232. A Novel Energy Management Approach in Smart Grid Challenges and Opportunities

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Abstract

From national economy to national security, electricity plays an important role in the development of any country. Economic dispatch of electrical energy is desired both at the supplier and user end Demand side management is a technique that keeps the balance between energy generation and utilization. Increasing contribution of renewable energy resources such as solar and wind is a motivation to design a new environment friendly interactive grid system. Many algorithms have been proposed in this regard, which minimizes the energy cost and peak hours based on evolutionary algorithms, game theory and stochastic programming. Integration of renewable energy resources is also a challenging task. Although a lot of work has been done in this domain yet it is an open and extensive area of research. In this paper we have designed a novel algorithm for home energy management with the integration of renewable energy resources that minimizes the electricity cost and peak energy demand. We have optimized the problem for both the user and supplier. Simulation result validates that our algorithm minimizes the energy cost and peak hour at a significant level.

Index terms— Smart grid (SG), demand side management (DSM), renewable energy resources, Optimization Algorithms (OA), Load Forecasting (LF), Machine Learning (ML)

1. Introduction

From National Economy to National Security, Electricity effects almost every walk of life so it is the need of time to have a power system that is capable of supplying un- interrupted, abundant, secure and affordable electricity. The traditional grid system was designed over 100 years before neither with the latest communication technologies nor with the aim of supporting a high tech global economy and enabling low carbon technologies, Demand side Management, energy efficiency and conservation. The famous blackouts [1,2] in 2003 and 2012 have also questioned the viability of existing grid systems. In these blackouts, More than 5 Million population in the American district of Columbia and Northeast were left without power for two days. In both the cases, Residents have no idea about what has happened to the national grid. So the traditional grid is unable to meet the requirement of the global world since it does not support robust information flow, in efficient at managing the peak load and a high level of renewable energy resources also poses a challenge to the traditional grid. Due to these reasons a State of the art Smart Grid is the need of time that can meet the requirement of the present world. Literature review reveals that the future grid is smart grid. Smart Grid is a combination of a physical power system and information system that connects a variety of equipment's and assets together to form a customer service platform [8].SG Incorporates advanced technologies of communication, distribution, automation, smart metering, distributed storage, safety and security to allow a significant increase in the reliability and robustness of the power which in turn can reduce the cost of electricity [5]. Demand Side Management (DSM) is an important feature of the smart grid that keeps the balance between demand and supply. It also enables the end user to schedule the electricity demand in response to the variations in the electricity cost overtime. Scheduling the electricity usage not only reduces the electricity billing cost but also minimizes the PAR. These two features make SG an attractive choice for both the utility and the customer. Some major benefits of SG are represented in figure many attempts have been found in the literature to schedule the power usage and a thorough investigation of these algorithms for minimizing the electricity cost reveals that the user comfort level is compromised. In this paper we compare the performance of state of the art heuristic algorithms for cost minimization which is done for the very first time. Our contribution also includes a Novel algorithm which achieves he electricity cost reduction without compromising on the user comfort. Simulation results show that our proposed method outperforms the other without compromising on the user comfort.

Fig (a) Smart Grid

2. Related Work

Since the Smart Grid forms a customer service platform, users can effectively reduce the electricity cost by scheduling their power usage based on real time pricing. With motivation of reducing the electricity cost, many power scheduling schemes have been proposed. In [7] authors show an appropriate total energy consumption for all appliances, however each appliance specific power is not mentioned. In [2] authors propose power scheduling schemes for both interruptible and non-interruptible appliances to minimize the electricity cost, however the peak electricity demand may occur when the electricity cost is low. In [4] electricity cost and peak power are reduced simultaneously, but assumption of the algorithm seems impractical. In [6] authors present an efficient model for DSM that can effectively reduce PAR and minimize electricity costs for residential, commercial and industrial consumer of electricity. Minimization of objective function is achieved through evolutionary algorithms. Propose scheme is beneficial for end users and utility company because of significant reduction in PAR and electricity cost. To strengthen the system, peak formation must be avoided. Most of the cost optimization algorithms suffer from peak formation In [1] authors propose an energy management scheme by using home area network [HAN] for residential users. They propose a solution for the peak formation. Their model is the combination of Real Time Pricing (RTP) and Inclining blockrates (IBR)[7]. They used Genetic Algorithm to minimize the objective function. Simulation results shows that proposed system is very effective in reducing the PAR and electricity cost

3. System Modeling

In a SG community, each smart user equipped with smart meter (SM) that allows bi-directional communication between energy providers and end users through some. The goal of SM is to provide real-time power consumption information to energy utilities and allow consumers to use electricity intelligently based on the dynamic pricing schemes. Usually, home Plug power line is used for wired networks in SG domain
and zigbee, Bluetooth and we are used for wireless communication. Our contribution is the multi objective optimization; we have formulated a multi objective optimization function which minimizes the electricity cost and waiting time at the user end.
Our major contribution is bridging the gap between demand and supply with specific uncertainties in RES and user demand response. In this paper, we have presented an efficient model for smart home infrastructure to minimize user electricity bills, optimized energy usage with integration of renewable energy resources RERs and maximize user comfort level.

4. Mathematical Modeling

We propose an efficient and smart model for home energy management (HEM) system comprising of N numbers of smart appliances connected with smart metering sys- tem. Let S be the set of smart appliances such as
$S_T = \{ S1, S2, S3; \cdot\cdot\cdot ; SN \}$

These appliances connected with smart energy scheduler (SES) through some wireless protocols (Wi-Fi and ZigBee) in home area network (HAN). SES optimizes energy consumption patterns of end users to reduce their electricity bills. For a particular day, we consider equidistance time slot of 1 hour (h).
Let T be the set of total time slots such as t 2 T = 1h; 2h; 3h; · · · ; 24h g.
Then hourly power consumption of single appliance in a day is given as,
$P_{S,T} = \{ P_{S,1} + P_{S,2} + \ldots P_{S,24} \}$
$P_{S,T} = \{ P_{S,1} + P_{S,2} + \ldots P_{S,24} \}$ denotes the power usage of particular appliance in time horizon of one day. The per day total energy consumption demand for all appliances is calculated as follows.

$$E_T = \sum_{t=1}^{T} P(N,T)$$

Where N is the number of appliances.

Problem Formulation

As mentioned earlier, it is necessary for residents to set some parameters for each Appliance that operated automatically. With this aim, assumption T_S, T_E ε t ($T_E > T_S$, T_S is starting time and T_E is ending time of Appliances that operated automatically and are function of time slots t, 180 slots in a day). Minimum operating time of device as well as the power rating of device D_a is supposed to be true for appropriate scheduling. Suppose T_L is time for Appliances that operated automatically, i.e., the minimum number of time slots required or used for the operation of device. Mentioned parameters are required to be programmed by users via an IHD to be transmitted to the EMC. Meanwhile, $T_E - T_S$ is supposed to be greater than T_L or equal to T_L, to elaborate this line take an example, if the heating system takes 4 hours to create required atmosphere, then value of $T_E - T_S$ must be a slot number that is greater than or equivalent to 30. While can't be greater than or equal to 180 slots of the day. Higher the Slots used more outcomes will be. As defined T_{SA} as the beginning of operation time (BOT) of a specific appliance. We already introduced the variables T_E, T_S, T_L and A_a, scheduling vector for power consumption of any specific appliance would be easily determined once we are provided with T_L.

Now for every appliance a εA_P, establishes a cluster of parameters having the OTI [T_{EA}, T_{SA}], LOT T_{LA}, and power consumption value per hour A_a. Moreover, OST t_a is set a variable. Having T_{SA}, T_{EA} and T_L, t_a ought to be higher than or equal to T_{SA} and smaller than or equal to T_{EA}-T_{LA}. In other words, the Span of OST of a is
$T_A ε[T_{SA}, T_{EA} - T_{LA}]$

For easiness we construct a vector, variable vector [t_1,t_2,….., t_a] which consists the OSTs for all AOAs. hence, we can finally describe a scheduling matrix W for power consumption for all AOAs as

W equivalent to $$\begin{Bmatrix} P|Pa^{(u)} = \frac{A_a}{8}, & \Delta\, a\, \varepsilon\, Ap, u\, \varepsilon\, [ta, ta + TLA] \\ Pa^{u} = 0 \quad , & a\, \varepsilon\, Ap, u\, \varepsilon\, t \setminus [ta, ta + TLA] \end{Bmatrix}$$

"W" is represented as matrix, in this matrix every row shows the power schedule of a certain appliance. While u Is the column for index. The expression
$u\ ε\ t \setminus [t_a, t_a + T_{LA}]$
denotes that u corresponds to excluding the span [t_a, $t_a + T_{LA}$]. Summation of entire values of each column vector in the power consumption scheduling matrix. A total power consumption scheduling vector would be found out as

$$\{P_{scd}=\{P_{scd} | P_{scd}^{(u)} = \text{Summation } P^{(u)} \}$$

In above written equation $P^{(u)}$ indicating U^{th} column in the power consumption scheduling matrix. Residents most often assume that home appliances can early finish their work. Thus, we have assumption that by lowering the delay time rate (DTR) of home appliances. The representation of DTR described as

$$DTR_A = \frac{Ta - Tsa}{Tea - Tla - Tsa}$$

Here DTR_A express for appliance A. DTR_A value shows that time period to operate the appliance if it is high so DTR_A value is high. 1 & 0 are used for lowest and highest values. For example, assume that a user assigned the variable OTI for a microwave as [T_{SM}, T_{EM}]and LOT as T_{LM}, and if microwave operated at time slot T_{AM}, the DTR_M will be 0; if it is started at time slot T_{EM}-T_{LM}, the DTR will be 1. By Introducing a delay parameter p>l and the relevant formula can be expressed as

$$\sum_{a\varepsilon A} p^{DTRa}$$

Since the delay parameter p>1, p ^{DTRa} geometrically increases as DTR_A continues to enhance. So this formula will be turning out with the lowest value. Hence, final optimization problem with the reduction of the electricity expenses, we also try to also minimize the above value.

From Scheduling optimization of Power consumption problem, It is cleared that we have:

Minimize w1*F1(Pscd)+w2*F2(DTR_A)

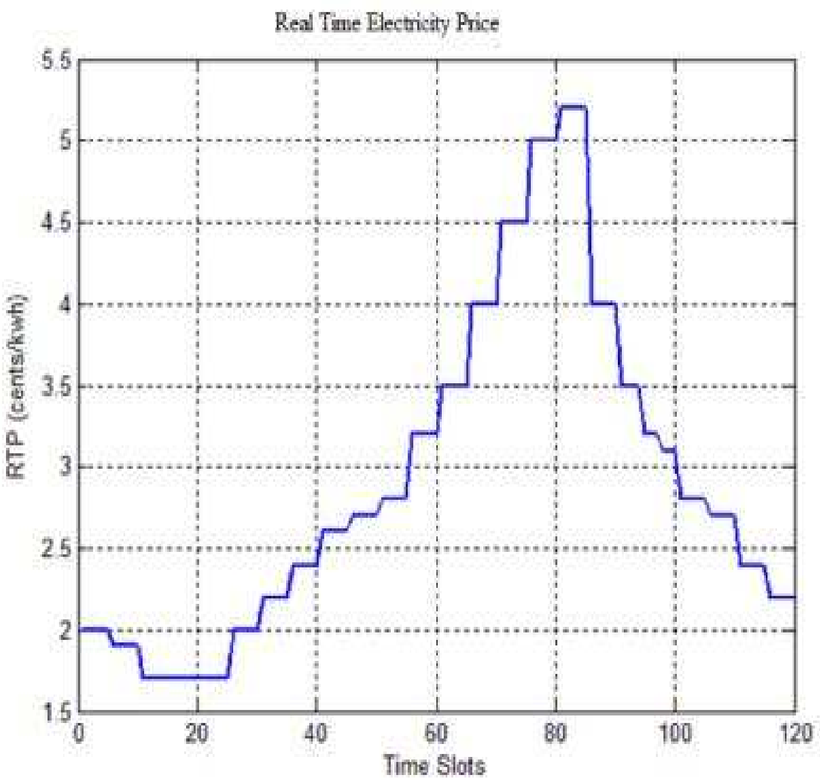
s.t. Ta E [T_{SA}, T_{EA} - T_{LA}]

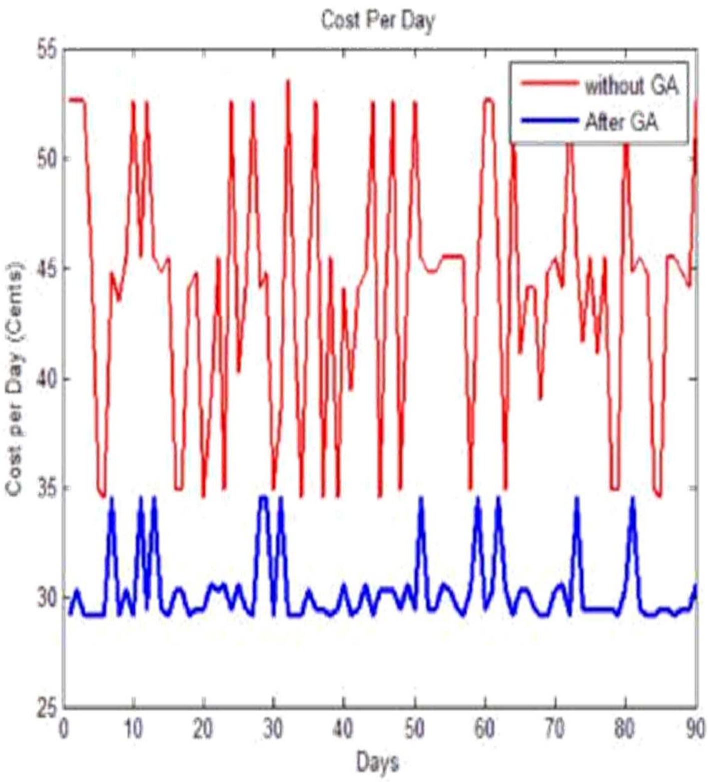
$F_1(P_{scd}) = \sum_{u=1} \text{prc}_u\ (p^u_{scd}).\, p^u_{scd}$

$F_2(DTR_A) = \sum_{a\varepsilon A} \text{p}^{\text{DTRa}}.\text{F1}(\text{P}_{\text{scd}})$

5. Simulation & Results

The simulations were done in MATLAB 2015. Simulation results reveal significant reduction in Electricity Bill with Peak Power management. The RTEP (time Electricity price function was obtained from illonois American Company. After applying the load management techniques by using the Genetic Algorithm (GA) Electricity cost was significantly reduced . Since GA is a heuristic based algorithm we used Monte Carlo Simulation method to validate our results. Another optimization techniques like Particle Swarm Optimization (PSO) & Ant Colony Optimization (ACO) can also be adopted to compare the reduction in electricity cost.





6. Future Work & Conclusion

Future work includes integration of renewable energies sources to save the natural reserves and enable the user to add the excessive energy and in return earn some monetary benefits. For optimization other optimization schemes like ant colony optimization (ACO) and particle optimization techniques can also be used for comparative analysis. Machine learning techniques can be used for th forecasting of future loads. Electric vehicles can be integrated in the grid to lessen the burden on natural fossil fuels.

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