Pakistan Journal of Engineering and Technology, PakJET
Multidisciplinary | Peer Reviewed | Open Access
Volume: 2, Number: 1, Pages: 9- 17, Year: 2019

Demand side Management for SMART Grid

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***Abstract*—**In this paper, we are going to suggest a prominent feature of smart Grid i.e. Demand side management. Smart grid is up to date facility used for bi-communication system of Generation, transmission and consumption. The fundamental principle of smart grid is demand response analysis. For supposition, we focus on three type of frequently used load which are base, continuous and discrete load. A sufficient volume of load in the form of diversified appliance of different power rating would be considered. Our main objective is the reduction of peak to average ratio enhances the efficiency of smart grid. For this, a revived scheme of electricity consumption pattern is required keeping in consideration reliability, feasibility and user preference. Subsequently, it will decrease the electricity production and consumption cost. Increasing the number of appliances would complicate the problem to some extent so making it more challenging. In theoretical work small numbers of appliances are taken. Genetic algorithm would be used to solve this specific problem. Simulation results would show the prove that there is an ultimate reduction in the cost by using the algorithm.

Index Terms—Genetic algorithm; Load scheduling; Smart grid; Energy management; Demand side management.

I. INTRODUCTION

Integration of latest communication and control techniques in the traditional grid system for the efficient way of transmission and distribution of electricity is called smart grid. Two main objectives are reduction in electricity cost by effective load management technique and decline in global warming by subsequent reduction in carbon emission. Demand side management is the prominent feature of smart grid for load management. Another unique feature of smart grid is dynamic pricing through the use of smart meter and automatic metering techniques; load in accordance to dynamic pricing scheme can be managed easily.

Dynamic pricing scheme are widely used to bring efficiency in grid system. Through pricing signal, user is enabled to modify its schedule. Keeping in consideration the next pricing scheme. This integration of dynamic pricing and user response. Primarily serve the reduction in peak to average ratio (PAR). For this different pricing scheme like Day-ahead pricing. Times of use, peak hour pricing or Real Time Pricing are used. All of these are expected nature except Real Time Pricing (RTP).

It is also very effective from market point of view. Change in the consumption pattern alters the electricity prices accordingly. Thus, the whole system brings the economy of production. The desired pattern of the load shape and the power network is achieved by the modification of consumer pattern through demand side management. Consequently, the load, with the user will. Is shifted from peak hour to off-peak hours, to reduce the cost.

Normally we apply six methods to shape loads of different types. These are peak clipping, valley filling, load shedding, flexible load shape, strategic conservation and strategic load growth.in peak clipping and valley filling method load is reduced by shifting it from peak to valley .by manipulating demand at consumer end, load demand is reduced in strategic conservation [1] method. Contrary to it, in strategic load growth [1-3] method demand is produced in off-peak hour that is at valley.in strategic load growth demand is modified only for those customer whose consent has attained and are ready to take part in DSM modeling. In case of load shedding we shift the load from peak hour to off-peak hour through scheduled load shedding

II. RELATED WORK

In [4] the role of communication technologies resources in the development of demand side management of a smart grid is discussed. Communication technologies are different from traditional computation in a way that they can easily map the applications separately. In Demand side management (DSM) we generally focus on the economic efficiency of the given system. A novel cost oriented optimization model is proposed to map the cloud computing resources in the cost efficient way. Uncertain factors are also considered in this research work which may include load prediction and unavailability of computing instances.

In [5] the price based and reward based approaches are used to propose the demand side management scheme of the cyber-physical smart distribution system. The fundamental objective is to maximize the profit. This research work also left consumers to choose economic criteria. The proposed frame work is being evaluated using IEEE 37 bus test system.

In [6] the contribution of renewable energy source along the demand side management (DSM) scheme of the grid is studied. Day ahead optimization process is used to reduce the monetary expenses of the consumers. The proposed algorithm is tested in a realistic scenario.

One of the key factor of demand side management (DSM) scheme is discussed in [7]. Demand response is a key factor of demand side management. In demand response strategy the consumer described its load plan to the supplier discussed the price scheme with the consumers.

Both parties are the beneficiaries in this scenario. it reduces the overall bill thus an incentive for consumer. It also helps to lessen the peak to average ratio which is beneficial for the supplier. As the additional power sources are not required and the fuel cost can be saved.

In [8] the monitoring of energy meters by using ‘Internet of Things’(IoT) is discussed. In this way supplier can buy surplus energy from consumer. In this work dynamic pricing problem is achieved by a convex optimization problem. In this research work it is proved that the energy is distributed in the system in an efficient way.

In [9] an instantaneous load billing scheme attracts the consumer to shift their load from peak hour to the off-peak hours. Condition for the existence of Nash equilibrium is also analyzed through this paper. In this research work there is no concept of central unit. Consumer share information with their neighbor by using distributed synchronous agreement based algorithm and gossip based algorithm.

In [10] a smart architecture is proposed to manage the load in smart buildings. The architecture is composed of the layered structure. Hence it allows the seamless integration of diverse techniques for optimal scheduling and dynamic pricing. The results are generated by using Matlab and the efficiency of the proposed work is confirmed.

In [11] in order to maintain coordination between consumer and supplier a new energy price scheme is put forward. We minimize the difference between the value and the cost of energy by an entirely new objective function. The main objective is to minimize the peak to average ratio (PAR). The performance is finally evaluated through computer based simulations. In [12] to evaluate demand side management (DSM) a methodology is proposed based on elasticity and time of use pricing concepts.

In [13] an optimization problem is suggested to minimize the price of consumption. An algorithm is proposed in a way that if minimizes the consumer’s wait time and by doing so it enhances the consumer’s comfort level.

In [14] the overload problem in thermal generation is addressed by hybrid distribution methodology. In this research work for power flow management, demand distribution along with demand response is controlled. The control action is evaluated through companies.

In [15] an instantaneous load billing scheme is adopted to attract the consumers. The objective function is implemented by analyzing the conditions for the existence of Nash equilibrium.

In [16] the concept of zero energy building is discussed. Renewable energy is supplied by using solar panel which also has the connection with grid. A control system controls the electrical technical building system.

In [17] the paid scheme of the user depends upon the energy profit of the consumer. Distributers put their maximum effort to diminish the difference between the instantaneous energy demand and average demand of the power system. By the game theory methodology user voluntarily cut down their consumption cost.

The minimization of peak to average ratio (PAR) of the load is accomplished by real time pricing scheme [18]. The user and the distributor communicate with each other to find the optimal prices. By doing this, the supplier can overcome the uncertainty of the load attached by the consumer and user can estimate the price of the energy consumed by the attached load.

In [19] the importance of smart grid (SG) over the traditional grid is described. Smart grids have some features which are not present in traditional grids like intelligence, adaption and flexibility to reduce the effect of outages in the society. An optimized methodology is discussed in this paper which increases the robustness of the smart grid (SG).

III. PROBLEM FORMULATION

Different types of appliance have different energy consumption. Each appliance shares the information of its type with energy management controller (EMC) which the schedule them accordingly. Price signal is supposed real time in nature, we multiply the hourly price signal with the energy utilized by the consumer at that time slot. So, the cost of energy consumption is given by following expression

Minimize

$$\sum_{t=1}^{24}\sum_{a=1}^{n}\sum_{b=1}^{m}\rho_{ab}(t)\times \text{ƞ}_{ab}(t)\times\omega(t) \ldots.1$$

Subject to

$$\sum_{t=1}^{24}\sum_{a=1}^{n}\sum_{b=1}^{m}\rho_{ab}(t)\times \text{ƞ}_{ab}(t)\leq \text{ʑ}(t)\ldots..2$$

$$\sum_{t=1}^{24}\sum_{a=1}^{n}\sum_{b=1}^{m}\rho_{ab}(t)=OPT_{ab}\ldots\ldots.3$$

$$\beta_a\leq 24-OPT_a \qquad \forall\ DL \ldots\ldots\ldots\ldots 4$$

$$\beta_a^s\leq\beta_a\leq\beta_a^s+OPT_a \quad \forall\ CL\ldots\ldots\ldots5$$

$$\beta_a=\beta_a^s \qquad \forall\ BL \ldots\ldots 6$$

$$\nabla_{Scheduled}<\nabla_{Unschedule} \ \ldots\ldots\ldots\ldots7$$

$$\partial_{Scheduled}^{T}=\partial_{Unscheduled}^{T}\ldots\ldots\ldots\ldots8$$

$$\epsilon_{min}\leq\ \epsilon\leq\epsilon_{max}\ldots\ldots\ldots\ldots\ldots\ldots\ldots..9$$

$$\partial(t)-\ \epsilon(t)>0\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 10$$

$$\rho\in\{0,1\}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..11$$

$OPT_{ab}=duty\ cycle$

$\text{ƞ}_{ab=}$ Power utilized by the appliance a of type b

ρ_{ab} ON/OFF state of appliance a of type b

$\omega(t)=price\ during\ time\ interval\ t$

ʑ(t)= max. Power limit at time interval t

$\beta=peak\ load$

$\epsilon=energy\ from\ RES$

Equation 2 represents that the energy consumption at that time is less than the maximum power limit at time interval ‘t’ resulting reduction in peak to average ratio. The length of operational time will be equal to ON/OFF state of appliance is represented by equation 3. Equation 4 shows that the discrete load can be scheduled in any time slot of the whole day. Equation 5 shows that for continuous load duty cycle is not interruptible. It means, once a load is connected, it cannot be removed unless it completes its duty cycle. Equation 6 shows that for basic load, there is continuous duty cycle throughout the day consequently we cannot apply demand side management (DSM) scheme here or load cannot be shifted.

Equation 7 shows that the peak of scheduled load is less than the peak of unscheduled load. Equation 8 shows that total load connected remain same whether applying algorithm or without algorithm. Equation 9 shows that the energy from renewable source will be greater than minimum load energy and less than maximum load energy. It means some power needed from wapda. Equation 10 shows that the difference between total connected load and renewable energy source will be positive. It means we cannot sale energy to wapda but we buy energy from wapda while equation 11 shows that the state of appliance whether it is in ON state or OFF state.

IV. PROPOSED ALGORITHM FOR DSM

Chromosomes of the population represent a viable solution to our problem i.e. it would be our main concern. Chromosomes represent the array of bits whose length is equal to number of appliances. Status of each bit demonstrates whether the appliance is ON/OFF. The number of controllable appliance which represents the length of chromosome is represent by ‘N’. Following are the major steps of Genetic Algorithm (GA).

Initial Population:

It is the first step towards Genetic Algorithm. User preference is the factor upon which the variation of dimension of initial population depends upon. There is a direct relation by the accuracy of solution and the number of population. However, increasing the population brings more complication to the algorithm. Suppose the initial population is M×N where 'M' is the population size and 'N' is the number of appliance.

Fitness Evaluation:

At this stage, fitness evaluation is done for each chromosome. For the purpose of representation, we suppose a chromosome [1 0 1 0 1 0 0] in which the status of 1st, 3rd and 5th is ON whereas the 2nd, 4th and 6th is OFF according to objective function. The appliance which has the ON-status in the array would be multiplied with their respective energy consumption. The result is then accumulated and overall electricity bill is calculated. For the next evaluation, we select that particular chromosome pattern which has the minimum electricity cost. Fitness function is calculated by the following expression

$$\text{Fitness}=\sum_{t=1}^{24}\sum_{a=1}^{n}\sum_{b=1}^{m}\rho_{ab}(t)\times \text{n}_{ab}(t)\times\omega(t)$$

Selection:

We use the random population only to initialize the process then the selected pattern is used for the further reference. New population can be generated by the process of crossover and mutation; new offspring is obtained from parent chromosome. Once again the fitness evaluation is performed here. Various methods can be applied for this selection but for this specific model, we will use tournament based selection method.

Crossover and Mutation:

Crossover and mutation can be done by various methods. Here we apply binary mutation and single point crossover. This is because of the discrete nature of our scheduling problem. Convergence point is the point where algorithm gets its optimal solution. Crossover and mutation are the two step which determine the point of convergence

Rate of crossover is directly proportional to the speed of convergence whereas there is an inverse relationship between the mutation rate and speed of convergence.

Elitism:

It is not necessary that we obtain the solution after the procedure of mutation and convergence. It might be possible that we get the optimal solution at the 1st step by random generation of the population. There is also probability that we lost optimal solution after the step of crossover and mutation. In this way elitism make it possible to keep the solution for the next population.

In this way, till the end result, it not only does the comparison but maintain its status. Following is suggested Demand Side Management (DSM) algorithm. The algorithm of DSM is as follows.

Table 1: Parameter of GA

Parameters	Value
N	6
Maximum generation	500
Size of population	200
P_C **(Crossover Rate)**	0.7
P_m **(Mutation Rate)**	0.3

V. CHARACTRISTIC OF THE SG

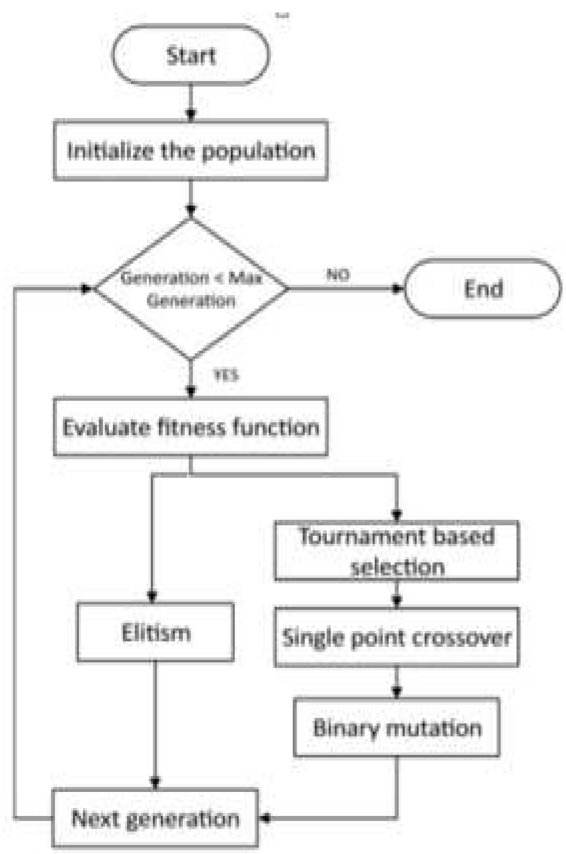

Figure 1: Flow Chart

There are different types of loads which can be controlled. Following are there details.

A. Domestic Area

In this case, we will consider a domestic consumer consisting of various type of load. In table 2 there are various load parameters; real time price signal is taken from [20] as shown in figure. Generally, we observe small duty cycle and low rating of power consumption at domestic level. Following is chart of appliances with different rating category in table 2.

Table 2: Parameters and Energy

Load Type	Loads	OPT(t)	Energy consumption (KWh)
Base Load	Load 1	20	1.6
	Load 2	24	0.6
Discrete Load	Load 3	5	3.6
	Load 4	4	1.5
Continuous Load	Load 5	11	6.5
	Load 6	8	1.7

VI. SIMULATION RESULTS

Different simulation results offer wide scope of manipulation of data and DSM application. Thus it will optimize the cost and PAR. In addition, SG pricing scheme is same for different types of users. When offered price is low, scheduled load is maximum through RTP signal thus reduction in bill of electricity.it is evident that by efficient load shedding regular basis electricity bill is reduced from 1685 $ to 1535$ per day resulting 8.90% reduction on daily basis. While the reduction in peak load from 2.735 KW to 1.835KW resulting in about 32.90% reduction in peak load Number of appliances that are controllable at residential are more than that of commercial. Thus RTP is more effectively applied at residential level as is evident from results.

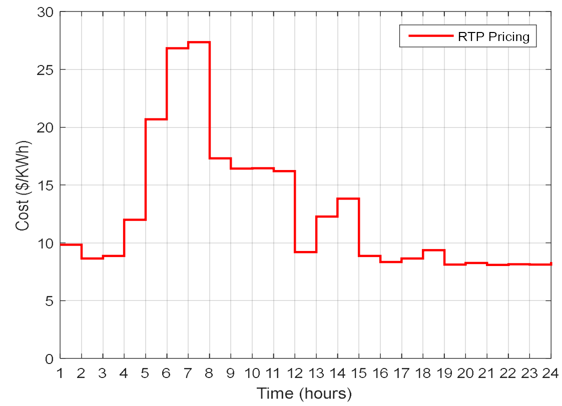

Figure 2: Real Time Price signal

Figure 3 elaborate the waiting time of appliances. Continuous load comprises of those particular appliances which have specific duty cycle and their duty cycle is not interruptible. It means, once a load is connected, it cannot be removed unless it completes its duty cycle. Those appliances whose duty cycle can be interrupted comes in the domain of discrete load. In this way, we can schedule continuous load at any time slot throughout the day subject to completion of its duty cycle which is equal to switched 'ON' time of appliance. Consequently, continuous load has maximum wait time. Discrete load has the waiting time in between of those two.

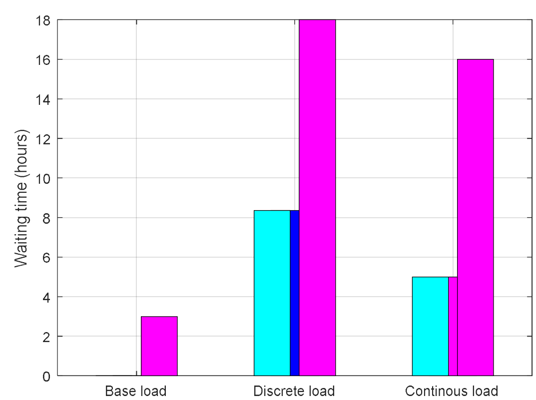

Figure 3: waiting time of multiple load

The profile of cost on daily basis consumption is shown in fig. 4. It can be clearly seen that after scheduling, bill has reduced. This has been achieved by managing the load rather than load shedding. The consumption remains same irrespective of scheduled and unscheduled load. The only thing is to bring modification in consumption profile and alternative energy source has not been utilized so far. However, we have categorized the appliance. Base load (BL) is not scheduled in appliance scheduling because this load is turned 'ON' throughout the day.

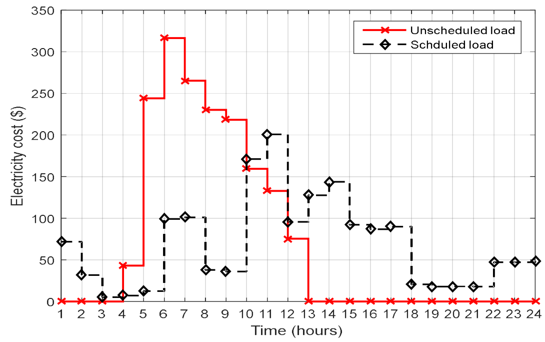

Figure 4: cost of energy consumption

Bill is reduced from 1685 $ to1535 $ which is roundabout 8.90 % reduction in the electrical charges. This reduction which contributes an important part in grid stability because of reduction in peak to average (PAR) results as shown in figure 6, there is a cost reduction owning to less reliance on peak power plants of power providers as shown in figure 5. Energy consumption which contributes an important part in regulating the electricity prices by the regulatory authority. Reduction in peak to average ratio brings the reduction in the price value of the next schedule.

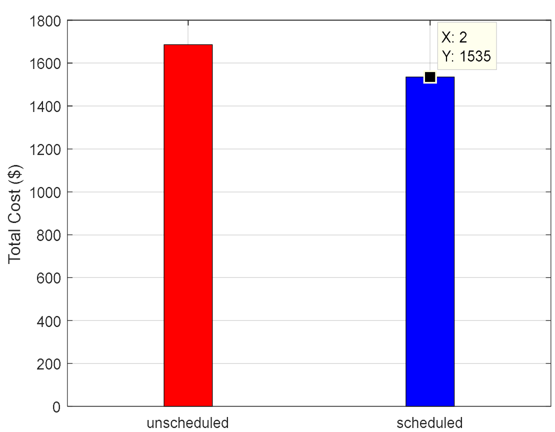

Figure 5: Total electricity bill

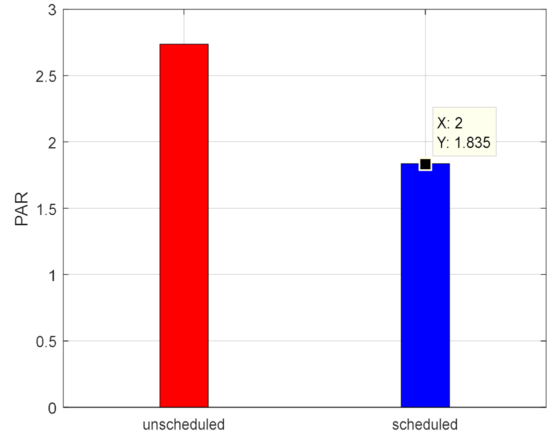

Figure 6: Peak to average ratio

Figure 7 shows Renewable energy source hourly generation with and without consideration efficiency. Also the radiation and temperature affects the generation which is maximum at day time and goes to zero at night. I general the efficiency band of solar generation is taken in between 18% to 22 %.and its consumption profile is shown in figure 8. From the figure we can see that Demand side management (DSM) controller played an important role in bringing the economy and efficiency in the system. The demand side management (DSM) controller's job is to modify the consumer's profile by giving response to Real time price signal which brings the reduction in overall electricity bill. It can also be seen that controller reduce the peas by managing the load.

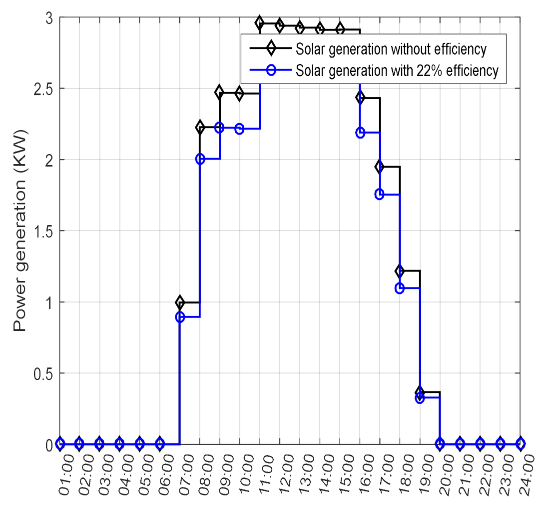

Figure 7: Generation of Renewable Energy

Controller also shares the burden of load with renewable energy sources by integrating them with system. Thus a further reduction in bill is achieved.

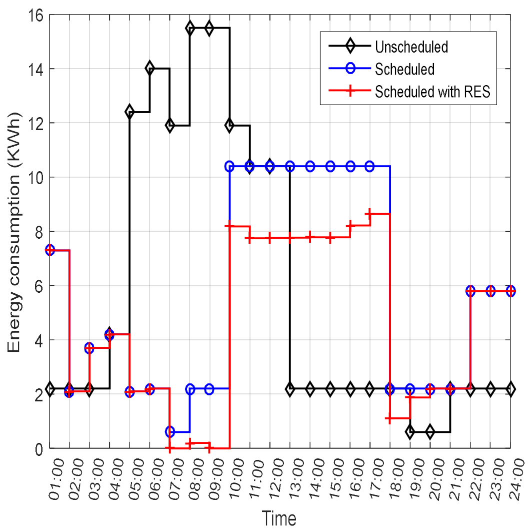

Figure 8: Schedule of Energy Consumption with RES

The whole procedure influences the end user to install the Renewable energy source at domestic level brings the stability and economy in the system which ultimately improve the efficiency. Daily consumption is shown in figure 9 which further strengthen the stance of reduction in consumption.
The reduction is achieved only by managing the time slots and shifting the peak hour's load to off peak hour load. Load shedding or other conventional method of reducing the load has not been utilized here. Only there has been some modification in consumption schedule keeping in consideration the user flexibility. By scheduling the consumption there has been valuable reduction and further reduction is achieved by the rescheduling through Renewable energy source.

The overall reduction with and without taking in account Renewable energy source is shown in figure 10. Scheduling without renewable energy source reduces cost from 2267 $ to 1568 $ which is roundabout 30.83 % reduction in electricity charges. Now, if we reschedule with Renewable energy source method, the reduction is from 2267 $ to 1231 $ which is equivalent to 45.7 % reduction in electricity charges. It is more than 21.5 % reduction as compared to scheduling by not considerable the Renewable energy source method. Thus, there is a considerable more reduction in bill if we integrate Renewable energy source with demand side management (DSM) as shown in the results.

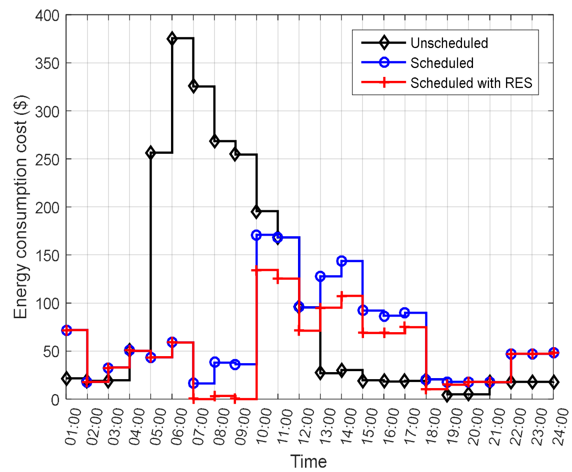

Figure 9: Cost Schedule of Energy Consumption with RES

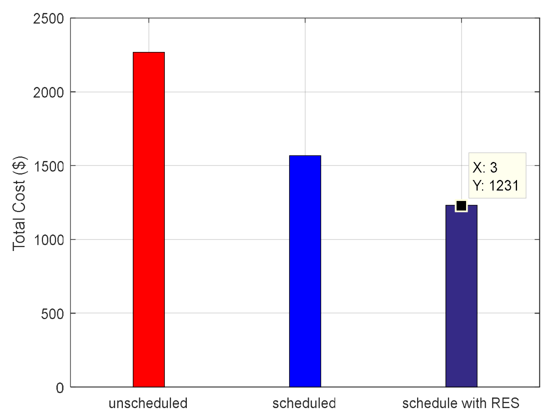

Figure 10: Total bill by using RES

Further, it can be shown that there is reduction in peak to average ratio which is approximately 35.03 % after the scheduling and with the combination of Renewable energy source. This reduction which contributes an important part in grid stability because of reduction in peak to average (PAR) results, there is a cost reduction owning to less reliance on peak power plants of power providers as shown in figure 11. Energy consumption which contributes an important part in regulating the electricity prices by the regulatory authority. Reduction in peak to average ratio also reduces the price value for the next time slot.

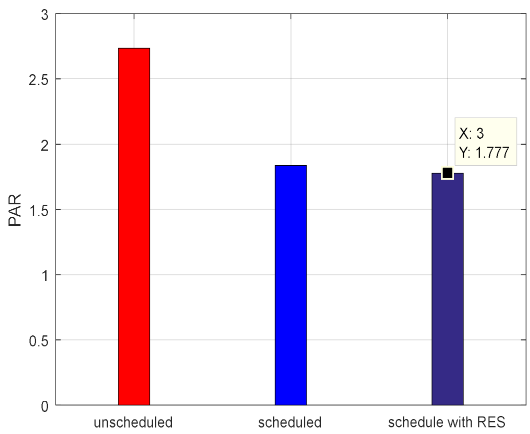

Figure 11: Peak to Average ratio

The table 5.2 represents different scenario of peak to average ratio while table 5.3 elaborate the cost of consumption for different scenario.

Table 3: Comparison in Peak to Average Ratio

Case	Unscheduled load	Scheduled load	Schedule with RES
Case 1	2.735	1.835	-
Case 2	2.735	1.835	1.777

Table 4: Comparison in Consumption cost

Case	Unscheduled load	Scheduled load	Schedule with RES
Case 1	1685	1535	-
Case 2	2267	1568	1231

Table 5.4

Table 5: Comparison of Cost reduction % and Peak to Average Ratio

Case	Reduction in cost %	Reduction in PAR
Case 1	0 8.90%	32.90%
Case 2	45.7%	35.03%

VII. CONCLUSION

In this research, a demand side management (DSM) algorithm has been proposed for energy management at the domestic level. The main focus was peak to average ratio (PAR) and electricity cost reduction by load scheduling. For simulation results, three types of load with various energy and operating constraints along with the integration of Renewable energy source has been discussed. First step of algorithm is to check the Renewable energy source availability up to its optimal level. In case of unavailability or incompatibility with demand scheduling is done by generating real time price signal by processor.

In the final results, the performance index of algorithm has been shown with ultimately reduction in consumption and cost. From statistically point of view, there has been 8.90 % reduction in cost without utilizing Renewable energy source and 45.7 % by integrating Renewable energy source with system.

In addition, 32.90 % reduction in peak to average ratio has been achieved without taken in account Renewable energy source and 35.90 % by considering the Renewable energy source in the system.

Table 5.3

Table 6: Comparison in Consumption cost

Case	Un scheduled load	Scheduled load	Schedule with RES	Cost Reduction %	PAR Reduction %
Case 1	1685	1535	-	8.90%	32.90%
Case 2	2267	1568	1231	45.7%	35.03%

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