# Demand Side Optimization in Smart Grid Using Harmony Search Algorithm and Social Spider Algorithm

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**Abstract.** Electricity is a valuable resource. With the increase of population, this valuable resource is being used inefficiently. To overcome this problem, electricity providers use various techniques like introducing different pricing schemes. In peak hours, when the usage of electricity is high, the utility increases the per unit cost. Therefore, usage of electricity in peak hours result in high electricity bills. The electricity bills can be reduced by efficiently scheduling the home appliances so that few appliances are operated during peak hours. For this purpose many techniques have been proposed. In this paper, we propose a Social Spider Algorithm (SSA) for Demand Side Management (DSM). Harmony Search Algorithm (HSA) has been adapted to evaluate the results of SSA. These algorithms schedules the appliances in such a way that the usage of electricity in peak hours is reduced. This results in reduction of electricity bill and Peak to Average Ratio (PAR).

## 1 Introduction

Electricity is one of the fundamental needs in the current era. Most of the things we see around us are powered by electricity. The number of devices that use electricity to operate are growing day by day. This is because things are becoming smart and computer-operated. The traditional grid system does not provide any communication system between the utility and consumers. This causes many problems. The users are unaware of the prices and the utility is unaware of the demand of the users. This lack of communication can cause many problems like high electricity bills, high peak hour usage, etc.

Smart Grid (SG) [1] overcomes the drawbacks of the traditional grid system. SG has the ability of monitoring the grid and incase of any failure it can heal itself. In SG, the flow of electricity and communication is bi-directional. The bi-directional communication keeps the users and the utility updated of the usage and demand. The bi-directional flow of electricity is a key element in the SG. In SG, users can generate their own power using solar panels or any other


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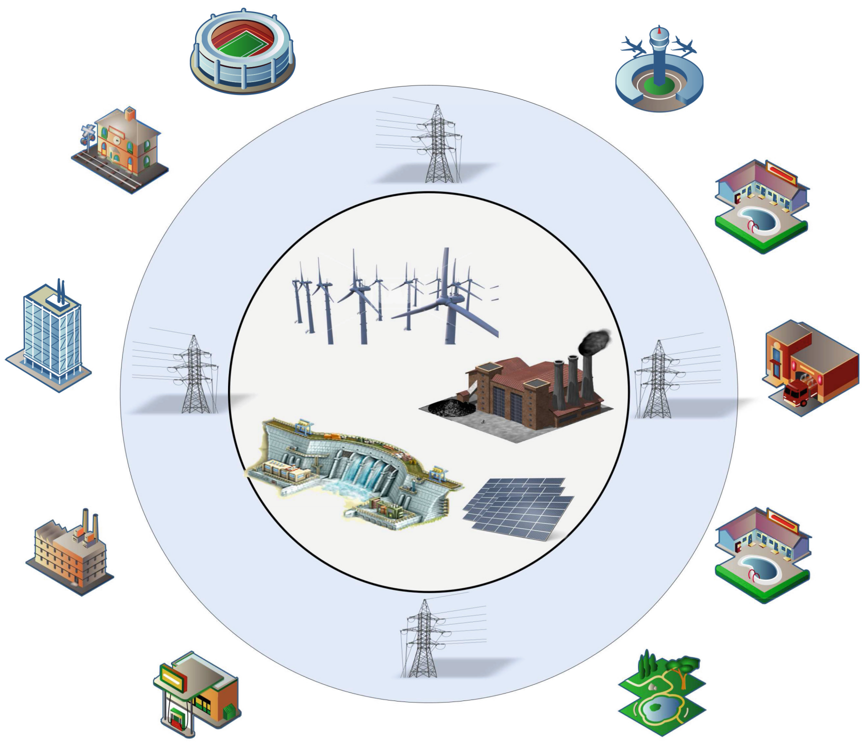

**Fig. 1.** An overview of Smart Grid

resources like mini-hydropower plants or wind. When the electricity exceeds the user demands, the users can then sell the extra electricity. This can be done by pushing the excess electricity back to the grid. Another advantage of sending electricity back to the grid is to enable the utility to meet high electricity demand (Fig. 1).

High demand of electricity at a specific time creates peak usage at that specific time. This peak is because the demand of electricity is higher than that available. To reduce the high demand, power to some areas is cut from time to time. This is called load shedding. In severe conditions where the demand is very high, the transmission grid might collapse. This might result in blackouts. To ensure reliability of the transmission grid, DSM [2] is used. DSM is the management of the load used by the consumers. DSM motivates users to shift their loads from peak hours to off-peak hours to avoid peak formation. However, inefficiently shifting loads may create peak usage at another time. Therefore, in DSM, efficient shifting of load is necessary. This is achieved by Home Energy Management Systems (HEMS). HEMS schedules the load according to the data received from the utility. Hence, reducing the electricity bill and the PAR.

## 2 Related Work

With the increase in population, the number of electric appliance required to fulfil the needs of humanity is also increasing. This increasing number of appliances require large amount of electric power. The traditional power grid system is unable to manage such high load requirements. This results in the increase in Peak to Average Ratio (PAR), which in return results in high electricity bills and power blackouts.

For this reason, researchers have proposed many Supply Side Management (SSM) and DSM techniques. These techniques help in reducing the total power consumption, PAR and electricity bills while increasing the user comfort. Some of the proposed techniques are discussed below (Fig. 2).

In [3], Integer Linear Programming (ILP) has been used for DSM. The main objective is to decrease the maximum load by reducing the peak hour usage. Three appliances are taken into consideration, non-shiftable, time-shiftable and power shiftable appliances. Non-Shiftable appliance are supplied with continuous power. The time shiftable appliances require a fixed power for some time slot. The controller can schedule the appliance at any time period but should provide it the fixed power that it requires. The power shiftable appliance can operate with a flexible power. They can be scheduled with a fixed power throughout the day, subject to the condition that they are provided the daily required power. Simulations are carried out for single and multi-home scenarios and the effects are discussed. However, UC and pricing signal have not been taken into consideration. In [4], authors have used heuristics techniques and proposed a hybrid

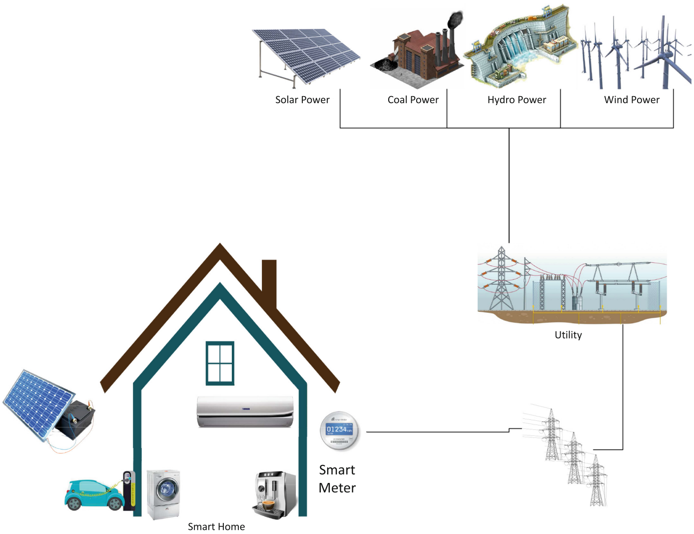


**Fig. 2.** Home Energy Management System

technique called Genetic Wind Driven (GWD) optimization. Real Time Pricing (RTP) scheme has been used as a pricing scheme. Authors have conducted simulations for single and multiple homes. The main objective is to maximize user comfort while minimizing cost and PAR. However, simulations show that there is a tradeoff between UC and PAR. In most cases, the UC is compromised from 50 to 90% in different techniques. Kai Ma *et al.* [5] have proposed their own optimization technique. Authors have discussed two types of appliances. The first type of appliances have flexible starting time and can be shifted in the scheduling horizon while the second type of appliances have flexible power rating. The electricity cost can be reduced if the starting time of the appliances is delayed to the time where the price is low. However, the user comfort will be affected in this case. If we consider the user comfort the electricity cost will increase. Therefore, the authors have proposed a scheme in which both UC and electricity bill has been considered. PAR has not been considered because there is a tradeoff between PAR and UC.

Samadi *et al.* [6] have discussed the side effects of the RTP Scheme. According to the authors, while using RTP, most of the load will be shifted to the time where the electricity price is comparatively low, thus increasing the PAR in the low cost time. This may result in high demand from the utility and maybe blackouts. Therefore, the authors suggest that a RTP combined with Inclined Block Rate pricing scheme is necessary. For scheduling the appliances the authors use Genetic Algorithm because other optimization techniques like PSO and game theory are non-linear. In [7], Zhuang Zhao *et al.* have discussed the EMS in home area network. The main objective is to reduce the electricity cost for the consumer and the PAR. RTP with IBR has been used as a hybrid pricing scheme. UC has been compromised in an effort to reduce cost and PAR.

In [8], authors proposed a scheme for balancing the user-comfort and electricity price keeping in view the user budget. PAR has been ignored. The main target of the authors is cost per unit satisfaction. Genetic Algorithm (GA) has been used because of its efficiency, convergence speed and flexibility and because GA searches for a globally optimal solution. In [9], authors have discussed the inefficient power consumption in industrial and residential buildings which leads to power blackout. GA techniques has been used and a reduction of 21.91% in PAR has been observed. The authors have not used any pricing scheme. Therefore, electricity cost has not been taken into consideration.

In [10], authors focus on the integration of RES to reduce the use of natural resources. Multi Knapsack Problem has been used using GA, binary particle swarm optimization and ant colony optimization. Authors say that in previous researches the of power consumption and user comfort have been ignored in previous studies. Three types of home appliances have been taken into consideration: fixed, shiftable and elastic. However, the author have ignored the initial installation cost of the RES and the maintenance cost.

In [11], RES with energy storage system has been introduced. The authors have used photovoltaic along with storage batteries. Using this technique, the load from the power grid and PAR has been decreased. But the effect on electricity cost and the cost of RES and energy storage system has not been addressed by the authors. Kanzumba *et al.* [12] have discussed Hydro Kinetic (HKT) system and battery storage system for generation and storage of power respectively. Time of Use (ToU) tariff has been used here. The main purpose here is to minimize the electric cost by maximizing the use of power generated by the HKT system. The HKT system supplies power to the load. If the load is less than the power generated by HKT then the extra power is stored in the batteries or sold to the grid depending on the state of the battery. In case the power supplied to the load is less than that generated by the HKT then the extra power is gained from the battery or the grid. The battery can also be charged from the power grid in off peak hours. Using this strategy, the electricity bill has been reduced. The UC has not been effected in any way, because of continuous power supply either from HKT, battery of the power grid. However, it would have been better if the charging of the battery from the power grid had been considered as it might affect the PAR because the battery is being charged in the off peak hours. If many consumers do so, it might affect the utility negatively. Moreover, the installation and maintenance cost along with the maintenance complexity of the HKT system has not been considered.

## 3 Problem Statement

The population of the world is increasing day by day. Ultimately, the usage of electricity is also increasing. Maximum usage of electricity by consumers create peaks in the usage of electricity. The time at which these peak are created are called peak hours. Peak hours are a problem for the stability of the utility. A utility can provide a specific amount of electricity per unit time. If the demand increases, blackouts are created. There are two ways to tackle this problem. The first is to increase the power generation. The second is to manage the consumer load in such a way that the demand at a specific time is less than or equal to the distribution. Since increasing the generation is not easy, therefore the utility increases the price of electricity in peak hours. This may result in higher electricity bills. This encourages the consumers to shift their loads to off-peak hours where the prices are comparatively low. Manually managing this load shifting is not easy. An Energy Management Controller (EMC) tackles this difficulty. An EMC schedules the appliances keeping in view the prices throughout the day and the usage constraints of the appliances.

## 4 Proposed Scheme

### 4.1 Classification

In SG, an EMC schedules the appliance according to their use. Here, we classify the appliance into two categories: base and shiftable appliances. These type of appliances are explained below.

#### 4.1.1 Base Appliances

These appliances are also known as fixed appliance because their operation time cannot be changed. For example, lights, fans, iron, toaster, microwave oven and coffee maker. The time slots of these appliances cannot be shifted.

#### 4.1.2 Shiftable Appliances

These devices are also known as Interruptible devices because their time slots as well as their length of operation can be modified. Example of these type of devices are air conditioner, refrigerator, water heater and space heater. These devices take part in the scheduling process.

**Table 1.** Load and time slots of appliances

| S.no | Appliance | Category | Power rating | Time slots |
|---|---|---|---|---|
| 1 | Air Conditioner | Shiftable | 1.44 | 10 |
| 2 | Refrigerator | | 0.73 | 16 |
| 3 | Water Heater | | 4.45 | 10 |
| 4 | Space Heater | | 1.50 | 11 |
| 5 | Lightings | Base | 1.8 | 9 |
| 6 | Fans | | 0.5 | 16 |
| 7 | Clothes Iron | | 0.8 | 8 |
| 8 | Microwave Oven | | 0.78 | 8 |
| 9 | Toaster | | 3.60 | 5 |
| 10 | Coffee Maker | | 4.40 | 9 |

### 4.2 Pricing Scheme

Different electric providers use different pricing schemes. In this case, we will use RTP pricing scheme. In RTP scheme, the smart meter obtained real time prices from the utility from time. The smart meter is connected to the EMC. The users can view the RTP prices from the EMC and can schedule their appliances accordingly.

### 4.3 Techniques

In SG, many techniques have been proposed to handle different problems. Many evolutionary algorithm have been used to schedule the appliances to get optimized results. In this paper, we will use HSA and SSO to schedule our appliances. We will compare the results of both the optimization techniques to study their optimization effect.

#### 4.3.1 HSA

Inspired from musicians, HSA [13] has been used in SGs for optimization. Musicians play random notes. These random notes are called Harmony Memory (HM). Now considering this HM, the musician plays another random note. If this note is better than the previous one, the musician replaces it in the HM. Similarly, HSA follows three steps: random HM generation, play based on the HM and finally pitch adjustment.

#### 4.3.2 SSA

SSA is a swarm optimization techniques which was introduced by Cuevas *et al.* [14] in 2013. It has been inspired by the social interaction of the social spiders. In a spider communal web, there are 2 types of spiders: male and female. The females comprise of about 70% of the web. The rest 30% are males. The males with the higher weights are called dominant males. The female spiders show attraction or dislike toward the dominant males based n their weight.

## 5 Simulations and Results

In this section, the results of the simulation are discussed. Simulations have been carried out to evaluate HSA and SSA. Hourly load, electricity cost, PAR and UC have been evaluated in each case. The simulations have been carried for a single home with 10 appliances [10]. Table 1 shows the appliances, their power ratings and length of operation. RTP pricing scheme has been used for calculating the electricity bill.

The hourly load of the appliances can be seen in Fig. 3. We can see that the unscheduled load create peaks in some places. These peaks result in increased PAR. After applying HSA and SSA techniques, we can see that the peaks have been shifted evenly. This results in reduction in PAR.

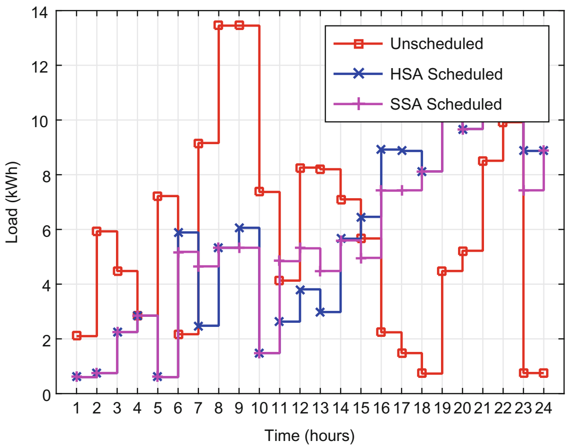


**Fig. 3.** 24 h Load

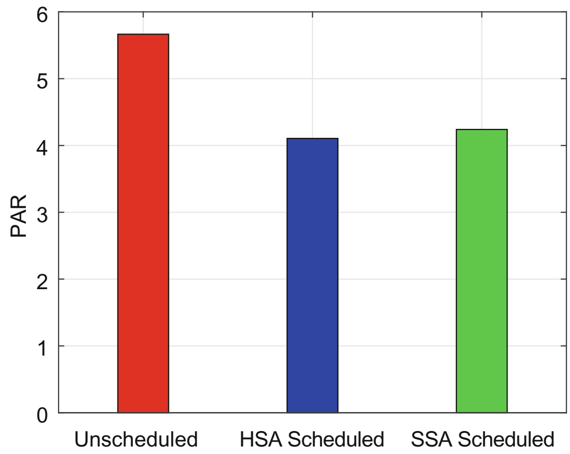


**Fig. 4.** PAR

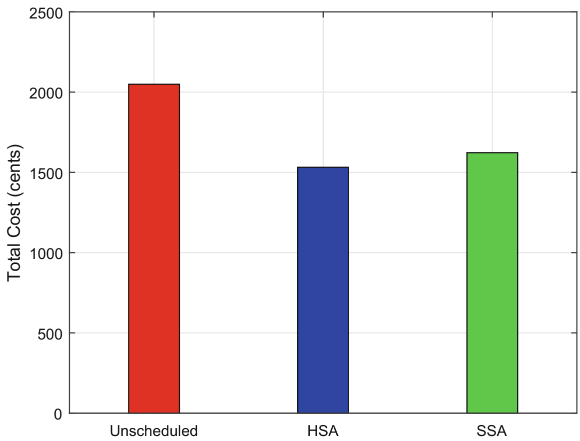


**Fig. 5.** Total cost

As discussed, after applying HSA and SSA techniques, the load is evenly distributed causing reduction in PAR. Since, we have 6 fixed appliances that cannot be shifted, therefore the PAR is slightly reduced. We can see that with a slight difference, HSA and SSA reduces PAR by 27.52% and 27.011% respectively. This difference can be observed in Fig. 4.

We know that both the algorithms work in such a way to shift the appliances from the peak price slots to the off-peak slots. Therefore, it is obvious that the scheduled cost will decrease from the unscheduled cost. This can be seen in Fig. 5. We can see that HSA reduces the cost by 25.03%, whereas SSA reduces the cost by 22.56%.

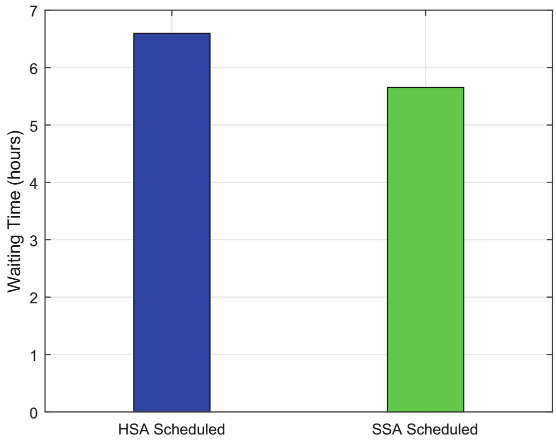


**Fig. 6.** Waiting time of shiftable appliances

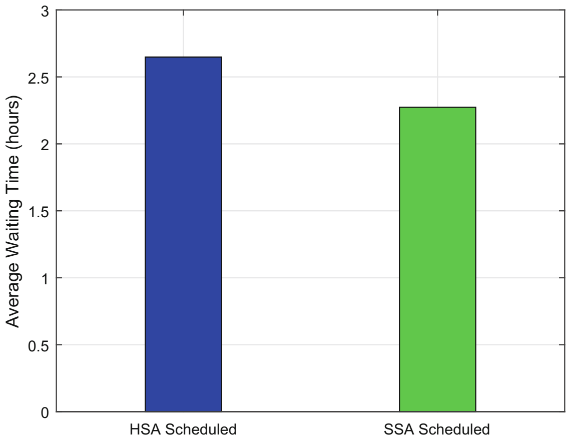


**Fig. 7.** Average waiting time of HSA and SSO

We know that there is always a tradeoff between electricity cost, PAR and UC. Since our objective is to reduce the electricity cost and PAR, therefore the waiting time will increase. This means that UC will decrease. In Fig. 6, we can see that the average waiting time of HSA is 2.6380 h. While the waiting time is 2.3724 h incase of SSA. This means that SSA does not effect the UC too much. The average waiting time can be seen in Fig. 7, which is 2.31 h incase of SSA.

## 6 Conclusion

In this paper, we introduced a SSA algorithm for DSM. Simulations have been performed for both SSA and HSA. The results of SSA have been compared with the results of HSA. Simulations show that in our scenario HSA performs slightly better than SSA in terms of reducing electricity cost and PAR. However, the average waiting time of HSA scheduled appliances is higher than that for SSA scheduled appliances. This means that compared to HSA, SSA reduces the cost and PAR without effecting the UC too much. So we can conclude that SSA is able to balance the tradeoff between PAR, electricity cost and UC.

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