A Robust Energy Management System for Smart Grid

N. Loganathan, K. Lakshmi and J. Arun Venkatesh

Abstract This paper presents an energy management system with reduced energy consumption as well as to look for alternative sources of energy which are cheaper to minimize the total cost of energy consumption. A cluster of interconnected price-responsive demands (e.g., a college campus) that is supplied by the main grid and a stochastic distributed energy resources (DER) e.g., a wind and solar power plants with energy storage facilities is considered. An energy management system (EMS) arranges the value responsive requests inside of the bunch and gives the interface to vitality exchanging between the requests and the suppliers, primary lattice and DER. Vitality administration calculation permits the bunch of requests to purchase, store and offer vitality at suitable times. To solve this EMS problem, an optimization algorithm base on linear programming (LP) approach has been implemented. Toward estimate the performance of the planned algorithm an IEEE 14 bus system was consider. The outcome show with the purpose of the group of load of energy management system with the planned approach increases the effectiveness by minimizing the losses while compared to existing method. Improvement in the method is the optimization problem having two sources vulnerability identified with both the generation level of the DER and the cost of the vitality acquired from/sold to the fundamental network, which is demonstrated utilizing robust optimization (RO) procedures. Shrewd grid (SG) innovation is utilized to acknowledge 2-route correspondence between the EMS and the primary lattice and between the EMS and DER.

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1 Introduction

Energy management incorporates arranging and operation of vitality related creation and utilization power. Goals are supply preservation, atmosphere insurance and expense reserve funds, while the clients have perpetual induction to the vitality they require. It is associated nearly to green administration, creation administration. Generation is the region with the biggest vitality utilization inside of an association.

In this paper propose a demand reaction model for a group of cost-responsive load organized through a Small Size of Electric Energy Management System (SSEEMS). Demands supply consumption in order toward the Demand Side Energy Management System (DSEMS) to be in give away for their power deliver. Base on the energy interest scope of utility and vitality cost data, the EMS ideally chooses the hourly power utilization for every interest and decides the aggregate force utilization to the vitality sources. It has considered three vitality sources, particularly, the primary lattice, photovoltaic and a wind force plant structure. The gathering of requests possesses a vitality stockpiling capacity to store vitality and to utilize it at suitable times when fancied. It supports market contribution of wind generation sizing and control of power flow batteries [1]. Through high saturation of wind energy, the information of uncertainties ahead can be extremely valuable to a number of determinations [2]. There exists a two-way communications system connecting each consumer to the energy supplier [3]. In the direction of address this problem [4] proposed a innovative billing approach, where each consumer is charged based on his/her direct load in each time period during the next operation period, synchronous and asynchronous algorithms were respectively developed in [4, 5] for the consumers to achieve their best possible strategies in a distributed method.

The demand, the storage space, space unit, and the distributed energy resources (DERs) occupation as a virtual power plant that buys and stores energy in time of low electricity costs, and sells energy in time of high prices [6]. Additional to demand response problems, robust optimization (RO) [7] and energy storage space process [8]. In addition [9] RO advance developed a conventional energy producer. Demand response [10, 11], the impact of price-based DR on voltage summary and losses of a distribution network was explored in [12]. It have been special aspects of the system operation, including network peak load, power losses, voltage profiles, and service dependability, are to be considered [13, 14] has been used in unlike power system optimization problems, management of distributed generation [15].

Renewable energy is the simply sustainable solution of secure energy which is environmental approachable [16], during current decade with advancement in the growing supplies of various sectors of the power industry for monitoring to grid as a systematic and practical solution to the utility grid [17]. Wind force determining systems can be extensively isolated into two gatherings: physical strategies and information driven techniques [18]. PI budgetary articulation for additional wellsprings of uncertainly, including model misspecification and clamor fluctuation [19, 20]. Proposed a straightforward charging methodology, where the shoppers were charged in corresponding to their aggregate vitality utilization for the following operation period.

Toward take care of this EMS issue, this paper proposes a calculation taking into account a linear programming (LP) model has been executed to amplify the utility for the gathering of interest with reverence to an arrangement of limitations, for example, least every day vitality usage, most extreme and least hourly load levels, vitality storage room breaking points, and power availability from the primary framework and the DERs. Determined the above point of view, the commitments of this paper is fourfold:

(1) To representation the indeterminate parameters in the calculation in through certainty interims that permits utilizing RO strategies.
(2) To data results from a handy contextual investigation that demonstrates the adequacy of the proposed neighborhood EMS calculation.

The paper is structured as follows: Sect. 2 provides the energy management system. Section 3 provides the energy management system algorithm. Section 4 presents the simulation results. Section 5 provides the conclusion.

2 Energy Management System

Energy administration is the positive, arranged and proficient coordination of obtainment, change, supply and utilization of vitality to get together the supplies, appealing into record ecological and budgetary goals. Vitality administration is a nonstop capacity of vitality chiefs. In the proposed EMS, PV exhibit's primary capacity is to create 500 kW vitality to supply the stores. The square diagram of EMS is showed up in Fig. 1. Wind farm produces 20 kW essentialness supply to the pile. The converter goes about as a buck bolster converter to manufacture the yield voltage range. From the DC converter the data indication of voltage and current is given to the MPPT controller. This controller discovers the bumble hail and prompts the IGBT entryway drive; this significantly diminishes the amount of emphases in the MPPT technique.

Wind homestead pitch controller has a dynamic control framework that can shift the pitch edge of the turbine cutting edges to diminish the torque delivered by the sharp edges in a settled rate turbine and to diminish the rotational pace in variable rate turbines. The variable rate operation of wind electric frameworks yields higher yields for both low and high wind speeds. Battery bank is utilized to store the DC vitality at the voltage of 115 kW. From the battery AC burdens are joined.

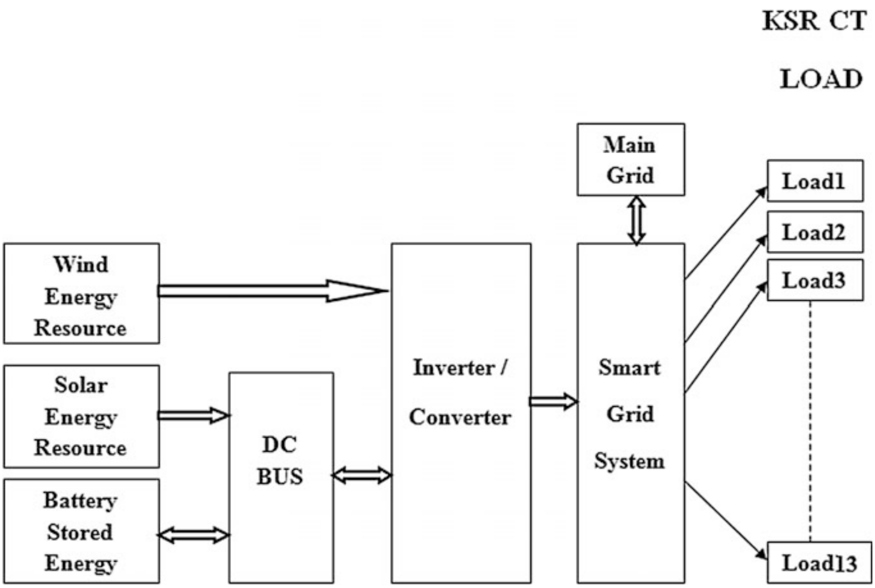

Fig. 1 Architecture of EMS

These AC burdens are organized as lighting burden which considered light and fan for the building considered. In the event that the heap interest is lower than the DERs yield, the abundance vitality will be utilized to implicate the battery. Battery will be totally charged, the force can be inverter from DC to AC for the usage of AC burdens or abundance vitality may be encouraged to the matrix. On the off chance that the DC supply does not exist or be just in part accessible and the interest is on the dc stacks, the battery will supply the force straightforwardly. On the off chance that the heap require be upper more noteworthy than the battery yield, the AC framework will give vitality when it is accessible.

3 Energy Management System Algorithm

3.1 LP Model

The orderly approach for numerical detailing of direct programming technique to take care of vitality administration issue is as per the following.

Step 1: Information the interest variables for ongoing information and pre decided information utilizing Neural Network (NN) of the vitality administration framework.

Step 2: Plan the interest capacity to be improved (greatest or least) as a straight capacity of the diverse variables.

Step 3: Plan the requirements of vitality administration framework, for example, asset constraints, business sector requests, between connections between diverse interest variables.

Step 4: From the considered contextual investigation thirteen unique sorts of requests accessible and three distinct sorts of vitality sources accessible. Let b_{kl} signify the quantity of units of vitality sources l in the unit of requests k, l = 1, 2, 3: k = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13. Let xj be the quantity of units devoured for interest. At that point the aggregate number of units of requests I in the favored source.

$$\sum_{k=1}^{13}\sum_{l=1}^{3} b_{kl}y_l \quad (1)$$

Step 5: Let c_k be the number of units of minimum daily requirement of the demand k and it can be expressed as follows

$$\sum_{k=1}^{13}\sum_{l=1}^{3} b_{kl}y_l \geq c_k \quad (2)$$

where k = 1, 2, 3, …, 13.

Step 6: For every source l, yl must be either positive or zero.

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

where l = 1, 2, 3

Step 7: Let d_l be the vitality administration framework yield of vitality source l. along these lines the aggregate yield of vitality administration framework is given underneath

$$m = d_1y_1 + d_2y_2 + \cdots + d_{13}y_{13} \quad (4)$$

Step 8: The most imperative normal for Prediction Intervals (PIs) is their scope likelihood. PI scope likelihood (PICP) is measured by tallying the quantity of target qualities secured by the built PIs.

$$\mathrm{PICP} = 1/p\sum_{k=1}^{n} d_k \quad (5)$$

PICP is a measure of legitimacy of PIs developed with a related certainty level.

Step 9: PI standardized found the middle value of width (PINAW) evaluates PIs from this viewpoint and measures how wide they are

$$\text{PINAW} = 1/\text{pS}\sum_{k=1}^{p}(V_k - M_k) \tag{6}$$

where V_k, M_k furthest utmost and lower cutoff of interest, S is the scope of the basic target characterized as the distinction between its base and greatest qualities. PINAW is the normal width of PIs as a rate of the fundamental target range.

3.2 Robust Model

The robust counterpart of model (7) is presented as the equivalent linear model below

$$\text{Min}\left[\lambda_t^s e_t^s + \lambda_t^w e_t^{AW} + \lambda_t^{PV} e_t^{APV} - \sum_{i=1}^{Nc} u_{i,t}(e_{i,t})\right]\sum_{h=1}^{24-t}[\lambda_{t+h}^s\{e_{t+h}^s\} + \lambda_{t+h}^w\{e_{t+h}^{AW}\} + \lambda_{t+h}^{PV}\{e_{t+h}^{APV}\} - \sum_{i=1}^{Nc} u_{i,t+h}(e_{i,t+h})] \tag{7}$$

The vulnerabilities in vitality value, primary framework, wind force and sun oriented force, separately, in a strong way. The variables of the hearty model are the variables of the introductory model its double variables, and some assistant variables. The double variables u_(i,t + h)(e_(i,t + h)) are identified with the instability in vitality value, while the double variables ∑_(t + h+1)^W and primary lattices are identified with the vulnerability in wind and sun oriented force. The helper variablesy_(t + h)^s, y_(t + h+1)^w and y_(t + h+1)^pv are utilized to accomplish a straight streamlining issue.

The parameters permit controlling the level of strength of the arrangement regarding the vulnerabilities in vitality cost from the fundamental matrix and in the sun oriented power and wind power creation, individually. In the event that we select zero, the effects of the value deviations on the goal capacity. The most extreme worth results in a preservationist choice that considers the synchronous effects of all value deviations on the goal capacity. Not as a matter of course number, the control parameters of wind uncertainty_ (t + h+1)^W, h = 1…24-t, can be chosen in the interim.

The parameters decide the insurance levels for limitation of the starting model against the instability in the accessible wind power production P_(t + h+1)^AW, h = 1…24-t. the control parameters of sun powered illumination level uncertainty T_(t + h+1)^PV, h = 1…24-t, can be chosen in the interim. These parameters decide the insurance levels for limitation of the starting model against the vulnerability in the accessible sun based force production P_(t + h+1)^APV, h = 1…24-t

For straightforwardness, take note of that the proposed vigorous model is not versatile, i.e., it has no plan of action. Accept that the primary framework and the vitality stockpiling give final resort adjusting vitality.

3.3 Calculation

Given the vigorous issue (7) in the past subsection, propose a vitality administration calculation, whose working is portrayed underneath:

Step 1: Instate t = 1.
Step 2: The cost of the vitality from the fundamental network for current hour is sent to the EMS administrator, e.g., 10 min before hour t.
Step 3: The wind maker sends the wind energy to be delivered in hour to the EMS administrator, e.g., 10 min before hour t.
Step 4: The sun oriented maker sends the sunlight based energy to be delivered in hour to the EMS administrator, e.g., 10 min before hour t.
Step 5: Value responsive requests send to the EMS administrator their heap levels and utilities for current hour t, and the remaining hours of the day, e.g., 10 min before hour t.
Step 6: Utilizing verifiable time arrangement of vitality costs from the primary matrix and wind power preparations from the DER, the EMS administrator registers limits at both vitality costs and wind and sun oriented creations for the remaining hours of the day. The EMS administrator is capable of the danger connected with the vulnerability demonstrating.
Step 7: The EMS administrator understands the powerful model (5.3) and acquires the divisions of vitality to be supplied from the fundamental network, the wind maker, the sun powered maker and the stockpiling unit, and in addition the vitality to be supplied to every specific request, the part of vitality to be put away, and the portion of vitality to be sold to the primary matrix in hour t.
Step 8: The EMS administrator conveys the ideal choices got in Step (7) above to both vitality suppliers and requests, e.g., 5 min before hour t.
Step 9: Redesign the hour counter. In the event that, go to Step (2). On the off chance that, the calculation finish up for the present day and moves to the following day.

In Step (6), the EMS fuses the new data it gets from hour, redesigning the determining of the certainty limits of the dubious information for the remaining hours of the day.

4 Result and Discussions

The proposed LP technique reproduction be developed with MATLAB 7.10 software package as well as the structure arrangement is Intel Core i5-2410M Processor by way of 2.90 GHz speed and 4 GB RAM. In proposed exertion three power sources, 13 load and IEEE 14 bus organization considered as container study, over specified moment in time intervals. The computational consequences of energy management system trouble attained by the projected LP technique for the three power sources analyzed.

4.1 Case Study—IEEE 14 Bus System

This revision is conventional absent at the situation of preparation, procedure, be in charge of with money-spinning estimate. They continue living of make use of in significant the importance in addition to stage point of observation of consignment buses, and real and reactive control flow larger than transmission lines, and real and

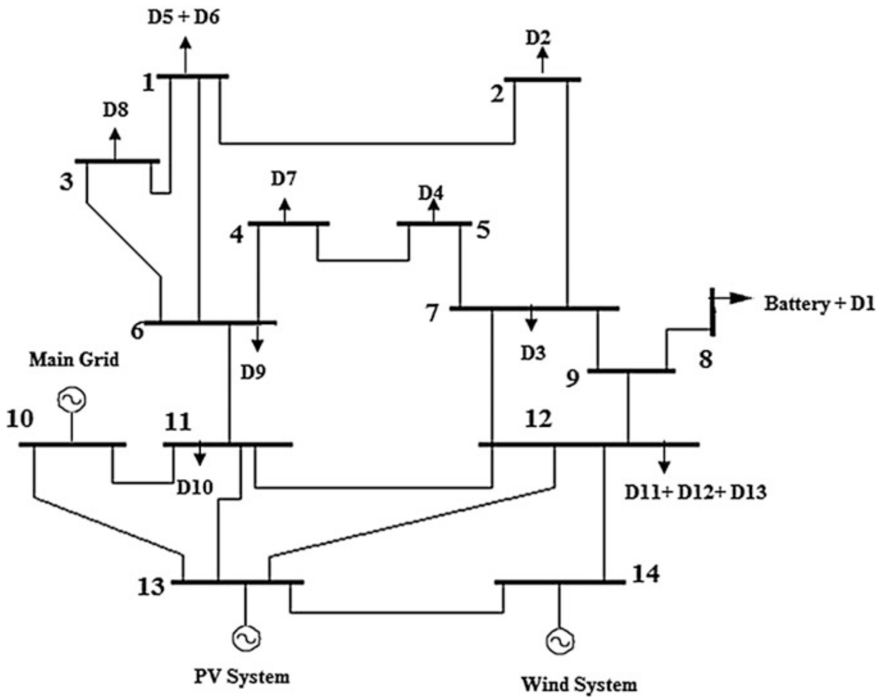

Fig. 2 IEEE 14 bus systems network

reactive energy by means of the function of be injected at the buses. For this occupation the linear programming method is use for arithmetic investigation.

The function of this project is to enlarge a MATLAB program make best use of the consumption of the group of load while it is subjected to a located of constraint. Figure 2 shows the whole load and the power sources. This LP algorithm allows the group of demand to purchase, stock up as well as put up for sale energy at appropriate times to regulate the hourly consignment level to analyze voltages, active and reactive power control on each buses second-hand for IEEE 14 bus systems. With principal IEEE 5 bus structure is calculated by using supply calculation as well as compared through MATLAB plan consequences and subsequently IEEE 14 bus system MATLAB program is executed with the part data. This category of study is positive used for solving the organize flow problem in diverse power systems which will practical to calculate the strange quantities. The energy management system considers 13 load positioned 14-bus scheme. The DERs with a power storage capacity are situated at bus 14.

4.2 Load Demand Data

This paper considers the EMS load situated within the K.S.Rangasamy College of Technology (KSRCT) campus. The main grid is associated to bus3. The whole control supplied beginning the DERs, main grid and power storage space facility. The accessible DSM capability is in use as a division of the listed require of the consequent hour. In adding, the devoted DSM capabilities include to exist put reverse to the demand during the same day in order to the behavior of power charge sensitive smart appliance. Condition an elevated degree of DERs generation is considered; the major giving of DSM is leveling the demand and dropping the DERs inconsistency.

4.3 Simulation Model for Proposed EMS

The representations have been elaborated and it works but the simulation times make it impossible to be used. One simulation with a very simple case take additional than 8 h to be run. However, taking into account that it has been part of this project, it is going to be explained. Demand side management toward the stand representation. Since it is a linear programming model, the mutual study just requires all the factor to facilitate be additional previously for each possibility. This means that if the reader has understood properly the mathematical formulation of previous chapter's equations should be enough to understand the whole model. The new factors in the system constraints of the base model have been highlighted in bold. This feature allows the model to curtail DERs while the overload of it avoids

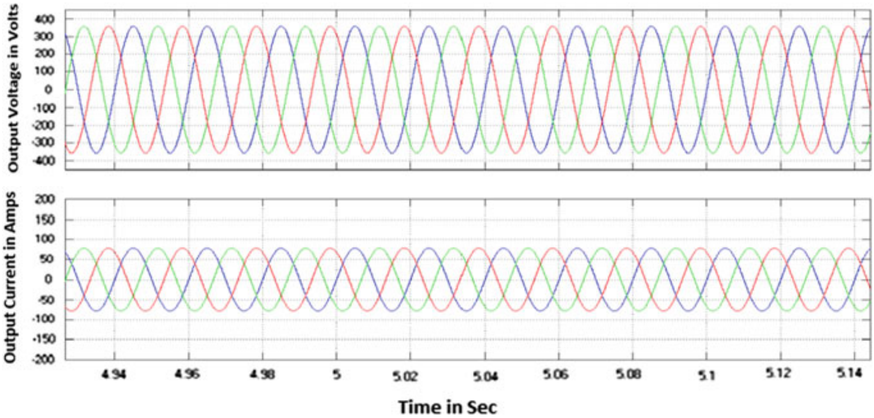

Fig. 3 Output voltages and current—wind system

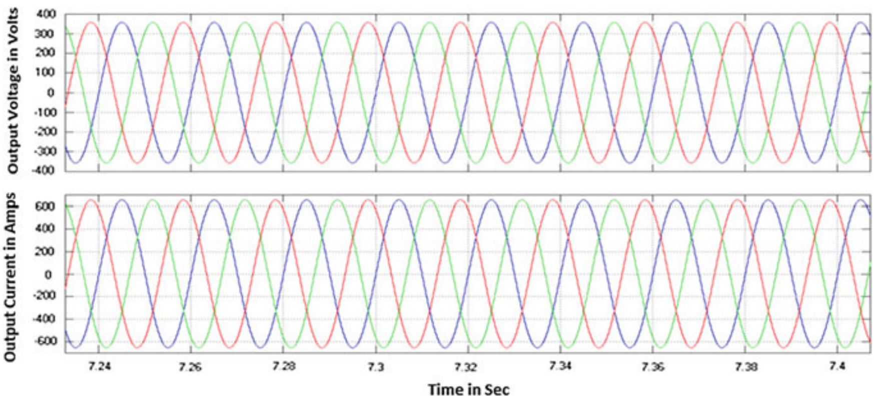

Fig. 4 Output voltages and current—PV system

achieve a practicable resolution (production larger that load) however at the same time wind curtailment is avoided.

If modeling of flexibility in the generation and load balances that evaluates requirement considering operational with capability price. The change contact simply on condensed require because the simply restriction happening shifted order that affects more than a few instants of instance is used for every day, the smallest size so as to has been calculated to produce the clusters. Within order to estimate the presentation of the mold and comprehend the contact of shift DSM on the demand-supply stability, this part presents a easy case learn for 24 h. The demand is modeled in a sinusoidal approach to afford various type of difference. The demand

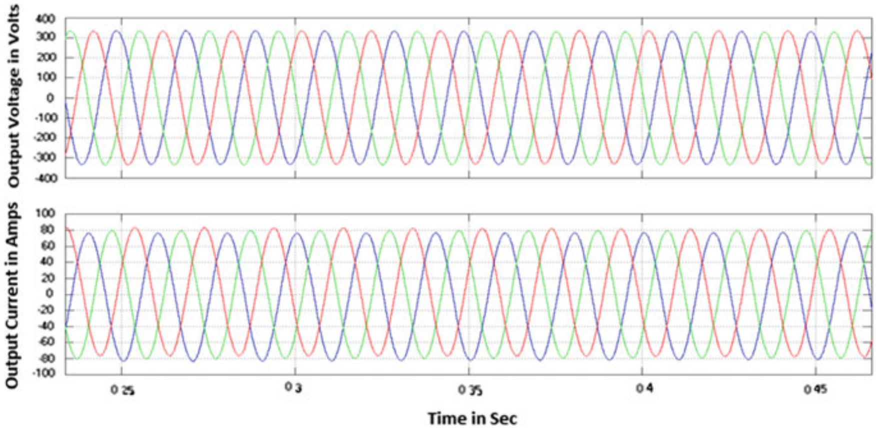

Fig. 5 Output voltages and current—academic block

Table 1 Consumption of power

Energy source	Rated capacity in KW	Output power in KW
Solar	500	252
Wind	42.5	28
Main grid	900	193
Total	1442.5	473

Total energy consumption in demand 469.55 kW

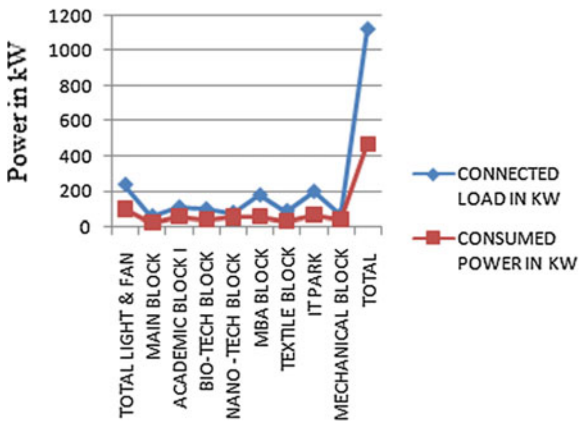

Fig. 6 Peak energy consumption at KSRCT

would not be sufficient to reach this product in a realistic submission, peripheral manage techniques would be required. DMS is that there are not efficiency losses in its utilization and it is a resource that would require just a change in the policies to be used.

The wind produces 28 kW from generating station. The wind power plant produces 28 kW and the waveforms for output voltage and current in the wind energy system are shown in Fig. 3. The photo voltaic power plant produces 252 kW and the waveforms for output voltage and current in photo voltaic energy system are shown in Fig. 4. The power consumed in academic block is about 60.4 kW and the waveforms for output voltage and current in the academic block are shown in Fig. 5. Consumption of power the various is shown in Table 1.

The Fig. 4 shows the entire connected demand and whole consumed power for the possible LP method of the point in time stage is shown in Fig. 6.

5 Conclusion

The projected method provides the actual time monitoring as well as control of load side management system. It improves the presentation of structure load to the stage of distributed energy resources infiltration. The photovoltaic and wind representation was planned using MATLAB. The peak demand of proposed system was satisfied from beginning to end in all the buses and also the protection system for photovoltaic and wind power place was implemented. The distributed energy resources, demand and the power from the main grid were related toward the IEEE fourteen bus system. While connecting all these energy sources to the bus system, the losses can be reduced by using the inductance in each bus. The proposed approaches satisfy the group of demands within the energy management system and in addition get better the system effectiveness and curtail the fatalities. The overload energy from distributed energy resources preserve also is store in the succession moreover it possibly will be utilize by the demand when in attendance is a demand of energy. The distributed energy resources used in the real time system improves the generation side flexibility.

Synchronization of value responsive requests through an EMS is imperative to encourage the correspondence of the requests with the suppliers and to perceive the full planned of SG innovation. The availability of 2-way correspondence empowers viable interest reaction that outcomes in most extreme utility for the requests. Instability demonstrating is imperative to stay away from interest confinement while minimizing supply cost (or expanding interest utility). A strong streamlining strategy gives an adaptable instability administration instrument that permits changing the favored level of conservatism. The proposed EMS calculation is most helpful at a group of interconnected cost responsive burden, for example, a KSRCT grounds. The proposed EMS is effectively executed at a little cost gave that SG innovation is sent, and along these lines, 2-way correspondence is accessible.

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