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].

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](image)

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
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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 2.6 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 $\rho$ is air density in kg/m³, A is sweep area in m² and $v_w$ is wind speed in m/s. Normally near sea shore temperature of 15°C and air has density of approximately 1.2kg/m³.

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

\[ P_{MHW} = 9.81 \times Q \times h \times \rho \times \eta \]

where \( Q \) is the volume metre per second, \( h \) is the net height in metre available, \( \rho \) is the density of water, \( \eta \) 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.

\[ P_{PV} = g \times A_m \times G_t \]

Where, \( g \) is efficiency of PV, \( A_m \) shows the area of a all cells perpendicular to irradiance (m²).

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

\[ P_{nt} = \frac{1}{2} \eta \rho \omega A_T \eta v_w^3 \]

\( P_{nt} \) is the representation of power used by the tides, \( \rho \omega \) is \( r \) density of water, \( A_T \) is the tidal blade area (m²), \( v_w \) is the speed of tides and \( \eta \) 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 1: Aspects of the energy repository development |
|-----------------------------------------------|
| ASPECT | PERFORMANCE | ADVANTAGE | DEPEND | ENERGY | STORAGE | POWER |
|-------|-------------|-----------|--------|--------|---------|-------|
| BATTERY | 10% | DEVELOPED | LESS | BIG | BIG |
| PH | 10% | DEVELOPED | BIG | SIZE | DEPEND | DEPEND |
| FUEL CELL | 75% | REVERSING | LESS | HYDROGEN | DEPEND | DEPEND |
| FLYWHEEL | 85% | DEVELOPED | BIG | LESS | BIG |
| SMES | 50% | DEVELOPED | BIG | LESS | BIG |
| CAES | 70% | DEVELOPED | BIG | BIG | |

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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. 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.

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