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Materials Today: ProceedingsXX (2016) XXX–XXX

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PMME 2016

Modeling and Optimization of Integration of Renewable Energy Resources (RER) for Minimum Energy Cost, Minimum CO_2 Emissions and Sustainable Development, in Recent Years: A Review*

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Abstract

The rising economic activities, growing population and improving living standards of world have led to a steady growth in its appetite for quality and quantity of energy services. As the economy expands the electricity demand is going to grow further, increasing the challenges of the more generation and stresses on the utility grids. Appropriate energy model will help in proper utilization of the locally available renewable energy sources such as solar, wind, biomass, small hydro etc. to integrate in the available grid, reducing the investments in energy infrastructure. Further to these new technologies like smart grids, decentralized energy planning, energy management practices, energy efficiency are emerging. In this paper the attempt has been made to study and review the recent energy planning models, energy forecasting models, and renewable energy integration models. Also various modeling techniques and tools are reviewed and discussed.

Selection and Peer-review under responsibility of International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

*Keywords:*Energy modeling; integration of renewable energy; energy modeling tools

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1. Introduction

Energy is a prime input to the economy and social developments of world. Energy consumption of any country speaks about the growth rate of that country in terms of Gross Domestic Product (GDP) and other growth indices. Currently the main commercial forms of energy used i.e. heat and electricity is the output of constrained fossil fuel reserves and subsequently leads to climate change mitigation and global warming. The decreasing R/P ratios of fossil fuels is a major concern now a days There are number of solutions available to tackle such problem as demand side management, supply side management, decentralized energy planning, increasing energy efficiency and use of renewable energy(RE). It is observed that large penetrations of RE in grid can solve this problem to maximum extent. A decentralized energy planning with the use of local available resources is also one of the solutions for such types of problems. For that micro level energy planning becomes pragmatic A lot of good research work is done and going on throughout the world in this area. Researchers have tried to solve the complex energy planning problem by modeling, simulation and optimization. An attempt has been made in this paper, to review the energy models on integration of renewable energy for sustainable development. The energy models are categorized in three sections namely reviews models, forecasting models and multi-objective models.

2. Review Models

The different energy models are reviewed by S. Jebaraj, (2006) based on the different category namely renewable energy models, optimization models and emission reduction models. K. UshaRao and V.V.N. Kishore (2009) reviewed different diffusion theory based models and their applicability to Renewable Energy Technologies diffusion analysis. A review of energy system models has been done by Subhes C. Bhattacharyya (2010) and concluded that the existing energy system models inadequately capture the developing country features and the problem is more pronounced with econometric and optimization models than with accounting models. In the same year Wei Zhou (2010) reviewed the current status of research on optimum sizing of stand- alone hybrid solar–wind power generation systems including various softwares used for simulation and modeling optimization. R. Luna-Rubio (2011) reviewed thoroughly Optimal sizing of renewable hybrids energy systems. The optimization methods are applied to renewable and sustainable energy such as Wind power, solar energy, hydropower, Bioenergy, Geothermal and hybrid systems and R. Banos (2011) concluded that the use of heuristic approaches, Pareto-based multi-objective optimization and parallel processing are promising research areas in the field of renewable and sustainable energy. The literature on power and supply sector developments is reviewed by Aqeel Ahmed Bazmi et al. (2011) and they analyzed the role of modeling and optimization in this sector, as well as studied the future prospective of optimization modeling as a tool for sustainable energy systems. M. Fadaee et al. (2012) reviewed stand-alone hybrid renewable energy system for Multi-objective optimization by using evolutionary algorithms and concluded that most popular applied methods are genetic algorithm and particle swarm optimization. In the same year PrabodhBajpai (2012) reviewed research on the unit sizing, optimization, energy management and modeling of the hybrid renewable energy system components based especially on developments in research on modeling of hybrid energy resources (PV systems), backup energy systems (Fuel Cell, Battery, Ultra-capacitor, Diesel Generator), power conditioning units (MPPT converters, Buck/Boost converters, Battery chargers) and techniques for energy flow management. Again a detailed analysis of optimum sizing approaches is done by O. Erdinc (2012) in the literature that can make significant contributions to wider renewable energy penetration by enhancing the system applicability in terms of economy. M. Mohammadi (2013) reviewed the simulation and optimization approaches to the use of hybrid renewable energy resources as micro grid in two modes, standalone and grid connected. A summary of different available approaches and those currently under research for optimal control techniques and objectives considered in the design of hybrid renewable energy systems is provided by M. Rizwan (2013), also he discussed the different approaches, Current status and future possibilities in system control. In the same year Wei Gu (2013) reviewed the modeling, planning and energy management of the CCHP microgrid and suggested that a combined cooling, heating and power (CCHP) microgrid with distributed cogeneration units and renewable energy sources provides an effective solution to energy-related problems, including increasing energy demand, higher energy costs, energy supply security, and environmental concerns. To get an optimum output power G.D. AnbarasiJebaselvi et al. (2013) reviewed the performance analysis of hybrid power systems, control methodologies and modeling techniques. A review of Multi-Objective Optimization for Sizing of Solar-Wind Based Hybrid Power System is done by S. K. Bhargava et al. (2014) and they suggested that for multi-objective optimization, Particle swarm optimization (PSO) tool can be a good approach for solving these types of problems. For stand-alone applications, AnuragChauhan et al. (2014) reviewed integrated renewable energy system based power generation; as per their configurations, storage options, sizing methodologies and control.

3. Forecasting Models

K.J. Sreekanth et al. (2011) presented a step wise regression model for forecasting domestic energy consumption based on a micro level household survey data collected from Kerala, a state in southern part of India. The either models developed also demonstrates or models demonstrate the influence of per capita land area, residential area among the higher income group while the average age and literacy forms significant variables among the lower income group on energy requirements. The cost effectiveness of centralized and Decentralized Distributed Generation (DDG) technologies is assessed by KapilNarula (2012) by employing the 'MESSAGE-Access' model. Delivery mechanisms are modeled to include mini-grid and stand-alone systems, and the analysis includes an estimation of rural household electricity demand from lighting and appliances. Will McDowall (2012) had used UK MARKAL to examine the implications of adopting a precautionary approach for bioenergy development in the UK, finding that aprecautionary approach adds to the cost of decarbonisation, but does not significantly alter the optimal technology mix. Yuanyuan Wang (2012) forecasted the electricity demand in China by using a seasonal ARIMA model. He also suggested that the PSO optimal Fourier method, seasonal ARIMA model and combined models of PSO optimal Fourier method with seasonal ARIMA, the modified models have higher accuracy in forecasting the results than the single seasonal ARIMA. Yusang Chang et al. (2012) projected an alternative projection of the world energy consumption in comparison with the 2010 international energy outlook and found that the EIA's projections were lower than their projections in the case of China, the U.S., India, Japan, and Mexico. They used two types of experience models, classical, kinked, and used a historical data to predict the alternative energy projections. In the same year ArgiroRoinioti (2012) used LEAP (Long range Energy Alternatives Planning System) as a main tool in the scenario analysis for modeling the Greek energy system in the scenarios of clean energy used and their implications. Philip Kofi Adom et al. (2013) modeled electricity demand in Ghana. The varying nature of electricity demands elasticity prior to and post the economic reform period in Ghana is analyzed using the fully modified FM-OLS. Else Veldman (2013) assessed the impact of changes in the future residential use on the electricity distribution grids by using a scenario-based methodology to model residential loads. It illustrates that scenarios resulting from varied economic and demographic developments, but also driven by the focus of energy policies, canhave considerable consequences on the loading and resulting required network capacities of electricity distribution grids. In the same year Oussama Ibrahim (2013) presented a multi-variable optimization for future electricity-plan scenarios in Lebanon. Two future electricity generation plan scenarios for Lebanon were investigated, where multi variables namely cost and environment and tariff where examined and tariff. Holt's exponential smoothing method has been used by Rajesh V. Kale (2014) to propose a forecast model. LEAP has been used to forecast electricity demand for the target year 2030 for the Indian state of Maharashtra. Probable projections have been generated using uniform gross domestic product (GDP) growth rate and different values of elasticity of demands. Three scenarios have been generated which include Business as Usual (BAU), Energy Conservation (EC) and Renewable Energy (REN). Madeleine McPherson (2014) forecasted long-term scenario alternatives and their implications using LEAP model application of Panama's electricity sector. He considered four scenarios, the business as usual scenario of the electricity generation trend over the last decade; which it was compared to three alternative scenarios which have more specific objectives. Among other three scenarios, scenario1 encourages climate mitigation without incorporating new technologies in the generation mix, Scenario2 maximizes resource diversity, and Scenario3 minimizes global warming potential. Hector Pollitt et al. (2014) considered future options for Japanese energy and climate policy. They also assessed the economic and environmental impacts of changing the share of electricity generated by nuclear power and varying the mid-term GHG targets using the global macro-econometric E3MG model, and suggested that a very high carbon tax rate would have to be imposed in order to achieve a 25% reduction in GHG emissions in 2020 simultaneously phasing out nuclear power.

4. Multi-Objective Models

The DSM issues and the modularity of expansion possibilities are modeled as an equivalent of a generating group, similar to the generating alternatives from the supply side with some operational restrictions by C. HenggelerAntunes (2004) using an MOMILP (Multi-objective mix integer linear programming) model to provide decision support in the evaluation of power generation capacity expansion policies. The objective functions are the total expansion cost, the environmental impact associated with the installed power capacity and the environmental impact associated with the energy output. Rodolfo Dufo-Lopez (2004) optimized PV-Diesel system by HOGA (Hybrid Optimization by Genetic Algorithms), a program that uses a genetic algorithm (GA) to design a PV-Diesel system, and compared it with a stand-alone PV system only.

S. Ashok (2007) developed a model to find an optimal hybrid system among different renewable energy combinations for a rural community, minimizing the total life cycle cost while guaranteeing reliable system operation. Solar PV, wind, micro-hydro with diesel and battery backup were considered as in the model. A case study was conducted by S. Ashok in a typical remote village of Western Ghats of Kerala, India. In the same year A.K. Akella (2007) proposed an integrated renewable energy system (IRES) which can satisfy the energy needs of an area in appropriate and sustainable manner. For renewable energy based rural electrification of remote areas, the IRES is modeled and optimized to meet the energy needs of the Jaunpur block of Indian state of Uttaranchal. On the basis of field data, the resource potential and energy demand have been estimated. The model has been optimized using LINDO software version 6.10

Jessica Beck (2008) developed a new approach for integrated resource planning (IRP), which supports the move towards sustainable energy networks. Global dynamic multi-objective optimization (DMOO) models were used to determine preferred energy network development pathways with regards to a range of relevant sustainability criteria over a strategic planning time frame. The viability of such plans was then explored through agent-based models. The combined approach was demonstrated for a case study of regional electricity generation in South Africa, with biomass as feedstock. Henrik Lund (2008) modeled two national energy systems, one for Denmark, including combined heat and power (CHP), and the other a similarly sized country without CHP (the latter being more typical of other industrialized countries). The model (Energy PLAN) integrates energy for electricity, transport and heat, includes hourly fluctuations in human needs and environment. GurkanKumbaroglu (2008) presented a policy planning model that integrates learning curve information on renewable power generation technologies into a dynamic programming formulation featuring real options analysis for the Turkish electricity supply industry. By using HOMER optimization software AnisAfzal (2009) have done a comparative optimization study of hybrid renewable energy systems for energy security for two locations namely, Amini in the Lakshadweep Islands and Hathras in the northern Indian state of Uttar Pradesh. To achieve the optimal cost of battery incorporated hybrid energy system for electricity generation, Ajai Gupta (2009) presented the development in the optimum control algorithm based on combined dispatch strategies. Four different scenarios were considered by A.B. Kanase-Patil et al.(2009) during modeling and optimization of Integrated Renewable Energy systems to ensure reliability parameters such as energy index ratio (EIR) and expected energy not supplied (EENS) by LINGO software version 10. The optimum system reliability, total system cost and the cost of energy (COE) have also been worked out by introducing the customer interruption cost (CIC). A Virtual Power Producer (VPP) is developed by Hugo Morais (2009) which works on mixed integer linear programming implemented in General Algebraic Modeling Systems (GAMS) for optimal scheduling of a renewable micro-grid in an isolated load area of Budapest Tech Renewable Equipment in Hungary. James Keirstead (2009) proposed the integrated energy modeling for urban energy systems to evaluate demand side management. He suggested that such models can be used for developing new energy distribution systems. Jeremy Lagorse (2009) developed a multi-agent system (MAS) for energy management of distributed power sources. Jose L (2009) modeled the most usual systems PV–Wind–Battery and PV–Diesel–Battery. He optimized the model for minimum Net Present Cost (NPC) in relation to the Levelized Cost of Energy (LCE). Y.P. Cai (2009) developed an interactive decision support system (UREM-IDSS) based on an inexact optimization model (UREM, University of Regina Energy Model) to aid decision makers in planning energy management systems. Uncertainties in energy related parameters are effectively addressed through the interval linear programming (ILP) approach, improving the robustness of the UREM-IDSS for real-world applications. M.

Broek, (2009) developed a toolbox that integrates ArcGIS, a geographical information system which elaborates spatial and routing functions, and MARKAL. He developed an energy bottom-up model based on linear optimization for devising blueprints of a CO_2 infrastructure in the Netherlands. The economic, energetic and environmental effects of the DER system were evaluated for an eco-campus in Kitakyushu, Japan by HongboRen and WeijunGao (2009). The MILP model minimizes overall energy cost for a test year by selecting the units to install and determining their operating schedules. A new solution methodology of the capacity design problem of a PV-Wind-Diesel-Battery Hybrid Power System is developed byA. Saif (2010) using Linear Programming (LP) model with two objectives: i) to minimize the total cost and ii) to minimize the total CO2 emissions, while capping the Expected Unserved Energy (EUE). Model inputs were extracted from real environmental and technical data. The results obtained were used to construct the Pareto front, representing the best trade-off between cost and emissions under different reliability conditions. In the same year A. Khalkhali (2010) used multi-objective genetic algorithms (GAs) for Pareto approach optimization of a solar system using modified NSGA II algorithms. The competing objectives were net energy stored and discharge time of Phase Change Materials (PCM) and design variables are some geometrical parameters of solar system. A novel multi-objective, multi-area and multistage model for the integrated generation mix and transmission corridors expansion/investment planning incorporating some sustainable energy development criteria is presented by ClodomiroUnsihuay-Vila (2010). The proposed MESEDES model is a ‘‘bottom-up” energy model which considers the electricity value-chain and three objectives as: (a) the minimization of expansion and operation costs of power generation and transmission corridors, investments cost in energy efficiency based on DSM programs CO_2 capture costs; (b) minimization of GHG emission and (c) maximization of the diversification of electricity generation mix. A multi-agent solution (MAS) in hybrid renewable energy generation system is presented by Zeng Jun etal. (2010). A macro MAS is also presented in detail with a framework containing its overall optimization function based on (Java Agent Development) JADE. C.X. Guo (2010) generated the Optimal Generation Dispatch (OGD) model and is solved by a particle swarm optimization algorithm on an IEEE 30-bus system, with wind power generation and coal-fired generation embedded. The simulation results also show that the integration of wind power will cause the increase of both the generation cost and the reserve capacity but will decrease the environmental emission. J.R. San Cristobal (2010) have shown how the VIKOR method, which introduces the multi-criteria ranking index based on the particular measure of “closeness” to the “ideal” solution, can be used in the selection of a Renewable Energy project for Spain. A novel multi-objective method is proposed by Pedro S. Moura (2010) to optimize the mix of the renewable system maximizing its contribution to the peak load, while minimizing the combined intermittence, at a minimum cost. In such model the contribution of the large-scale demand-side management and demand response technologies were also considered in this model. HananeDagdougui et al. (2010) represented a model of an integrated hybrid system based on a mix of renewable energy generation/conversion technologies (e.g., electrolyzer, hydroelectric plant, pumping stations, wind turbines, fuel cell). The goal of this model was to satisfy the hourly variable electric, hydrogen, and water demands for specific application area in Morocco. C. Dumitru (2010) modeled the solar-wind-hydroelectric hybrid system in MATLAB/SIMULINK environment. The application was made useful for analysis and simulation of a real hybrid solar-wind-hydroelectric system connected to a public grid. Application was built on modular architecture to facilitate easy study of each component module influence. SubhashMallah (2010) derived detailed MARKAL simulations for power sector in India to show that an aggressive implementation of renewable energy technologies lead to sustainable development. RohitSen (2011) developed a model for electricity generation from a mix of renewable resources to satisfy the electrical needs of an off-grid remote village, Palari in the state of Chhattisgarh, India. Applying HOMER software, an analysis was done for choosing the best hybrid RETS system and then compared it with conventional grid extension. With the help of HOMER simulations, the optimized sizing of Small-Hydro power (SHP), wind turbine generator, solar photovoltaic’s (SPV) and Biodiesel Generator (BDG) systems was obtained. Yong Zeng et al. (2011) proposedextensions of deterministic optimization approaches, a number of inexact ones for dealing with uncertainties associated with energy systems planning and GHG emission mitigation. These methods were broadly categorized into fuzzy mathematical programming (FMP), stochastic mathematical programming (SMP), and interval mathematical programming (IMP). Each of these methods could deal with an individual type of uncertainties that can be expressed as fuzzy sets, probability density function, and intervals. A model using Analytic hierarchy process (AHP) for the selection and prioritization of various renewable energy technologies for electricity generation is presented by Muhammad Amer (2011). Renewable energy resource such as Wind energy, solar photovoltaic, solar thermal and biomass energy options are used as the alternatives in the decision model. A fuzzy mixed integer goal programming model (FMIGP) is developed by A.M. Jinturkar (2011) for rural cooking and heating energy planning in the Chikhlitaluka of Buldhana district, Maharashtra. The multi-objectives considered to minimized cost, minimized emission, maximized social acceptance and maximized use of local resources. In the same year Tolga Kaya (2011) proposed a modified fuzzy TOPSIS methodology for the selection of the best energy technology alternative. The sources considered for the integration were Conventional, Nuclear, Solar, Wind, Hydraulic, Biomass, and CHP. A multi-criteria decision making (MCDM) studies were conducted on energy issues such as Technical, Economic, Environmental and Social. Roberto Carapellucci (2011) proposed an innovative approach for optimizing the energy island; it is based on a hybrid genetic-simulated annealing algorithm and aims to minimize the unit cost of electricity. The work is done to develop a simulation tool for evaluating energy and economic performance of renewable energy islands, including various electricity generation technologies (photovoltaic modules, wind turbines and micro-hydroelectric plants), integrated with a hydrogen storage system, comprising an electrolyzer, a hydrogen storage tank and a fuel cell. To satisfy the optimum configuration of the three multi-objectives as load demand with minimum Inequality coefficient (IC), total cost throughout the useful life of the installation (ACS), and maximum Correlation coefficient (CC), S. Farahat (2012) developed a novel sizing method for hybrid solar-wind system to calculate the optimal sizing of each supply based on multi-objective particle swarm optimization algorithm (MOPSO) and non-dominated sorting genetic algorithm (NSGA-II). Monica Alonso et al. (2012) concluded that the Genetic algorithm is a good method to solve large scale, combinatorial optimization problem, such as reactive power planning in order to increase the DG penetration level at distribution networks increasing, at the same time, the voltage stability. The hourly simulation of the intermittent RES generation is performed by EmmanouilVoumvoulakis (2012) on WASP-IV model (Wien Automatic System Planning) software tool to estimate residual load curves on a monthly basis, to examine the impact of large scale integration of intermittent energy sources, required to meet the 2020 RES target, on the generation expansion plan, the fuel mix and the spinning reserve requirements of the Greek electricity system. A case study of University campus is modeled by John Glassmire (2012) using HOMER software for modeling Electricity demand savings from distributed solar photovoltaic. RE sources as such wind- and photovoltaic-based stand-alone systems on the basis of life cycle energy analysis are modeled and optimized by J.K. Kaldellis (2012) and ensured the energy autonomy of a typical remote consumer under the condition of minimum life cycle (LC) energy content. By using HOMER software Omar Hafez (2012) presented the optimal design and comparative studies for a diesel-only, a fully renewable-based, a diesel- renewable mixed, and an external grid- connected micro grid configuration. Various renewable energy options such as solar photovoltaic (PV), wind, micro-hydro and batteries are considered as possible options in the micro grid supply plan. Jing Li et al. (2012) proposed a simple algorithm and demonstrated to determine the required number of generating units of wind-turbine generator (WT) and photovoltaic array (PV) as well as the associated storage capacity for a stand-alone micro grid. A case study on the real data of the Zhoushan islands, China was studied. Jose Ramon San Cristobal (2012) developed a goal programming model, based on a multi-source multi-sink network, in order to locate five renewable energy plants for electric generation in five places located in the autonomous region of Cantabria, in the north of Spain. A multi-objective linear programming (MOLP) model is developed by Andrew Arnette (2012) that can be used to determine the optimal mix of renewable energy sources and existing fossil fuel facilities on a regional basis. The model was optimized for five different scenarios using Pareto optimal frontier. Andrea G. Kraj (2013) developed a multi-objective optimization using an evolutionary algorithm to evaluate objectives within the geographical and economic constraints of the simulated Multi-Renewable Energy Systems (MRES) configuration. The objectives are to maximize renewable energy generation, minimize costs, and maximize system reliability to meet a given demand load. The four main types of sources were considered as steam turbines, internal combustion engines, micro-turbines, and fuel cells by Bianca Howard (2013) and developed a methodology by using nonlinear integrated programming technique for combined heat and power's potential to meet New York City's sustainability goals. Nadine Wittmann (2013) presented a model based on microeconomic analysis of decentralized biomass CHP plants for Germany using a setup of nested constant elasticity of supply (CES) production function approach to minimize production costs in terms of substrate costs. In Thailand, for three objective functions such as minimizing power generation expansion cost, CO2 emissions and external costs simultaneously, K. Promjiraprawat and B.

Limmeechokchai (2013) have developed the optimization model using multi-objective and multi-criteria optimization to solve MOPGEP problem. A multi-Objective design procedure is proposed by S.V Karemore (2013) using the genetic algorithm (GA) and integer programming with LPSP concept which has the ability to attain the global optimum with relative computational simplicity to minimize system cost and Loss of supply probability for Wind-PV hybrid system. GautamGowrisankaran et al. (2013) developed a theoretical model of electricity system operations that allows for endogenous choices of generation capacity investment, reserve operations, and demand-side management. They also estimated the model using generator characteristics, solar output, electricity demand, and weather forecasts for an electric utility in southeastern Arizona. Joy P. Vazhayil (2013) developed a weight-restricted stochastic data envelopment analysis (DEA) model which is most appropriate for efficiency optimization of power sector strategies. Each portfolio is optimized taking into account the objectives of cost minimization and comprehensive risk and barrier reduction. The portfolios are further combined and optimized at a higher level with respect to higher level objectives, namely, economic growth, energy equity, energy security and climate sustainability. For assessment of massive integration of photovoltaic system considering rechargeable battery in Japan, Ryoichi Komiyama (2013) developed a model using a high time-resolution optimal power generation mix model. The model is allowed to explicitly consider actual PV and wind output variability in 10-min time resolution for 365 days. AnjaKostev et al. (2013) proposed a novel concept for renewable energy network covering entire renewable value chain with division on supply, demand and technology sections within municipal energy systems of Cirkulane, Slovenia. Jessen Page et al. (2013) developed a multi energy model capable of supporting city administration and their counter parts in energy utilities in planning the construction and operation of energy infrastructure within the city. The multi energy tools were applied to the aggregate energy model to analyze the impacts of different energy strategies. A model is developed by Ryoichi Komiyama (2013) which explicitly considers actual PV and wind output variability in 10-min time resolution for 365 days in Japanese electricity grid. D. Suchitra (2013) proposed a Multi-Objective Genetic Algorithm using the Non Dominating Sorting procedure for populations (NSGA-II). Optimization was carried out for the system using insolation data and fuel prices in two regions, namely Zaragoza, Spain and Chennai, India. Shyamsundar (2014) discussed the modeling, simulation and optimization of integrated alternative source of energy system with grid substations, when there is a lack of energy in grid substation to meet the demand of customer load. The modeling and simulation of the system was done by using HOMER software and the software solved the optimization problem to minimize the total cost of system and maximum utilization of alternative source of energy. A Genetic Algorithm based optimization technique is developed by S. Kumar Ramoji (2014) to optimally size a proposed PV-wind hybrid energy system, incorporating a storage battery to minimize the formulated objective function, i.e. total cost which includes initial costs, yearly replacement cost, yearly operating costs and maintenance costs and salvage value of the proposed hybrid system. BinayakBhandari (2014) developed a mathematical modeling of various renewable power systems, particularly PV, wind, hydro and storage devices, and also summarized mathematical modeling of various MPPT techniques for hybrid renewable energy systems. MihalyDomb et al. (2014) studied ten technologies of power generation and seven technologies of heat supply in a multi-criteria sustainability assessment frame of seven attributes, which were evaluated based on a choice experiment (CE) survey. They revealed that the concentrated solar power (CSP), hydropower and geothermal power plants are favorable technologies for power generation, while geothermal district heating, pellet- based non-grid heating and solar thermal heating can offer significant advantages in case of heat supply. A novel approach by using a particle swarm optimization (PSO)-simulation based approach for optimal design of hybrid renewable energy systems is proposed by MasoudSharafi et al.(2014) including wind turbine, photovoltaic panels, diesel generator, batteries, fuel cell, electrolyzer and hydrogen tank. MihalyDombi et al. (2014) revealed the most beneficial RES technologies with special respect to sustainability. Ten technologies of power generation and seven technologies of heat supply were examined in a multi-criteria sustainability assessment frame of seven attributes which were evaluated based on a choice experiment (CE) survey.

5. Conclusion

Different energy models have been reviewed. In the study of review models some researchers have reviewed the energy planning models for formulating the policies of energy sector. Some reviewed the types of models such as deterministic, stochastic, top down and bottom up models.Various optimization techniques are also reviewed by some researchers. The various number of computer tools used for the modeling and optimization are reviewed extensively. A large number of renewable energy models, hybrid energy models are also reviewed. A variety of instruments, utilities, components used in the integration of renewable energy resources are reviewed thoroughly.

In the review of forecasting models it particularly observed that forecasting models have been used extensively for energy planning. For forecasting the energy demands regression analysis, LEAP (Long range Energy Alternatives Planning System), MARKAL simulations have been used by many of the researchers. GDP, GNP, population, gross income, per capita income, energy production, energy security are the important parameters considered for the modeling. In recent years, short term, medium term, and long term models have been developed by various researchers. Most of the energy planners concluded that renewable energy resources are the most important energy alternative for the conventional fuels and also considered maximum penetration of these resources in to the grid for their planning.

As extensions to the forecasting models, the complex energy management system requires the integration of RES in to the grid. This integration is termed as penetration of RES in grid. The variable and uncertain nature of the RES leads the researchers and planner to form multi-objective models of the above system. The multi-objective includes the cost of energy generation, use of local resources and CO_2 emission reduction mainly. Many of the modelers used these three main objectives in their models. The modeling is divided in regular mathematical techniques and new modified mathematical techniques. Econometrics is the main part considered by all of the researchers. The techniques like linear programming, nonlinear programming, stochastic mathematical programming, interval mathematical programming, and fuzzy mathematical programming were generally used. The new advanced techniques like Pareto optimal frontier (POF), Particle swarm optimization (PSO), Analytical hierarchical process (AHP), Genetic algorithm, evolutionary algorithms are also used for modeling and optimization. The renewable energy resources are considered in a variety of manner to the variety of combinations with conventional resources also like solar, wind, biomass, CHP, small hydro, tidal power, geothermal, gas turbine, battery storage, diesel generating sets, coal thermal power plant.

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