Hybrid Renewable Energy Grid Connected Systems: A Review

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ABSTRACT:

This Paper is a review of hybrid Power based Grid connected renewable energy systems technologies, important issues, challenges and possible solutions, considering a combination of multiple generation sources including solar energy, wind energy. Applications of hybrid energy systems, advantages of hybrid energy systems, issues and problems related to hybrid solar PV and wind energy integration systems and an overview of possible solutions for renewable energy systems are presented. The objective of this paper is to present a literature review of the recent developments and trends pertaining to Grid- Connected hybrid renewable electricity to supply A.C Loads. Finally, this paper highlights the future developments in Hybrid electric power systems to increase the utilization of power generated from renewable energy sources (RES's), which represent a promising sustainable solution for power generation and also Suggestion for hybrid Renewable system implementation are discussed.

Keywords: Solar PV, Wind, Hybrid energy, Grid Connected system, solar-wind integration.

I. INTRODUCTION:

The centralized power generation has been dominating power scenario for a long time. These systems utilize conventional energy resources for electricity generation. However, worldwide urge to reduce dependency on fossil fuels and mitigate climate changes has increased pressure to alter current generation paradigm. Power generation by RES's is becoming more popular and economical than the traditional generation systems to supply reliable power in areas not served by conventional power grids. RES's are unpredictable and fluctuating in nature and also typically produce low power compared to traditional generation[1]. Hence, some means of integrating multiple sources are required to Provide a more reliable and sustainable energy. The integration of various RES's forms a hybrid renewable energy system (HRES), which provides continuous power to the consumers versus a System based on a single source. The HRES sources require Power converters for the efficient and flexible interconnection of RES's to work either in a standalone or grid-connected mode.

However, the HRES with an unpredictable nature for PV and wind cannot supply sufficient and stable power to meet the power demand. To ensure the dynamics of the HRES, several stable power sources, such as batteries, fuel cells (FC), super-capacitors, or diesel generators, must be integrated into the HRES especially in standalone mode and into the utility in grid- connected mode. In addition to the various benefits, the HRES has numerous technical challenges on the system power quality, such as power fluctuation because of the presence of a new source or plug-and-play feature of RESs, voltage and frequency deviation caused by the transition from grid-connected to standalone mode and vice-versa. Therefore,

the HRESs must have the ability to mitigate the power quality issues to supply high-quality and more reliable steady power. The power quality and system stability can be achieved by an appropriate control technique embedded into the power converter control circuit. However, the main challenge is to design suitable control strategies for the HRES to overcome the above challenges.

II. HYBRID RENEWABLE ENERGY SYSTEMS:

Due to the fact that solar and wind power is intermittent and unpredictable in nature, higher penetration of their types in existing power system could cause and create high technical challenges especially to weak grids or stand-alone systems without proper and enough storage capacity. By integrating the two renewable resources into an optimum combination, the impact of the variable nature of solar and wind resources can be partially resolved and the overall system becomes more reliable and economical to run.

Hybrid renewable energy system (HRES) combines two or more renewable energy sources like wind turbine and solar system.-PV modules produce outputs that are determined mainly by the level of incident radiation. As the light intensity increases, photocurrent will be increased and the open-circuit voltage will be reduced. The efficiency of any photovoltaic cell decreases with the increasing temperature which is non-uniformly distributed across the cell. The solar output power can be smoothed by the distribution of solar power in different geographical areas[2].

Wind turbines (WTs) are classified into two types: horizontal-axis WT (HAWT) and vertical-axis WT (VAWT). The highest achievable extraction of power by a WT is 59% of the total theoretical wind power. Figures 1&2 shows the Solar PV and Wind systems.

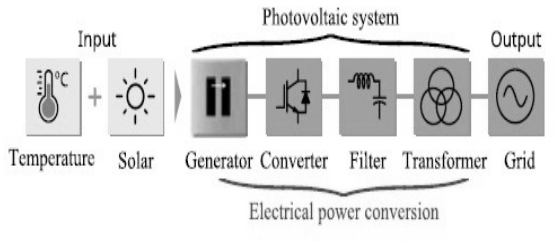


Fig 1.Architecture of Solar PV System.

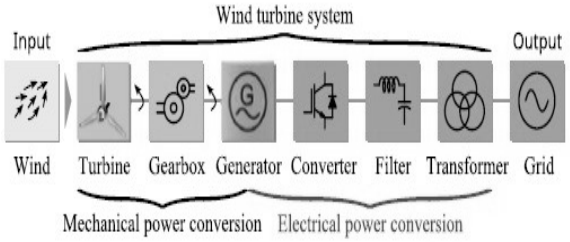


Fig 2.Architecture of Wind Power System.

HYBRID SOLAR PV-WIND SYSTEMS

Hybrid solar PV and wind generation system become very attractive solution in particular for grid connected applications[20]. Combining the two sources of solar and wind can provide better reliability and their hybrid system becomes more economical to run since the weakness of one system can be complemented by the strength of the other one. The integration of hybrid solar and wind power systems into the grid (shown in fig 3.) can

further help in improving the overall economy and reliability of renewable power generation to supply its load. Similarly, the integration of hybrid solar and wind power in a stand-alone system can reduce the size of energy storage needed to supply continuous power[22].

Hybrid solar-wind systems can be classified into two types: grid-connected and stand-alone. Literature reviews for hybrid grid-connected and stand-alone solar PV and wind energies were conducted worldwide by many researchers who have presented various challenges and proposed several possible solutions[19]. Due to the nature of hybrid solar PV and wind energies, optimization techniques can play a good role in utilizing them efficiently. Graphic construction methods, linear programming, and probabilistic approach are few examples of optimization techniques that have been developed for techno-economically optimum hybrid renewable energy system for both types.

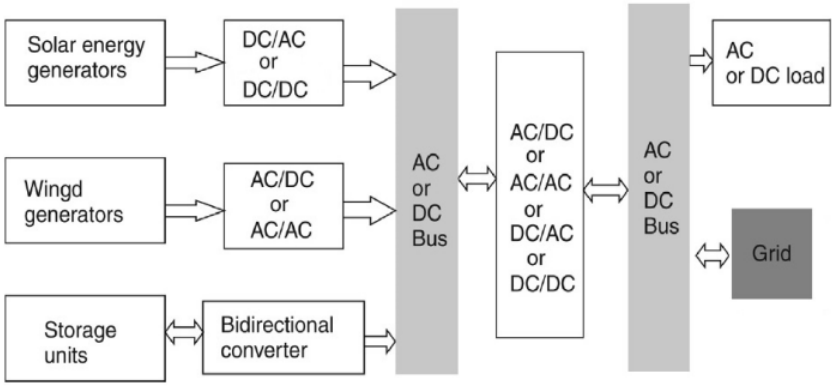


Fig 3. Basic component of solar–wind hybrid renewable energy system.

Advantages Of Hybrid Systems

1- A hybrid energy system can make use of the complementary nature of various sources, which increases the overall efficiency of the system and improve its performance (power quality and reliability). For instance, combined heat and power operation, e.g. MT and FC, increases their overall efficiency [3]&[4-6]or the response of an energy source with slower dynamic response (e.g. wind or FC) can be enhanced by the addition of a storage device with faster dynamics to meet different types of load requirements[7]&[8-10].

2- Lower emissions: hybrid energy systems can be designed to maximize the use of renewable resources, resulting in a system with lower emissions.

3- Acceptable cost: hybrid energy systems can be designed to achieve desired attributes at the lowest acceptable cost, which is the key to market acceptance.

4- They provide flexibility in terms of the effective utilization of the renewable sources.

ISSUES WITH HYBRID RENEWABLE ENERGY SYSTEMS

Though a hybrid system has a bundle of advantages, there are some issues and problems related to hybrid systems have to be addressed[23]:

1- Most of hybrid systems require storage devices which batteries are mostly used. These batteries require continues monitoring and increase the cost, as the batteries life is limited to a few years. It is reported that the battery lifetime should increase to around years for the economic use in hybrid systems.

2- Due to dependence of renewable sources involved in the hybrid system on weather results in the load sharing between the different sources employed for power generation, the optimum power dispatch, and the determination of cost per unit generation are not easy.

3- The reliability of power can be ensured by incorporating weather independent sources like diesel generator or fuel cell.

4- The stability issue. As the power generation from different sources of a hybrid system is comparable, a sudden change in the output power from any of the sources or a sudden change in the load can affect the system stability significantly.

5- Individual sources of the hybrid systems have to be operated at a point that gives the most efficient generation. In fact, this may not be occur due to that the load sharing is often not linked to the capacity or ratings of the sources. Several factors decide load sharing like reliability of the source, economy of use, switching require between the sources, availability of fuel etc. Therefore, it is desired to evaluate the schemes to increase the efficiency to as high level as possible.

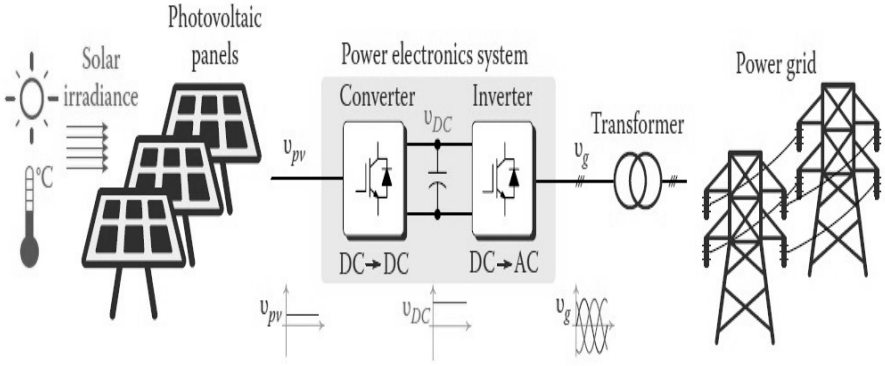
III. GRID CONNECTED SYSTEMS

Different grid connected configurations are shown in figure 4. The choice of the layout for particular location depends upon geographical, economical, and technical factors[20-21,24].

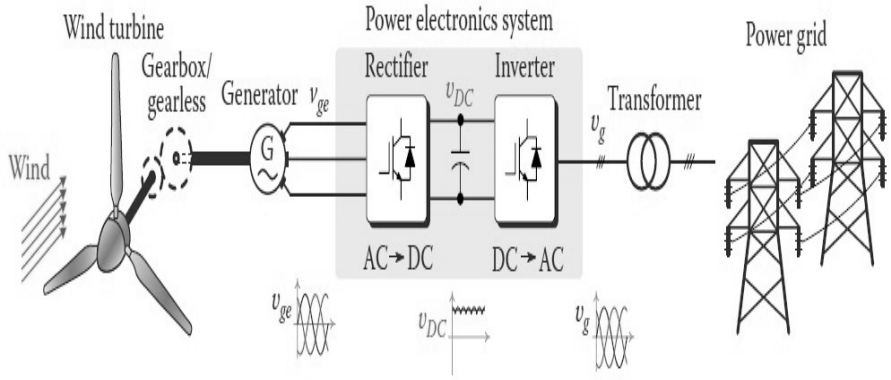
 Grid connected PV energy conversion system shown in Fig.4(a). The DC energy source from solar PV system is passed through power electronics system and converted DC into AC before being delivered to the main AC bus bar. An inverter, main, takes the responsibility of feeding the ac grid from this dc power.

 Grid connected wind turbine energy conversion system shown in Fig.4(b), The AC Power from wind turbine passed through appropriate power electronic devices, before being connected to the grid. Here conversion takes place from AC to DC and DC to AC. finally connected to AC Power Grid.

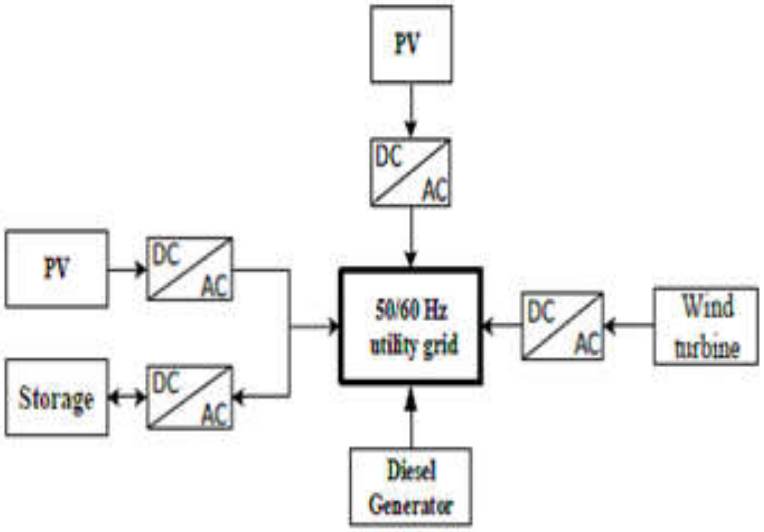
 Grid connected PV-wind energy conversion system shown in Fig. 4(c), the power sources do not need to be installed close to each other, and they do not need to be connected to one main bus. The sources are distributed in different geographical locations and connected to the grid separately.



a. Grid Connected PV energy conversion system



b. Grid Connected Wind energy conversion system



c. Grid Connected distributed AC Bus Solar-Wind turbine energy conversion system

Fig 4. Different grid connected configurations

IV. LITERATURE REVIEWS

In this paper a literature review is carried out related to grid integration of Hybrid Energy based Renewable Sources. Number of authors/researchers has presented the various issues, challenges and their possible solutions in the context of grid integration. The increasing use of the Renewable Energy Sources (RES) and the intermittency of the power generated by them create stability, reliability and power quality problems in the main electrical grid. below tables shows the literature review based Solar, Wind, solar and wind integration systems.

Table.1: Literature Review Based on Solar Integration

S.No.	TITLE	AUTHOR	ALGORITHM	OUTCOME
1. 1	Design of a photovoltaic electric power system for an Indian village	H. Saha	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.	Oppurtunities for utilization of stand-alone Hybrid (PV+Diesel+ Battery) power systems in hot climates	S.M. Shaahid and M.A. Elhadidy	Analytical Method	Investigated the sizing of battery storage for PV/ diesel/ battery hybrid system for a typical residential and commercial building in Dhahran.
3.	The design of photovoltaic plants: an optimization procedure	B. Bartoli,V. Cuomo, C.Serio and VSilvestrini	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.	An analytical method to describe the optimal size of a photovoltaic plant	L. Barra, S.Catalanotti, F.Fontasa & F.Lavorante	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. 2	The loss of power supply probability as a technique for designing stand-alone solar (photovoltaic) systems	E. Ofry and A.Braunstein	Graphical Method	A direct relationship between the PV array area and the battery capacity to minimize the PV system is suggested.
6. 3	A combined optimization concept for the design and operation strategy of hybrid PV energy systems	G.C. Seeling-Hochmuth	Genetic Algorithm	Developed a method to jointly 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.

7.	5	Proposed generalized models for estimating the reliability of stand-alone solar photo-voltaic power system	M.H. El-Maghraby, Y.A.Abed & M.A.El-Sayes	Mathematical Model	Proposed and developed a mathematical model for a standalone solar PV system with Loss of Load Probability (LOLP) reliability index.
8.	6	Loss of power supply probability of standalone photovoltaic systems: a closed form solution approach	I. Abouzahr and R. Ramakumar	Mathematical Model	Presented closed form approach to stand-alone solar PV system to calculate Loss of Power Supply Probability (LPSP) under various operating conditions.
9.	9	Cost benefit analysis of a photovoltaic energy storage electrification solution for remote islands	J.K.Kaldellis, E.L. Kaldelli and K. Kavadias	Mathematical Model	Formulated a methodology to maximize PV contribution and minimize the cost of electricity generation along with best suitable storage devices available.

Table. 2: Literature Review Based on Wind Integration

S.No	TITLE	AUTHOR	ALGORITHM	OUTCOME
1.	The performance of a remote wind/ diesel power system	A.J. Bowen, M. Cowie and N.Zakay	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.
2.	Dynamic modelling and robust regulation of a no storage wind/ diesel hybrid system	I. Kamwa	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.

3.	Application of design space methodology for optimum sizing of wind battery systems	A. Roy, S.B. Kedare and S.Bandyopadhyay	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.
4. 2	A probabilistic method for the evaluation of the performance and the reliability of wind/ diesel energy systems	E.S.Gavanidou,A.G. Bakirtzis &P.S.Dokopoulos	Probabilistic Method	Presented a probabilistic method to evaluate performance of wind/diesel energy system by constraining the wind generation.
5. 3	Probabilistic evaluation of the performance of wind/ diesel energy systems	A.C.Saramourtsis, A.G. Bakirtzis, and E.S. Gavanidou	Probabilistic Method	Described a probabilistic method for predicting the economic performance and reliability of autonomous energy systems
6. 4	The economic viability of commercial wind plants in Greece: a com-plete sensitivity analysis	J.K. Kaldellis and Th. J.Gavras	Economic Commercial Method	Discussed the influence of governing techno-economic parameters on economic behavior of commercial wind park
7. 6	Cost benefit analysis of remote hybrid/ diesel power stations: a case study Aegean Sea islands	J.K. Kaldellis and K. Kavadias	Mathematical Algorithm	Concentrated on a detailed energy production cost analysis in order to estimate the optimum configuration of a wind/ diesel/ battery standalone system.

Table 3: Literature Review Based on Solar and Wind Integration

S.No	TITLE	AUTHOR	ALGORITHM	OUTCOME
1. 2	Comparison results of two optimization techniques for a combined wind and solar power plant	M.T.Samarakou, M.Grigoriadou and C. Caroubalos	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.
2. 6	Proportion assessment of combined PV/ wind generating systems	A.M. Al- Ashwal & I.S.Moghram	Simple Analytic Method	Introduced a simple and efficient method to assess the optimal proportion of combined PV and wind generator system.
3.	Impact of integrating the photo-voltaic and wind energy sources on generation system reliability and operation economics	A. Jain, J. Choi and B. Kim	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.
4. 3	Optimum photovoltaic array size of a hybrid wind/ PV systems	B.S. Borowy and Z.M. Salameh	Least Square Method	Used the least square method to find the best fit of wind turbine and of commercial wind park.
5.	Generation unit sizing and cost analysis for stand-alone wind, photovoltaic and hybrid wind/ PV systems	W.D. Kellog, M.H. Nehrir, G.Venkataramanan and V. Gerez	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.
6.	Optimization of a combined wind and solar power plant	J.C. Hennet and M.T. Samarakou	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).
7.	Optimal unit sizing for a hybrid wind/ photovoltaic generating system	W. D.Kellog, M.H. Nehrir. G.Venkataramanan and V. Gerez	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.
8. 4	Sizing of a stand-alone hybrid wind/ PV system using a three event	D. Bagul, Z.M. Salameh and B.S. Borowy	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

	probability density approximation			increase in the effort and system cost.
9. 9	Alternative energy facilities based on site matching and generation unit sizing for remote area power supply Weather Based	P.K. Katti and M.K. Khedkar	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.

V. ISSUES, CHALLENGES AND POSSIBLE SOLUTIONS

Renewable energy sources are intermittent in nature hence it is therefore a challenging task to integrate renewable energy resources into the power grid. Some of

the challenges and issues associated with the grid integration of various renewable energy sources particularly solar photovoltaic and wind energy conversion systems[19]. Further these challenges are broadly classified into technical and non-technical and described below.

A. Technical Issues: The following are the technical issues are described as

1.Power quality:

(a). Harmonics,

(b). Frequency and voltage fluctuation.

2. Power fluctuation:

(a). Small time power fluctuations,

(b). Long time or seasonal power fluctuations.

3. Storage,

4. Protection issues

5. Optimal placement of RES,

6. Islanding

Apart from aforesaid technical issues some of the nontechnical issues are also presented in this paper.

B. Non- Technical Issues

1. Lack of technical skilled man power

2. Less availability of transmission line to accommodate RES

3. RES technologies are excluded from the competition by giving them priority to dispatch which discourage the installation of new power plant for reserve purpose.

SUMMARY AND FINDINGS

Table 4 summarizes main challenges for grid-connected hybrid solar PV and wind systems with possible solutions or mitigations.

Table 4. Main challenges and possible solutions for grid-connected system

No.	References	Challenges	Solutions
1	11& 16 11 & 17 19	Voltage fluctuation due to variations in wind speed and irregular solar radiation	Series and shunt active power filters. Power compensators such as fixed/switched capacitor or static compensator. Less sensitive customer's equipment to power disturbance/ voltage distortions and utilities line conditioning systems
2	18	Frequency fluctuation for sudden changes in active power by loads	PWM inverter controller for regulating three-phase local AC bus voltage and frequency in a microgrid.
3	11, 16 & 17	Harmonics by power electronics devices & nonlinear appliances.	PWM switching converter and appropriate filters.
4	11 & 12 15 13 & 14	Intermittent energy's impacts on network security	Accurate statistical forecasting and scheduling systems. Regression analysis approaches and algorithms for forecasting weather pattern, solar radiation and wind speed. Increase or decrease dispatchable generation by system operator to deal with any deficit/surplus in renewable power generation. Advanced fast response control facilities such as Automatic Generation Control and Flexible AC Transmission System.
5	11	Synchronization	The most popular grid synchronization technique is based on phase-locked loop. Other techniques for synchronization include detecting the zero crossing of the grid voltages or using combinations of filters coupled with a non-linear transformation.

VI. Hybrid system implementation:

Table 5 shows the important suggestions for hybrid renewable system implementation.

Table 5. Suggestion for hybrid system implementation

S.No	Issue	Comments
1.	Converters losses	The loss involved with electrical power converters are actually reduced to some sufficient stage; on the other hand, it should be guaranteed that there's minimal quantity of electrical power reduction within these converters
2.	Life-cycle	The life-cycle associated with storage units, such as batteries along with UCs, should be improved upon by means of innovative systems
3.	Disposal of storage equipment	The convenience connected with storage space products, like power packs and also other storages, is among the significant problems for producers

4.	Renewable energy sources	Photovoltaic and other renewable energy options require break-through systems for removing much more quantity of use full strength. The poor effectiveness involving a solar PV is often an important barrier inside stimulating its use
5.	Control unit	With the entire supplement associated with unique turbines inside developing a hybrid renewable energy system raises the strain about power alteration devices. Any possible hybrid renewable energy system requires the feasible associated with right keeping track of design system that will record important info to its productive functioning. Each time almost any mismatch inside the power generation in addition to desire exists the system may open the circuit breakers with regard to much better safety in addition to functioning
6.	Grid control	For controlling different generators which are linked to the hybrid renewable energy system, to the function of saving power and carry through the load demand a development of a small grid system required
7.	Manufacturing cost	This making price tag of renewable energy sources needs a significant lessening considering that the higher capital price tag causes an elevated payback time. cost lessening will supply a motivation on the marketplace to be able to apply like devices
8.	Load management	The particular renewable resources tend to be independent of the load variations and as such suitable energy management should be designed, in order that the prolonged existence on the hybrid renewable energy system can be increased. Big deviation inside the load could even result in a whole system fall
9.	Stability	Hybrid renewable energy system depends on weather conditions so that theirs is needed to carry out transient analysis of the system for varying constraint like solar radiation, wind velocity, load demand
10.	Government support	For reducing the cost of components, production costs of generation and wide deployment of Hybrid renewable energy system network, it is essential to give subsidy on renewable energy goods from central to the state government .

VII. CONCLUSIONS:

In this paper, provided a review of challenges and opportunities on grid integration of solar PV, Wind, solar and wind energy sources issues and their possible solutions available in the literature have been presented. The main challenge for the stand-alone system as well as grid-connected system is the intermittent nature of Renewable's like solar PV and wind sources. By integrating the two resources into an optimum combination, the impact of the variable nature of solar and wind resources can be partially resolved and the overall system becomes more reliable and economical to run. The number of new technologies for hybrid renewable energy system design are discussed in the literature. Table 5 presents some important suggestion for Hybrid system implementation are discussed.

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