islanding with a 0.44 MW power imbalance. In the first scenario, three mini-hydro of DGs were used. The second scenario used a two mini-hydro of DGs with one solar PV of DG which is covered approximately 33% of the load. Figure 11 illustrates the system frequency for both scenarios. From this result, it is clear that increased PV penetration leads to a higher rate of change in frequency and more frequency deviations, as demonstrated in Table 3.

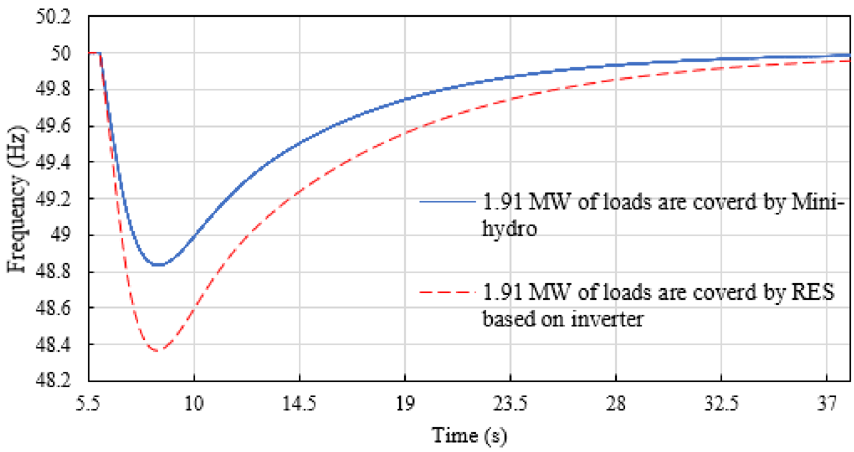

Figure (11). Frequency response of intentional islanding for two scenarios.

Table (3). The Parameters of the electrical network after intentional islanding occurs

Parameter	Three mini-hydro DGs Without RES based on inverter (Scenario 1)	Two mini-hydro DGs With 33% PV penetration (Scenario 2)
$P_{deficit}$ (MW)	0.44	0.44
ROCOF	0.71	0.97
Nader frequency (Hz)	48.83	48.37

Table (4) shows a comparison in electrical networks parameters before/after intentional islanding occurs. It worth mentioning that the load shedding scheme does not utilize because the spinning reserve is adequate to keep the system frequency within allowable range.

Table (4). The Parameters of the electrical network before / after islanding mode occurs

Parameter	Before islanding mode	After islanding mode	
		Scenario 1	Scenario 2
P_{Grid} (MW)	0.44	0	0
$P_{GENERATORS}$ (MW)	5.739	6.179	6.179
TSR (MW)	0.771	0.333	0.074
TLSA (MW)	0	0	0

To applied the load shedding scheme on the islanded electrical distribution network in the second scenario, the output power of PV generator decreases from 1.913 MW to 0.846 MW. The amount of power generated from the PV system essentially depends on the solar radiation. Therefore, a sudden change in the solar radiation during islanding mode affects the PV generator output power. In this case, PV generator power is reduced by 1.067 MW due to an abrupt decrease in solar radiation at simulation time 50 seconds. The proposed load shedding scheme is applied to keep the system frequency within allowable ranges. It can be seen in Figure 12, the system frequency after shedding 0.96 MW of loads which is distributed between all consumers. Table (5) shows a comparison in electrical networks parameters before/after decreasing in generated power of PV system in islanding mode.

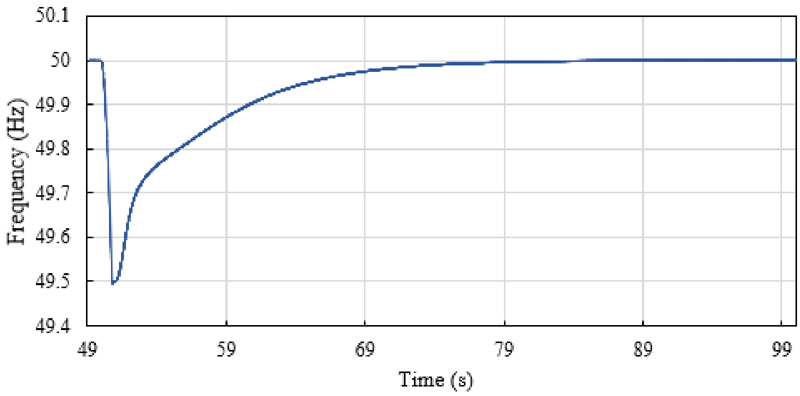

Figure (12). Frequency response after decreasing in generated power of PV system in islanding mode.

Table (5). The Parameters of the electrical network before /after decreasing in generated power of PV system in islanding mode

Parameter	Before decreasing in PV penetration	After decreasing in PV penetration
$P_{GENERATORS}$ (MW)	6.179	5.186
TSR (MW)	0.074	0
TLSA (MW)	0	0.919
Nader frequency (Hz)	50	49.5

4 CONCLUSION:

The paper describes a successful implemented load shedding scheme at consumer level to prevent the blackouts. It used the GEO to find the optimal selection of loads to be curtailed from the electrical network using a proposed smart power socket. This study presented an efficient link between the control room in utility grid with the appliance loads in the end user in the electrical network through IoT technology. The results show a real time control of load connected via smart power socket with a measurement and monitoring of power consumption, current, voltage, frequency and power factor. The Internet of Things (IoT) has transformed real-time decision-making by offering valuable insights that improve efficiency, predictive maintenance, and user experiences across industries. Despite its benefits, IoT implementation faces challenges in security, scalability, interoperability, and data management. Advancements like 5G, edge computing, and enhanced cybersecurity are poised to overcome these obstacles, further expanding IoT's potential in real-time decision-making. In the future work, it can be developed this project to apply energy management system to reduce the electricity bills.

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