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Optimization Techniques for Energy handling System in a Microgrid

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Abstract: ***The energy from the renewable energy sources primarily depends on the geographical factors. Intermittency is a major issue for renewable energy sources which will result in comparatively high electricity generation cost and a proper need of an energy management system. In an intelligent era, the increasing penetration level of solar photovoltaic (PV) energy is becoming a tedious task. Hence, an energy management system is required to control the energy flow when there is more than one source connected. Real time energy management becomes challenging because of the time varying prices of electricity, mismatch of generation and demand etc. So, they are widely related to the optimization techniques. This paper explains a broader review of various challenges on integration of Renewable energy sources to the grid. Also, an extensive review of numerous approaches of Energy management system is given in this paper. Different optimization techniques are discussed along with its advantages and limitations for better and more optimized Energy management in the micro grid. A proper energy management system helps to decrease the electricity prices as well as increases the power system reliability. Also, improves the grid stability.***

Keywords: ***Energy Management System, Grid connected Renewable Energy source, PV-Battery storage, Renewable energy, Solar power forecasting.***

I. INTRODUCTION

According to a report published by the United Nations (UN) in June2019, India is expected to overtake China around 2027 as the most populous country across the globe. Due to the increase in population growth, India's demand for electricity is also increasing. So, India's renewable energy use is expected to grow simultaneously at a huge rate for a sustained GDP rate of 9% by 2031-32 [1]. Investing in a new conventional power plant to meet the growing demand will be costlier than solar due to rapid fall in solar prices in recent years [2]. So, with the objectives of a clean, cheap, reliable and environmental-friendly energy to the customers, the Renewable Energy Sources (RES) are being utilized and promoted. With the rise in energy demand, numerous techniques on effective utilization of RES are being studied and implemented.

Among the various RES, the solar and wind energy systems are playing vital role due to their availability. Though solar and wind energy are available in larger scale, due to their intermittent nature, the grid connected RES are unreliable. Often the grid engineers feel that the integration of RES will make the grid unstable due to their intermittent and flexible nature. So, there is a need for a battery storage with energy management system (EMS) that will maintain the energy level in the battery to match the generation with the load pattern of the grid. Whenever the demand mismatches with the production, the energy balance will be achieved through the battery storage. Hence, a grid connected Photovoltaic (PV) system with battery storage is the need of today's society. With the higher consumer's reliability requirement from the utility providers, the generation pattern should be matched with the load demand pattern. Though, the power reliability depends on many factors like region variations, population, time varying prices, system configuration etc., the reliable power supply through the storage facility is based on the flexibility of the grid and precise forecasting of generation and demand. The forecasting method is to decrease the renewable generation uncertainty so that its fluctuation can be predicted more accurately. Due to the vast distribution of solar energy in India throughout the year, the integration of solar PV system with the grid is considered here. The solar PV power production which is to be forecasted mainly depends on irradiation, temperature difference, and moisture in the atmosphere, shading, maintenance and many more. The accuracy of the prediction is usually assessed by considering the differences between the predicted and the actually occurred values [3]. Generally, the PV performance prediction models are physical approaches like numerical weather prediction (NWP) and statistical approaches, where a mathematical relationship is learned based on the accessible data. This includes Machine learning methods, artificial neural network (ANN), Data mining etc. Satellite based Forecasting method is also one of the methods but have greater inaccuracies than physical or statistical approaches [4]. Based on the historical learning and physical model, energy forecasts will be effective only through plant accessibility and accurate weather predictions.

Prediction of Solar PV System output

The accuracy of overall energy management between the generation and demand side depends on the accuracy of the employed prediction methods. The various prediction techniques proposed by different researchers for PV power prediction are discussed below.

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Authors Yu, T. C., & Chang, H. T [5] proposed a method to predict the electrical energy produced by the Photovoltaic systems using the ANN technique. The proposed technique uses the learning rule of back propagation to train the neural network to accurately estimate the electrical energy produced. The proposed model predicted the energy produced under various weather conditions.

Though, it was able to handle the large amount of data sets, the proposed method would have given better results if solar cell shading and elevation of Sun are also considered as the input parameters.

Authors Saberian, A., Hizam, H., Radzi [6] proposed a modelling method using the ANN which accurately predicted the PV power. Mathematical equations that uses feed forward back propagation and general regression neural network (GRNN) had been used to estimate the produced energy of the solar panel. The mapping feature of neural network is considered to be very flexible. Also, they have the capacity to generalize the limited data points and deliver better outcomes at fresh data points. The proposed model shows good performance thereby considering appropriate for forecasting.

For a photovoltaic (PV) system with a battery storage, an operational dispatch control algorithm had been built [7]. The algorithm works on the forecasting of solar and load to mitigate the metered load's peak demand by considering a Numerical weather prediction (NWP). In this paper, the Linear programming method is used to achieve a battery dispatch schedule.

Authors Navaeefard, A., Tafreshi, S. M., Barzegari, M [8] proposed an optimal sizing method for Micro grid connected distributed energy resources. The micro grid is in this paper comprises of PV/wind hybrid system with a storage facility. The proposed methodology considers the probabilistic wind uncertainty which results in an increased wind turbine production but operational costs also rise simultaneously. To achieve best global solutions, Particle swarm optimization method is used.

Authors Parisio, A., Rikos, E., Tzamalis, G., & Glielmo, [9] developed a Model Predictive Control (MPC) strategy for modelling and optimization of micro grid under several aspects like economic dispatch, unit commitment, energy storage etc. Mixed integer linear programming algorithm is used to solve the optimization problem. The power forecasting model is achieved from Support Vector machine (SVM) toolbox in Matlab.

Authors N. Premalatha and Dr. A. Valan Arasu [10] predicted the solar radiation of Madurai location in India using ANN. The proposed technique uses the learning rule of back propagation to train the neural network where the input parameters are the ambient temperature and the humidity records of Madurai. The proposed model when trained by Gradient descent back propagation with a learning algorithm, it shows that the mean percentage error is 6.65% and mean square error is 0.008. It is also suitable to forecast the solar radiation in South India. This prediction of solar radiation can be used for the prediction of solar power for energy management in grid.

Authors Grimaccia, F., Mussetta, M., & Zich, R [11] implemented a Neuro-fuzzy model for the forecasting of Solar PV power production. For solving difficult forecasting problems, an evolutionary algorithm is used which uses heuristic search techniques for training Artificial neural network. During this process, distinct time horizons were measured like short term, medium term, long term and predictions for distinct lead times were used for distinct purposes. This was considered as an effective implementation for forecasting solar PV power production.

Authors Buwei, W., Jianfeng, C., Bo, W., & Shuanglei, F [12] developed a new technique for predicting the PV energy in a more accurate manner through Support Vector Machine (SVM) based on data fusion. The information from satellite, weather forecast information (NWP) and measured power information are used. The methodology involves pre-processing the data sets of these information's and fusing them with machine learning methods. High quality of PV energy forecast and reduction of errors between the remote sensing information's are achieved.

The National Weather Service (NWS) was developed to forecast the solar generation using machine learning methods [13]. Multiple regression methods are studied and compared to generate predictive models including SVM and linear least squares with various kernel features. Therefore, with the help of machine learning methods, the predictive models can be derived from historical solar radiation data and forecast information. SVM is capable of handling the nonlinear information.

Authors Jang, H. S., Bae, K. Y.,Park, H. S., & Sung, D. K. [14] develops a forecasting model based on different satellite images and SVM learning system. The prediction model was able to predict the future clouds and solar irradiance in the range of 15-300 minutes in various locations of South Korea. The proposed SVM system attained high efficiency by minimizing the forecasting errors and maximizing predictive model generalization capability. The SVM is one of the most leading regression methods capable of overcoming certain neural network limitations like over fitting, and other computational issues.

Authors Wolff, B., Kühnert, J., Lorenz, E., Kramer in paper [15] correlated the notions of NWP and satellite based prediction with a statistical approach i.e support vector regression (SVR), which was applied to a big dataset of all the PV measurements and the physical and satellite based cloud motion vector (CMV) prediction measurements for PV power forecasting. The optimization of SVR parameters was carried out on the preselected test set to obtain high quality predictions. SVR forecasts resulted in better outcomes than the physical approach.

Authors Cui, M., Zhang, J., Hodge [16] quantified and analyzed the reliability advantages of enhanced solar power predictions in power system. An expected synthethic reliabilty (ESR) had been developed to thoroughly assess the link between solar power forecasts and the system's reliable effectiveness. The simulation based on the IEEE 18 bus system indicated that the reliability of the system increases if solar power prediction is significantly improved.

Grid integration of PV system

Generally a Grid which is integrated with solar PV system and battery storage comprises of solar PV array, inverter, battery bank and charge controller. Fig.1. shows the architecture of a grid integrated with solar PV system with battery storage.

The charge controller regulates the battery bank by making sure that the battery bank is neither overcharged nor over discharged. The array generated surplus DC energy is converted to AC by the inverter and delivered via grid to the load. Even when grid is not available, this type of system can supply AC power as battery storage will supply DC input to the inverter in addition to the solar PV array. When grid is available, the system operation is same to the system without back up.

The battery bank is maintained in float charge condition. If Demand is more than the production of PV power then, PV output will be used plus the additional amount will be met by the storage. That is from Battery to the consumer at low cost. Solar PV system modelling is designed to achieve maximum power from load demands [17]. Energy storage system is therefore essential in order to balance supply and demand.

According to NSGM India reports [18], Total installed Power Generation capacity was 351 GW. Out of which solar capacity installed was 26.03 GW as on January, 2019. Indian Government had taken various policies and initiatives to promote solar energy. But, integrating the PV system with grid has many challenges [19] like

- Grid stability
- Higher curtailment rate
- Reliability issues
- Difficulty in scheduling, etc.,

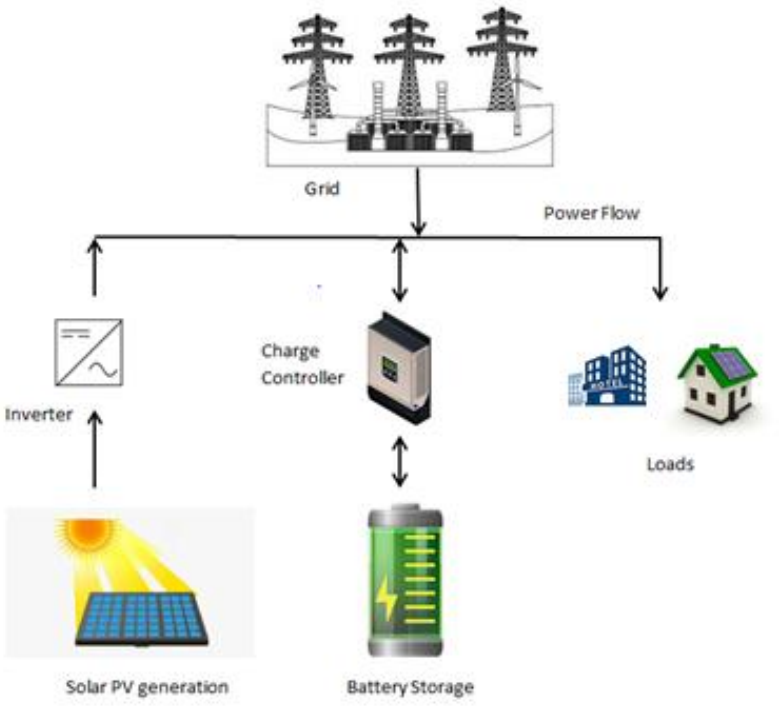

Fig.1. Architecture of a Grid integrated solar PV system and a battery storage.

The various challenges raised due to the integration of PV systems with the grid are published by different researchers. They are discussed in this section. Julio Romero Agüero and Steve J. Steffel reported the impacts of PV-DG integration on power distributions system in North America. Various PV-DG integration challenges were observed which were caused by the utility scale PV-DG plants on the distribution sector like reverse power flow, voltage rise, voltage fluctuations etc. The impacts were studied to govern the seriousness of those in steady and dynamic state. They concluded with some mitigation techniques like use of more advanced STATCOMS, distributed storages, capacitor banks etc.,[20].

Author C.L Masters discussed the steady state voltage rise when connecting the small generators to 11 kV networks [21]. When linked to 11kV network, there were many factors that determined the amount of generation. Also, it is concluded that as the distance from the primary substation increases, the actual amount of electricity that can be accepted will be decreased. Different problems and their solutions were also discussed.

Martin Braun, Thomas Stetz [22] also discussed the new standards for connection and parallel operation of generators in low-voltage (LV) network. The different reactive power supply methods (Q-methods) were discussed. PV generators technically contributed to reduce the voltage at their PCC. But the PV generators cannot reduce voltage within the +-2% of variation. It was concluded that for a highly rigid system, the reactive power requirement will be more to reduce the voltage rise caused by PV power injection.

Yuzure Ueda, Kosuke Kurokawa [23] addressed the problem of avoiding the over voltage at grid connected PV generation system. The paper discusses the factors affecting the output energy loss like balancing of generation voltage and demand voltage, uneven voltage rise in low voltage network and their mitigations. Also, discusses the present control of Power conditioning subsystem's (PCS's) overvoltage protective function. The influence of high installation costs of the PV- battery system in the German low voltage distribution grids was studied [24].

For analyzing purpose, the simulation was done on two different models. One is Low voltage grid model and the other is PV-battery system model. Depending on the PV and load profiles, energy management algorithm of Sol-ion system was applied with the objective of maximization of self-consumption at the point of common coupling. This energy management strategy shifts the grid injection of the generated PV energy from the morning/noon hours with low load demand to the afternoon/evening with high load demand. It was concluded that PV- battery systems can reduce the loading of grid components as well as reduce the grid losses.

As per the study report of India's renewable electricity roadmap 2030 [25], the government of India had increased its renewable energy goals from 175 GW by 2022 to 500GW by 2030. So, the existing grid will be upgraded by developing a two way communication between the utility and the consumer so as to manage the power consumption smartly as well as promote active customer participation. With the distributed generation (DG) and storage facility, the variations in the demand on the grid will decrease. This will give profit for the utility. For this an effective Energy Management system has to be designed which should consider the effective integration and utilization of RES which is a challenge.

So, a comprehensive review is performed on the various grid integrated solar PV systems and the implementation of various energy management strategies. The various techniques used by the different authors in their research articles were reviewed. This paper discusses the various challenges related to the integration of Renewable source to the grid and their solutions through energy management systems. These energy management strategies comprises of the optimization techniques that includes the exact mathematical models and approximate methods as explained in Fig.2. The various energy management techniques which are constructed on the Exact Mathematical models are reviewed in section 2. The different energy management techniques which are based on the approximate methods are discussed in section 3.

II. ENERGY MANAGEMENT TECHNIQUES BASED ON EXACT MATHEMATICAL MODELS

This section reviews the different approaches of energy management used in grid integrated solar PV generation systems. Some of the research papers reviewed in this section uses linear programming method, Mixed Integer Linear Programming method, Quadratic Programming method, Lagrange Relaxation method and Dynamic Programming method.

The optimal power flow management mechanism for grid connected PV system with storage is proposed by the authors [26]. This is for the intensive penetration of PV production into the grid by peak shaving service at a reduced cost. For this, the optimization was performed using Dynamic Programming (Bellman Ford Algorithm) and then it is compared with the simple rule based management. Here, Ageing of batteries is considered as a parameter in the optimization process. Grid management become easier because of the peak shaving so that integration of PV power could be done into the grid.

Mixed Integer linear programming is used for the large scale deployment of low voltage distribution grid tied PV battery systems [27]. It aims to reduce the conversion stages to minimum, while retaining AC supply voltage to the apartments in order to avoid any modifications in the existing installation. Also, an optimal control for a residential ac micro-grid, is proposed where the power injection by the thermal and electrical energy storage systems are scheduled in order to minimize the operational cost of the system.

The hourly scheduling and dispatch of battery in a grid connected PV battery system [28] is discussed by the authors. The paper describes the three modes of operation for a PV/ battery system that is charging state, idle state and discharging state. Based on the PV power prediction, Battery storage system is used. Here, Lagrange Relaxation method is proposed as well as Network flow programming (NFP) method is used which is a special case linear programming. The NFP, is used to reduce the dispatch cost of PV/battery. A linear relationship between the battery power and current is found. For producing exactly similar amount of current, power used for charging battery is more than that for discharging the battery. It is concluded that, depending on the size of the battery and the technique for utilization, the use of PV/ battery can influence on the pricing and the congestion mitigation, peak load reduction, unit commitment of costly units.

Authors Davis Torres, Jorge Crichigno, Gregg Padilla, Ruben Rivera in [29] proposes a method to satisfy the increasing energy demand by scheduling and thereby increasing the profit for utility company. Here, the Linear Programming method (Simplex method) is used. The method optimizes the schedule to increase the time between minutes to hours but is long and complicated for more variables. This method has an assumption that the input and output should have linear relationship.

Authors Chiara Bordin, Harold Oghenetejiri, Andrew Crossla addresses the operational pattern of an off grid power system and how it impacts the degradation costs of batteries [30]. Battery degradation is considered to be a problem as there is continuous charging and discharging of the battery. With the help of the proposed Linear programming method, the importance of the hybrid/grid integrated system with energy management is proved. But, the time consumption by the linear programming is high.

Authors Michael Urbina, Zuyili has addressed the Solutions for scheduling PV-battery system to model the uncertainty in PV generation [31]. The proposed method is Mixed Integer Linear Programming and Fuzzy optimization. Unit commitment and Economic dispatch problems are solved using the above two algorithms. Then, the results from the two methods are compared to one of the traditional methods using IEEE 118 bus system. The savings can be increased if the PV generation is increased because the load will require less number of units. The above method proved to be effective in order to address the uncertainty in PV generation. Authors Daud Mustafa Minhas, Raja Rehan Khalid, Georg Frey addresses the uncertainty in PV generation & consumer consumption triggered because of the difference in the forecasted and the measured values due to varying atmospheric and consumer behaviour [32]. Lyapunov Optimization method is used in this paper.

The proposed method involves the day ahead solar power predication and load demands, balancing of load demands, segregating real time uncertainties, balancing of supply and demands. Though the iterations are fast, the construction of Lyapunov functions becomes difficult.

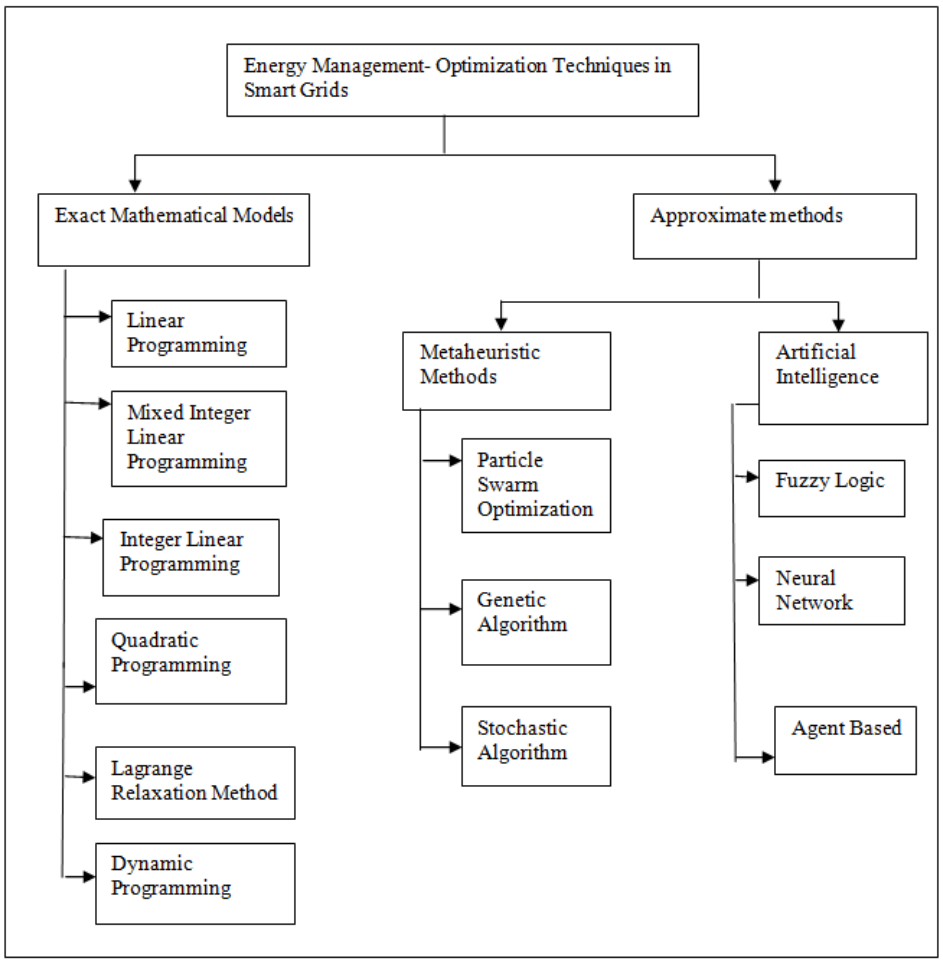

Fig.2. Classification of Optimization Techniques used in Energy management system

III. ENERGY MANAGEMENT TECHNIQUES BASED ON APPROXIMATE MODELS

This section reviews different approaches to Energy management used in grid integrated solar PV generation systems. Some of the research reviewed in this section uses Artificial Intelligence methods like Fuzzy logic systems, neural network methods and Agent based. It also includes, population based method like Particle swarm optimization.

Priyanka Chaudhary, M Rizwann focuses on the best prediction of the incoming Photovoltaic energy and estimate the electricity generation from PV system [38]. The algorithm used for energy management for the smart grid environment is the neural network algorithm. With neural network, better and adequate results were found and performance of the system under Demand response was found to be satisfactory. To check the results from the proposed algorithm, the results were compared with other existing approaches like ANN and were found to be satisfactory.

Authors MD Alamgir Hossain, Hemanshu Roy emphasizes on the difficulty to determine optimal operating point of a storage system for saving cost & minimising energy waste [39]. Particle Swarm Optimization (PSO) algorithm is used for the application of real time energy management. Here, Optimization model is developed to optimize the battery energy. Also, various cost functions were analyzed for charging as well as discharging energy from the battery. Dynamic Penalty functions were multiplied to the charging component of function manage battery efficiently by studying their behaviours. Degradation costs of the battery were not considered.

Authors Dima El Nabouch1, Natalie Matta from paper [40] focuses on the agent based algorithm that would allow energy to be used more efficiently while reducing costs and integrating distributed renewable energy sources. Joelle Klaimi†, Rana Rahim-Amoud from paper [41] focuses on reducing the cost of energy purchase during peak hours and increasing the battery life. This is achieved by using intelligent storage based system. The multi-agent system has 4 components as discussed. They are- Storage agent, Grid agent, Producer agent and Consumer agent.

Authors Yann Riffonneau, Arnaud Delaille in paper [42] assures the supply of loads at the lowest prize by optimizing the solar power use. Deterministic Algorithm is used which identifies the energy load pattern that guarantees the supply of loads at the reduced price, taking into consideration the availability of PV power, load demand and instant electricity grid prices. One of the disadvantages of this methodology is that it has a longer run time.

Authors Francesco Conte, Stefano Massucco in paper [43] emphasizes on the maximization of the financial benefit as required by its distinct generation profile. Mixed integer Stochastic optimization algorithm identifies the daily power generation profile based on PV power forecast and Real Time Operation Control (RTOC) adjusts the Battery energy storage systems (BESS) power exchange to achieve the intended profile.

Table 1 Summary of the Literature review of Energy Management Techniques based on Exact Mathematical Models

Authors/ Reference	Issue Addressed	Algorithm	Advantages	Limitations
Yann Riffonneau ,Saddiak Bacha, Stephane Ploix [26]	Focuses on the optimal power flow management mechanism for grid connected PV system with storage for intensive penetration of PV production into the grid by peak-shaving service is proposed at a reduced cost	Dynamic Programming (Bellman-Ford Algorithm)	Reduce CO emissions and Grid management is easier.	Needs high memory when the study period is long. Reactive Power flow management is not considered.
Enrique Rodriguez, Dias Emillio J [27]	Large scale deployment of low voltage distribution grid PV battery systems	Mixed Integer Linear Programming	Reduces Operational costs of the residential micro grid by 28%	Separate Mathematical solver is needed . Distribution losses are not reduced
Authors Bo Lu, Mohamad Shahidepo ur [28]	Emphasizes on hourly scheduling and dispatch of battery in grid connected PV battery system. Also uses NLP method.	Lagrange relaxation method	The use of PV/ battery can influence on the pricing and the congestion mitigation, peak load reduction, unit commitment of costly units.	Varies according to the strategy of utilisation and sizing of the battery.
Davis Torres, Jorge Crichigno, Gregg Padilla, Ruben Rivera [29]	Focuses on the point to satisfy the increasing energy demand by scheduling and thereby increasing the profit for utility company	Linear Programming	Optimizes the schedule to increase the time between minutes to hours. Also, Fast and adaptable.	Long and complicated for more variables
Chiara Bordin, Harold Ogheneteji ri, Andrew Crossla [30]	Addresses the operational pattern of an off grid power system and how it impacts the degradation costs of batteries	Linear Programming	Shows the significance of hybrid system design.	Time consuming and Current production data on degradation is not i deal for predicting lifetime costs resulting from the duty cycle
Michael Urbina, Zuyili [31]	Addressed the Solutions for scheduling PV battery system to model the uncertainty in PV generation	Mixed Integer Linear Programming + Fuzzy Optimization	savings are increased if the PV generation is increased	Low speed and computation time is more.

Daud Mustafa Minhas, Raja Rehan Khalid, Georg Frey [32]	Deals with the uncertainty in PV generation & consumer consumption	Lyapunov Optimization	Fast iterative method.	Difficult to construct Lyapunov functions.
Elizabeth L Ratnam, Steven R Wellr [33]	Emphasizes on increasing the daily savings or the revenue of a residential PV battery system and reducing the impact of the residential PV battery system on the grid.	Quadratic Programming	Almost all the consumer's shows savings in operation when energy shifting technique was applied.	For customers who noticed negative savings in operation , financial benefits, metering topologies etc. were not characterized.
Chee Lim Nge, Ole-Morten [34]	Focuses on an Intelligent Energy management scheme that keeps generation and consumption balanced	Lagrange relaxation method	Compared to normal PV systems, high total revenue is observed. Also, power fluctuation is compensated.	Depends on the sizing of the battery.
Chee Lim Ege, Lars Norum, Iromi [35]	Aims to maximize the income over a specific period of time while meeting energy constrained stored by the battery	Lagrange relaxation method	Reactively compensate forecasting errors or system modelling.	Cannot be used if the answer must be integer or derivatives for constraints do not exist.
M.K.C. Marwali Haili Ma [36]	Emphasises on an effective strategy that manages the short term resources for integrated utility grid and PV generation with battery storage	Lagrange relaxation method + Dynamic programming	By integrating battery storage, we can decrease the load by according to the PV utility grid demands.	Low speed.
Luu Ngoc An and TRAN Quoc-Tuan [37]	Aims to minimize the system's cash flow and power trading in two kinds of tariffs- Autonomy tariff and dynamic tarif	Dynamic programming	Performance is better than rule based method.	Low speed.
Julio Pascual , Javier Barricarte [46]	Focuses on the energy management approach for residential renewable based microgrid that aims at acquiring a smooth power profile for exchanging power with the main grid	Linear Programming	Improved grid quality and stability as power fluctuations decreases, avoiding of overvoltage in low voltage grids when power is being penetrated to the grid.	Time consuming.

Table 2 Summary of the Literature review of Energy Management Techniques based on Approximate methods

Authors/ Reference	Issue Address	Algorithm	Advantages	Limitations
Michael Urbina, Zuyili [31]	Addressed the Solutions for scheduling PV battery system to model the uncertainty in PV generation	Fuzzy optimization + Mixed Integer Linear programming.	savings are increased if the PV generation is increased	Low speed and computation time is more.
Priyanka Chaudhary, M Rizwann [38]	Focuses on the best prediction of the incoming Photovoltaic energy and estimate the electricity generation from PV system	Neural network algorithm and results are compared with existing ANN approach	Better Adequacy and Reliability& Performance of the system under DR found satisfactory	High processing time. Need a lot of training for data set.
Alamgir Hossain, Hemanshu Roy [39]	Emphasizes on the difficulty to determine optimal operating point of a storage system for saving cost & minimising energy waste	Particle Swarm Optimization	Reduction of operational costs by 12% as compared to the original cost over a time horizon of 96 hours	Does not consider the battery's degradati on cost
Dima El Nabouch1, Natalie Matta [40]	Focuses on the agent based algorithm that would allow energy to be used more efficiently while reducing costs and integrating distributed renewable energy sources.	Multi Agent Based	Minimizes the energy cost and satisfy customer's needs	Energy storage systems are not used thereby reducing the performance.
Joelle Klaimi†, Rana Rahim-Amoud [41]	Focuses on reducing the cost of energy purchase during peak hours and increasing the battery life.	Multi Agent Based	This is achieved by using intelligent storage based system	Joelle Klaimi†, Rana Rahim-Amoud [33]
Riffonneau, Y., Delaille, A., Barruel, F., & Bacha [42]	Assures the supply of loads at the lowest prize by optimizing the solar power use	Deterministic Algorithm	Identifies the energy load pattern that guarantees the supply of loads at the reduced price.	Longer run time.
Conte, F., Massucco,S., Saviozzi, M., & Silvestro [43]	Emphasizes on the maximization of the financial benefit as required by its distinct generation profile	Stochastic Algorithm	The optimization procedures provide applicable results for the uncertainty management due to PV fluctuations in order to optimally exploit BESS.	Effectiveness can be enhanced by more advanced model of PV forecasting.
Ahmed Mohamed and Osama Mohammed [44]	Aims to reduce the power drawn from the grid and and keeping the battery's SOC above 60% to avoid high tariffs.	Fuzzy systems	High precision	Lower speed, longer run time. Restricted no. of usage of input variables.
He Zhang and Arnaud Davigny [45]	Aims at reducing the electricity bill, load shedding, Carbon dioxide emissions	Fuzzy systems	High precision. The storage system can adjust the grid power in the peak period and off peak period to redu-ce the electricity bill and CO2 emissions.	Lower speed, longer run time.

Authors Ahmed Mohamed and Osama Mohammed aims on reducing the power drawn from the grid and keeping the battery's SOC above 60% [44]. The SOC level will allow the power stored in the batteries to change the peaks, thus avoiding high tariffs. Here, Fuzzy system technique is used. In the proposed fuzzy system, two fuzzy variables function as inputs and one fuzzy variable functions as output. Twelve distinct combinations were found and since it is a rule based system, many rules were listed and accordingly different cases were studied.

For commercial buildings, authors He Zhang and Arnaud Davigny proposes a Energy management technique which uses Fuzzy logic integrated to photovoltaic and storage system which aims at reducing the electricity bill, load shedding, Carbon dioxide emissions [45]. Certain parameters like Production of PV power, electricity price variation, and various types of consumptions should be taken into account.

Authors Julio Pascual , Javier Barricarte in paper [46] focuses on the energy management approach for residential renewable based microgrid that aims at acquiring a smooth power profile for exchanging power with the main grid. Some advantages are improved grid quality and stability as power fluctuations decreases, avoiding of overvoltage in low voltage grids when power is being penetrated to the grid. Summary of all the research articles implementing different Energy management Techniques described in the literature review is summarized in the table.

IV. RESULT AND DISCUSSION

This paper compares the different energy management techniques used in a Grid integrated renewable energy source with battery storage. According to the research studied on various Energy management techniques, Dynamic Programming under exact mathematical model is considered as one of the best method for optimization of energy management.

Although it requires a high memory, its computational parameters are well selected. Computation time can be reduced by modifications. Quadratic programming also gives good results but is only suitable for small variables. Lagrange Relaxation method involves less number of variables and converts difficult problems to an easier one. But, better results depend on the sizing and utilization of the battery. Mixed Integer Linear programming method gives good results but distinct mathematical solver is needed. Linear programming is time consuming as it needs lot of mathematical calculations and gets complicated as the variables increase. Approximate methods that involves Metaheuristic as well as Artificial Intelligence methods (AI) have computational simplicity. It is observed that all the artificial intelligence techniques require high processing time and a large dataset for training. With the help of AI, real time issues can also be addressed thereby increasing the importance for both grid and consumers.

V. CONCLUSION

An efficient Energy management system shows it's significance when more than one energy source is used to supply a certain load. This system helps to understand the flow of energy throughout the system. There are many optimization techniques that are used for the energy management. Dynamic Programming to be considered the best method since it can optimize better than the other techniques resulting in an effective energy management system. Different AI techniques are used for PV power forecasting making the predictions more accurate than other traditional methods which helps in decision making of Energy management system. A proper energy management system helps to decrease the electricity prices as well as increases the power system reliability.

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