Some findings of Hybrid Sustainable Energy System for Standalone and Grid Connected Operation: Types, Storage Options, Trends for Research and Control Strategies

Ashwani Kumar, V. M. Mishra, Rakesh Ranjan

Abstract: This article presents some critical findings of various issue concerning to HSES like types, storage, trends for research and control strategies of HSES. Various interconnection techniques for HSES are presented. It has been made a short review of Mathematical model for renewable energy sources. Conclusion and result of control strategies work of HSES, Storage techniques of HSES for energy flow management is presented. Finally, it has been made a summary of the future analysis, challenges in techniques and improvements of HSES based power generation techniques for Isolated and grid connected applications.

Index Terms: Sustainable energy, hybrid power system, Modeling control strategies.

I. INTRODUCTION

There is no reason to doubt that in the future our existence will be more and more dependent upon the energy. Specially in developing countries energy condition are improved by renewable energy sources from last many year. And for conventional source it becomes difficult to match increase demand of electricity. Renewable energy source generally does not require fuel and mostly eco-friendly but it is fluctuating in nature. Difficulty in availability and remoteness makes conveyance of sustainable energy sources costly. Grid extension is also not cost effective [1]. Sustainable source are the optimal outcome to provide power in remote zones. Also to meet the energy requirement locally available energy source is best. Various researchers proposed renewable hybrid power system to supply the remote areas. there are various sources like PV, wind, biomass, fuel cell which can be utilized for power production[2]. HSES has been advised by different explorer to supply electricity in distant zones. To achieve reliability of supply combination with rechargeable batteries for energy supply system during peak load periods and operation with some other kind of generator is considered for isolated utilization. These arrangements are permanently provided along with storage option to rectify the unreliable manner of sustainable energy genesis like PV and Fuel [3].

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Control strategies are the backbone of HSES that perform the communication and passes the information together with several elements of structure. Control strategies modifies the result of sustainable energy sources and in addition schedules the storage and load connected to grid. This limits the storage option and protect it [4].Whenever extra efficiency is accessible, it may be feeded to repository blocks to stock extra output. When demand is more than supply then stored energy is utilized [5].But some times it is required to connect conventional energy source with SES to bear the load [6]. This Paper imparts a survey on different issue related to HSES in isolated approach, types, storage, trends for research and control strategies of HSES.

II. INTEGRATION SCHEME

There are following basic arrangement to integrate distinct sustainable energy provenance like, DC linked scheme, AC linked scheme, Hybrid linked scheme [7].

A. Stand-alone hybrid systems

There are two design of Stand-alone hybrid systems, dc link and unify ac linked system. According to this system, power device, repository device and burden are linked to dc link by means of suitable equipments as shown in fig 2.1[8,9].

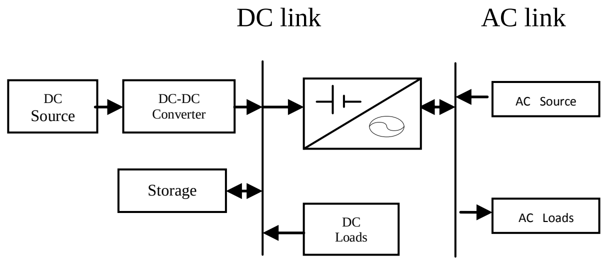

Fig 2.1 DC Bus

Also in AC link scheme, repository cells, loads and energy producer are integrate to ac link by means of suitable power electronic equipments as depicted in fig. 2.2

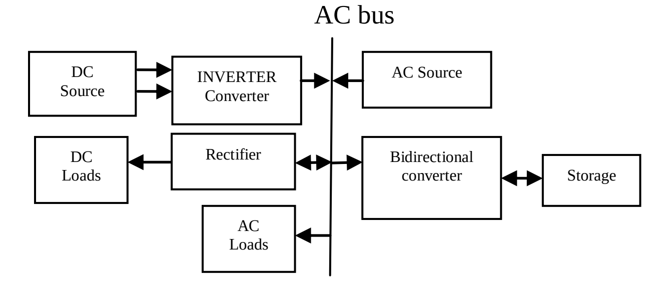

Fig 2.2 AC Bus

It is advance structure, which provides the increasing energy needs [10]. In parallel scheme the ac genesis and different loads are right away coupled to ac linked bus as shown in fig.2.3 [11, 12].Such scheme makes system robust and insure reliability.

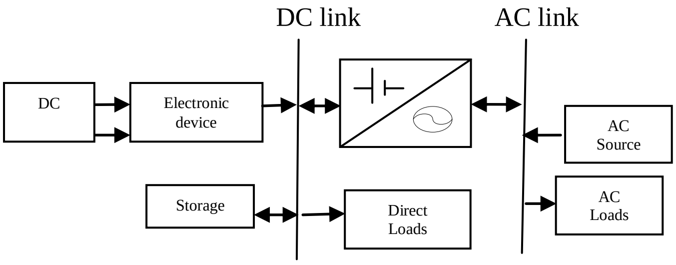

Fig 2.3 Parallel

In distributed configuration there is restriction for connection of single source to the load at a particular case as shown in fig.2.4 [13].

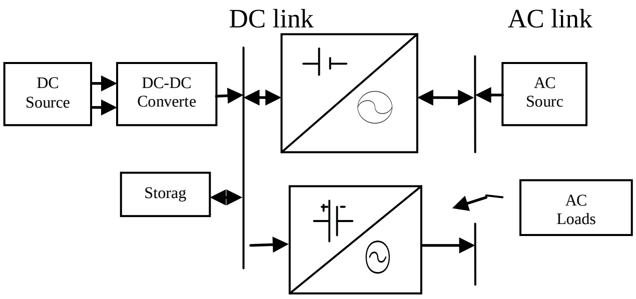

Fig 2.4 Distributed stand-alone hybrid system configuration

B. Grid tied systems

Various grid tied scheme are depicted in fig.2.5 and fig.2.6 The structure for specific site rely on geological, financial, and scientific factors [14, 15].

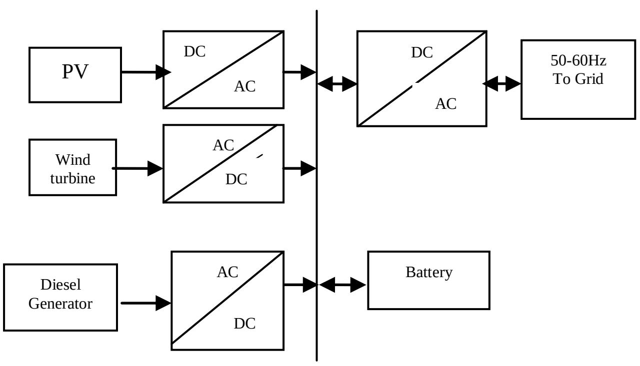

Fig 2.5 Centralized dc- bus

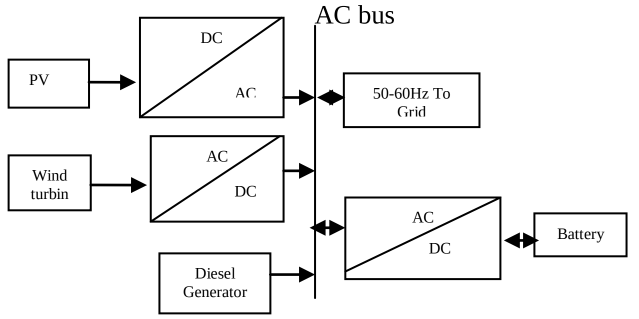

Fig 2.6 Centralized ac-bus

In this layout storage and source are connected at one site and is coupled to a prime ac link bus, by means of electronic devices [16]. A grid connection is also provided with filter.PLL technique is used to synchronize the two systems. In grid connected configuration it is not required to installed energy sources close to each other. [17]. The energy generated by several source is needed to be equivalent for different condition according to grid as depicted in fig.2.7 [18, 19].

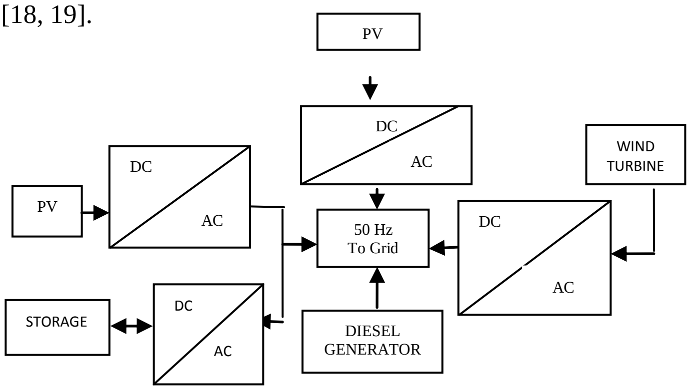

Fig 2.7 various standalone grid connected hybrid arrangement.

III. MODELING OF SUSTAINABLE ENERGY GENESIS

A. Modelling of wind conversion system

Blades on the rotor convert wind kinetic energy into mechanical energy. This energy is transmitted by means of drive train to the alternator. The power of air flow at speed of v_w passing through area of A can be determined

$$P_w = \rho A$$

Where ρ is air density in kg/m^3, A is sweep area in m^2 and v_w is wind speed in m/s. Normally near sea shore temperature of 15^{0}C and air has density of approximately 1.2kg/m^3.
And wind potential grabbed by blades interchange to mechanical potential should be measured by

$$P_M = \rho A C_p$$

Where C_p coefficient of power for wind blade.This coefficient of power for the modern age turbine lie between 0.19-0.49.

B. Modeling of Micro hydro Energy system

Energy captured from falling water which transfer its kinetic energy to the shaft in hydro power generation. This rotates the generator for the production of electricity. The power which can be generated in hydro plant in watts can be calculated by following formula

$$P_{MHPS} = 9.81\, QH_{net}\eta_0\rho_w$$

where Q is the volume metre per second, H_{net} is the net height in metre available, ρ_W is the density of water, η_0 is the efficiency of hydro plant with turbine.

C. Modeling of solar photovoltaic system

Being more practical it is for the interest and analysis of performance that assessment should be done for maximum power. For the available radiation and suitable temperature calculation are done according to the manufacturing data available mentioned on the pv modules.

$$P_{PV} = \eta_g\, N\, A_m\, G_t$$

Where, g is efficiency of PV, A_m shows the area of a all cells perpendicular to irradiance (m^2).

D. Modeling of fuel cell system

This technique uses hydrogen-rich fuel to produce electron by use of two electrode. These electrode passes current to the load connected externally:

$$2H_2+4OH^- \rightarrow 4H_2O+4e^-$$

Electrons are produced by reaction which can give electricity is an electrochemical process, and that can be taken through load. Fuel cell gives dc voltage which can be utilized in different use by inverting in to AC as well. Equation based on hydrogen fuel cell is mainly combustion reaction given below as:

$$2H_2 + O_2 = 2H_2O + \text{electrical energy}$$

E. Mathematical model of Tidal system

The tidal energy modeling is identical to the wind model in various ways. Equation adopted to imitate a turbine model

$$P_{mt} = \frac{1}{2}\eta\rho_{water}A_T v_{water}^3$$

P_{mt} is the representation of power used by the tides, ρ_{water} is r density of water, A_T is the tidal blade area (m^2), v_{water} is the speed of tides and η is the efficiency. Cost of installation is much greater than life maintenance cost.

IV. STORAGE

Storage option very essential for ensuring continuity of supply [20]. Various types of energy storage used in HSES [21]. Best solution for the storage used are batteries [22].

A. Battery storage system

Oldest electrical storage system is batteries which stores energy in form of chemical energy. It is environmental friendly and can be easily installed next to load. [23][24].

B. Superconducting energy conversion (SMES) system

This system stores magnetic energy initiated by the dc in coil associated with electronic device and cooled by it's below the superconducting critical temperature. Energy is stored by circulating dc current flow [25].

Considerable issue for the development of magnetic storage are high system cost and environmental requirement [26].

C. Super capacitors energy storage

Density level of super capacitor are higher as compare to batteries so these capacitor are connected in series which further connected in parallel with adjacent modules the voltage range of 180–480 V for safety and reliability point of view [27].

D. Energy stored in flywheel

In case of flywheel Energy stored depend upon directly to the square of the rotational speed and it's weight. Normally Flywheel energy storage released its energy when torque is applied to load [28][29]. Stored kinetic energy of flywheel is converted to electricity, when power is required. Flywheel efficiency varies from 75% to 90% [30-31].

E. Pumped hydro storage (PHS)

This technique of storage is very old having high performance. It repository time is very large. Normally it has two vertically separated reservoirs [32].Efficiency is in range of 55%-75% which depends upon the penstock size type of turbine and rating of generator for pumped storage. Pumped hydro system requires special geographical condition [33, 34].

F. Compressed air energy storage (CAES)

CAES is equivalent storage option having large capacity as pumped hydro storage of 60MW and above. The rating of CAES storage option lies between 05–350 MW [35, 36]. Its storage span is higher than other techniques which may be of one year and efficiency is in between 55-80%[37-38].

G. Hydrogen storage

Hydrogen gas is originated through electrolysis action by usage of off-peak hour power from sustainable energy sources and hydrogen is generated by electrolysis process of water [39]. Fuel cells is key technology for portable and stationary power. Performance can be analyze and improved implementing power electronic devices [40]. Various characteristics of each energy storage are given below:

Table I: Aspects of the energy repository development

ASPECT	PERFORMANCE	ADVANCEMENT	PRICE	ENERGY STORAGE	POWER STORAGE
BATTERY	80%	DEVELOPED	LESS	BIG	BIG
PH	80%	DEVELOPED	BIG	SIZE DEPENDENCE	DEPEND UPON HIGHT
FUEL CELL	55%	DEVELOPING	LESS	HYDROZEN DEPENDENCE	DEPEND ON FUEL
FLYWHEEL	85%	DEVELOPED	BIG	LESS	BIG
SMES	92%	DEVELOPING	BIG	LESS	BIG
CAES	70%	DEVELOPED	BIG	BIG	BIG

V.CONTROL STRATEGIES

In modernistic time, immense work in field of sustainable domain attracts fieldworkers. It is observed that many investigator investigating on two broad conception, i.e., layout of HSES and accomplishment of sustainable system. Majority of investigation material related to modelling and mitigation of control problems are available through out literature. This research finding consider hybrid sustainable models and mitigation techniques. In extention to this, individual contents correlated to modeling are also included. This article is formed according to the formulation and techniques used by many researchers to attain a best structure. Various performance optimization strategies are discussed here [42].

A. Design Optimization

The experimenter go through comprehensive optimization objectives [43]. One may be such goal to get proper size of sustainable hybrid design. Which may be achieved by best determination of sustainable source with optimal size. By this technique one can design the capacity of sustainable system factors through optimizing the value of plant [44].

B. Artificial intelligence (AI) approach

There is no requirement of statistics for designing of combined power source in remote location when we use Artificial intelligence techniques [45]. Various techniques are available in research articles like PSO, artificial intelligence (ANN)[46], Genetic Algorithm (GA)[47], Grey wolf optimization (GWO)[48], honey algorithm, Blue whale optimization [49], fuzzy approach (FL), or a combination of any of above techniques. Genetic algorithm have been also utilized to optimize and mitigate power quality issues in system[50]. In many cases, Robust control has been implemented as tool to examine AI techniques.

C. Iterative approach

Sometimes iterative program approach is used to regulate the integrated energy system. And it ends up to optimal design is achieved. Many authors follow the storage option, PV panel ratings and wind rated power [51].

D. Probabilistic approach

This approach is used to design the size of HSES because it may change the parameter of renewable source. Probabilistic approach deals with radiation available and change in wind speed for the calculation of integrated system design. Dynamic variation of HSES cannot be identify by this techniques which is one of the disadvantage [52].

E. Graphical construction method

Different graphical optimization algorithms have been given in historiography. Only two variable were under consideration in this technique whether it is PV or Wind [53].

F. Globally standard computer tools for designing

HOMER is popular tool available for the sizing of HSES. This is done by decreasing the investment and increasing the use factor. Such software tools are for calculation of optimal performance on the basis of present cost [54].

G. Performance optimization

Researchers are not only worry about optimal sizing but also about perfect design and control strategies for the appropriate operation of sustainable systems. Main function of controllers is to operate HSES maintaining MPPT, improving the power profile, robust stability, reduced voltage flicker and advanced low voltage ride through feature [55].

H. Online control

Real time simulators are also used for the analysis of power system now a day. In HIL simulation a prototype controller use only low power signals between a prototype controller and a plant [56].

I. Operating point optimization

Many AI techniques are being used to keep the system to work at MPP. Various operating point algorithm is used for PV-Wind HSES to generate optimum energy to compensate the load demand [57].

J. Converter control

The characteristics of sustainable energy based system can be adjusted by changing the converter parameters [58]. In view of fault single line to ground on grid side in absence of any storage device voltage source inverter (VSC) can control smooth operation in the system [59].

K. HSES Control

Quality profile of power can be improved by the appropriate selection and management of HSES. Energy capturing option for the purpose of energy depository with a hybrid magnetic bearings (HMBs); having SMBs and AMBs implemented with robust technique with the help of zero bias method has also matured[60].

VI. CONCLUSION

An extensive review covering all the concerned aspects of HSES covering type's, storage, trends for research and control strategies of HSES has been presented. Sizing techniques algorithms implemented by various investigator for type of storage options are discussed. It has been observed that ANN techniques give relatively better result in order to find the reduced cost. Still It has been found much more work is required in this area of HSES; any how further exploration and attempts are mandatory to enhance power quality issues and storage option for their lower cost. In case of standalone condition load can result in transient condition which may collapse whole HSES. For such scenarios various optimization algorithm for controller of the HSES is to be carried out. It is also discovered that investigator have gone through different control techniques for the evolution of hybrid power. Power quality, LVRT and power stability investigation were the research objective of different investigator. Also it is observed that available FACT devices are integrated using conventional control techniques or power convertor control methods.

The consequences of computational intelligence in different issue of HSES especially in the field of optimization and control has acquired enormous focus.

REFERENCES

1. Nizar Aawar and Rahman, Arkadan, 'Optimal Control Strategy for Hybrid Electric Vehicle Power train' IEEE JEST in PowerElectronics, Vol. 03, June 2015.
2. P.K.Goel et al. Fellow, Isolated Wind Hydro Hybrid System Using Cage Generators and Battery Storage IEEE transactions on industrial electronics, vol. 58, no. 4, April 2011.
3. Cheng-Wei Chen et al. IEEE ' Modeling and Controller Design of a Semi isolated Multi input Converter for a Hybrid PV/Wind Power Charger System' IEEE transactions on power electronics, vol. 30, no. 9, sep 2015.
4. H.C. Chiang et al. 'Design and Implementation of a hybrid regenerative power system combining grid–tie and uninterruptible power supply functions' IET Renew. Power Gen., 2010, Vol. 4, Issue. 1, pp. 85–99.
5. Md. Ibrahim et al. ' A Review of Hybrid Renewable Energy Systems for Electric Power Generation' Journal of Engineering Research and Applications ISSN: 2248-9622, Vol. 5, Issue 8, August 2015, pp.42-48.
6. Dada Delimustafic, Jasmina Islambegovic, Abdulah 'Model of a Hybrid Renewable Energy System: Control', SED 1081-1086 IEEE.
7. K K Prajapat, Abhishek Katariya Simulation and Testing of Photovoltaic with Grid Connected System 2011 IEEE International Conference on Computational Intelligence and Communication Systems.
8. Chunhua Liu, Member, IEEE, K. T. Chau, Senior Member, IEEE, and Xiaodong Zhang, Student Member, IEEE 'An Efficient Wind–Photovoltaic Hybrid Generation System Using Doubly Excited Permanent-Magnet Brushless Machine' IEEE transactions on IE, vol. 57, no. 3, march 2010.
9. Swati Negi et al. ' Hybrid Renewable Energy System': A Review International Journal of Electronic and Electrical Engineering. ISSN 0974-2174, Volume 7, Number 5 (2014), pp. 535-542.
10. Anurag Chauhan, R.P. Saini ' A review on Integrated Renewable Energy System based power generation for stand-alone applications: Configurations, storage options, sizing methodologies and control' RSER 38 (2014) 99–120.
11. J.M. Lee* and B.H. Cho* PSSC Strategy for Fuel Cell Hybrid Vehicle, 2008 IEEE.
12. Jing Shi, et al ' The Application of Active Superconducting DC Fault Current Limiter in Hybrid AC/DC Power Supply Systems' IEEE transactions on superconductivity, vol. 18, no. 2, june 2008.
13. Fengge Zhang et al. 'Simulation Research on Wind Solar Hybrid Power System Based on Fuzzy-PID Control' Proceeding of ICEMS 2007, Oct. 8~11, Seoul, Korea.
14. Swati Negi and Lini Mathew HRES: A Review IJEEE. ISSN 0974-2174, Volume 7, Number 5 (2014), pp. 535-542.
15. Badoud, M. Khemliche 'Modelling. design and control of wind diesel hybrid power system using bond graph' 2013 IEEE.
16. T. Aboul et al. Utilization of the Modulated Power Filter Compensator Scheme for a Grid Connected Rural Hybrid Wind/Tidal Energy Conversion Scheme 2010 IEEE EP&EC.
17. P.K.Ray et al. Dynamic Modeling and Control of Renewable Energy Based Hybrid System for Large Band Wind Speed Variation 2015 IEEE.
18. Md. Maruf et al. 'Dynamic Modeling and Simulation of a Remote Wind Diesel-Hydrogen Hybrid Power System' 2010 IEEE EP&E Conference.
19. Chunhua et al. IEEE 'An Efficient Wind–Photovoltaic Hybrid Generation System Using Doubly Excited Permanent-Magnet Brushless Machine' IEEE transactions on IE, vol. 57, no. 3, march 2010.
20. Jing et al. 'The Application of Active Superconducting DC Fault Current Limiter in Hybrid AC/DC Power Supply Systems' IEEE transactions on AS , vol. 18, no. 2, june 2008.
21. Xiaoyu Wang and Meng Yue 'Modeling and Control System Design for an Integrated Solar Generation and Energy Storage System with a Ride-through Capability' 2012 IEEE.
22. Puneet Goel et al. Senior Member IEEE Modeling and Control of Autonomous Wind Energy Conversion System with Doubly Fed Induction Generator2012 IEEE.
23. Vigneshwaran Rajasekarani et al. 'Maximum Power Point Tracking and Frequency Control for Hybrid Wind Diesel System Supplying an Isolated Load' 978-1-4673 2012 IEEE.
24. Fezzani et al. 'MATLAB-Based Modeling of Shading Effects in Photovoltaic arrays' ICS&T Automatic control & computer engineering December 21-23, 2014.
25. A.V. et al. 'Implementation of MPPT Control Using Fuzzy Logic in Solar-Wind Hybrid Power System' 978-1-4799/15/2015 IEEE.
26. Nishad Mendis et al. 'Operation of a Wind-Diesel- Battery based Hybrid Remote Area Power Supply System' 6th ICECE 2010, 18-20 December 2010, IEEE.
27. A. Andrijanovits et al. 'Comparative Review of Long-Term Energy Storage Technologies for Renewable Energy Systems ELEKTROTECHNIK AISSN 1392 12152012. No. 2(118).
28. Ajai Gupta et al. Modelling of hybrid energy system Part I: Problem formulation and model development Renewable Energy 36 (2011) Elsevier.
29. Jing Zhao et al. 'Research on the Torque and Back EMF Performance of a High Speed PMSM Used for Flywheel Energy Storage Energies 2015, 8, 2867-2888 ISSN 1996-1073.
30. Hussein Ibrahim et al. 'Comparison and Analysis of Different Energy Storage Techniques Based on their Performance Index 2007 IEEE.
31. M.A. Guerrero, E. Romero, Overview of Medium Scale Energy Storage Systems Power Electronics & Electric Systems, School of Industrial Engineering.
32. A.M.Shiddiq Yunus 'Overview of Storage Energy Systems for Renewable Energy System Application' 3rd (MICEEI 2012), Nov 28-Dec 2012.
33. Michelle Lim, Mohit Chhabra Frequency Variations in Hybrid Renewable Energy Network with Integrated Storage, Wide-Area Monitoring, Control & Protection2011 IEEE.
34. Paul Denholm et al. 'The Role of Energy Storage with Renewable Electricity Generation' Technical Report NREL/TP-6A2-47187 January 2010.
35. B. Ould. Bilal Methodology to Size an Optimal Stand-Alone PV/wind/diesel/battery System Minimizing the Levelized cost of Energy and the CO2 Emissions ICAEE 2011: 27-28 December 2011, Bangkok, Thailand.
36. Randa Kallel et al. 'Control Management Strategy of Stand-Alone Hybrid Power Micro-System using Super-Capacitor' IJRER, Vol.4, No.1, 2014.
37. Madaci Mansour 'Case Study of a Solar Pumped Storage Prototype Station Implementation Designed for the Region of Ghardia IJRER, Vol.6, No.2, 2016.
38. Whei-Min et al.'Neural-Network-Based MPPT Control of a Stand-Alone Hybrid Power Generation System' IEEE transactions on PE, vol. 26, no. 12, December 2011.
39. XIE Chang-jun and QUAN Shu-hai 'Control Strategy of Hybrid Power System for Fuel Cell Electric Vehicle based on Neural Network' Optimization Proceedings of the IEEE September 2008.
40. A.Hajizadeh et al. 'Fuzzy neural control of a hybrid fuel cell/ baery distributed power generation system' IET Renewable Power Generation March 2008.
41. Taekwon Kim et al.'A Smoothing Method for Wind Power Fluctuation Using Hybrid Energy Storage', Korea 978-1-4799- 7949-3/15/2015 IEEE.
42. A.V. Pavan Kumar et al. 'Implementation of MPPT Control Using Fuzzy Logic in Solar-Wind Hybrid Power System" 978-15/2015-IEEE.
43. Sanjoy Debbarma et al. 'Frequency Control of Autonomous Hybrid Power System using Smart Controllable Load", Shillong India ISBN: 978−81−925974−3−0/2015.
44. Sukhwinder Singh et al. 'Robust Load Frequency Control of Micro Grids Connected with Main Grids in a Regulated and Deregulated Environment" 978-1-4799-4040-0/14/2014 IEEE.
45. Arash Jamehbozorg et al. 'A Robust Control Approach to Smooth Output Power of Wind Units Using Hybrid Storage Systems Considering State of Charge" 978-1-4799-3656-4/14/2014 IEEE.
46. Swati Rawat et al. 'Load Frequency Control of a Hybrid Renewable Power System with Fuel Cell System" 978-1-4799-6042-2/14/2014 IEEE.
47. T.Praveen Kumar et al. 'Unit Power Control and Feeder Flow Control Strategies for a Grid-Connected Hybrid System" 2013 (ICPEC), 978-1-4673-6030-2/13/2013 IEEE.
48. S.Srinivas et al. 'Integration of PV/Battery Hybrid Energy Conversion System to the Grid with Power Quality Improvement Features IEEE 2013 8th ICEEV.

49. Abderrezzak Bouharchouche EI Madjid Ghennam Berkouk Tarrak "Renewable Energies Control and Energy Management of a Grid Connected Hybrid Energy System PV' l 978-1-4673-5271-0/13/2013 IEEE.
50. S K Sinha et al "Four Area Load Frequency Control of Interconnected Hydro- thermal Power System by Intelligent PID Control Technique" 978-1-4673-0455-9/12/2012 IEEE.
51. Meena Tushir et al. 'Application of a Hybrid Controller in Load Frequency Control of Hydro-Thermal Power System' 978 -1-4673-0766-6/12/2012 IEEE.
52. Mousa et al. 'Frequency Control of Isolated Wind and Diesel Hybrid Micro Grid Power System by Using Fuzzy Logic Controllers and PID Controllers" 978-1-4673-0378-1/11/2011 IEEE.
53. R.Dhanalakshmi et al. "Application Of Multi Stage Fuzzy Logic Control For Load Frequency Control Of An Isolated Wind Diesel Hybrid Power System" 978-1-4673- 0178-7/11/2011 IEEE.
54. T. R. Mtshali et al. 'Simulation and Modelling of PV-Wind-Battery Hybrid Power System" 978-1-4577-1002-5/11/2011 IEEE 2010 IEEE International Energy Conference.
55. Nishad Mendis et al. "Application of a Hybrid Energy Storage in a Remote Area Power Supply System" 978-1-4244-9380-7/10/2010 IEEE.
56. Nishad Mendis et al.' Operation of a "Wind-Diesel-Battery based Hybrid Remote Area Power Supply System" 6th ICECE2010,18-20 December 2010, Dhaka, 978-1-4244-6279-7/10/2010 IEEE.
57. David Hern et al. 'Robust Optimal Control Strategies for a Hybrid Fuel Cell Power Management System" 978-1- 4244-5226-2/10/2010 IEEE.
58. Puneet Goel et al 'Autonomous Hybrid System Using SCIG for Hydro Power Generation and Variable Speed PMSG for Wind Power Generation' PEDS2009.
59. Gerard Robert et al. 'Optimal Design of Reactive Power PI Regulator for Hydro Power Plants' 17th IEEE ICCA September 3-5, 2008978-1-4244-2223-4/08/2008 IEEE.
60. G. Robert et al. 'Robust Digital Automatic Reactive Power Regulator for Hydro Power Plants", 1-4244-0632-3/07/2007 IEEE.

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