Home Energy Management System Using Whale Optimization Algorithm

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***Abstract*—HEMS is one of the fastest growing technology that is used to minimize the electricity usage and bills in residential houses. In recent years, many experts have proposed a large number of methods for scheduling different electrical devices. However, these systems were complex and had slow convergence rate, which degraded their overall performance. In this paper, an effective and novel approach is designed that is based on Whale Optimization Algorithm (WOA) for scheduling various home appliances. The proposed WOA method works in two scenarios one is when three home appliances are working and in the other five home appliances are working. In order to attain the desired results, the information about different electrical devices such as their power and energy consumption is gathered. This information is then given to the metaheuristic WOA algorithm along with its configurational parameters. The WOA utilizes this data to schedule the different electrical devices for a defined number of iterations. In each iteration, the load demand and cost utilization are determined in terms of fitness function. The combination with the best fitness value is saved for final results. The same process is repeated for every iteration. In the end, the value of load demand and cost are compared with the actual load demand and the ideal value is selected for the proposed plan. The performance of the proposed WOA model is analyzed and compared with the conventional PSO and normal models in the MATLAB environment. The results obtained proved that the proposed model is more efficient and stable in managing loads with minimizing costs.**

Keywords: ***Whale Optimization Algorithm, Home Energy Management System, Energy Management, Demand Side Management, Optimization Algorithm, etc.***

I. Introduction

The main aim of Home Energy Management System (HEMS) is to optimize the different energy and renewable resources without compromising with the comfort of customer[1].Despite the fact that available electric appliances have become energy efficient, but saving energy alone is not sufficient. Therefore, all such appliances must be regulated, and their switching periods can be monitored by using HEMS. The HEMS is a device that is implemented in the residential consumer's house to assist the consumers in monitoring their energy usage which in turn will reduce the consumer's energy bills [2]. The primary goal of using Home Energy Management System is to allow consumers to control and monitor their energy consumption, or to utilize it in more efficiently[3]. To do so, the customer must ensure how electricity is consumed in their residence, but that can only be estimated if electricity is monitored throughout the house. The basic block diagram of HEMS system is shown in fig 1.

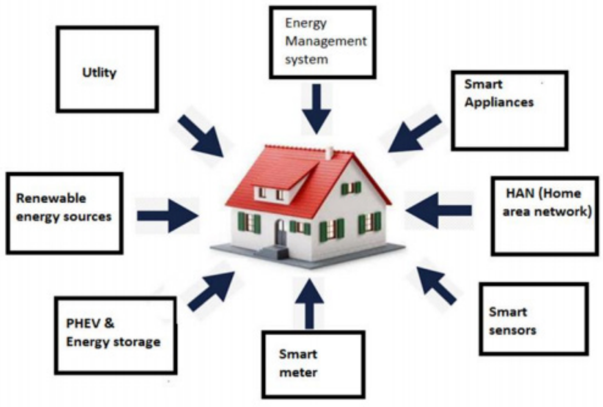

Fig.1: HEMS Block Diagram

A. *Benefits of HEMS Adoption*

Home Energy Management systems are usually used as a method to overcome prices and overcome the environmental effect of electricity production, transmission, storage, and utilization. Some of the main advantages of HEMS are;

Information: Home Energy Management System can provide temperature and weather data to the consumers.

Energy Management: Home Energy Management System can provide real-time access to detail full info about a house's electricity consumption behavior. With this unrivalled level of insight, a consumer can identify a problem, including a leak or surge in his home's electricity usage, identify the main cause, and act immediately to contain and resolve the problem, either on line and offline [4].

Remote Control: Aside from the economic and environmental benefits of HEMS, the consumer can

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monitor and control the light sources, heaters, airflow, and other circumstances of a residence even when they are not physically present. Controlling the Home Energy Management System from a distant place is possible using a Mobile-phone, tabs, or lap-tops that display the interface on the screen of users and interact directly with the Home Energy Management System.

Other Benefits: In order to effectively deliver services and increase their performance in the energy delivery process, an energy supplier or other services provider can gain access to domestic energy usage behavior and identify energy consumption patterns among their consumers.

B. Demand Side Management

Management of Demand-side with in distribution network has a wide range of management of energy. As the competitive environment in the electricity sector began, the destiny of DSM managed by the utility changed. Numerous nations are developing a new framework for a competitive environment of electricity market. A tool of analytics should be formed to use the constricted consumption data necessary to address reliable DSM options to recognize demand patterns and the impact of different DSM methods and policies on request and to correctly utilize resources[5]. In addition, investigators need comprehensive information about the structure and fundamentals of electricity consumption, both on sides of supply and demand of DSM research as an IRP (integrated resource planning)

Demand Response: Demand response is a smart grid concept or methodology of DSM that allows end consumers to interact in the energy market and handle their power consumption[6]

Need of Scheduling Household Equipment's: By scheduling household equipment's, HEMS can help to decrease total energy demand while maintaining consumer comfort. The most popular way to plan home loads is to reduce energy costs by lowering power consumption at peak hours. Consumers who participate in Demand Response programs can save money on their energy costs by reducing their consumption at peak hours and shifting peak load to off-peak times with the help of an efficient scheduling controller[7].

Schedulable home appliances, like electric vehicles, washing machines, clothes dryers, air conditioners, and water heaters and non-schedulable home devices, like ovens, lamps, microwaves, laptops, televisions, and printers can be turned on or off at any moment, Various schedule management methods have been used to construct optimum device power consumption scheduling which include; rule based, AI and optimization techniques. However, scheduling through optimization techniques has gained much importance and produce good results in shifting loads.

C. HEM Scheduling by Optimization Techniques

In general, optimization is the process of finding the best approaches to problems after determining the objective function, which is then constrained. The use of fully automatic Demand Response is critical for obtaining better Home Energy Management Systems. On the basis of Demand Response signals, an optimization strategy was established to reduce tariffs for end consumers by ensuring that home appliances operate effectively at various costs [8]. A number of optimization algorithms are available for scheduling. The results obtained from these optimization algorithms revealed that by shifting energy needs to off-peak hours, consumers can save 22 percent on their energy bills. Different techniques for scheduling load demand are explained in the next section

II. Literature Survey

A large number of researchers have already proposed a number of methods and techniques for effective scheduling of electrical devices, some of them are discussed here; Sukhlal Sisodiya, [9], employed DR (Demand Response) for an integration of ESSs (energy storage systems) such as UPS (uninterruptible power supply) and EV (electric vehicle) with utility to save the electric energy and reduce the bills of houses. S. Sisodiya and G. B. Kumbhar, [10], provided fundamental knowledge for the implementation of optimized scheduling algorithms for the DSEM (Distribution System Energy Management), HEM (Home Energy Management), and BEM (Building Energy Management) strategies. N. Ainsworth, *et al*., [11], suggested an innovative method to designing Home Energy Management Systems relying on behavioral regulation approaches, that does not need precise modeling or estimates and are extremely sensitive to changing circumstances. M. S. Ahmed, *et al.* [12], introduced a real-time optimal schedule controller for a Home Energy Management System, which manages energy usage using a modern BBSA (Binary Backtracking Search Algorithm) to schedule different appliances so that overall load demand is reduced. M. S. Ahmed, *et al*. [13]: Suggested an ANN controller that reduced the energy usage for household devices at a particular period and kept the overall power usage below its demand level without disrupting consumers lifestyle. M. S. Hoosain and B. S. Paul, [14], implemented the DR model by using utility switching off/on smart power plugs in the houses without wires depending on peak and off-peak times through connectivity via its smart grid so that an energy efficient intelligent house can be created with less electricity bill. D. Zhang, *et al*, [15]: proposed a multidisciplinary method that incorporates data structure architecture, optimization, and machine learning, to create a DR and HEMS models so that needs of real-world scenarios can be fulfilled. A. R. Jordehi,

[16], Implemented a GWO algorithm to solve the issue of optimum device scheduling in HEMS, for two separate households, each with its own collection of devices. S. Khemakhem, *et al*. [17], focused to underline the impact of plug-in electric vehicle integration in DR systems by defining the required plug-in electric vehicle power to be absorbed during off-peak time frames (home-to-vehicle technology) or infused during peak hours (vehicle-to-home technology) in the case of a power shortage or excess.

From the literature survey conducted, it is observed that most of the researchers proposed techniques that were focused on reducing the load demand and electricity bills. However, these techniques were not efficient enough and had several disadvantages. The traditional techniques usually get stuck in the local optima and also had slow convergence rate, that made these methods complex and difficult to use. Moreover, not a single preference element was used in the traditional models which means that device prioritizing for a changeable cause has not been realized. This resulted in relocating appropriate devices instead of replacing a redundant device. In addition to this, if weather is taken into consideration in managing loads, loads are reduced significantly and electricity can be effectively distributed among the different electrical equipment's. The conventional techniques didn't focus on the changing weather conditions for managing and maintaining loads in Home management systems, which degrades their overall performance. Inspired from these findings, a new and effective approach needs to be developed that can reduce loads effectively under different weather conditions.

III. Present Work

In order to overcome the problems of traditional approaches, this paper proposed an effective and novel approach that works on using different electrical home appliance with minimum cost utilization. The proposed model is based on the Whale Optimization Algorithm (WOA) for scheduling the loads. The WOA algorithm is used in the proposed work because it has high convergence rate and effective enough to solve the scheduling issue for home appliances.

In addition to this, the proposed model focuses on the varying weather conditions. The weather conditions result in utilization of different electrical equipment's that are used occasionally. So, this factor plays a very important role in scheduling the different appliances.

IV. Methodology

The process opted in the proposed WOA model in order to reduce the load demand and cost utilization is shown in Fig. 2.

Step 1: The first and the foremost step is to start the model and collect data. The data is loaded from the different electrical appliances such as TV, refrigerator, ACs, Heaters and so on. The data loaded from these electrical appliances include the information regarding their power and energy consumption.

*Step 2***:** Once the information of all electrical appliances is collected, the next step is to schedule these devices. For this, a metaheuristic WOA is used in the proposed work. The proposed WOA is analyzed for two scenarios. In the first scenario, the load and cost consumption of 3 electrical devices which include HAVC, electric water heater and electric water pump is generated. Table 1 represents the three dives along with their power rating.

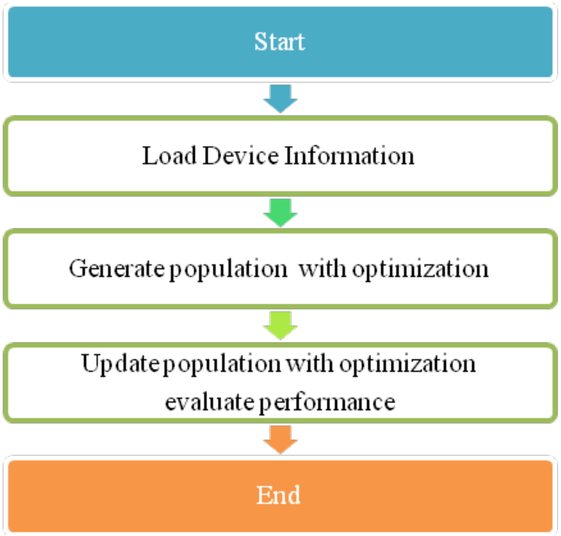

Fig. 2: Flowchart of the Proposed WOA Model

Table 1: Three Device Parameters

Appliances	Power Rating(kW)
HAVC	3.5000
Electric Water Heater	4.5000
Electric Water Pump	1.5000

In the second case, the load demand and cost utilization is generated for five home appliances i.e. HAVC, electric water heater, electric water pump, electric vehicle and UPS that are operating at same time. Table 2 demonstrates the power rating of five devices used.

Table 2: 5 Device Configuration Parameter

Appliances	Power Rating (kW)
HAVC	3.5000
Electric Water Heater	4.5000
Electric Water Pump	1.5000
Electric Vehicle	5.0000
UPS	5.0000

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Step 3: Once the information is generated for both scenarios, the next step is to initialize the WOA algorithm along with its configurational parameters. The various configurational parameters are given in table 3.

TABLE 3: WOA CONFIGURATION PARAMETER

Parameter	Value
Population	10
Iteration	50
A	2 to 0
L	-1 to 1
Constant b	1
P	Random [0 1]

Step 4: The WOA then generates the random population in terms of scheduling various electrical devices for ON/OFF. The generated population is firstly evaluated by the fitness function to check the cost and demand load requirements for a particular device combination. Out of number of fitness values, the best fitness is chosen for that particular iteration.

Step 5: In the next step, the population is updated and load and cost values are evaluated in the next iteration. This process is repeated for given number of iterations so that required load with minimum cost can be achieved.

Step 6: Once the best scheduling pattern is achieved with fulfillment of load and less cost values, it is considered to be final plan for the proposed system.

Step 7: Finally, the results obtained from the WOA scheduling are then compared with the traditional PSO and normal models and are discussed in the next section.

V. RESULTS AND DISCUSSION

The efficiency of the proposed WOA approach is analyzed in the MATLAB software. The simulation outcomes were attained for both cases i.e. for three home appliances and for five home appliances in terms of their load demand and cost utilization. The results obtained for the proposed WOA model were analyzed and compared with the traditional PSO and normal models and are discussed briefly in this section.

A. Phase 1: For Three Home Appliances

The performance of the proposed WOA system is evaluated and compared with the conventional PSO and normal models in terms of their load demand and is shown in fig 3.

Fig. 3 illustrates the comparison line graph of load demand for proposed WOA model and conventional PSO and Normal systems. From the graph, it is observed that the load demand in traditional PSO and Normal model is quite high i.e. around 56.7kW and 44.5kW respectively even when only three devices are operating at a given time. However, this is not the case in proposed WOA system, whose demand load line is straight with load value equal to only 36 kW.

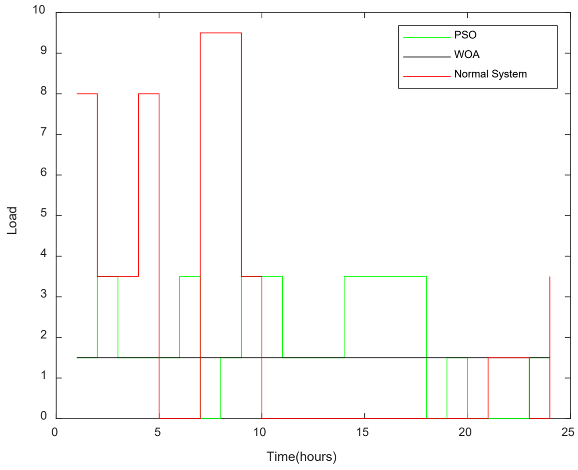

Fig. 3: Comparison of Load Demand for Three Home Appliances

Moreover, the performance of the proposed WOA method is determined and compared with traditional PSO and Normal systems in terms of their cost value. The cost utilization for three home appliances is showed in fig 4.

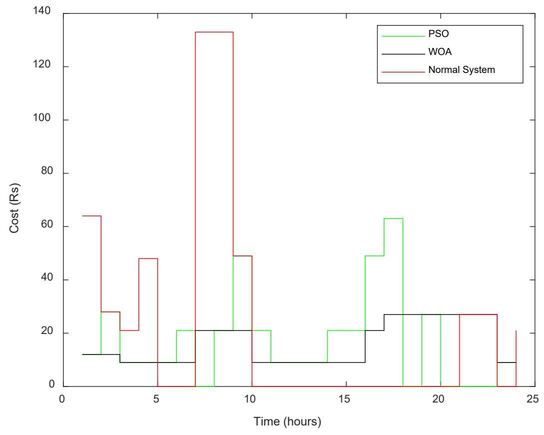

Fig. 4: Comparison of Cost Utilization for Three Home Appliances

Fig 4, represents the comparison graph for proposed WOA model and conventional PSO and Normal systems in terms of their cost/Hour value. From the graph, it is observed that the value of cost attained in the proposed WOA is quite low when compared with the traditional PSO and normal models. The value of cost attained in the proposed WOA model came out to be 369 rupees per day. While as, in case of traditional PSO and normal models the value of cost utilization came out to be 391/day and 594/day respectively. The exact value of load demand and cost utilization attained in the proposed WOA and conventional PSO and normal model are given in table 4.

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Table 4: Comparison of Total Load and Cost/Day for Three Home Appliances

Method	Load (in kW)	Cost/day (in Rs./-)
Normal	56.7	594
PSO	44.5	391
WOA	36	369

B. Phase 2: For Five Electrical Home Appliances

The performance of the proposed WOA system is analyzed and compared with the traditional models in terms of the load demand for five electric appliances and is shown in fig 5.Fig 5, demonstrates the comparison line graph of load demand for proposed WOA model and conventional PSO and Normal systems, when five home appliances are working simultaneously.

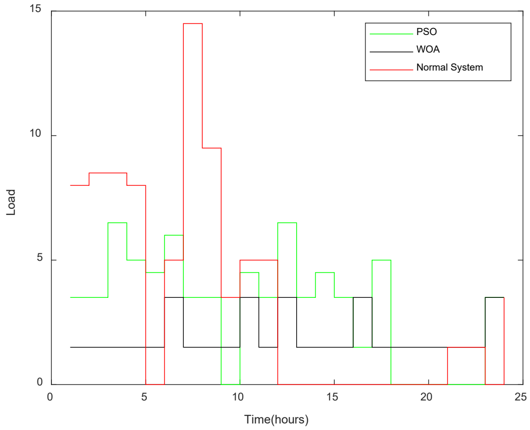

Fig. 5: Comparison of Load Demand for Five Home Appliances

From the graph, it is observed that the load demand in proposed WOA system came out to be 46kW only for 5 home appliances. While as, the load demand value in conventional PSO and Normal model is quite high i.e. around 77.5 kW and 86.5kW respectively for five electrical home appliances. This shows that the proposed model is more effective in scheduling the devices than traditional models.

Furthermore, the performance of the proposed WOA method is analyzed and compared with classical PSO and Normal systems in terms of their cost utilization value per hour. The cost utilization for five home appliances is showed in fig 6.

Fig 6 represents the comparison graph for proposed WOA model and standard PSO and Normal systems in terms of their cost/day value. From the graph, it is observed that the value of cost attained in the proposed WOA model came out to be only 453 rupees per day, when five electrical home devices are working at a particular time. However, when we talk about the cost value of traditional PSO and normal models, their value came out to be quite high i.e. 594/day and 818/day respectively. The precise values of load demand and cost utilization obtained in the proposed WOA and traditional PSO and normal model are given in table 5.

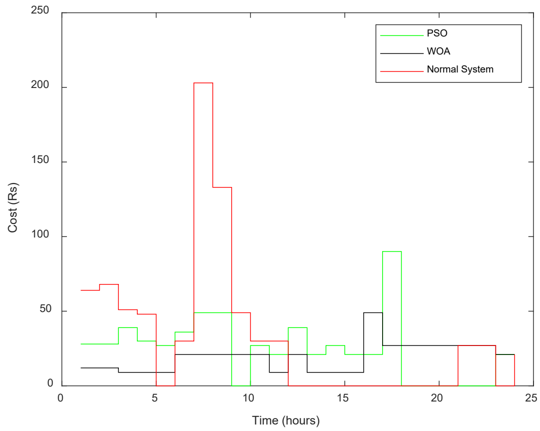

Fig. 6.Comparison of Cost Utilization for Five Home Appliances

Table 5: Comparison of Total Load and Cost/dayfor 5 Home Appliances

Method	Load (in kW)	Cost/day (in Rs/-)
Normal	86.5	818
PSO	77.5	594
WOA	46	453

From the graphs and tables, it is observed that the proposed WOA model is more efficient and reliable in shifting loads with minimum cost utilization.

VI. Conclution

The proposed WOA model is simulated and analyzed in the MATLAB simulation software. the simulation results were obtained for two cases i.e. for three electrical devices and for five electrical devices. The performance of the proposed model WOA model is also compared with the conventional PSO and normal models in terms of their load demand and cost utilization.The value of load demand attained by the proposed WOA model came out to be 36kW only for three home appliances. While as, the value of load demand obtained in the traditional PSO and normal models is equal to 44.5kW and 56.7kW respectively for three home appliances. Furthermore, the value of cost utilized for three home appliances in traditional PSO and normal models came out to be 391/day and 594/day respectively. On the other hand, the value of cost utilization by the proposed WOA system is equal to 369/day only. Similarly, the results attained for the load demand and cost utilization when five home appliances are working simultaneously. The load demand and cost utilization values attained by the traditional

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PSO and normal models came out to be 77.5kW, 86.5kW respectively and 594 per day, 818 per day respectively. While as the value attained by the proposed WOA model in terms of their load demand and cost utilization came out to be 46kW and 453rupees/day. These outcomes obtained prove that the proposed WOA algorithm outperforms the traditional PSO and normal models in terms of their load demand and cost utilization.

References

[01] U. Zafar, S. Bayhan and A. Sanfilippo, "Home Energy Management System Concepts, Configurations, and Technologies for the Smart Grid," in IEEE Access, vol. 8, pp. 119271-119286, 2020

[02] Ayodeji Amoo, Franco Cano Flores, Saurabh Ranalkar, "Home Energy Management System", 2016

[03] Mahapatra, Bandana & Nayyar, Anand. (2019). Home energy management system (HEMS): concept, architecture, infrastructure, challenges and energy management schemes. Energy Systems

[04] N. Jaber, "Efficient Home Energy Management System," 2014 6th International Conference on New Technologies, Mobility and Security (NTMS), 2014, pp. 1-4

[05] H. T. Dinh, J. Yun, D. M. Kim, K. Lee and D. Kim, "A Home Energy Management System With Renewable Energy and Energy Storage Utilizing Main Grid and Electricity Selling," in IEEE Access, vol. 8, pp. 49436-49450, 2020

[06] M. Liska, M. Ivanic, V. Volcko and P. Janiga, "Research on Smart Home Energy Management System," 2015 16th International Scientific Conference on Electric Power Engineering (EPE), 2015, pp. 459-463

[07] B. Asare-Bediako, W. L. Kling and P. F. Ribeiro, "Home energy management systems: Evolution, trends and frameworks," 2012 47th International Universities Power Engineering Conference (UPEC), 2012, pp. 1-5

[08] D. Setlhaolo, X. Xia, and J. Zhang, ''Optimal scheduling of household appliances for demand response,'' Electr. Power Syst. Res., vol. 116, pp. 24–28, Nov. 2014.

[09] Sukhlal Sisodiya, "A Home Energy Management Incorporating Energy Storage Systems with Utility under Demand Response using PSO", IEEE, 2018

[10] S. Sisodiya and G. B. Kumbhar, "Demand-side resources for electric energy management," ICEES 2018, IEEE Proceedings, vol. Accepted, pp. 1–6, Feb 2018.

[11] N. Ainsworth, B. Johnson, and B. Lundstrom, ''A fuzzy-logic subsumption controller for home energy management systems,'' in Proc. NAPS, Charlotte, NC, USA, Oct. 2015, pp. 1–7.

[12] M. S. Ahmed, A. Mohamed, T. Khatib, H. Shareef, R. Z. Homod, and J. A. Ali, ''Real time optimal schedule controller for home energy management system using new binary backtracking search algorithm,'' Energy Buildings, vol. 138, pp. 215–227, Mar. 2017.

[13] M. S. Ahmed, A. Mohamed, H. Shareef, R. Z. Homod and J. A. Ali, "Artificial neural network based controller for home energy management considering demand response events," 2016 International Conference on Advances in Electrical, Electronic and Systems Engineering (ICAEES), Putrajaya, 2016, pp. 506-509:

[14] M. S. Hoosain and B. S. Paul, "Smart homes: A domestic demand response and demand side energy management system for future smart grids," 2017 International Conference on the Domestic Use of Energy (DUE), Cape Town, 2017, pp. 285-291:

[15] D. Zhang, S. Li, M. Sun and Z. O'Neill, "An Optimal and Learning-Based Demand Response and Home Energy Management System," in IEEE Transactions on Smart Grid, vol. 7, no. 4, pp. 1790-1801, July 2016

[16] A. R. Jordehi, "Optimal Scheduling of Home Appliances in Home Energy Management Systems Using Grey Wolf Optimisation (Gwo) Algorithm," 2019 IEEE Milan PowerTech, Milan, Italy, 2019, pp. 1-6

[17] S. Khemakhem, M. Rekik and L. Krichen, "Impact of Electric Vehicles integration on residential demand response system to peak load minimizing in smart grid," 2019 19th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), Sousse, Tunisia, 2019, pp. 572-577.