

Demand Side Energy Management for Linear Programming Method

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Abstract

This paper presents an optimization method to the Demand Side Energy Management System (DSEMS) of a given consumer (e.g. an industrial compound or university campus) with respect to hourly electricity prices. The demands can be supplied through the main grid and stochastic Distributed Energy Resources (DERs), such as wind and solar power sources. To solve this DSEMS problem and optimization algorithm based on Linear Programming (LP) approach has been implemented. The objective of the proposed method is to maximize the utilization of the cluster of demands. This LP algorithm allows the cluster of demand to buy, store and sell energy at suitable times to adjust the hourly load level. To evaluate the performance of the proposed algorithm an IEEE 14 bus system was considered. The results shows that the cluster of demands of energy management system using the proposed approach increasing the efficiency and minimizing the losses than the existing methods.

Keywords: demand side energy management, demand response, distributed energy resources.

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1. Introduction

This paper addresses undersized size exciting energy systems and Demand Side Energy Management System (DSEMS) problem within a Small Size of Electric Energy Management System (SSEEMS) using Linear Programming (LP) method. In this paper propose a demand response model for a cluster of price-responsive demands interconnected through an SSEEMS. The working of the DSEMS of this cluster of demands is as follows. Demands supply consumption information to the DSEMS that is in charge for their energy supply. Given the demand ranges and function information of the different demands, and based on energy price information, the DSEMS optimally decide the hourly energy consumption for each demand and sends the total energy consumption to the energy suppliers.

Demand Side Energy management includes planning and operation of energy coupled production and consumption of units. Demands offer consumption in order to the DSEMS that is in charge for their energy supply. The operation of Demand Side Energy Management System (DSEMS) is crucial for cluster of demands with their energy supply. Based on the power demand range of a utility and power cost information, the DSEMS optimally decides the hourly energy consumption for each demand and determines the total power consumption to the energy sources. It has considered three energy sources, namely, the main grid, photovoltaic and a wind power plant system. The group of demands owns an energy storage ability to store energy and to utilize it at suitable times as soon as desired. Demands offer consumption in order to the DSEMS that is in charge for their energy supply. The DSEMS optimally decides the hourly energy consumption for each demand and send the total energy consumption to the energy suppliers. The cluster of demands owns an energy storage facility to store energy and to construct use of it at right period as needed.

With high penetration of wind energy, the knowledge of uncertainties ahead can be extremely valuable to a number of energy system operation and management procedures, including but not limited to, optimal operation reserve determination [1], system steady-state security assessment [2], economic generation scheduling and dispatch [3], the excellent approximation and generalization capabilities, neural networks (NNs) are widely used for wind energy forecasts [4]. It supports market participation of wind generation sizing and control of flow batteries [5]. Reliability benefits of energy storage in a system with high wind penetration including the improvement of wind capacity credit are quantified in [6], the impact of storage on

improving the economic performance, reliability and the integration of renewable sources in a micro grid-based environment [7]. The operating cost categories have been modelled using the approach presented in [8].

In a real-time pricing based DSM framework, the billing mechanism is of great importance since it may significantly affect the consumers' motivation to participate in the DSM program. However, there has only been limited work investigating this important billing issue. [9] Proposed a simple billing approach, where the consumers were charged in proportional to their total energy consumption for the next operation period. To address this problem [10] proposed a new billing approach, where each consumer is charged based on his/her instantaneous load in each time slot during the next operation period, synchronous and asynchronous algorithms were respectively developed in [10] and [11] for the consumers to achieve their optimal strategies in a distributed manner, proposed based on the proximal decomposition method [12].

In addition, there exists a two-way communications network connecting each consumer to the energy provider [13], DR is able to reduce peak demand, thereby alleviating the need to operate high-cost high-emission generating units [14], DR can be used as a perfect complement to the uncertain renewable energy resources such as wind [15]. Location [16] reported that U.K. DR potential is able to reduce its peak demand by more than 15%. Renewable energy is the only sustainable solution of secure energy which is environmental friendly [17]. In recent decade, with advancements in telecommunications and the increasing requirements of various sectors of the power industry for monitoring to grid as a scientific and practical solution to the utility industry [18]. The impact of price-based DR on voltage profile and losses of a distribution network was explored in [19]. It have been different aspects of the network operation, including network peak load, network losses, voltage profiles, and service reliability, are to be studied [20]. To solve this DSEMS problem, this paper propose an algorithm base on a Linear Programming (LP) model has been implemented to take full advantage of the effectiveness for the group of demand with value to a set of constraints such as minimum daily energy consumption, highest and lowest amount hourly load levels, energy storage limits, and energy accessibility from the main grid and the DERs.

The paper is structured as follows: Section 2 provides the demand side energy management system. Section 3 provides the Implementation of LP method to solve the DSEMS problem. Section 4 presents the results and analysis. Section 5 provides the conclusion.

2. Demand Side Energy Management System

Demand side energy management has forecast function of energy-related production and utilization units. The main objectives of DSEMS are resource conservation, environment protection and price savings, at the same time as the users have permanent access to the energy they required.

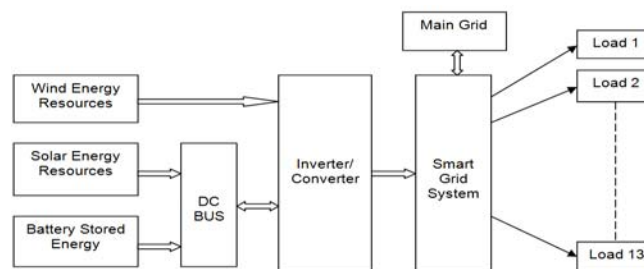


Figure 1. Block Diagram of DSEMS

It is essential to incorporate the energy management in the organizational arrangement, thus the energy management can be implemented. Responsibilities and the communication of the resolution maker must be regularizing. The Wind and Solar energy is a realistic energy supply which make high-quality use of wind and solar energy. Block diagram of demand side energy management system is shown in Figure 1. This method can not only supply a agreement of low cost and high reliability for a quantity of area where energy conduction is not

suitable such as limit resistance and install a new area which resolution the emergency of energy sources and environment pollution. It is very complex to make use of the solar and wind energy all climate presently during solar system or wind system separately, for the constraint of time and area. So a structure that is based on renewable resources but at the equivalent time reliable is needed and wind/solar system with battery storage can meet up this constraint. Providentially, the problems can be moderately overcome by integrating the resources to form DG system, using the strength of one source to overcome the limitation of the other source.

3. Implementation of LP Method to Slove the DSEMS Problem

The step by step approach for mathematical formulation of linear programming method to solve energy management problem is as follows.

Step 1:

Input the demand variables for real time data and pre determined data using Neural Network (NN) of the energy management system.

Step 2:

Formulate the demand function to be optimized (maximum or minimum) as a linear function of the different variables.

Step 3:

Formulate the constraints of energy management system such as resource limitations, market demands, inter- relation between different demand variables.

Step 4:

From the considered case study thirteen different types of demands available and three different types of energy sources available. Let a_{pq} denote the number of units of energy sources q in the unit of demands p , $q = 1, 2, 3$; $p = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13$. Let x_q be the number of units consumed for demand. Then the total number of units of demands I in the preferred source.

$$\sum_{p=1}^{13} \sum_{q=1}^3 a_{pq} x_q \quad (1)$$

Step 5:

Let b_p be the number of units of minimum daily requirement of the demand i and it can be expressed as follows:

$$\sum_{p=1}^{13} \sum_{q=1}^3 a_{pq} x_q \geq b_q \quad (2)$$

Where $q = 1, 2, 3 \dots 13$

Step 6:

For each source q , x_p must be either positive or zero.

$$x_q \geq 0 \quad (3)$$

Where $q = 1, 2, 3$

Step 7:

Let c_p be the energy management system output of energy source q . Thus the total output of energy management system is given below:

$$z = c_1 x_1 + c_2 x_2 + \dots + c_{13} x_{13} \quad (4)$$

Step 8:

The most important characteristic of Prediction Intervals (PIs) is their coverage probability. PI coverage probability (PICP) is measured by counting the number of target values covered by the constructed PIs.

$$PICP = \frac{1}{n} \sum_{p=1}^n c_p \quad (5)$$

PICP is a measure of validity of PIs constructed with an associated confidence level.

Step 9:

PI normalized averaged width (PINAW) assesses PIs from this aspect and measures how wide they are:

$$\text{PINAW} = \frac{1}{nR} \sum_{p=1}^n (U_p - L_p) \quad (6)$$

Where U_p , L_p upper limit and lower limit of demand, R is the range of the underlying target defined as the difference between its minimum and maximum values. PINAW is the average width of PIs as a percentage of the underlying target range.

4. Results and Analysis

The proposed LP method simulation were developed using MATLAB 7.10 software package and the system configuration is Intel Core i5-2410M Processor with 2.90 GHz speed and 4 GB RAM. In proposed work three energy sources, 13 demands and IEEE 14 bus system considered as case study, over specified time intervals. The computational results of EMS problem attained by the proposed LP method for the three energy sources analyzed.

4.1. Case study – IEEE 14 Bus System

This study is accepted away at the state of planning, operation, control and cost-effective forecast. They exist of use in decisive the magnitude and phase angle of load buses, and active and reactive power flow greater than conduction lines, and active and reactive power with the purpose of be injected at the buses. For this work the linear programming method is used for mathematical analysis. The purpose of this project is to expand a MATLAB program maximize the utilization of the cluster of demands when it is subjected to a set of constraints. Figure 2 shows the total demands and the energy sources.

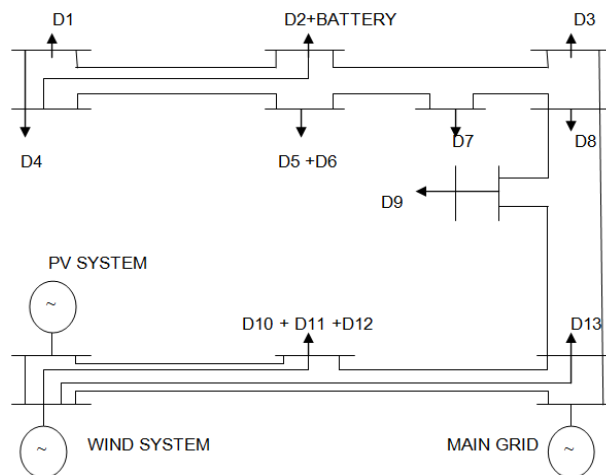


Figure 2. IEEE 14 Bus system Network

This LP algorithm allows the cluster of demand to buy, store and sell energy at suitable times to adjust the hourly load level to analyze voltages, active and reactive power control on each buses used for IEEE 14 bus systems. By primary IEEE 5 bus system is designed by using hand calculations and compared with MATLAB Program results and then IEEE 14 bus system MATLAB program is executed with the contribution data. This type of analysis is useful for solving the power flow problem in different power systems which will useful to calculate the unknown quantities.

1) Load demand data:

This paper considers the DSEMS demands located in the K.S.Rangasamy College of Technology (KSRCT) campus.

Table 1. Load Demand Data @ KSRCT

H O U R	Lig ht & fan	Mech dep	Acad emic bloc ki	Te x Til e	Acade mic block ii	Bio- tech 1	Com me -rcial	Mba Bloc k	Bio - tec h 2	New host el	Ct mai n bloc k	It par k	Mo t - ors	Tot al
12.10 PM	114. 5	32.1	28.1	49. 1	5.4	37.8	11.9	74.6	7.1	28.4	30	64.5	10. 1	493. 6
1.51 PM	113. 2	31.9	63.1	28. 3	10.2	22.2	13.7	44.7	2.2	35.3	32.1	86.5	10. 4	493. 8
2.11 PM	109. 9	34.8	56.2	48. 8	11.2	25.9	13.2	75.2	6.8	38.2	68.1	93.7	10. 4	592. 4
3.26 PM	108. 4	29.3	43.5	40	10.5	32.6	13.2	75.4	7.2	28.1	34.9	85.5	9.8	518. 4
4.05 PM	86.2	25.6	35	30. 9	8.9	4.8	13.9	50.7	7.2	27.5	29.2	91.9	0	411. 8
5.20 PM	70.1	11	8	4.8	6.6	5.7	13.2	25.2	1.2	37.5	29.5	66.9	0	279. 7
6.10 PM	66.3	10.3	5.8	4.8	0.44	6.9	12.7	23.8	4.9	39.5	11.7	41	0.3	228. 4
7.54 PM	63.9	7.8	5.1	2.7	1	32	9.6	4.5	0.7	36.7	5.6	18	0.6	188. 2
8.10 PM	64.9	7.7	4.5	4.1	1.1	3.2	11.4	7.8	0.8	36.1	2.9	11.6	0.7	156. 8
9.37 PM	49.2	6.2	4.4	4	1	3.4	9.2	3.6	0.8	36.3	2.9	20	5.7	146. 7
10.30 PM	62.3	6.2	4.3	3.9	1	2.9	9	3.8	0.8	26.9	2.9	15.2	5.1	144. 3
11.11 PM	53	5.6	4.1	4	1	3.3	9	3.7	0.7	26.9	3	14.2	5.1	133. 6
12.48 AM	51.3	4.5	4.1	3.8	1.1	3.1	8.9	3.5	0.8	26.8	2.9	13.7	5.3	129. 8
1.26 AM	50.3	4.3	4.3	3.9	0.9	3	8.7	3.5	0.8	26.7	3	14.4	1	124. 8
2.40 AM	48.9	4.8	4.3	3.9	1	3	8.7	3.5	0.7	26.8	2.9	14	0.9	123. 4
3.29 AM	47.5	4.6	4.4	3.9	1	3.1	8.8	3.5	1.3	26.9	3	14	0.9	122. 9
4.19 AM	47.1	4.5	4	3.6	0.8	3.2	8.7	3.4	1.7	26.8	3	14.1	1	121. 9
5.05 AM	47.4	4.7	4.2	4	0.5	3.3	8.5	3.5	1.5	26.8	3	14.3	1.1	122. 8
6.47 AM	40.6	4.9	4.1	4.3	0	3.1	8.6	3.6	6.4	43.1	2.9	19.9	0.4	141. 9
7.53 AM	50.9	5.2	4	4.3	0	2.7	8.5	3.9	1.6	58.5	4.1	27	0	170. 7
8.50 AM	94.1	14.4	7.8	23. 3	3.3	21.1	9	48.7	3.4	41.9	10.4	55.2	0	332. 6
9.55 AM	106. 9	42.9	32.3	46. 4	9.7	33.8	12.4	81.9	10. 7	43.4	20.7	98.5	0	539. 6
10.35 AM	109. 5	34.2	48.4	43. 6	11.2	34	13.3	82.2	10. 2	45.5	30.5	99.9	12. 6	575. 1
11.55 AM	108. 8	35.2	55.2	41. 6	5.6	40.5	13.4	88.6	9.8	44.7	28.1	101. 2	9.6	582. 3

The DERs and an energy storage facility are located at bus 14. The main grid is connected in to the bus3. The total power supplied from the DERs, main grid and energy storage facility. The available DSM capacity is taken as a fraction of the scheduled demand of the corresponding hour. In addition, the committed DSM capacity has to be put back to the demand during the same day in order to the behavior of energy price sensitive smart appliances. If a high degree of DERs generation is considered, the main contribution of DSM is leveling the load and reducing the DERs variability. The hourly load level for different demands and collected the data on 22.09.2014 - 23.09.2014 at 12 PM - 11AM from Thursday to Friday in KSRCT.

4.2. Simulink Model for Proposed DSEMS

The model has detailed simulation with a little time interval takes more than 6 hours to run. Demand side management uses the base model of linear programming. The collective analysis just requires all the factors that were further in the past for each opportunity. This characteristic allows this model to restrict DERs when the overload of it avoids achieving a reasonable solution (generation greater than demand).

Permanent magnet synchronous generators (PMSG's) are logically used in small wind turbines for several reasons collectively with high efficiency, gearless, simple control. This system procedure assumption of wind turbine, the maximum output energy of wind generator depends on the greatest tip speed ratio. A wind turbine operates by extract kinetic energy from the wind passing throughout its wind turbine rotor. The MPPT is controlled to track the maximum energy of the wind turbine. The wind produces 290 volts output voltage from generating station. The wind produces 7.5 amps output current from generating station. The photo voltaic produces 86 KW from generating station. The main grid produces 77 kW from demand side. The output voltage and current in the main grid is shown in Figure 3. The IT Park consumed 44.95 kW from load side. The output voltage and current in the IT Park is shown in Figure 4.

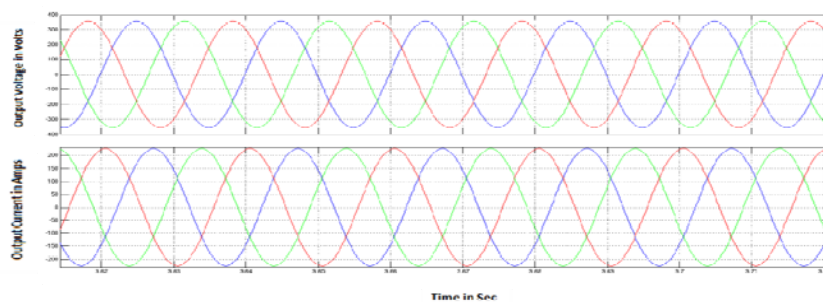


Figure 3. Output Voltage and Current-Main Grid for Demand Side

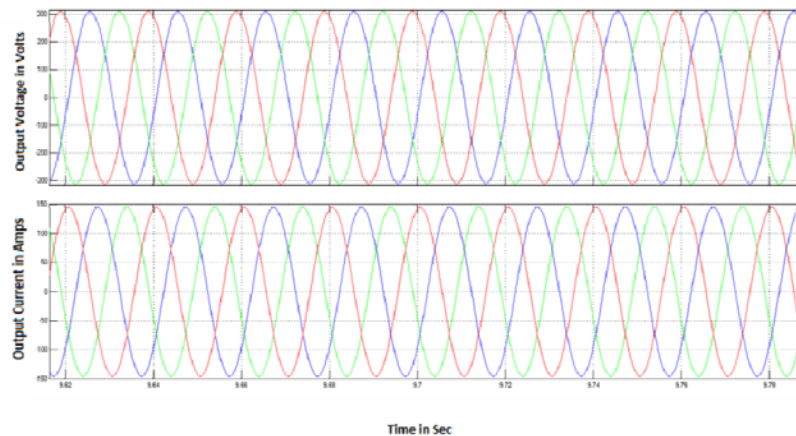


Figure 4. Output Voltage and Current-IT Park for Demand Side

DSM results in reduction of losses and proper utilization of the resources. This modeling shows flexibility in generation and load balance that evaluates requirement considering operational and capacity cost. The changes impact only on curtailed demand because the only constraint on shifted demand that affects several instants of time is for each day, the minimum size that has been considered to generate the clusters. In order to evaluate the performance of the model and understand the impact of shifted DSM on the demand-supply balance, this subsection presents a simple case study for 24 hours. The demand is modeled in a sinusoidal

way to provide some sort of variation. The demand would not be enough to achieve this result in a practical application, external control techniques would be necessary. The Figure 5 shows the total connected load, total consumed power for the feasible LP method of the time period.

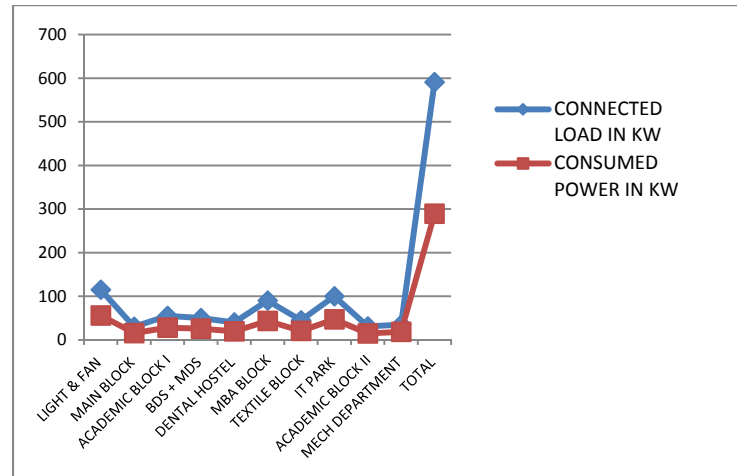


Figure 5. Peak Power Consumption at KSRCT

5. Conclusion

The proposed method provides the actual time monitor and control of demand side management system. It improves the performances of structure demand to the level of distributed energy resources diffusion. The photovoltaic and wind model was considered using MATLAB. The overload energy which is produced from photovoltaic and wind power plant it transferred to the electrical network. The energy consumption of IEEE 14 bus system has been determined using LP method in all the buses and demand is satisfy with protection system for photovoltaic and wind power plant was implemented. The proposed advance satisfies the cluster of demands in the energy management system and also improves the system efficiency and minimizes the losses. The excess energy from distributed energy resources can also be store in the battery and it could be utilize by the load when there is a demand of energy.

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