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Application of a Multi-Objective User-Centric Method to Energy Management in Smart Home Considering Consumer Privacy

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Abstract
This paper investigates smart home energy management in consideration of tradeoffs between residential privacy and energy costs. A multi-objective approach that minimizes energy costs and maximizes privacy protection is proposed. This approach leads to a multi-objective optimization problem in which the two objectives addressed in separate dimensions. PSO algorithm that employs a stochastic search used for power scheduling of home appliances and uses deterministic battery control developed accordingly. The proposed approach can avoid some drawbacks faced by conventional weighted-sum methods for multi-objective optimization. Simulations reveal that the proposed approach can maintain a reasonable energy cost while robustly preserving user privacy at a sensible level, finally the numerical results shown and analyzed.

Keywords: Energy Management**,** Smart Home, Optimization, Consumer Privacy

1. INTRODUCTION

With the advent of real-time monitoring and information transfer systems, demand side management and IoT technology, powerful networks have emerged as a new generation of powerful systems replacing traditional powerful networks. One of the most important features of the network, which has intelligent intelligence from the previous generation and differentiated, can control and control this network, so that it can consume atmospheric energy. As a result, you expect smart grids to build, security standards, and heating features as well. There are few ways to consider the specific privacy of smart grids. One of the most common methods is to change the pattern of energy consumption using different sources. Stored units or energy extraction from the environment can also be used to cover power consumption.

In this regard, a multi-objective optimization (MOP) transaction is formulated that includes cost criteria and specific thermal criteria in different dimensions. After properly solving the multi-objective optimization, at this stage I can influence an energy management system and as a result it can determine the consumption of home appliances. In the sponsor hybrid algorithm, a programmatic random search method for flexible home appliance power consumption is flexible and acceptable change in response to electricity price and heat variance function can be a special feature and be selected to a set of solutions suitable for you. . The final planning for the appliance will be determined by the solution that minimizes its distance from an ideal solution for using a Pareto Bidebi boundary, or in other words the image of an optimal Pareto set, using the objective functions.

2. Related Work

Reference [1] presents the operation schedule for electrical power supply and consumers equipped with home energy management system (HEMS) and building energy management system (BEMS) through energy management in each home. In the reference [2], according to the use of energy storage resources as well as renewable energy sources for consumption in the home sector, a diverse and extensive study has been done. Reference [3] discusses the use of energy storage devices, including batteries and electric vehicles in the management of household loads. Reference [4] provides a method for monitoring and controlling solar and wind power plants in the field of home energy management. Reference [5] presents an algorithm based on the sorting method for scheduling home appliances on a large scale. Reference [6] presents an algorithm for improving the planning of home appliances by considering the characteristics of human behavior. In reference [7], simultaneous programming of home appliances and electric vehicles is analyzed by linear programming method mixed with integer. In the reference [8], a nonlinear multi-objective planning model mixed with integer is used for the optimal use of energy in a smart home. In addition to reducing the cost of energy consumption of subscribers, an optimal planning in the use of home appliances is presented. In reference [9], past scientific articles in the field of smart home energy management have been purposefully reviewed and compared. In this reference, several modeling methods such as mathematical optimization, predictive control model, innovative control, etc. to obtain a suitable operation plan and Achieving the right production and consumption decisions is provided. Reference [10] suggests a multi-objective optimization model of the day-ahead for building energy management system under load-time demand, in which the solar energy source with other production sources with the aim of economic optimization and welfare of residents Has been integrated. Reference [11] suggests how to control smart home appliances as part of the home automation process.

3. Suggested Model

In this study, a multi-objective optimization model is proposed to minimize energy costs and maximize consumer privacy. The method eventually becomes a multi-objective optimization problem with two objectives in separate dimensions. To solve this problem, a particle swarm optimization algorithm that has good performance in minimizing mathematical functions has been used for random search and power supply scheduling of home appliances. Smart home energy management system based on input information such as the next day electricity price, ambient temperature, etc., which receives responsive and non-responsive loads from the upstream distribution network, environmental information and consumption forecast the next day, the next day program (Includes photovoltaic units, storage, etc.).

In the research of this article, a smart home equipped with energy management system, photovoltaic generator, electric energy storage (battery), smart home appliances and responsive to electricity prices is considered. Home appliances are divided into two categories: the first category is unpredictable and therefore not responsive to time-varying electricity prices, and therefore their time of use and consumption are unchangeable, including lighting, TV and computer. cited. The second category is smart appliances that can be moved and their consumption can be changed, including washing machine, dishwasher and clothes dryer. Smart homes are considered to be connected to the grid and can exchange energy with it at the price of electricity market. The energy management system plans the time of use of home appliances (responsive loads), the time of charging and discharging of energy storage resources, as well as the time and amount of purchase / sale, from / to the upstream network according to the predicted prices. The energy management system selects the operating times of smart devices in such a way that the cost of electrical energy is minimized in the desired time horizon and the privacy of its consumers is maintained. In smart homes, due to the existence of storage and photovoltaic generator, it is possible to sell energy to the upstream distribution network, which can significantly reduce the cost of operating the smart home or even make a profit in some cases.

The objective function of the energy management system is expressed as minimizing the cost of operating the smart home for one day according to Equation (1):

$$min\left\{cost = \sum_{t=1}^{T} c_t \times \Delta t\Big(P_{nr_t} + \sum_i \sum_j P_{r_{ijt}} \times X_{ijt} - E_t^s\Big) + \sum_{i=1}^{Ni} day\_cost_i\right\} \tag{1}$$

The objective function of the problem can also be expressed by considering the electric energy storage and the photovoltaic generator according to Equation (2):

$$cost = \sum_{t=1}^{T} c_t \times \Delta t\begin{pmatrix} -\eta^{B'}\,(E^{Bn}.x_t^{Bn}) + (1-\eta^B)(E^{Bp}.x_t^{Bp}) \\ -P_{PVt} + P_{nr_t} + \sum_i\sum_j P_{r_{ijt}} \times X_{ijt} \end{pmatrix} + \sum_{i=1}^{Ni} day\_cost_i \tag{2}$$

The last phrase related to the cost of electricity is as follows, which is actually the cost of power consumption in a residential house:

$$P^h = P_{HA}^h + S\,(h) \tag{3}$$

In the above relation, where P^h represents the power consumption in time intervals, P_{HA}^h which is the total power consumption of all types of household appliances in the form of relation (4) and S(h), which is a function of charge and discharge in the form of relation (5).) Is expressed:

$$\sum P_a^h + \sum P_b^h + \sum P_c^h \tag{4}$$

$$S(h) = S^+(h) - S^-(h)$$
$$S^+(h) = max\,\{S(h), 0\}$$
$$S^-(h) = -min\,\{S(h), 0\} \tag{5}$$

Finally, the objective function related to the cost of electrical power and the objective function expressing consumer privacy are expressed as follows, which aims to minimize them:

$$F_{cost} = \sum_{h=\xi} (P^h \times \Delta h) \times \lambda^h \tag{6}$$

$$F_{privacy} = \frac{1}{|\xi|}\sum_{h\in\xi} (P^h)^2 - \Big(\frac{1}{|\xi|}\sum_{h\in\xi} P^h\Big)^2 \tag{7}$$

In relation (7), ξ represents the index of the set of time intervals, P^h is the power consumed in the time intervals.

4. Simulation and analysis of results

According to the mathematical model presented in the previous section, the results of the implementation of the optimization mechanism to improve the cost and energy consumption management of intelligent equipment as well as improving consumer privacy in the MATLAB software environment implemented and the output It is extracted by linking this software and Excel software.

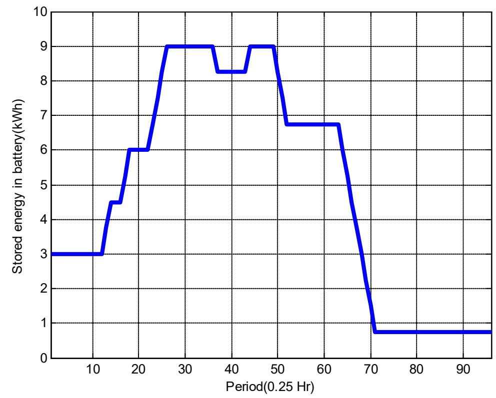

Figure 1. Energy stored in battery storage systems for a 24-hour period in a smart home

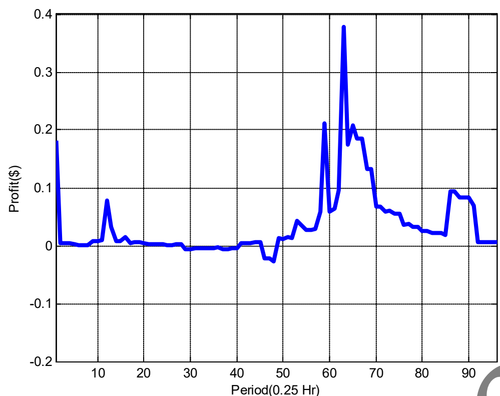

Figure 2. Benefits of high-grid smart home electricity exchange over a 24-hour period

Providing the infrastructure needed to turn a typical home into a smart home requires significant costs that are not considered important in some studies. However, in a technical-economic study, the cost of investment must be considered in order to achieve the correct result. Since this cost is added to the cost function as a fixed number, it has no effect on the details of the smart home appliance simulation results and only increases the final operating cost.

If the initial investment cost of any of these accessories, including solar cells, single-phase converters and batteries, is not taken into account, the day-to-day operating costs will be as shown in Figure 3. It can be seen that with the assumptions made, the use of the above equipment in the smart home is still profitable and quite economical, even in terms of investment cost. For example, in the simulation, if the investment cost is taken into account up to about $ 2,000, including the maintenance cost, the daily cost of the smart home will be close to zero and will only go out of revenue.

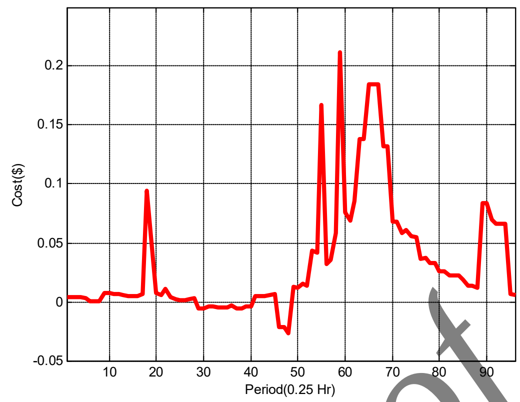

Figure 3. Cost of operating a smart home during the day without considering solar cells, single phase converters and battery storage systems

5. Conclusion

In order to evaluate the efficiency of the proposed method, a case study was conducted and the obtained numerical results were evaluated and evaluated. It was evaluated that in both cases the results show the economics of using this equipment. Proposing an efficient and powerful optimization method, how to model the specifications and technical and economic constraints of the building, as well as how to take into account the network loads are some of the items described in this article that can be used in future scientific and applied research. Be used. To continue this research, various suggestions such as considering uncertainty for various factors such as grid load, etc., considering other renewable energy sources such as wind and fuel cells and also using other innovative and meta-heuristic optimization algorithms Suitable for design and operation of green and smart buildings, especially zero energy buildings, can be provided.

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