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Linear Programming Approach to the Residential Load Energy Management System

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Abstract: This paper proposes an effective method to the Residential Load Energy Management System (EMS) of a given consumer (e.g. house) with respect to hourly electricity prices. This paper considers a collection of compound charge reactive loads in a township. The loads can be provided through the main grid and arbitrary Distributed Energy Resources (DERs), such as the wind and photovoltaic power sources. The suggested EMS has the competence that each consumer can engage their own plan to govern the present load and prices in the electrical distribution system. To resolve this EMS problem an effective algorithm based on Linear Programming (LP) approach has been implemented. The main target of the suggested method is to maximize the utilization of the group of loads when it is subjected to a set of constraints. This Linear Programming approach algorithm permits the collection of loads to purchase, store and sell energy at suitable times to regulate the hourly load level. To assess the performance of the suggested algorithm an IEEE 14 bus system was considered. The results exhibit that the collection of loads of energy management system using the suggested approach increasing the efficiency and minimizing the losses than the previous methods.
Keywords: Energy Management System, Distributed Energy Resources (DER's), Linear Programming (LP), Price responsive demands and optimization algorithm.

I. INTRODUCTION

In recent years, renewable energy and distributed generation systems (DGSs) have attracted increasing attention and have been extensively researched and developed. They gradually alter the concepts and operations of conventional power generation systems. The rise in several countries makes it possible that this kind of DGS can be practically applied to a grid-tied system or an isolated system with wind power, solar energy, hydropower, etc. [1]. The operation of Energy Management System (EMS) is important for the collection of loads with their power supply. Based on the power demand range of a utility and power cost data, the EMS effectively determines the hourly energy consumption for each demand and concludes the total power consumption of the energy resources. It has considered three power generation sources, namely, the central grid, photovoltaic and a wind generation system. The collection of demands owns an energy storage capacity to store energy and to use it at suitable times as soon as desired. The load and the Distributed Energy Resources (DERs) functions as a virtual power plant that purchases and stores energy in hours of low electricity charges, and vends energy in hours of high charges [2].Nowadays Distributed generation (DG) has profited immensely because of the influence of environment and economic concerns. An energy management challenge with a less volume electric energy system using Smart Grid (SG) technology was considered in [3]. The model of SG considers an energy system with the intention to merge the measures of all consumers in such a way that all the generators and consumers must perform to effectively distribute sustainable, cost-effective, and protected electrical power supply. Other than the demand response problems, Robust Optimization (RO) [4], has been used in different power system optimization problems. In [5] use RO method to the arrangement with the unit commitment problem, integrate equally wind power generation and pumped storage hydro power plant. Also in [6], RO approach developed a conservative power producer. Management of distributed generation [7], and energy storage process [8].To solve this EMS problem, this paper suggests an algorithm based on a Linear Programming (LP) model has been implemented to maximize the utility for the collection of demand with respect to a set of conditions such as minimum daily energy consumption, maximum and minimum hourly load levels, energy storage limits, and power availability from the main grid and the DERs. Given the above matter, the contributions of this paper are categorized into four parts: 1) LP-based energy management algorithm runs by the limited group of consistent price-responsive demands, which can be supplied all the way through the central grid, arbitrary DERs, and an energy storage facility. 2) Results from the project show that the efficiency of the proposed EMS algorithm. The rest of this paper is structured as follows: Section II throws light on basic concepts and the required information about energy management system architecture and its operational characteristics. Section III deals with the basic structure and mathematical formulation of linear programming method to solve the energy management problem. Section IV presents the

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simulation results of project. Finally in section V, the relevant conclusion and the main references of this paper are highlighted respectively.

II. EMS ARCHITECTURE AND OPERATIONAL CHARACTERISTICS

Energy management is the favourable, strategic and effective coordination of attainment, alter, supply and utilization of energy to reach the supplies, attractive into account atmospheric and monetary objectives. Energy management is an incessant function of energy managers. It is monumental to integrate the energy management in the structure of the organization so that the energy management can be accomplished. It is suggestible to setup a separate organizational unit "energy management" in large companies. Facility management is the vital part of energy management because the large proportions (avg. 25 per cent) of complete operating costs are energy costs.

In the proposed EMS, PV array's primary function is to produce 0.4MW energy to supply the loads. The block diagram of EMS is shown in Fig. 1

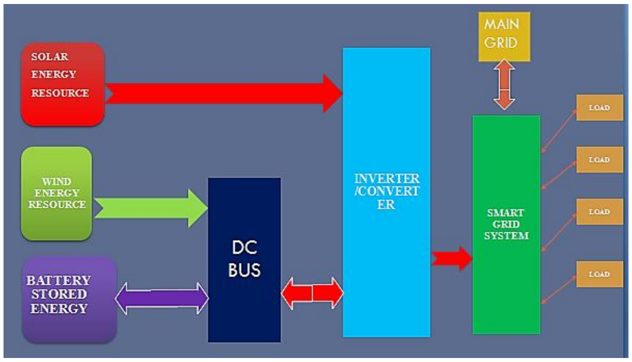

Fig.1 Block Diagram of EMS

Wind farm produces 0.02MW energy supply to the load. The converter works as a buck boost converter to amplify the output voltage range. From the DC converter, the input signal of voltage and current is given to the maximum power point tracking (MPPT) controller. This controller finds the error signal and activates the IGBT gate drive; this highly decreases the number of iterations in the MPPT technique.

Wind farm pitch regulator has an active control system that can adjust the pitch angle of the turbine blades to reduce the torque produced by the blades in a fixed speed turbine and to reduce the rotational speed in variable speed turbines. The adaptable speed operation of wind power generation systems yields optimum responses for both low and high wind speeds. A battery bank is used to store the DC energy at the voltage of 115kW. From the battery, AC loads are connected.

These AC loads are prioritized as lighting load which accounts light and fan for the building considered. If the load demand is lesser than the DERs output, the surplus energy will be utilized to incriminate the battery. The battery will be completely charged, the power can be inverted from DC to AC for the utilization of AC loads or surplus energy may be given to the grid. If the DC supply does not exist or be only partly available and the demand is on the dc loads, the battery will supply the power directly. If the load require being upper greater than the battery output, the AC grid will supply energy when it is available.

III. IMPLEMENTATION OF LP METHOD TO SOLVE THE EMS PROBLEM

It is a mathematical technique for maximizing or minimizing a linear function of several variables. Such as output or cost function. The step by step approach for mathematical formulation of linear programming method to solve energy management problem is as follows.

A. Step 1: Input the load variables for real time data and pre determined data using Neural Network (NN) of the energy management system.
B. Step 2: Formulate the demand function to be optimized (maximum or minimum) as a linear function of all distinctive variables.
C. Step 3: Formulate the constraints of energy management system such as resource limitations, market demands, inter- relation between different demand variables.

D. Step 4: From this project thirteen different types of demands available and three different types of energy sources available. Let a_{pg} denote the number of units of energy sources g in the unit of demands p, g =1, 2, 3: p = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13. Let x_g be the number of units consumed for demand. Then the total number of units of demands p, in the preferred source.

$$\sum_{p=1}^{13}\sum_{g=1}^{3} a_{pg}\, x_g \qquad \dots(1)$$

E. Step 5: Let b_p be the number of units of minimum daily requirement of the demand p and it can be expressed as follows

$$\sum_{p=1}^{13}\sum_{g=1}^{3} a_{pg}\, x_g \ \geq\ b_p \qquad \dots(2)$$

Where p=1, 2, 3…13

F. Step 6: For each source g, x_g must be either positive or zero.

$$x_g \ \geq\ 0 \qquad \dots(3)$$

Where g = 1, 2, 3

G. Step 7: Let c_g be the energy management system output of energy source g. Thus the total output of energy management system is given below

$$c_1x_1 + c_2x_2 + c_3x_3 + \cdots \dots\dots\dots\dots + c_{13}x_{13} \qquad \dots(4)$$

Finally, load scheduling was done based on linear programming approach. Production units and dynamic residential loads have the specific load profile i.e., every dynamic load has separate load profile based on that they will order to energy management system. Consequently, EMS sends information to the distributed generation resources in the micro grid. Then the DG's send respective energy to the EMS. Finally, EMS distributes energy to the required loads based on LP approach in an optimization procedure

IV. PROPOSED SYSTEM

For this work, the linear programming approach is used for mathematical analysis. The purpose of this project is to expand a MATLAB program maximize the utilization of the collection of demands when it is subjected to a set of constraints. Fig. 2 shows the total loads and the energy sources. For the identification purpose 1, 2, 3 and 4 are pv, wind, central grid and battery respectively. Remaining all arrow symbols are demands.

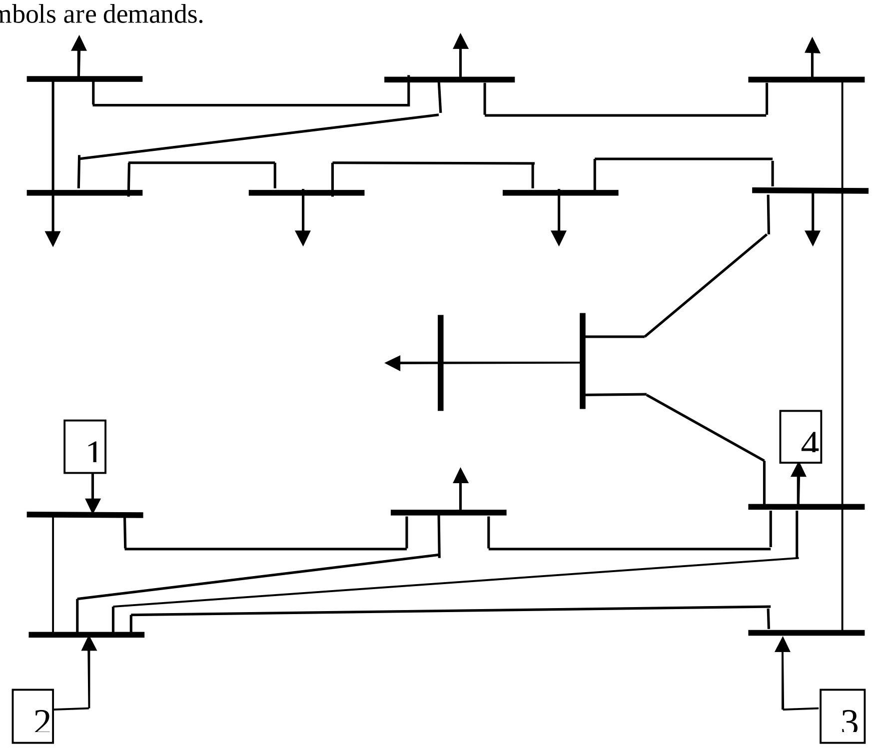

Fig. 2 IEEE 14 Bus Systems Network

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The proposed LP method simulation were developed using MATLAB 2017a and SIMULINK version 9.2 software packages and the system configuration is Intel Core i5-6200U Processor with 2.40 GHz speed and 8 GB RAM. In proposed work three energy sources, 13 demands and IEEE 14 bus system considered over specified time intervals. The computational results of EMS problem attained by the proposed LP method for the three energy sources analysed

A. Subsystems

1) *Pv System:* The PV Array block implements an array of photovoltaic (PV) modules. The array is a collection of strings of modules connected in parallel, each string consisting of modules connected in series. The PV Array block has five parameter model using a current source I_{lg} (light-generated current), a diode (I_0 and nI parameters), series resistance Rse, and shunt resistance R_{sh} to depict the irradiance and temperature-dependent I-V characteristics of the modules. This parameter is available only if display I-V and P-V characteristics of is set to one module @ 25^0c & specified irradiances or array @ 25^0c & specified irradiances. Enter a vector of irradiances in watts per square meter. The default value:[1000 500 100].Irradiance was given by 1-D Lookup table. Regarding PV Farm, we have sunlight from morning 06:00 AM to evening 06:00 PM. So we have only data in those hours. The irradiance data and respective graph are shown below.

Table: I PV Farm Generation Profile

Time(hours)	Irradiance(w/m^2)
00.00	0
01.00	0
02.00	0
03.00	0
04.00	0
05.00	0
05.30	0.000009
06.00	0.049
06.30	1.5
07.00	3
07.30	36
08.00	69
08.30	152.5
09.00	236
09.30	314
10.00	392
10.30	449.5
11.00	507
11.30	516.5

Time(hours)	Irradiance(w/m^2)
12.00	526
12.30	519.5
13.00	513
13.30	492
14.00	471
14.30	408
15.00	346
15.30	262.5
16.00	179
16.30	109.5
17.00	40
17.30	20
18.00	0
18.30	0
19.00	0
20.30	0
21.00	0
22.00	0
23.00	0

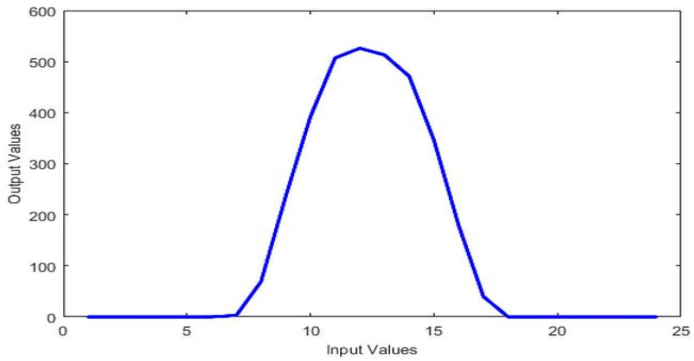

Fig.3 Generation Profile of PV Farm

2) *Wind System:* Three 1.5 MW turbines contributed to form a 4.5 MW, connected to a 25KV distribution system exports power to a 120KV grid through a 25KM, 25KV feeder Wind turbines using a doubly –fed induction generator (DFIG) has wound rotor induction generator and an AC/DC/AC/IGBT – based Pulse Width Modulation converter modelled by voltage sources. The stator winding is connected directly to the 60Hz grid and its rotor windings are fed at adjustable frequency through the AC/DC/AC converter. The DFIG technology allows extracting maximum energy from the wind for low wind speed by optimizing the turbine speed while minimizing mechanical stresses on the turbine during gusts of wind.

Table. II Wind Generation Profile

Time(hours)	Wind Speed(m/s)
00.00	9
01.00	9
02.00	9
02.30	8.5
03.00	8
03.30	9.5
04.00	11
04.30	9.5
05.00	8
05.30	9.5
06.30	9
07.00	7
07.30	7.5
08.00	8
09.00	8
10.00	8
10.30	8.5
11.00	9
11.30	8.5

Time(hours)	Wind Speed(m/s)
12.00	8
12.30	10.5
13.00	13
13.30	12
14.00	11
14.30	10
15.00	9
15.30	8.5
16.00	8
17.30	9.5
18.00	11
19.00	11
19.30	9.5
20.00	8
21.00	9
22.00	13
22.30	14
23.00	15
24.00	8

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V. CONCLUSION

The suggested method provides the monitoring and control of demand side management system. It enhances the performance of system load to the level of distributed energy resources saturation. The photovoltaic and wind model was designed using MATLAB. The surplus energy which is produced from photovoltaic and wind power plant it shifted to the electrical network. The energy consumption of IEEE 14 bus system has been determined using LP method at all the buses and demand is satisfied with protection system for photovoltaic and wind power plant was implemented. The suggested method satisfies the collection of demands in the energy management system and also enhances the system efficiency and reduces the losses. The surplus energy from distributed energy resources can also be stored in the battery and it could be used by the load when there is a requirement of energy.

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