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Integration of Renewable Energy Sources Using Artificial Intelligent System

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ABSTRACT: Economic and geopolitical limitation on global non-renewable energy supplies will force many nations, especially the developing countries, to accelerate their use of local renewable energy sources. The study reveals the research referring to the optimal configuration and Intelligent Control of Hybrid System. The system uses Renewable Energy i.e. Photovoltaic Cells, Biomass, Wind Energy, Small Hydro Power, etc. in association with the National Grid System and Diesel Generators. These independent renewable energy systems have become much popular due to increase in the cost of conventional sources of energy and reduction in the prices of Solar PV panels, wind turbines and Biomass system.

This study presents a system in which a common junction is formed with different sources of energy in order to attain most economical output having the least operating cost. Artificial Intelligent System is basically used as an intelligent control managing system for optimizing the integrated system that prioritizes the sources in the order they should be connected to the load. The control system reads the load voltage and frequency and determines an error depending on how high or low is the voltage and frequency. Finally on the basis of the droop characteristics, the error is then processed by the fuzzy system to give an output that is used to determine which sources need to be connected to the load. The outcome of the proposed technique validates that the developed system would be dexterous mechanism yielding an economical solution on one hand and increase in renewable energy contribution on the other.

KEYWORDS: Rural Electrification, Integrated Renewable Energy System (IRES), Artificial Intelligent System

I.INTRODUCTION

In the present scenario, one cannot imagine life without electricity. The structure of the electricity sector has been evolving over the past decade. In most of the states of India, there has been a shift from vertically integrated electric utilities to various degree of market liberalization and/or unbundling of generation, transmission and distribution services.

Presently, India is 3rd largest producer of electricity after US and China [1], even though it suffers a major shortage of electricity generation capacity. Some of the areas of the country receive only an hour of electricity every day. The electricity sector in India is having an installed capacity of 249.488 GW as of June 2014. The main source of energy comes from Non Renewable sources consisting about 87.70% while the Renewable Power Plants contribute the remaining 12.30% of the total installed capacity as shown as in Fig1 [2].

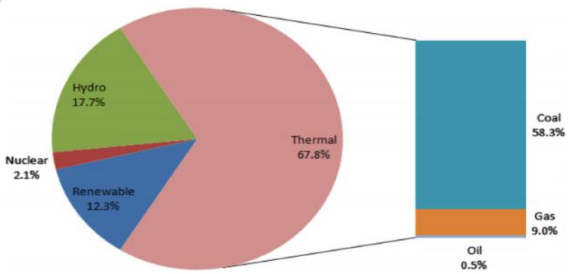

Fig.1 Overview of Indian Power Sector

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According to the 12th plan of Central Electricity Authority (CEA) of India, the gross energy generation in the country has been assessed as 1023 BU [3] from the power plants in operation and those expected to be commissioned during the year in consultation with generating companies/ State Electricity Boards (SEBs) and also taking into consideration the proposed maintenance schedule of the units during the year. Also the demand for the energy consumption in India would reach to 1048 BU of which only 995 BU is available in the country. Hence alternative sources of energy should be introduced at grass root level to fulfill the increasing demand and need of the hour. Also the fact should be taken into consideration that energy management is very much essential and hence proper steps should be taken for the implementation of Intelligent Control Circuitry.

Today India has significant potential for generation of power from renewable energy sources like wind, small hydro, biomass and solar energy. India is endowed with economically exploitable and viable hydro potential assessed to be about 84,000 MW at 60% load factor. In addition, approximately 31,150 MW in terms of installed capacity from Small, Mini, and Micro Hydel schemes have been assessed along with other renewable energy technologies, including solar photovoltaic, solar thermal and biomass power. The cumulative achievements of different types of renewable energy sources up to Feb. 2014 are given in Table1 [4].

According to a survey in 2013, 38.5% of the total energy consumption is domestic, 35.5% is commercial and the remaining 26% is industrial. The commercial consumption of electricity basically comprises of 22.7% from agricultural consumption and the rest from public, lightning and water works [5]. From the above postulates, it is seen that approximately 74% of the total energy is consumed as domestic, agricultural and commercial purposes. Hence with the help of good management and Intelligent Control System, a lot of energy could be conserved thus addressing the problem of electricity crisis more appropriately. Hybrid Intelligent and Management Control System is the future of all energy distribution system since it can save up to 20-30% of the fuel consumption.

About 69% of the total population of the country resides in rural areas of which 94.6% of the villages are completely electrified as given in Table2 [6]. Substantial proportion of Indian population lives in rural areas that are geographically isolated and are often too sparely populated or have a very low electricity demand to justify the extension of the grid

Table.1 Renewable Energy Installed Capacity in India

TYPE	TECHNOLOGY	INSTALLED CAPACITY (MW)
GRID CONNECTED POWER	Wind	20,298.83
	Small Hydro Power	3,774.15
	Bagasse Cogeneration	2,512.88
	Solar	2,208.36
	Biomass Power and Gasification	1,285.60
	Waste to Power	99.08
SUB TOTAL (GRID CONNECED POWER		**30177.9**
OFF GRID/ CAPTIVE POWER	Bagasse Cogeneration	517.34
	SPV Systems (> 1 KW)	159.77
	Biomass Gasifiers – Industrial	146.40
	Waste to Power	119.63
	Biomass Gasifiers – Rural	17.63
	Water Mills / Micro Hydro	10.18
	Aerogenerator / Hybrid Systems	2.18
SUB TOTAL (OFF GRID/ CAPTIVE POWER)		**973.13**
TOTAL		**31151.03**

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According to 2011 census records, rural households which are using firewood, crop residue and cow dung as primary cooking fuel is about 62.5%, 12.3% and 10.9% respectively [7]. The unavailability of electricity is the main obstacle in the development of these areas.

Table.2 Percentage of Electrified Villages in India

S.No.	Percentage of Electrified Villages	Total No. of States	Name of the States
1	100 %	9	Andhra Pradesh, Delhi, Goa, Haryana, Karnataka, Kerala, Punjab, Sikkim and Tamil Nadu
2	(90 – 99) %	12	Assam, Bihar, Gujarat, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Chhattisgarh, Maharashtra, Mizoram, Rajasthan, Uttaranchal and West Bengal
3	(81 – 90) %	4	Jharkhand, Manipur, Meghalaya, Uttar Pradesh
4	(71 - 80) %	4	Arunachal Pradesh, Nagaland, Orissa, Tripura

So, with the configuration of a widespread junction for different sources of energy and optimizing their respective precedence based on the availability of customary as well as peak demand of electricity, about 5.8% of the total villages in the country need to be electrified.
The basic power supply options for the village electrification are shown as in Fig.2.

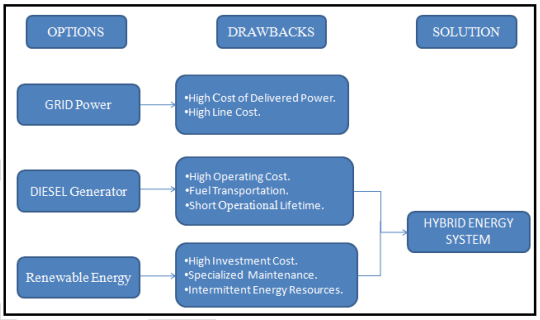

Fig.2 Power Supply Options for Village Electrification

II. INTEGRATED RENEWABLE ENERGY SYSTEM (IRES)

Renewable Energy generation from wind, solar, small hydro power and other sources has been increased substantially during past few years and forms a significant proportion in the total generation. This renewable generation is concentrated in few states, to the extent that it cannot be called marginal generation and serious thought needs to be given to balance the variability of such generation. There is an ambitious programme for increase of such Renewable Generation and therefore, it is imperative to work out a way forward for facilitating large scale integration of such variable Renewable Energy Sources (RES), keeping in view the security of the grid.
Moreover, as we move towards a tighter frequency band, it becomes even more challenging to balance this variable RES. Generation from RE Sources depends on nature, i.e. wind velocity and sunshine. The variability of RES power can be addressed through improved forecasting techniques, which are still evolving. When the percentage of RES becomes significant, special attention needs to be paid to accurately forecast their output.
India is a country of continental size and this is helpful in balancing the variable output of renewable energy sources located in few states by integrating them into all India grids. The inter-state and inter regional transmission infrastructure is being developed and it is expected that all the five electrical regions of India would be synchronously connected by 2014.

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The concept of IRES to integrated renewable energy sources viz. small hydro, solar, biomass, wind etc. depends upon their availability and meet the various energy needs of a given area on appropriate and cost-effective manner. The IRES is more reliable than individual energy system for the development of rural area because of the following postulates:-

- Increase in agriculture output due to availability of energy and fertilizer.
- Timely availability of critical inputs to village in terms of energy and commodities.
- Generate more employment in village and local small industries
- Improve the life style and stopping the migration to the cities.

2.1 Need for Artificial Intelligence in Integration of Renewable Energy Sources

Renewable Energy Integration is characterized by self-sustainability, fault tolerance, reliability, security and power quality. To achieve these objectives, efficient, fast, and scalable optimization and control algorithms are required. These algorithms should be capable of processing information intelligently and taking critical decisions dynamically.
Though conventional techniques are successful in solving most of the problems, there are situations where they lead to unsatisfactory results. These include:

- Various forecasting tasks, like renewable energy forecasting, storage forecasting and demand forecasting, that need intelligent rules.
- The use of new equipment like storage systems, where monitoring and mapping of faults to different fault conditions of the equipment is difficult.
- The use of new equipment like power electronic interfaces, where monitoring and mapping of faults to different fault conditions and development of control mechanisms is challenging.
- The inclusion of renewable energy sources, for which the calculation of generation units to be committed and the economic scheduling of these units for optimal operation is highly complex.

Hence the conventional way of modelling the algorithms for these types of situations needs to be augmented or replaced with intelligent techniques that are robust and fault-tolerant.

III. CONTROL SYSTEM DESIGNING

As the supply of fossil fuel dwindles and carbon dioxide pollution increases, the need for alternative energy sources has become apparent. In response to this need, renewable energy sources such as biomass, solar, small hydro and wind energy have been developed. The goal for this paper is to determine which of the above renewable energy sources will most adequately satisfy society's energy needs with the least negative impacts on the environment.
The paper describes the environmental statistical factors to the sizing parameters and consequently to the costs of each renewable source. However, since the sizing is not univocally defined, the paper takes the battery autonomy as 'variable' and executes on it and optimization process finalized to minimum overall cost. A step-by-step optimization procedure is described including: sizing criteria of the renewable generator; the database utilized and its analysis; power generation estimation algorithm and finally annual cost estimation.
R. Ramakumar and William L. Hughes [8] discussed some of the technical, economic, and socioeconomic aspects of the application of renewable (solar) energy sources for rural development in resource-poor population-rich developing countries. Joshua Goldade et al. [9] developed a controller that uses fuzzy logic to control various subsystems of the Alternative Multisource Power System (AMPS) controller. The reasons for this were to maximize the systems output from wind and solar resources and minimize detrimental effects to the fuel cell and battery. The application of load control using a novel frequency and voltage sensing device was given by Krishnan Pandiaraj et al. [10]. The device used a low cost microcontroller to monitor the system frequency and voltage. A fuzzy control system was then developed which made intelligent load switching decisions using inputs from the measurement algorithms coupled with expert knowledge expressed in the form of control rules. Later Ajai Gupta et al. [11] developed a mixed integer linear mathematical programming model (time-series) to determine the optimal operation, optimal configuration including the assessment of the economic penetration levels of photovoltaic array area and cost optimization for a hybrid energy generation system. Pedro S. Moura et al. [12] proposed a novel multi-objective method to optimize the mix of the renewable energy sources like wind power, solar power and hydropower, maximizing its contribution to the peak load while minimizing the combined intermittence at a minimum cost. Demand Side Management (DSM) and Demand

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Response (DR) technology reduced the needs of new intermittent capacity by adjusting the consumption in real time, to face production variations. Arabali, M. Ghofrani et al. [13] evaluated the efficiency of a hybrid system that combines renewable energy generation and energy storage to meet the controllable heating, ventilation and air-conditioning of HVAC load. GA-based optimization is proposed to minimize the cost and increase the efficiency of the system.
An attempt has been made to review the available literature covering the present investigation. The relevant literature was collected, grouped under different heads and is presented in the subsequent tables.

Table.3 Literature Review of Solar Integration Based Research Work

S.No.	AUTHOR	TITLE	ALGORITHM	OUTCOME
1	H. Saha	Design of a photovoltaic electric power system for an Indian village	Centralized and Decentralized Techniques	Modular nature of solar photovoltaic cells and storage batteries were used either as Centralized or Decentralized system in a village. Analysis of the electrical energy demand and its techno-economic analysis have shown that the Centralized approach is about five times more cost effective than the Decentralized approach.
2	E. Ofry and A. Braunstein	The loss of power supply probability as a technique for designing stand-alone solar electrical (photovoltaic) systems	Graphical Method	A direct relationship between the PV array area and the battery capacity to minimize the PV system is suggested.
3	B. Bartoli, V. Cuomo, F. Hontana, C. Serio and V Silvestrini	The design of photovoltaic plants: an optimization procedure	Analytical Method	A simple analytical method to predict the fraction of load fulfilled by solar photovoltaic stand alone plant and solar photovoltaic plant with battery backup is discussed.
4	L. Barra, S. Catalanotti, F. Fontasa and F. Lavorante	An analytical method to describe the optimal size of a photovoltaic plant	Simplified Method	Developed a simplified method for optimal sizing of photovoltaic stand alone system and obtain the performance of the system for many parameters like area, load, storage value and solar flux using meteorological data.
5	M.H. El-Maghraby, Y.A. Abed and M.A. El-Sayes	Proposed generalized models for estimating the reliability of stand-alone solar photovoltaic power system	Mathematical Model	Proposed and developed a mathematical model for a stand-alone solar PV system with Loss of Load Probability (LOLP) reliability index.
6	I. Abouzahr and R. Ramakumar	Loss of power supply probability of stand-alone photovoltaic systems: a closed form solution approach	Mathematical Model	Presented closed form approach to stand-alone solar PV system to calculate Loss of Power Supply Probability (LPSP) under various operating conditions.
7	G.C. Seeling-	A combined optimization	Genetic	Developed a method to jointly

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	Hochmuth	concept for the design and operation strategy of hybrid PV energy systems	Algorithm	determine the sizing and operation control of hybrid PV systems and applied the genetic algorithm to optimize the system through the search of different possible options of an optimal operation strategy.
8	S.M. Shaahid and M.A. Elhadidy	Oppurtunities for utilization of stand-alone hybrid (PV+Diesel+Battery) power systems in hot climates	Analytical Method	Investigated the sizing of battery storage for PV/ diesel/ battery hybrid system for a typical residential and commercial building in Dhahran.
9	J.K. Kaldellis, D. Zafirakis, E.L. Kaldelli and K. Kavadias	Cost benefit analysis of a photovoltaic energy storage electrification solution for remote islands	Mathematical Model	Formulated a methodology to maximize PV contribution and minimize the cost of electricity generation along with best suitable storage devices available.

Wind energy is another renewable energy source that has been taken up seriously in developing nations for augmenting the existing electrical supply or for providing electrical mechanical motive power for remote area and agricultural applications in the absence of a centralized power supply.

Table.4 Literature Review of Wind Integration Based Research Work

S.No.	AUTHOR	TITLE	ALGORITHM	OUTCOME
1	I. Kamwa	Dynamic modelling and robust regulation of a no-storage wind/ diesel hybrid system	Modeling and Simulation	Discussed high penetration autonomous wind-diesel energy systems comprising of at least two dynamic energy control devices. The first device maximized the power output of the wind turbine within mechanical design limits and the second device was added to keep conventional regulator of the diesel for continuous output as per the requirements of the consumer.
2	E.S. Gavanidou, A.G. Bakirtzis and P.S. Dokopoulos	A probabilistic method for the evaluation of the performance and the reliability of wind/ diesel energy systems	Prabablistic Method	Presented a probabilistic method to evaluate performance of wind/ diesel energy system by constraining the wind generation.
3	A.C. Saramourtsis, A.G. Bakirtzis, P.S. Dokopoulos and E.S. Gavanidou	Probabilistic evaluation of the performance of wind/ diesel energy systems	Probabilistic Method	Described a probabilistic method for predicting the economic performance and reliability of autonomous energy systems
4	J.K. Kaldellis and Th. J. Gavras	The economic viability of commercial wind plants in Greece: a	Economic Commercial Method	Discussed the influence of governing techno-economic parameters on economic behaviour

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Vol. 3, Issue 11, November 2014

		complete sensitivity analysis		of commercial wind park.
5	A.J. Bowen, M. Cowie and N. Zakay	The performance of a remote wind/ diesel power system	Analytical Method	Analyzed the field data to implement wind/ diesel/ battery hybrid system for household demand. It was observed that the annual wind generated was greater than the annual household demand. However, one quarter of energy consumed by the household must be provided by the diesel generator while the one-fifth of the wind energy provided to the system was to be dumped.
6	J.K. Kaldellis and K. Kavadias	Cost benefit analysis of remote hybrid/ diesel power stations: a case study Aegean Sea islands	Mathematical Algorithm	Concentrated on a detailed energy production cost analysis in order to estimate the optimum configuration of a wind/ diesel/ battery stand-alone system.
7	A. Roy, S.B. Kedare and S. Bandyopadhyay	Application of design space methodology for optimum sizing of wind battery systems	Modeling and Simulation	Proposed a technology for optimum sizing of different components of a stand-alone wind battery system on the basis of time series simulation of system performance. The results concluded that the design of only stand-alone wind system is possible and the cost of energy of the system is sensitive to the magnitude of average demand and the wind regime.

The inconsistent supply of solar and wind energy resources necessitates the use of hybrid systems in which the solar and wind energy systems can be combined for maximizing the availability of any one or both of the resources for electricity generation. Different combinations of Wind/ PV/ Battery or Wind/ PV/ Diesel or Wind/ PV/ Battery/ Diesel hybrid systems are then possible.

Table.5 Literature Review of Solar and Wind Integration Based Research Work

S.No.	AUTHOR	TITLE	ALGORITHM	OUTCOME
1	J.C. Hennet and M.T. Samarakou	Optimization of a combined wind and solar power plant	Optimization Technique	Discussed an approach to optimize hybrid PV/ Wind/ Battery system with conventional power plant and calculated optimal system configuration on the basis of Life Cycle Cost (LCC).
2	M.T. Samarakou, M. Grigoriadou and C. Caroubalos	Comparison results of two optimization techniques for a combined wind and solar power plant	Simplex and Modified Steepest Descent Algorithm	Compared the results of two optimization technique based on simplex and modified steepest descent algorithm for PV/ Wind/ Battery hybrid system.
3	B.S. Borowy and Z.M.	Optimum photovoltaic array size of a hybrid	Least Square Method	Used the least square method to find the best fit of wind turbine and

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Vol. 3, Issue 11, November 2014

	Salameh	wind/ PV systems		solar panels sizes for hybrid wind/ PV system.
4	D. Bagul, Z.M. Salameh and B.S. Borowy	Sizing of a stand-alone hybrid wind/ PV system using a three event probability density approximation	Probability Method	Discussed the three event probability method for the sizing of a stand-alone hybrid wind/ PV system. The results indicated that the three event approximation increased the accuracy of the system without any significant increase in the effort and system cost.
5	W. Kellog, M.H. Nehrir. G. Venkataramana n and V. Gerez	Optimal unit sizing for a hybrid wind/ photovoltaic generating system	Numerical Algorithm	Developed a simple numerical algorithm to find out optimum combination of wind/ PV system considering economic factors. It was observed that the cost of energy for hybrid system was justified, if the grid line extension was 1.5miles or longer.
6	A.M. Al-Ashwal and I.S. Moghram	Proportion assessment of combined PV/ wind generating systems	Simple Analytic Method	Introduced a simple and efficient method to assess the optimal proportion of combined PV and wind generator system.
7	W.D. Kellog, M.H. Nehrir, G. Venkataramana n and V. Gerez	Generation unit sizing and cost analysis for stand-alone wind, photovoltaic and hybrid wind/ PV systems	MATLAB	Carried out a comparative study of wind alone, PV alone and hybrid wind/ PV power generating systems for a typical house and it was found that the hybrid PV/ wind proved to be the best while considering the unpredictable nature of wind and solar resources.
8	A. Jain, J. Choi and B. Kim	Impact of integrating the photovoltaic and wind energy sources on generation system reliability and operation economics	Modeling and Simulation	Presented an approach for the impact assessment of the generation system integrated with solar PV and wind energy systems. These models were finally combined to evaluate the reliability index, Loss of Load Expectation (LOLE) using discrete state algorithm.
9	P.K. Katti and M.K. Khedkar	Alternative energy facilities based on site matching and generation unit sizing for remote area power supply	Weather Based Model and Numerical algorithm	Presented the decision support technique to optimize generation capacity of wind alone, PV alone and integrated wind/ PV power system for stand-alone application using weather based model and a simple numerical algorithm.

Biomass is yet another renewable energy resource that has always been popular in rural areas of developing nations due to its sustainable availability.

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(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2014

Table.6 Literature Review of Biomass Integration Based Research Work

S.No.	AUTHOR	TITLE	ALGORITHM	OUTCOME
1	S. Rana, R. Chandra, S.P. Singh and M.S. Sodha	Optimal mix of renewable energy resources to meet the electrical energy demand in villages of Madhya Pradesh	Modeling and Simulation	Predicted Life Cycle Cost (LCC) for rural villages of Madhya Pradesh and applied biomass gasifier, biogas technology and photovoltaic systems for electricity generation as per the availability of resources in 83 villages.
2	M.R. Nouni, S.C. Mullick and T.C. Kandpal	Providing electricity access to remote areas in India: Niche areas for decentralized electricity supply	Decentralized Supply Method	Presented a study undertaken for identifying niche areas in India where renewable energy based decentralized generation options can be financially more attractive as compared to grid extension.
3	A. Perez-Navarro, D. Alfonso, C. Alvarez, F. Ibanez, C. Sanchez and I. Segura	Hybrid biomass-wind power plant for reliable energy generation	Analytical Method	Developed an innovative system combining a biomass gasification power plant, a gas storage system and stand by generators to stabilize a generic 40 MW grid connected wind-park.

Micro Hydro Power (MHP) plants and water wheel technology have been found well suited for hilly areas and can be used individually and/ or along with other renewable energy systems for rural electrification as demonstrated in the following work.

Table.7 Literature Review of Small Hydro Integration Based Research Work

S.No.	AUTHOR	TITLE	ALGORITHM	OUTCOME
1	J.K. Kaldellis and K.A. Kavadias	Optimal wind/ hydro solution for Aegean Sea Island's electricity demand fulfilment	Optimal Method	Analyzed the possibility of combination of wind-hydro energy station for a medium size island of Aegean Archipelago on techno-economic basis.
2	E.M. Nfah, J.M. Ngundam, M. Vandenbergh and J. Schnid	Simulation of off-grid generation options for remote villages in Cameroon	HOMER	Simulated two hybrid options for remote villages in Cameroon using HOMER software. The micro-hydro/ LPG/ Battery storage and PV/ LPG generator/ Battery storage options have been studied for different locations near the flow of river Mungo and solar resource of potential of Garoua village.
3	J.K. Kaldellis, M. Kapsali and K.A. Kavadias	Energy balance analysis of wind-based pumped hydro storage systems in remote island electrical networks	Analytical Method	Introduced Pumped Hydro Storage (PHS) systems in isolated electrical grids leading to face both the high electricity production cost and continuously increasing power

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International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 3, Issue 11, November 2014

				demand encountered in island regions.

The design of an integrated renewable energy system requires a thorough examination of sizing methods, approaches and the optimization tools used by the researchers and is demonstrated as in the following research work.

Table.8 Literature Review of Integrated Renewable Energy Resources Based Research Work

S.No.	Author	Title	Algorithm	Outcome
1	J.P. Torreglosa, P. García, L.M. Fernández and F. Jurado	Hierarchical energy management system for stand-alone hybrid system based on generation costs and cascade control	Cascade Control Technique	Presented an Energy Management System (EMS) for stand-alone hybrid systems composed by Photovoltaic (PV) solar panels and a Wind Turbine (WT) as primary energy sources and two energy storage systems, which are a hydrogen system and a battery as secondary sources.
2	S.M. Shaahid and M.A. Elhadidy	Economic analysis of hybrid photovoltaic–diesel–battery power systems for residential loads in hot regions—A step to clean future	Analytical Method	Analyzed long-term solar radiation data to assess the techno-economic feasibility of utilizing hybrid PV–diesel–battery power systems to meet the load of a typical residential building
3	Dulal Ch. Das, A.K. Roy and N. Sinha	GA based frequency controller for solar thermal–diesel–wind hybrid energy generation/energy storage system	Modeling and Simulation	Considered autonomous hybrid generation systems consisting of wind turbine generators (WTGs), solar thermal power system (STPS), solar photovoltaic (PV), diesel engine generators (DEGs), fuel cells (FCs), battery energy storage system (BESS), flywheel (FW), ultra capacitors (UCs) and aqua electrolyzer (AE) for simulation studies.
4	O.C. Onar, M. Uzunoglu and M.S. Alam	Dynamic modeling, design and simulation of a wind/fuel cell/ultra-capacitor-based hybrid power generation system	Simulation of Model	The authors proposed herein a dynamic model, design and simulation of a wind/FC/UC hybrid power generation system with power flow controllers for a grid-independent user.
5	Jae-Shik Park, Takeshi Katagi, Shigehiro Yamamoto, and Takeshi Hashimoto	Operation control of photovoltaic/diesel hybrid generating system considering fluctuation of solar radiation	HOMER and Other Control Methods	Proposed an operation control method of the photovoltaic/diesel hybrid generating system for a small ship in consideration of the fluctuating electric power of PV system due to the solar radiation. The aim of the operation control is to make the storage capacity of the battery minimum while the diesel generator keeps the output constant with high efficiency in

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(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2014

				spite of the fluctuating PV power.
6	Joseph Kenfack, François Pascal Neirac, Thomas Tamo Tatietse, Didier Mayer, Me´dard Fogue and Andre Lejeune	Microhydro-PV-hybrid system: Sizing a small hydro-PV-hybrid system for rural electrification in developing countries	MATLAB	Proposed a Micro-hydro and Solar Photovoltaic hybrid system which is simulated and sized according to the seasonal variations of both solar and hydro resources.
7	O. Erdinc and M. Uzunoglu	Optimum design of hybrid renewable energy systems: Overview of different approaches	MATLAB	Provided a model with a combination of different renewable sources of energy i.e. wind, solar, hydro based energies, etc. with back-up units to form a hybrid system which provided a more economic, environment friendly and reliable supply of electricity in all load demand conditions compared to single-use of such systems.

3.1 Sizing of Renewable Energy Systems

This study has the objective of creating an algorithm for feasibility assessment and recommendations of sizing of hybrid renewable energy systems. This involves the development of an algorithm which would analyse information input about the climate of the area and the load demand. As the load demand is variable, other electrified rural areas with similar loads or population structures can be used to estimate the load profile of the proposed area for electrification. The sizing of the system can be carried out by using the following equations [10]:

a) Micro Hydro Sizing

$$P_{MHG} = \frac{9.81 * Q * \rho * h}{1000} \; kW$$

b) Bio Generator Sizing

$$P_{BGG} = \frac{Total\ biogas\ generated\ (m^3/day) * CV_{BG} * \eta_{CBG}}{860 * (Operating\ Hours/Day)} \; kW$$

c) Bio Mass Generator Sizing

$$P_{BMG} = \frac{Total\ Fuelwood\ Available\ (Ton/yr) * 1000 * CV_{BM} * \eta_{CBG}}{365 * 860 * (Operating\ Hours/Day)} \; kW$$

d) Photo Voltaic Generator Sizing

$$A = \frac{\left[PVG\ Direct\ Load + \frac{Battery\ Load}{H * \eta_{CHG} * \eta_{DCHG}}\right] - TDE_{Surplus} * \eta_{INV}}{H * \eta_{PVG} * \eta_{INV}} \; m^2$$

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International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2014

e) Diesel Generator Sizing

$$P_{DEG} = \frac{TDE_{Netload} - (TDE_{Surplus} * \eta_{INV})}{Operating\ Hours * Loading(\%)}\ kW$$

f) Battery Sizing

$$P_{BATT} = \frac{(TDE_{Surplus} * \eta_{CHG}) + Max\ surplus\ energy\ from\ DEG}{DOD * \eta_{CHG} * \eta_{INV}}\ kWh$$

Where,

CV_{BG} = Calorific Value of Bio Gas i.e. 4700kcal
η_{CBG} = Bio Gas Conversion Efficiency
CV_{BM} = Calorific Value of Bio Mass i.e.4015kcal
η_{CBM} = Bio Mass Conversion Efficiency
η_{CC} = Efficiency of Charge Controller
η_{CHG} = Battery Charging Efficiency
η_{DCHG} = Battery Discharging Efficiency
$TDE_{Surplus}$ = Total Daily Surplus Energy from Renewable, kWh
η_{INV} = Efficiency of Inverter
η_{PVG} = Efficiency of PV Generator
$TDE_{Netload}$ = Total Daily Net Load Demand, kWh

3.2 Algorithm Used

In today's electric power systems, power electronic converters play an increasingly important role for integration of renewable energy resources and energy storage devices. Power converters are key components that physically connect wind power, solar panels and batteries to the grid. Traditionally, those converters are controlled using standard control mechanisms. However, recent studies indicate that such mechanisms show serious limitations in their applicability to dynamic systems.

The paper focuses on the algorithm to employ dynamic programming technique to develop optimal control method for integration of renewable energy resources. The dynamic programming principle is implemented through an artificial intelligent system thereby simulating a common junction for different renewable sources of energy hence achieving the most economical output at the least operating cost.

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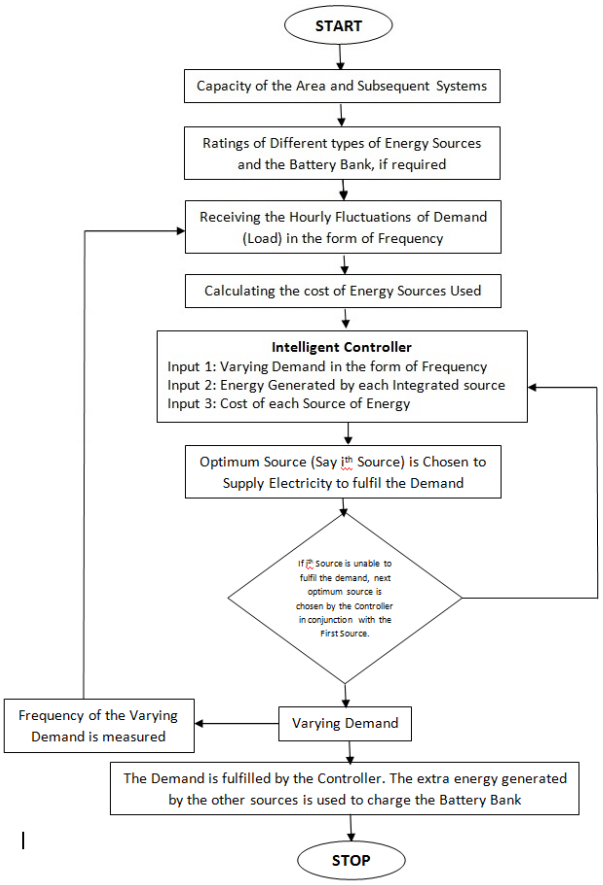
(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2014



IV. CONCLUSION

Renewable energy sources are generally intermittent and it is necessary to control them because of their capricious environment. To increase the reliability of renewable energy systems, systems with manifold sources must be considered. As more sources are incorporated into a renewable energy system, the system becomes harder to control thus producing wobbly output i.e. difficult to be optimized. It has been found that an Intelligent System having a controller can maximize the output of the renewable energy sources while attaining an optimized and cost-effective source thus yielding an economical solution and augment to renewable energy contribution.

To design the simulation model of the controller, several sub models have to be developed. To ensure the practicality of the simulation of controller, physical elements of the system are tested to find their parameter values. Intelligent System controller has been developed to control the requisite parameters passably without any significant alteration of other thus offering a robust, low cost control solution pertinent to an ample range of autonomous systems with an abridged requirement for customization.

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