Solving Demand Response in Smart Grid Optimization Problem Using Particle Swarm Algorithm

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ABSTRACT

Through the passing of time, Demand Response programs have demonstrated to be a valuable resource option, this is because of its capability of lower the electricity cost by shifting consumers electricity usage during peak periods in response to time-based rates or other forms of financial incentives. In addition, this is a resource that has a big potential of expansion because of the constantly grid modernization. In this paper, we will solve a system optimal (SO) model for demand response in smart grid which objective is to minimize total electricity cost, through the application of Particle Swarm metaheuristic.

KEYWORDS: Demand response, Smart Grid, Particle Swarm

1. Introduction

Nowadays the field of energy production must front many challenges, such as develop new strategies for energy generation, satisfy the demand of their customers, reduction of the industry's overall carbon footprint [1] . In addition, the integration of unconventional methods of obtaining energy and the customers acquisitions of atypical electronic devices, have increased the complexity of the calculation of how much electricity they must load to their customers. However, in the smart grid era, power flows are bidirectional, and consumers can actively contribute towards a more reliable, efficient, and flexible power grid [2], providing an opportunity for customers to participate in the operation of the electric grid, this participation consists in first, the customers can offer an incentive to change their consumption patterns as, direct load control programs, load curtailment programs, demand bidding programs, and emergency demand reduction, the second one is related to energy prices in this kind of participation the consumers are charged with different rates at different consumptions times. Therefore, the retail electricity tariff is affected by the cost of electricity supply [3]. With this participation the enterprises can make that customers modify their electricity consumption achieving this way.

2. Approach to PSO

Particle Swarm Optimization (PSO) is a bio-inspired algorithm introduced by Kennedy and Eberhard in 1995[], the influence was of the design of this algorithm was to reproduce the way that a school of fish or a flock of birds navigate or forage, The PSO algorithm is similar to a search algorithm in that it uses a large population of individuals called particles to find the best solution in a given multidimensional search space. Particles represent potential solutions, and their location represents the value of the objective function to be optimized. Particles continue to search through hyperspace for the best result, in the process particles record the best location given by a fitness function that evaluates if the particle is near to the optimal solution, also if in the movement they are improving, they record the current velocity and direction, finally they compare and define among the particles which global location is the best [].

To give a mathematical approach, in equation (1) I'm going to illustrate the movement that each particle makes to a new position, while they update their velocity [].

$$X_i(t+1) = X_i(t) + V_i(t+1)$$

Where $X_i(t+1)$ is a vector that describes the next position and, $X_i(t)$ represents the current one, also $V_i(t+1)$ the vector´s velocity that shows the upcoming direction and movement intensity of each particle. In addition, the particle´s velocity is stochastically updated by all founded optimal positions of each particle, and by the historical global best position among all particles, we can see this in Equation (2) [].

$$V_i(t+1) = w * V_i(t) + \varphi 1 \cdot r1 \cdot \left(P_{i,best} - X_i(t)\right) + \varphi 2 \cdot r2 \cdot \left(P_{glob,best} - X_i(t)\right)$$

where φ1 and φ2 are positives numbers which represent the acceleration constants, r1 and r2 define the weight factors and $r1, r2 \epsilon [0,1]$, $P_{i,best}$ and $P_{glob,best}$ are the individual and global best particle positions, respectively. It is important to mention that when w, the inertia weight, is equal to one, we are talking about the original PSO algorithm, if is not, we refer to the canonical PSO algorithm [].

These iterations continue until, the particles find a location that is close enough to the desired outcome or the threshold of allowed iterations is exceeded [].

3. Problem Formulation

In this part we are going to show the formulation of the used optimization model, that describes the users' energy consumption based on their behavior, this one explicitly considers users possible preference on convenience over cost-saving, this model was chosen because as they mentioned most DSM literature assumes minimizing cost is the only objective for users, which is unrealistic, because when customers use electricity is mainly driven by convenience, coincident demand occurs, resulting in electric load peaks that greatly increase the generation costs, with this information we are going to present the system model [].

Consider a system with n users and a set of appliances A for each user. Assume each user i has a daily energy demand $D_{i,a}$ for appliance a ∈ A. We define a 24-hour daily cycle with t ∈ T = {1, 2, · · ·, 24}. Further, let $E_{i,a}$ be the maximum amount of energy consumed by user i on appliance a during one unit time, the decision variable $x_{i,a}^{t}$ is the amount of energy consumed on appliance a by user i at time t, and the system model for the energy controller can be formulated as it is shown in the equations bellow:

$$SO: min \sum_{t=1}^{T} f(l_t) \cdot l_t$$

s.t: $$lt = \sum_{i=1}^{n} \sum_{a \in A} x_{i,a}^{t} \quad \forall t$$

$$\sum_{t=1}^{T} x_{i,a}^{t} = D_{i,a} \quad \forall i, a$$
$$x_{i,a}^{t} \leq E_{i,a} \quad \forall i, a, t$$
$$x_{i,a}^{t} \geq 0 \quad \forall i, a, t$$

Where T is the set of time periods indexed by t, l_t are the total electricity loads and $f(l_t)$ represents the unit electricity (generation) cost at time t.

3.1. PSO Parameters.

4. IV. Guidelines for Graphics Preparation and Submission

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[8] W.-K. Chen, *Linear Networks and Systems.* Belmont, CA, USA: Wadsworth, 1993, pp. 123–135.

[9] Philip B. Kurland and Ralph Lerner, eds., *The Founders' Constitution.* Chicago, IL, USA: Univ. of Chicago Press, 1987, Accessed on: Feb. 28, 2010, [Online]. Available: http://press-pubs.uchicago.edu/founders/

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[11] *Motorola Semiconductor Data Manual*, Motorola Semiconductor Products Inc., Phoenix, AZ, USA, 1989.

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[15] D. Ebehard and E. Voges, "Digital single sideband detection for interferometric sensors," presented at the 2nd Int. Conf. Optical Fiber Sensors, Stuttgart, Germany, Jan. 2-5, 1984.

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