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A New Heuristically Optimized Home Energy Management Controller for Smart Grid

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Abstract—Recently, Home Energy Management (HEM) controllers have been widely used for residential load management in a smart grid. Generally, residential load management aims to reduce the electricity bills and also curtail the Peak-to-Average Ratio (PAR). In this paper, we design a HEM controller on the basis of four heuristic algorithms: Bacterial Foraging Optimization Algorithm (BFOA), Genetic Algorithm (GA), Binary Particle Swarm Optimization (BPSO), and Wind Driven Optimization (WDO). Moreover, we proposed a hybrid algorithm which is Genetic BPSO (GBPSO). All the selected algorithms are tested with the consideration of essential home appliances in Real Time Pricing (RTP) environment. Simulation results show that each algorithm in the HEM controller reduces the electricity cost and curtails the PAR. GA based HEM controller performs relatively better in term of PAR reduction; it curtails approximately 34% PAR. Similarly, BPSO based HEM controller performs relatively better in term of cost reduction, as it reduces approximately 36% cost. Moreover, GBPSO based HEM controller performs better than the other algorithms based HEM controllers in terms of both cost reduction and PAR curtailment.

key Terms: Real time pricing, home energy management, scheduling, heuristic algorithms, peak to average ratio

I. INTRODUCTION

The ever increasing energy demand has created problems like blackout, load shedding, voltage instability, frequency drop, etc. As a solution, two approaches are nowadays in practice: (i) increasing the generation capacity, and (ii) managing the load according to existing power generation capacity through Home Energy Management (HEM) system [1]. The earlier approach majorly depends on the installation of new power generation substations. In the later approach, Demand Side Management (DSM) programs are utilized which aim to manage the load according to existing generation capacity through scheduling techniques. In fact, the scheduling techniques are optimization algorithms for managing the load between on-peak hours and off-peak hours while taking into account user and utility requirements. Substantial research efforts have been made to investigate the scheduling problem in the residential sector (refer to Fig. 1 for a pictorial view of the residential area based smart grid). For example, the authors in [2] used Mixed Integer Linear Programming (MILP) to schedule residential appliances. They integrate Photovoltaic (PV), storage, lighting, heating and air conditioning systems. Case study results show a reduction in cost and Peak-to-Average Ratio (PAR), however, system complexity is increased. In [3], Mixed Integer Non-Linear Programming (MINLP) is used to schedule appliances belonging to multiple classes. Similarly, in [4], [5] MILP and MINLP are used for appliance scheduling to reduce the electricity cost. In [6], Bacterial Foraging Optimization Algorithm (BFOA) is implemented for resource scheduling problem in grid computing aiming at electricity cost minimization. MINLP and Genetic Algorithm (GA) are used in [7] for controlling home appliances. The authors in [8] use GA for scheduling in residential appliances subject to electricity cost reduction. In [9], Binary Particle Swarm Optimization (BPSO) is used for scheduling interruptible load. Their simulation results verify the effectiveness of BPSO in terms of electricity bill reduction and energy profile stability. Similarly, [10] studied load shifting techniques in HEM system by using Particle Swarm Optimization (PSO). Cost and energy minimization were the objectives of this study. A comparative study of PSO and Wind Driven Optimization (WDO) is conducted in [11] to solve the problem of residential load management. The simulation results show that the performance of WDO is better than PSO in terms of user comfort and electricity cost reduction.

The mathematical techniques like MILP and MINLP are quite beneficial but at the cost of high computational complexity [2], [7]. On the other hand, heuristic algorithms (e.g., GA, BPSO, and BFOA) are flexible for specified constraints, easy in terms of implementation and have low computational complexity [12]. In this paper, we use four heuristic algorithms; BFOA, GA, BPSO, and WDO to solve the load scheduling problem. We choose these algorithms due to their self-organization, self-optimization, self-protection, self-healing and decentralized control system [12]. These algorithms are tested with the simulative consideration of a HEM system in Real Time Pricing (RTP) environment. Simulation results show that each algorithm is capable of reducing cost and PAR in comparison to the unscheduled load, however, there is a trade-off between cost and PAR in
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