Fast Particle Swarm Optimization in Smart HEMS

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Abstract

Under the smart grid, home energy management system can use a variety of ways to reduce the power consumption of the user, such as the positive response to the electricity price policy which transforms part of electrical appliances from the high price period to the low price period"; Make full use of distributed energy to generate electricity to reduce the purchase of electric energy from the power grid; Sell excess electricity generated by distributed energy to power grid; Charge the energy storage system at low electricity price and discharge at high price, etc. This is the most common kind of optimal scheduling algorithm.

Keywords

Home Energy Management System, Smart Home, Household Electricity.

1. Introduction

The household energy management system based on smart grid includes five functional modules, which are: user setup module, detection module, prediction module, optimization scheduling module and equipment monitoring module. The optimized scheduling module is the core of the home energy management system, it can optimize the adjustable electrical appliances and energy storage equipment according to user set parameters of electrical appliances, equipment actual working state [1-3], environmental conditions, price information, distributed energy output forecast information to achieve a predetermined set of optimization objectives, such as minimizing the cost of electricity to users and so on.

Home energy optimization control is one of the important branches of home energy management system (HEMS), but the lack of effective intelligent optimization algorithm has restricted the practical application of home energy optimization control. In this article, through analyzing working characteristic of the household appliances, household electric equipment was divided into rigid load, simple adjustable load, battery equipment (including electric cars), HVAC(heating, ventilation, and air conditioning system) equipment, etc. and established the corresponding load model, using power grid, photovoltaic power generation and energy storage battery that three kinds of energy as the source of smart home, with electricity cost and comfort level as the optimization indexes, established home energy optimization control model of the coordinated control of the hybrid energy, and put forward a intelligent solving method based on improved fast particle swarm optimization (APSO) 1-4-3],, work out the optimal time of electric appliance, the required power of each time in room temperature control system and the charge and discharge power of each period of the storage battery. According to electricity situation of one day in summer, built model and used MATLAB to simulate, verifying the validity of the model and algorithm.

2. The integrated control model and algorithm design of household electricity

Home energy system consists of power grid, photovoltaic power generation and battery group, we can get formula (1) by law of conservation of energy:

$$E_{GR}(t)+P_{PV}(t)*\Delta t=P_B(t)*\Delta t+P_H(t)*\Delta t + P_{EV}(t)*\Delta t*x_{EV}(t)+e_{unc}(t)+e_{noni}(t) \quad (1)$$

Of those:

$E_{GR}(t)$——the electric energy algebraic sum interacted between family and the grid in the period of time t;

The family should pay to the grid electricity costs as shown in formula (2):

$$f_1=\sum_{t=1}^{T} prc(E_{GR}(t))*E_{GR}(t) \quad (2)$$

Among them, the family and the power exchange price $prc(E_{GR}(t))$ is:

$$prc(E_{GR}(t))=\begin{cases} C_1\ ,\ E_{GR}(t)\geq 0 \\ C_2\ ,\ E_{GR}(t)\leq 0 \end{cases} \quad (3)$$

Of those:

C_1、C_2 Represent the price of electricity the user purchase and sale in the period of time t respectively.

Family room satisfaction can be reflected by the departure degree that the actual indoor temperature value deviates from the set value in every period of time, that is, deviation from the set value is greater, the satisfaction is poor, the low comfort. The satisfaction at room temperature is expressed by weighted formula as shown in formula (26), and transform the room temperature satisfaction into comfort cost through coefficient ξ_2:

$$f_2=\sum_{t=1}^{T}\xi_2\,|\,T_{in}(t)-r_T^H(t)| \quad (4)$$

2.1 Integrated control model of household electricity

In the home energy management system, assume the control value $x(t)$ is:

$$\begin{aligned} x(t)&=[x_1(t),x_2(t),x_3(t),x_4(t),x_5(t),x_6(t),x_7(t),x_8(t)]' \\ &=[x_{noni1}(t),x_{noni2}(t),x_{noni3}(t),x_{noni4}(t),x_{noni5}(t),x_{EV}(t),P_H(t),P_B(t)]' \end{aligned} \quad (5)$$

The state variable $u(t)$ is:

$$\begin{aligned} u(t)&=[u_1(t),u_2(t),u_3(t),u_4(t),u_5(t),u_6(t),u_7(t),u_8(t)]' \\ &=[e_{noni1}(t),e_{noni2}(t),e_{noni3}(t),e_{noni4}(t),Q_{EV}(t),T_{in}(t),Q_B(t),E_{GR}(t)]' \end{aligned} \quad (6)$$

The home energy management system based on user satisfaction at room temperature, that is, maximum comfort and the least expensive as the goal. So the family energy optimization control model is:

$$\min\ f=\omega_1*\sum_{t=1}^{T}\xi_1*prc(u_8(t))*u_8(t)+\omega_2*\sum_{t=1}^{T}\xi_2*|\,u_6(t)-r_T^H(t)| \quad (7)$$

Equation of state:

$$\begin{cases} u_i(t)=P_{iN} * \Delta t * x_i(t) \quad , \ i=1,2,3,4 \\ u_5(t+1)=u_5(t)+\eta_{cha} * P_{EV} * \Delta t * x_5(t) \\ u_6(t+1)=e^{-\Delta t/RC} * u_6(t)+R*\left(e^{-\Delta t/RC}-1\right)*\Delta t * x_6(t)+\left(1-e^{-\Delta t/RC}\right)*T_{out}(t+1) \\ u_7(t+1)=u_7(t)+\gamma(x_7(t))*\Delta t * x_7(t)-Q_{loss}(x_7(t)) \\ u_8(t)=\sum_{i=1}^{4} u_i(t)+P_{EV}(t)*\Delta t * x_5(t)+\Delta t * x_6(t)+\Delta t * x_7(t)+e_{unc}(t)-P_{PV}(t)*\Delta t \end{cases} \tag{8}$$

Of those:

$$\begin{aligned} &\gamma(x_7(t))=\begin{cases} \gamma_C & , \ x_7(t)>0 \\ 1/\gamma_D & , \ x_7(t)<0 \end{cases} \\ &Q_{loss}(x_7(t))=\begin{cases} Q(\Delta t) \ , & x_7(t)=0 \\ 0 & , others \end{cases} \\ &e_{unc}(t)=\sum_{i \in A_{unc}} P_{iN} * \Delta t * x_i(t) \end{aligned} \tag{9}$$

Condition constraint:

$$s.t.\begin{cases} \sum_{t=\tau+1}^{\tau+\lambda_i} x_i(t) \geq \lambda_i * \left(x_i(\tau+1)-x_i(\tau)\right) \quad , \\ \qquad \tau \in [\alpha_i-1, \beta_i-\lambda_i] \ , \ i=1,2,3,4 \\ 0 \leq x_6(t) \leq P_H^U \\ \gamma_D * \tau_D * Q_B^L / \Delta t \leq x_7(t) \leq \tau_C * Q_B^U / (\gamma_C * \Delta t) \\ Q_{EV}^L \leq u_5(t) \leq Q_{EV}^U \ \text{且} \ u_5(\beta_5) \geq 0.9 * Q_{EV}^U \\ T_{in}^L \leq u_6(t) \leq T_{in}^U \\ Q_B^L \leq u_7(t) \leq Q_B^U \\ u_8(t) \leq P_{GR\bullet\max} * \Delta t \end{cases} \tag{10}$$

2.2 Design of algorithm

There are two kinds of variables in model, continuous variable and 0-1 discrete variable which bound by room temperature, battery energy storage and photovoltaic power generation simultaneously. That is a optimization problem with nonlinear variable parameters and is hard to find out a satisfactory solution set. However, As a kind of global optimization algorithm based on swarm intelligence, the fast particle swarm optimization can achieve effective search in complex space and can find the optimal or approximate optimal solution of complex optimization problems in a limited time [5-6]. So this paper has adopted a intelligent solving method based on improved fast particle swarm optimization to find out household energy optimization control model[7].

The solution steps of improved fast particle swarm optimization are:

(1) Initialize the particle swarm. The corresponding upper and lower bounds of control variable in particle $x_1(t), x_2(t), x_3(t), x_4(t), x_5(t), x_6(t)$, $x_7(t)$、$x_8(t)$ are [0,1], [0,2], [-0.8,0.8] respectively and initialize randomly in the corresponding range;

(2) Update the particles, of those, $x_1(t), x_2(t), x_3(t), x_4(t), x_5(t), x_6(t)$ are discrete variables, $x_7(t)$, $x_8(t)$ are continuous variables;

(3) Update the random attenuation factor alpha of those, alpha=alpha*gama:

(4) Find the global optimal individual, and update the best individual, calculate fitness value of the adjusted particles. The fitness function is the objective function with constrain, introduce penalty function while it is not satisfy the constraints;

(5) Go to (2) to iterate until the maximum number of iterations.

3. Simulation of household energy optimization control strategy

In this section, we will name all the equipment except batteries and photovoltaic power generation equipment "The basic equipment". Considering the power consumption and comfort, the objective of optimization control is to minimize the power consumption and the cost of comfort. Iteration process is shown in Figure 1.

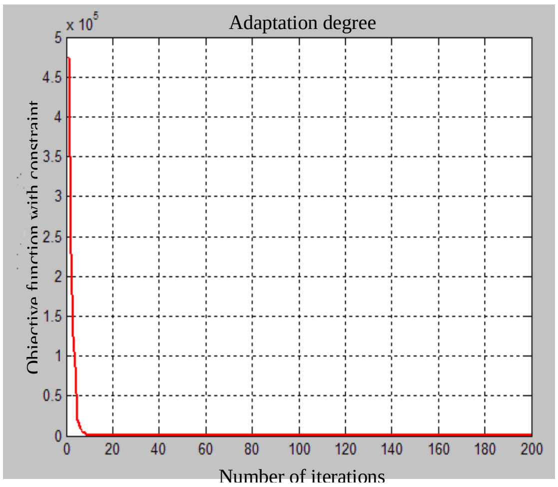

Figure 1. Iteration process

Simulation result of the interactive energy of family and grid is shown in Figure 2, the cost of power consumption: 21.0145 yuan.

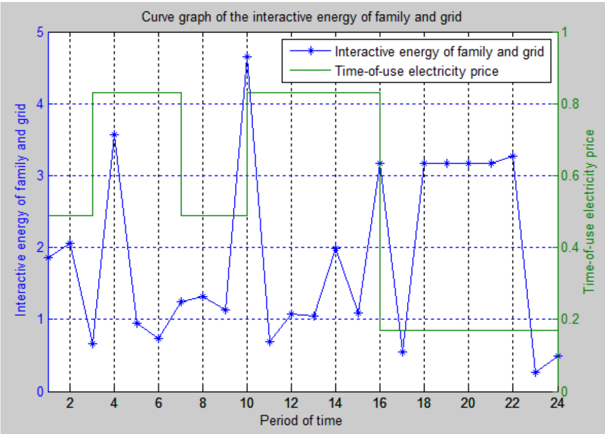

Figure 2. The interactive energy of Family and grid

Simulation result of indoor temperature control is shown in Figure 4, the cost of comfort transformation: 27.9069 yuan.

4. Conclusion

The simulation results have shown that, in the case of considering the grid, distributed photovoltaic power generation, battery powered supply electricity collaborative, home energy optimization control strategy can satisfy the user comfort and minimize the power consumption, which has provided strong technical support to the popularity of home energy management system.

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