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A demand response modeling for residential consumers in smart grid environment using game theory based energy scheduling algorithm

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Abstract In this paper, demand response modeling scheme is proposed for residential consumers using game theory algorithm as Generalized Tit for Tat (GTFT) Dominant Game based Energy Scheduler. The methodology is established as a work flow domain model between the utility and the user considering the smart grid framework. It exhibits an algorithm which schedules load usage by creating several possible tariffs for consumers such that demand is never raised. This can be done both individually and among multiple users of a community. The uniqueness behind the demand response proposed is that, the tariff is calculated for all hours and the load during the peak hours which can be rescheduled is shifted based on the Peak Average Ratio. To enable the vitality of the work simulation results of a general case of three domestic consumers are modeled extended to a comparative performance and evaluation with other algorithms and inference is analyzed.
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1. Introduction

In today's world, the power sector is facing many difficulties due to growing consumption, aging of infrastructure and rising costs. Smart grids promise the energy producers and consumers for a reliable and efficient power system. To impose this idea into real time, several aspects need to be imposed such as proper communication system between consumers and utility providers and efficient energy management to control the system in proper working condition. Metering and billing have to be carried out astutely, as the consumers may be charged for their non-linear load usage. Residential consumers may end up with new tariffs where they will be charged for different types of power usage. Hereafter consumers have to be tech savvy for being economic and environmental friendly. This aspect leads to the concept of Demand Response (DR) [1–3] to play its key role in electricity markets. Demand side management (DSM) refers to programs implemented by utility companies to control the energy consumption at the consumer side [1–3]. The requirements between the energy provider and the customer are coordinated by the Demand Response (DR) strategy [2–6]. The strategy emboldens the customer to reduce the

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peak-demand in response to the incentives. By incorporating DSM techniques at the distribution end of the power system the gap between supply and demand can also be reduced. The major objective of DSM is to encourage customer to participate in schemes to reduce peak demand and shifting the load. One such mechanism is DR, in which the system allows end users to alter their load pattern to reduce the overall peak of the system.

A complete survey on demand response in smart grid with exhaustive analysis of mathematical problems is resolved for future extensions of DR using hierarchy game [2], and coupled constraint game is elucidated. For future aspects, complete analysis and structure of DR schemes start from policies, programs initiated, potential benefits, control devices for demand response, and smart technologies for the scheme. The communication technologies, different monitoring systems, and handling loads in a smarter approach are explained in a nutshell [3,6,7]. The future aspects of the DR are potentially explained by the methods of tracking with advanced control theory with new controllers and optimization methods are elaborated. In recent years, the effective emphasis on game theory approaches on DSM techniques for energy scheduling in residential users had been modeled in different strategies [9–15] with respect to solutions done by heuristic optimization [22] and linear programming techniques [23]. Hitherto, various approaches of game theory approaches on demand side management are analyzed and modeled depicting the major concern of utility user interaction, customer benefits and effective energy scheduling development for reduction of cost. Noncooperative game model considering the channel impairments by developing dual optimality conditions is proposed in [8]. It exhibits different objective functions among the users and the utility by assuming a DSM game. In paper [9] the author formulates energy scheduling problem for residential consumers using coupled constraint game. In this the solution is handled by two cases by temporally coupled constraint. An evolutionary non cooperative game for the users and utility is observed with different constraints of power in a two level game [10] which is analyzed as multiple time constraints are not considered. User comfort in DR is modeled in [11] as a simple approach with a game based on modified regret matching procedure and borrows with the users for reducing the energy bill. A mathematical optimization technique and game theoretic approach are analyzed by the concept of incentive based management presented in [12,13] both for centralized and decentralized schemes. Interaction among the users is formulated in [14] as a repeated game chain in order to solve the issue of discomfort with a game strategy of incentive compatible obtain joint comfort and billing cost minimization. In the proposed games [15,16] authors deal with aggregate game handling to improve the behavior of selfish consumers using proximal point algorithm [15] and cheat proof analysis [16]. In [18] Stackelberg game is approached in order to reduce total in convinces created in consumers achieving load curtailment. Different strategies using game theory approaches and other programming analysis have been analyzed in the past literature exhibiting new strategy for the way of minimizing cost for the consumers and maximizing the peak to average ratio (PAR) for the utility. The strategy used in the past literature exhibits all the versatility of cost minimization, considering tariff schemes, comfort of users and also maximizing PAR. Thoroughly analyzing and understanding the past literature, the authors proposed a novel concept of indulging a situation of DR congestion case with a strategy of reducing cost and maximizing profit. There is a possibility of the DR scheme to go in vain. This strategy is used by incorporating a new algorithm for exhibiting the realization to minimize cost and maximize profit among the users and utility.

The motivation behind using game theory approach on demand response modeling is the understanding of communication between two sources of utility and user. Generalized Tit for Tat (GTFT) based method can reduce the cost between different users which effectively adjourns the case of DR congestion. Tit for tat is traditionally defined as a game played between two players. As in for many players and for highly interact able environment, a better strategy is required. On this effect it is reasonable to model the scheduling by incorporating a cooperative game. In the proposed work the authors handle GTFT mechanism to model the energy scheduling problem in DR modeling. The main objective is to minimize cost and maximize PAR of the utility.

The main contributions of the model are as follows:

- A generalized tit for tat based cooperative energy scheduling game is proposed in a smart grid environment.
- A very simple and feasible solution is obtained by handling the cost reduction and PAR maximization overall.
- Extensive simulations are carried out by developing this algorithm in hold with the strategy of win stay lose shift for the consideration parameter of managing DR congestion.
- The past literature has invoked different algorithm approaches considering the cost, comfort and PAR. The condition of DR congestion is not handled. However developing a DR scheme is necessary in a smart grid environment for energy savings. But the necessity of holding the scheme is successfully evaluated in this algorithm using mainly the strategy done by the consumers.

Fig. 1 exhibits the hand in hand gesture of information technology and electrical scenario in the present technological generation. This enables the utility and the users to actively engage in these DR programs. In this paper a new methodology is proposed between the utility provider and the user using game theory decision making strategy. The main objective is to develop a DSM using a game theory algorithm providing different optimum pricing schemes for each user under the utility provider. The algorithm depends basically on each user deciding on their own winning strategy and secondarily on all other participant individual decisions. Furthermore, in order to reduce demand, the utility company will announce the demand period. Hence users will avoid using loads at peak time using DR programs. Consider a situation where electricity is cheap at 10:00 am. Most customers will switch on their appliances at this time thus increasing the demand and thereby defeating the purpose of DR program. Simulation results with MATLAB and computational simulation domain show the effectiveness of the decision making scheme by the consumers with utility provider and work dynamically for different analysis of user profile.

The outline of this paper is structured as follows. Section 2 explains the background of game theory and the proposed methodology. The flowchart and implementation steps of methodology with problem statement with mathematical

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