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A Novel Optimization Approach for Smart Grid Systems with Nano-sized Objects

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Rapid technological advancement has led to breakthroughs in several fields, including the smart grid and the nano sized objects. The usage of nano objects has grown dramatically during the recent years on a global scale. Integration of different supporting protocols and technologies addressing storage, sensing, processing power, connectivity, and other areas is a barrier to effective nano-based deployment. Future power grid generations are anticipated to rely heavily on sensors, actuators, and transducers to deliver real-time energy monitoring services. While this may appeal to consumers because it offers them the ability to manage and monitor their energy consumption in real-time, the smart grid may be the most efficient option from an energy conservation approach. This study presents an Enhanced Greedy Particle Swarm Optimization (EGPSO) for optimizing energy usage in nano objects based smart grid systems that will enable smart homes. Evaluating the architecture of the proposed protocols that are going to be used, the workings of the system, and the challenges in the design of the system are all necessary steps before the suggested design can be used to EGPSO of the Smart grid system itself. The study's findings reveal that the evaluations of the suggested method performs better than existing methods in terms of accuracy, energy consumption, computing time and cost efficiency. Several technological difficulties may be resolved in future research ideas to utilize nano-based objects in smart grid and high-level knowledge.

Keywords: Smart Grid system, Nano sized objects, Smart home, Enhanced Greedy Particle Swarm Optimization (EGPSO).

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1. INTRODUCTION

Everything that can transmit and receive data may be networked using the nano objects, including wireless sensor networks, smartwatches, robots, cars, and other mobile devices. Each nano object requires a unique identification. The usage of nano objects has grown dramatically during the recent years on a global scale. The development of smart cities, home monitoring systems, farming, healthcare systems, etc. are all examples of important uses for the nano technology. While the nano objects have numerous potential uses, there are still obstacles that must be solved before these apps can achieve widespread acceptance. Integration of different supporting protocols and technologies addressing storage, sensing, processing power, connectivity, and other areas is a barrier to effective nano-based deployment [1]. Smart Grid (SG), also referred to as the smart electricity network, has the potential to overtake all other networks in size shortly. Knowledge and different communications capabilities will be included in every link in the power grid's supply chain, from power plants to end users, enabling very granular and precise remote monitoring and management of the power grid. Smart houses, for example, will include smart meters and smart appliances, while smart power plants and smart energy distribution networks will have various sensors and actuators. Reversible connectivity among smart devices allows the SG to keep a close eye on the power grid and exert good management over it [2].

Future power grid generations are anticipated to rely heavily on sensors, actuators, and transducers to deliver real-time energy monitoring services. Nano components has evolved into a technology that makes it possible to offer creative answers to problems with the power grid system. To communicate their valuable information with the internet and online applications, Nano sized sensors are widely utilized in the power grid system, which enables better grid management [3-4] This paper's primary goal was to optimize the energy usage using the proposed EGPSO for a nano sized based smart grid.

The rest of this study is organized as follows: Part II contains a literature survey. Part III introduces the

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suggested method. The results and discussion are presented in Part IV. Part V contains the conclusion.

2. RELATED WORKS

An IoT-Based Smart Grid using Hybrid Decision Tree presents a clever solution for intrusion detection in these kinds of networks [5]. Authors of [6] suggested a new smart energy meter that adopts an nano object based approach, along with the costs and advantages that come with everything. The created gadget features several communication interfaces. The meter features a multi-protocol connection that makes it simple to integrate with any monitoring software program. Research [7] provided an edge computing system for nano object based smart grids to address the drawbacks of the current cloud computing paradigm in power systems, where numerous challenges, such as fully addressing the demands of high bandwidth with low latency. Based on machine learning and statistical models, authors of [8] offered a system for the detection of energy theft that is referred to as the smart energy theft system (SETS).

3. PROPOSED METHODOLOGY

This research will focus on the deployment of design using nano objects in situations like smart grids and smart homes where the two cannot be separated. A grid server will frequently deliver the service to clients. All facets of the power supply are managed by the grid server [9-10]. When energy usage in one region is not excessive, energy will be redistributed to other areas in this scenario.

3.1 Nano Object Based Smart Grid System

We provide an nano object based smart grid design with four layers, which is based on the network and is depicted in Fig. 1.

Things layer: Defined as connections, sensor technologies, and controllers that gather information and transmit it to top levels or perform tasks supplied by upper layers.

Network layer: Used to link the Things layer to the top levels. The network layer manages access and establishes actual, safe, as well as economical final communications.

Middleware layer: The core of the nano object-based SG. Fog, edge, and large analysis and processing of information are covered in this layer. Towards this layer, AI knowledge is deployed [11].

Application layer: Nano object-based SG technologies are employed in urban, rural, residential and commercial, environments. This layer includes all internetwork programs and strategies [12].

The system will be in charge of energy consumption management and the smart grid servers, both of which are controlled by SCADA (Supervisory Control and Data Acquisition). The second, it's a server and app in the cloud that controls things like home automation and smartphone

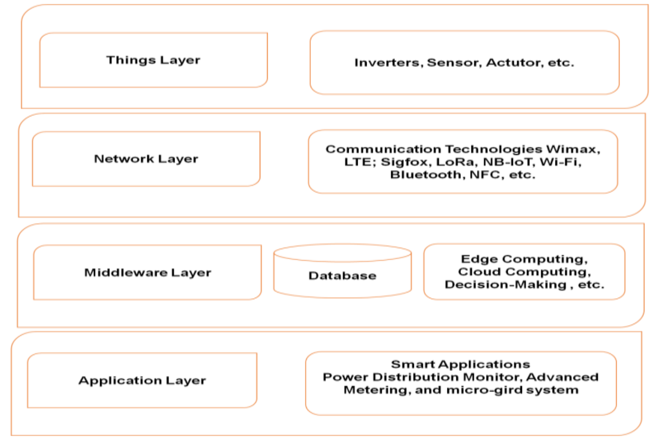

Fig. 1 – Layer-based smart grid systems

notifications for consumers. An Area ID (AID) is a collective identifier for a group of residences. The Gateway ID (GID) identifies the home gateway device in each residence. These definitions will aid in energy tracking, management, and reshuffling. With the help of an AID server, a smart grid can determine how much power a certain area needs [13-15]. The Node ID (NID), which is specific to each sensor in a house, is managed by a microcontroller connected to a Home Gateway. A unique identifier, or Device ID (DID), is assigned to every consumer device, and a unique identifier, or User ID (UID), is assigned to each user in a household. DID and UID are used for data authentication, alert message delivery, and remote monitoring.

3.2 Network Topology

A mesh network topology will be used to connect every home in a certain region via Home Gateway. This network design makes it feasible to employ Radio Frequency (RF) in communication between Home Gateways, also known as Wireless Mesh Networks (WMN), which lowers the cost of deployment. In a broader sense, we can assist WMN using LoRa technology.

3.3 Network Protocol

In this study, several protocols are employed. For instance, the device layer adheres to the IEEE 1901.2010 standard, but the sensors use BLE or Zigbee. A home gateway built on a Raspberry Pi minicomputer will connect and continue to process all of the protocols. The implementation of various sensor devices will help home automation and energy management. Some electrical equipment, for instance, can be shut off automatically when a motion sensor doesn't identify a human in space. Through the HTTP protocol, the home gateway regularly uploads the smart meter's energy use sensor data to the cloud. In contrast, a home gateway can process XMPP commands from users, allowing users to transmit commands to manage their home appliances from their smartphones [16-17].

3.4 App Server

For use with the FCM connection server, this part supports both the Hypertext Transfer Protocol (HTTP) and the XMPP protocol. The FCM connection server is intermediate between the app customer and the server app. The FCM/GCM connections service is responsible for receiving messages from the application server and relaying them to the client application. The FCM/GCM connection server is responsible for relaying messages to the client app. Each client application requires registration and a unique identifier before it may be used. By using this technology, homeowners may keep tabs on their energy consumption and make adjustments as needed to save money.

3.5 Enhanced Greedy Particle Swarm Optimization (EGPSO)

A greedy algorithm works by choosing a course of action that at the moment appears to be locally optimum while anticipating finding a practical solution in a reasonable length of time. The decision may be predicated on prior decisions, but neither future decisions nor other decisions that are a part of the sub problem will ever have an impact on it. Until a completely closed feature is formed, the greedy method selects the closest feature to solve the better selection problem.

There are two essential phases in the improved greedy-based PSO solution. In the first phase, we use a greedy method to identify certain squares in the search space where the most sensor nodes' signals are seen. In other words, the greedy algorithm seeks to position relay nodes (RNs) to lower sensor nodes' energy consumption. We are not seeking a comprehensive solution from the greedy algorithm because it is utilized to speed up convergence in the PSO. We instrument and run the PSO with the aid of that list of squares after the greedy algorithm provides the list of squares that the Relay Node (RN) needs. The following notations must be stated to describe how our greedy algorithm functions. Let Rgreedy be an order m, n, zero-one matrix, with

$$Q_{greedy}[j][i] = \begin{cases} 1, & if\ GREEDY\ puts\ an\ RN\ in\ square\ (ji, i) \\ 0, & Otherwise \end{cases} \quad (1)$$

The total number of RNs that the greedy algorithm recommends being distributed throughout the search space is Q_{greedy}. It is obvious that is a $Q_{greedy}0 \le j < a$, $0 \le i$

The PSO is a basic population-based search method in which the particles change their locations and velocities by their individual and collective optimal placements. The locations of the population indicate potential solutions, and their prior experiences are used to update the velocity. Using equation (2), the particle's location and speed are updated.

$$y_j^{s+1} = y_i^s + u_j^{s+1} \quad (2)$$

$$u_j^{s+1} = \varepsilon u_j^s + d_1\beta_1(y_{pi}^{best} - y_j) + d_2\beta_2(y_h^{best} - y_j), \quad (3)$$

where y represents the particulate location, u the particle velocity, s the iteration number, i the particulate number, the inertia weight, d_1 and d_2 the acceleration constants, β_1, and β_2 are two distinct random numbers in the range [0, 1], and y_p and y_h represent the individual and global positions, respectively.Iteration ends with an assessment of the fitness values of the best candidate solutions according to the chosen approach.Better-fitting possible values are kept and employed in the following iteration. The EGPSO flowchart is shown in Fig. 2.

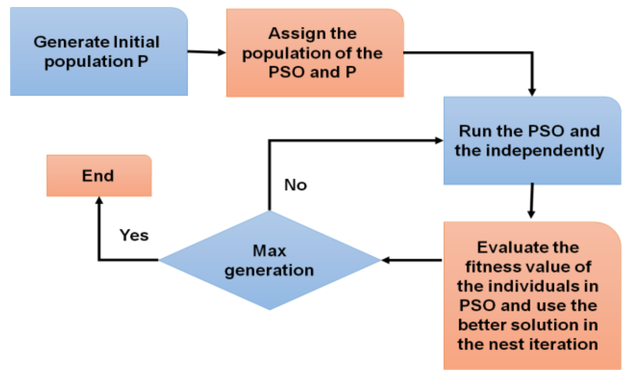

Fig. 2 – Flowchart of EGPSO

Once the greedy algorithm has finished running, the PSO algorithm is then executed. The greedy algorithm yields two extremely significant bits of knowledge:

- The optimum number of RN required to support all sensor nodes
- The optimization algorithm spaces where nurses are most likely to be located.

The PSO will be properly configured to solve the RNP issue using these two outputs from the greedy method. Since the EGPSO only has one target, the optimization problem must be handled properly. Consequently, the weighted sum approach is presented to enable the EGPSO to handle optimization issues. The process of EGPSO is shown in Algorithm 1.

Algorithm 1: EGPSO Algorithm

Input: Set $\boldsymbol{Q}$
Output: Q_{greedy}
Set $\boldsymbol{Q_i} = \boldsymbol{Q}$
Create a zero matrix $\boldsymbol{Q_{greedy}}$eedy of order j and i
While $\boldsymbol{Q_i} \neq \boldsymbol{null\ do}$
$J = ComputingInfluence(Q_i)$
$J(j, i) = max(J)$
$Q_{greedy}[j][i] = J$
for each sensor h in where h is at$(\boldsymbol{j}, \boldsymbol{i})$ do
if the distance from $(\boldsymbol{y}, \boldsymbol{u})$ $\boldsymbol{to}$ $(\boldsymbol{j}, \boldsymbol{i}) \le \boldsymbol{c_{greedy}}$then
delete h from Q1
end if
end for
end while
return$\boldsymbol{Q_{greedy}}$
End

4. RESULT AND DISCUSSION

In the research, the proposed model is activated, and its efficacy is compared to that of existing models like the Whale Optimization Algorithm (WOA), Glow-Warm Swarm Optimization Algorithm (GSOA), and Harris-Hawks Optimization Algorithm (HHOA)compared to the proposed method. The suggested methods are compared to another set of existing methods like cloud-fog computing, fog computing, and edge computing. The suggested and existing methods were used to analyze performance metrics such as accuracy, energy consumption, computing time, and cost efficiency. Table 1 depicts the performances analysis.

Table 1 – Performances analysis of the proposed and existing methods

Methods	Performances analysis			
	Accuracy	Computing time	Energy consumption	Cost efficiency
WOA	81%	350(s)	75J	83%
GSOA	89%	300(s)	63J	91%
HHOA	93%	400(s)	67J	85%
EGPSO [Proposed]	99%	250(s)	45J	98%

Accuracy is the degree to which a measurement's result complies with a value or standard. Accuracy is not necessary for a precise set of measurements. To determine how accurate a statement is, divide the total number of statements by the number of specific categories.

$$Accuracy = \frac{(\mathrm{TP} + \mathrm{TN})}{(\mathrm{TP} + \mathrm{TN} + \mathrm{FP} + \mathrm{FN})} \qquad (4)$$

Fig. 3 depicts the comparison of accuracy. The suggested method has 99 % accuracy and it is higher than the existing approaches, such as WOA, GSOA, and HHOA.

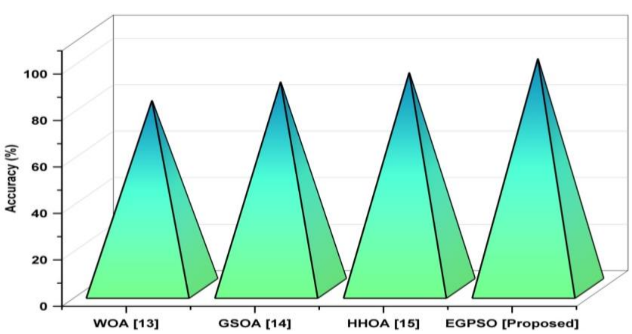

Fig. 3 – Comparison of the accuracy

Fig. 4 depicts the computing time. Computation time refers to how long it takes to do a mathematical or computational task. The amount of time it takes to complete a calculation is inversely proportional to the number of times the rule is applied when the analysis is expressed as a sequence of rule applications. In a logic-gate quantum computer, the number of successful unitary transformations is inversely proportional to the time required for a single quantum parallel calculation. When compared to WOA, GSOA, and HHOA, the proposed approach take 250s of computation time than the existing techniques.

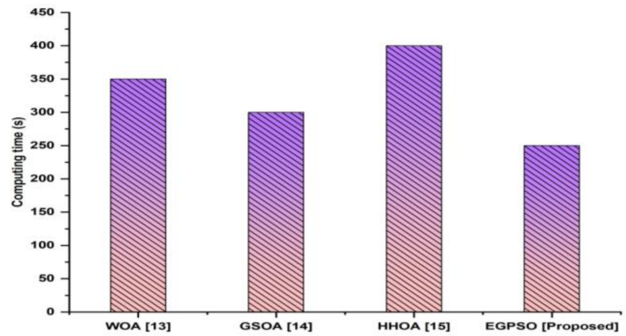

Fig. 4 – Comparison of the computing time

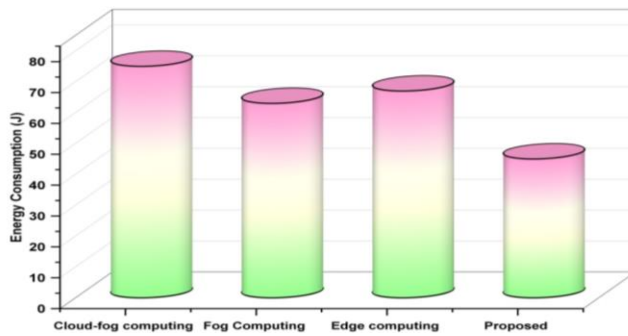

Fig. 5 – Energy consumption of the proposed and existing methods

Fig. 5 shows the energy consumption. The total amount of energy consumed by service providers, such as individuals, businesses, and agriculture, is known as energy consumption. Energy is defined as that which is utilized by the final consumer, excluding energy used by the energy industry itself. The suggested method use 45J of energy and it is effective than the existing methods like cloud-fog computing, fog computing, and edge computing.

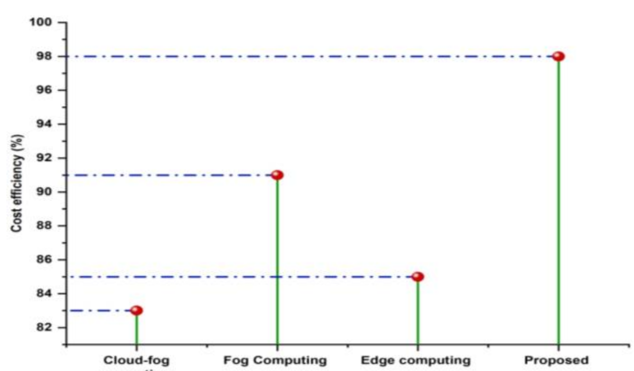

Fig. 6 – Cost efficiency of the proposed and existing methods

The term "cost efficiency" refers to the method of cutting expenses by enhancing an existing procedure. The target is to boost the bottom line through reduced operational costs and more overall efficiency. Fig. 6 depicts the cost efficiency. When compared to the existing techniques like cloud-fog computing, fog computing, and edge computing, our research has 98 % of higher cost efficiency.

5. CONCLUSION

Smart grid and smart house technologies are now possible because of the nano object's availability, which has also changed advanced communication technology. We proposed EGPSO method to optimize the energy usage in nano object based smart grids enabling smart homes. Accuracy, energy usage, computing time, and cost efficiency were examined. EGPSO results were 99 % of accuracy, 45J of energy consumption, 250 sec of computing time, and 98 % of cost efficiency. We must utilize the Internet, which is particularly prone to assault, to monitor and manage devices. Attackers can modify information that sensors and smart meters results in significant financial losses. We should consider the resource constraints of devices while creating secure communications for these devices in the smart grid and decide on certain security measures for them. Several technological difficulties must be resolved in future research areas to utilize nano-based objects in smart grid and reach high-level knowledge.

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Новий підхід до оптимізації для систем Smart Grid для нанорозмірних об'єктів

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Швидкий технологічний прогрес призвів до прориву в кількох галузях, включаючи інтелектуальну мережу та нанорозмірні об'єкти. За останні роки використання нанооб'єктів у глобальному масштабі різко зросло. Інтеграція різних допоміжних протоколів і технологій, що стосуються зберігання, датчиків, обчислювальної потужності, підключення та інших областей, є перешкодою для ефективного розгортання на основі нанотехнологій. Очікується, що майбутні покоління електромереж будуть значною мірою покладатися на датчики, приводи та перетворювачі для надання послуг моніторингу енергії в реальному часі. Хоча це може сподобатися споживачам, оскільки дає їм можливість керувати та контролювати споживання енергії в режимі реального часу, інтелектуальна мережа може бути найефективнішим варіантом підходу до енергозбереження. У цьому дослідженні представлено вдосконалену оптимізацію сукупності частинок (EGPSO) для оптимізації використання енергії в системах інтелектуальних електромереж на основі нанооб'єктів, які створять розумні будинки. Оцінка архітектури запропонованих протоколів, які будуть використовуватися, роботи системи та проблем, пов'язаних із проектуванням системи, є необхідними кроками перед тим, як запропонований дизайн можна буде використовувати для EGPSO самої системи Smart Grid. Результати дослідження показують, що оцінки запропонованого методу працюють краще, ніж існуючі методи з точки зору точності, енергоспоживання, часу обчислення та ефективності витрат. Декілька технологічних труднощів можуть бути вирішені в майбутніх дослідницьких ідеях щодо використання нанооб'єктів у розумних мережах і знаннях високого рівня.

Ключові слова: Система Smart Grid, Нанорозмірні об'єкти, Розумний дім, Покращена оптимізація сукупності частинок (EGPSO).