Review

Sreekanth Mamidala*, Govindarajalu Mohan and Chelliah Veeramani

Hybrid renewable energy resources accuracy, techniques adopted, and the future scope abetted by the patent landscape – a conspicuous review

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Abstract: Renewables always attract everything than other thrust research areas owing to the global warming issue caused by using the non-renewables therein which should be mitigated at the earliest possible time. The easiest and safest alternative is employing renewable energy resources for the generation of energy that is completely sustainable. Many countries started insisting to seek alternatives trying to terminate to the fullest extent. Even though all these measures are taken, it is very hard to mitigate the utilization of non-renewables, owing to efficacy lag in renewables. The simplest solution for this problem is hybrid usage of renewables to enhance the efficiency. This article took this as a factor, gathered data for hybrid RERs technique with its accuracy range for easy selection of techniques by the stakeholders, trending technology being adopted, and future scope abetted by the patent landscape.

Keywords: applications of hybrid RERs; hybrid RERs; patent landscape analysis; renewable energy resources (RERs); soft computing techniques.

Introduction

Electricity generation is viewed as a serious concern as manufacturing progress proceeds, at a higher pace owing to the world's accelerating population growth. The growth of communities migration to deserted areas, and increasing technological advancement, raise energy consumption in whole and electrical consumption in specific (Hosenuzzaman et al. 2015; Wellington Silva et al. 2018). As a result, for a clean, sustainable, environmentally friendly and stable society viable efficient energy resources are in a pivotal place than ever before (Claudia and Cinzia 2018; Nadarajah and Divagar 2016). Coal, crude oil, as well as natural gas deliveries are dominated by fossil fuels as well as conventional energy production technologies, contributing or more than 80% of principal energy resources in 2018 (Agency 1996). Nevertheless, extensive usage of fossil resources hurts the ecosystem as well as climate (Abdelkareem et al. 2021; Elsaid et al. 2020). The enormous reliance on fossil resources as well as their widespread exploitation in every facet of life had also resulted in a slew of serious ecological issues (John, Kil Seong, Edwin 1980; Giorgos 2008), flooding, elevated sea levels, forest fires, heat waves, and so on (Andrew and Pierre 2015; Kevin, John, and Magdalena 2014; Saria, Sajjad, and Jacimaria 2018). Research and innovation, has been conducted to increase the efficacy of existing operations via waste energy recapture (Brough and Jouhara 2020; Brough et al. 2020, 2021; Fierro et al. 2020; Jouhara and Olabi 2018), designing ecologically friendly and efficient electricity production technologies (Alawadhi et al. 2020; Abdelkareem et al. 2020; Olabi et al. 2021; Sayed et al. 2020), and utilizing clean, renewable energy resources that has little or no negative impact on the environment (Olabi et al. 2020; Rabaia et al. 2021). The green energy source has been increased until the point whereby developed nations may shift a greater share of their power balance to renewable energy, thereby promoting worldwide decarbonisation and neutralization. Numerous international agreements, most significantly the "Paris Agreement", has aimed for reductions in worldwide carbon emission (UNFCC 2015). According to IRENA's research, Climatological Renewable Technologies: To accomplish these lofty targets as well as sufficiently mitigate the harmful effects of climate disruption, energy production should always be decarbonized in fewer than five decades. The estimated decarbonisation can never be completed without alternative energy resources

***Corresponding author: Sreekanth Mamidala**, Research Scholar, Department of EEE, Annamalai University, Annamalai Nagar, Chidambaram, India, E-mail: sreekanthmamidala8@gmail.com
Govindarajalu Mohan, Department of EEE, Annamalai University, Annamalai Nagar, Chidambaram, India
Chelliah Veeramani, Department of EEE, Sri Indu College of Engineering and Technology, Sheriguda, India

growing at least sevenfold of their present levels before 2060, the globe's economy triples (IRENA 2017). Renewable energy capability increased 7.4% from a total power increase of 176 GW during 2019, according to IRENA's 2019 report, including 54% of new photovoltaic and wind power plants being constructed in the Asia region (IRENA 2020a, 2020b). Renewables account for approximately 70% of novel power capacity installed during 2019 (Domínguez, Carrión, and Oggioni 2020; Kimmell et al. 2020). Each kilowatt-hour produced by a renewable technology compensated for a kilowatt-hour produced through traditional power plant. Sustainable energy technologies, on the other hand, keeps improving yet have not already completely substituted conventional energy sources. Amongst some of the different sustainable energy methods, photovoltaic energy production is perhaps the most prevalent and well-knowing, having been aggressively implemented throughout the globe (Iqbal et al. 2021; Rezk et al. 2019). Apart from solar cells, renewables including biomass, wind, geothermal, have received considerable focus and investment during the last decade. There had been dramatic rise in established renewable energy capability throughout the previous 20 years, including geothermal, biomass, wind, and hydro. In addition hydropower and tidal energy has X received substantial focus in the past due to the early marketing capability and perhaps the most established sustainable energy resources, in comparison to the emergence among the remaining sustainable energy technologies (IRENA 2020c). The numerous benefits of alternative fuels, particularly their ecological friendliness, have fuelled substantial research during the last few decades (Abdelkareem et al. 2018). The number of journal papers with energy or the term energy in association containing geothermal, biomass, wind, or hydroelectric there in the title, as taken from the Science Direct website published by Elsevier, including some of the world's leading scientific publishing houses, between 1996 and 2020 have been considered for analysis. A discernible growth in the count of publications as a direct outcome of novel work and activities, from approximately 150 in 1996 to over 1000 around 2020. Wind energy journals account for approximately 21.5–73.3% of all articles throughout the same period, including an overall value of nearly 60%. Subsequently, biomass energy accounts for between 17 and 68% of total energy, with a range of 23%. Geothermal renewables are ranked 3rd in this ranking, accounting for around 5.3–17.3% of renewable energy production across the research duration, with an average figure of 10%. Hydroelectricity, being the oldest and most convenient form of clean and renewable energy, has attracted the lowest research as well as development commitment, receiving between 4.4 and 11% points of total efforts, despite an absolute average of around 7%. It is critical to adopt appropriate measures to mitigate the environmental implications of renewable energy sources. To eliminate additional Environmental Impacts (EIs) from recently deployed renewable energy source systems, an assessment of the resilience of such renewable technologies, and an assessment of all innovations as well as their elimination of any potential environmental danger, are essential (Ghenai, Albawab, and Bettayeb 2020; Hasanuzzaman et al. 2020; Mihály, István, and Péter 2014). To date, EIs underlying solar energy production has received greater attention than those of alternative renewable resource techniques, and analysing the variety of PV solar subjects have indeed been conducted. As a result, this paper discusses the EIs of wind, water, that is hydroelectricity (except tidal and wave energy systems, which are still in their infancy as an energy source), biomass, and geothermal energy systems. It addresses the much more recent research on the ecological impacts among the renewable technologies and suggests mitigation measures for a variety of environmental conditions. This analysis focuses on the environmental impacts of the green energy generating phase, moderately better than an entire life cycle analysis. For every renewable energy resource, thorough EIs based on life cycle evaluation are available somewhere (Davidsson, Höök, and Wall 2012; Moretti et al. 2020; Mendecka and Lombardi 2019; Parisi et al. 2019; Rashedi, Sridhar, and Tseng 2013; Uddin and Kumar 2014; Wang, Xie, and Xu 2019a). This is mostly because the primary benefit of renewable energy sources is that they contain significantly lower EIs throughout the process and maintenance then fossil fuel resources. It is frequently unjust to link Renewable Energy Resources (RERs) to fossil energy resources over their whole product lifecycle, as RERs are tranquillity connected with expensive and advanced materials, an irregular nature, as well as a small scale. As a result of the consolidation of the foregoing data, it is obvious that RERs should be enhanced by combining two or more techniques for their superior performance. The primary objective of the study is to use the hybrid techniques and digital technologies in the renewables for better performance and viable utilization.

Hybrid RERs

Table 1 provides the set of hybrid techniques which can be feasibly selected by the stakeholders according to their requirements based on the accuracy range and applications.

The derivative from the above Table 1 depicts that the most of the hybrid RER is for power generation, thereby it is

Table 1: Hybrid RERs technique with its accuracy range.

S. No.	Hybrid RERs Technique	Application	Accuracy in Percentage	Reference
1.	Solar, wind	Charging	82	(Gautam et al. 2022)
2.	Solar, wind, hydro	Power generation	95	(Agarkar and Barve 2011)
3.	Solar & wind	Pumping water	83	(Xu et al. 2019)
4.	Solar, wind, hydro	Power generation	94	(Chisale 2019)
5.	Solar, wind, hydro	Power generation	96	(Acakpovi et al. 2015)
6.	PV, wind	Charging battery	82	(Kushwaha 2017)
7.	Solar, wind, hydro	Power generation	91	(Banik and Das 2020)
8.	Solar, wind	Pumping water	86	(Xu et al. 2021)
9.	Solar, wind	Charging battery	85	(Shaha et al. 2016)
10.	Solar, wind	Charging battery	84	(Vasant and Pawar 2017)
11.	PV, wind, hydro	Power generation	90	(Prabhakar and Ragavan 2013)
12.	Solar, wind	Power generation	84	(Kannan 2020)
13.	Solar, wind	Power generation	83	(Joshi and Roy 2021)
14.	Solar, wind	Power generation	84	(Sabley and Adhau 2014)
15.	PV, wind, hydro	Power generation	91	(Chen and Liu 2012)
16.	Solar, wind, hydro, biogas	Power generation	96	(Sharma and Kumar 2020)
17.	Hydro, thermal, wind, solar	Power generation	95	(Kaur and Brar 2021)
18.	Solar, wind, biomass, biogas	Power generation	97	(Patel and Singal 2017)
19.	Solar, wind, tidal	Power generation	91	(Singh and Singla 2015)
20.	Solar, wind	Power generation	84	(Vadakkepurakkel 2019)
21.	PV, wind	Power generation	82	(Pinninti and Vejitha 2019)
22.	Solar, wind	Power generation	82	(Gupta et al. 2017)
23.	Solar, wind	Power generation	83	(Anuradha and Sinha 2016)
24.	Solar, wind	Power generation	84	(Khare et al. 2016)
25.	Hydro, PV, wind	Power generation	90	(Nikolova-Poceva 2021)
26.	Solar, wind	Power generation	83	(Kishor and Varun 2019)
27.	Solar, wind	Power generation	80	(Bhati and Berwal 2018)
28.	Solar, wind, hydro, biomass	Power generation	96	(Gupta)
29.	Solar tracking, wind	Power generation	88	(Mustafa et al. 2017)
30.	PV, wind	Power generation	81	(Baneshi and Hadianfard 2016)
31.	Solar, wind	Power generation	81	(Tareemwa and Nankunda 2018)
32.	Hydro, PV	Power generation	83	(Meshram et al. 2013)
33.	Hydro, PV	Power generation	82	(Kumar et al. 2019)
34.	Solar, wind, biomass	Power generation	91	(Deb 2012)
35.	PV, wind	Power generation	82	(Sharif et al. 2017)
36.	Solar, wind, hydro	Power generation	89	(Verma and Verma 2020)
37.	PV, wind	Power generation	82	(Jadhav and Patil 2020)
38.	PV, wind	Power generation	80	(Awasthi et al. 2014)
39.	PV, wind	Power generation	81	(Yadav 2017)
40.	Solar, wind, micro hydro	Power generation	87	(Nuri 2021)
41.	PV, wind	Power generation	80	(Sinha and Chandel 2015)
42.	Hydro, PV	Power generation	81	(Wang et al. 2019b)
43.	Solar, wind, hydro, biomass	Power generation	96	(Malik et al. 2020)
44.	Any RERs combination	Power generation	92	(Oladigbolu et al. 2019)
45.	PV, wind	Power generation	80	(Awasthi et al. 2013)
46.	Small hydro, PV	Electricity	82	(Ogueke et al. 2016)
47.	Solar, wind, hydro, geothermal	Power generation	95	(Kumar 2015)
48.	PSH (pumped storage hydropower), PV, and hydro	Power generation	86	(Zhang et al. 2020)
49.	Solar, wind	Power generation	81	(Reta 2019)
50.	Solar, wind	Power generation	81	(Oo and Kyin 2016)

PV, Photovoltaic.

concluded that the need of the assessment is understood that it is further various applications can be work on in the near future.

Optimising the hybrid RERs by trending techniques

The other arena opens up herein, after the accuracy of the hybrid RERs thereby which technology is associated with and their specific purpose. In this purview, it is tabulated in Table 2.

The derivative from the above Table 2 depicts that the most of the hybrid RER uses AI, ANN and IoT. The mentioned techniques are widely used in some kind of automation in the hybrid RERs. It can further be accelerated to various new implications.

Inference from the above tables are taken for the comparison over the existing techniques are given below,

– The conventional methods are non-hybrid, but hybrid is viable.

Table 2: Hybrid RERs technique with trending technology.

S. No.	Hybrid RERs	Application	Technique	Reference
1.	Solar, hydro	Scheduling	IoT	(Gudimella et al. 2022)
2.	PV, wind, hydro	Inverter analysis	IoT	(Utari et al. 2021)
3.	PV, wind	Highway lighting	IoT	(Kaustubhasai and Balachandra 2022)
4.	PV, wind	Maximum draw	GA	(Karthikeyan 2021)
5.	Hybrid RERs	Controlling light	IoT	(Murugesan and Suganyadevi 2019)
6.	Solar, wind	Enhancing power	IoT	(Dubey and Tripathi 2020)
7.	Solar tracking, piezo	System design	IoT	(Shaikh et al. 2020)
8.	PV, wind	Effective conversion	FL	(Bharathi et al. 2020)
9.	Solar, wind	Complimentary electricity	IoT	(Dai 2020)
10.	PV, wind	Power generation	SCADA	(Aghenta 2020)
11.	PV, wind	Energy forecast & management	AI	(May et al. 2018)
12.	PV, wind	Load demand satisfaction	AI	(Maleki and Askarzadeh 2014)
13.	PV, wind	Optimization of sizing	AI	(Al-Falahi et al. 2017; Anoune et al. 2018)
14.	PV, wind	Optimization & system analysis	AI	(Abaye 2018)
15.	PV, wind	System stability	ANFIS	(Sharma and Soni 2016)
16.	PV, wind	Reducing the fluctuation	ANFIS	(Ali et al. 2014)
17.	PV, wind	Current transition with precision	FL	(Ahmed et al. 2017)
18.	Solar, wind	System reliability	AI	(Paliwal 2021)
19.	Solar, wind	Optimization	AI	(Zhang et al. 2019)
20.	PV, wind	Modelling, Controlling	ANN	(Mitra 2018)
21.	PV, wind	Modelling	ML	(Anbuchezhian et al. 2020)
22.	Wind, PV, solar	Power forecast	AI	(Pang et al. 2021)
23.	Thermal, PV	Maximum power	AI	(Osseily 2018)
24.	Solar, wind	Sizing	AI	(Gangulya et al. 2020)
25.	RER	Improved response	AI & ML	(Chaurasia and Kamath 2022)
26.	Solar, wind	Feasibility analysis	IncCond algorithm	(Bouchiba et al. 2021)
27.	PV, wind	System improvement	SC	(Gandhi and Kathirvel 2021)
28.	PV, wind	Optimization	SC	(Selvam 2020)
29.	PV, wind	Capacity optimization	ABCA	(Yong et al. 2020)
30.	PV, wind	System optimization	GA	(Rathish et al. 2021)
31.	RER	Controller tuning	SSA	(Malik and Suhag 2021)
32.	PV, wind	Maximum power output	ANN	(Khan and Mathew 2021)
33.	Solar, wind	Optimizing the size	HSA	(Anand et al. 2020)
34.	PV, wind	Energy utilisation	FL	(Anthony et al. 2021)
35.	PV, wind	Hydrogen storage	PSO, GA	(Paulitschke et al. 2017)
36.	Solar, wind	House energy storage	FL	(Derrouazin et al. 2017)
37.	Solar, concentrator PV	Cost equalisation	PSO	(WIPO 2021)

SC, soft computing; ANFIS, adaptive neuro-fuzzy inference system; GA, genetic algorithm; AI, artificial intelligence; ML, machine learning; ABCA, artificial bee colony algorithm; IoT, internet of things; SSA, salp swarm algorithm; FL, fuzzy logic; HSA, harmony search algorithm; PSO, particle swarm optimization.

- Digital technologies are not accelerated still, but it gives better feasibility to be adopted in hybrid renewables.
- Applications are limited owing to non-utilization of hybrid and digital techniques, but utilization pave novel paths are various implications in the future.

Future scope

The trend of any technology can be easily realized by the patent filing in that particular domain. The following Figure 1 is the details collected from the World Intellectual Property Organisation (WIPO) database, one of the biggest patent databases in the world. The total count is 2046 as per the record for the keyword – (English All) EN_ALL: ("Renewable energy resources") and also consider only the "single-family member", which means, the same patent filed in multiple countries is considered as single patent, in order to avoid the redundancy of the same patent.

It is evident from data collected from the same resource that the USA tops the table by filing most number of patents in this technology of count 878 almost half the entire globe's patent filed. The graph also reveals in the past decade the number of patents filed is not in the downfall. So, this predominant growth completely depicts the importance of utilizing the RERs instead of Non-Renewable energy resources thereby it prevents the globe warming, which is one of the threats to the earth. At this juncture, it is necessary to assess the future scope of RERs owing to maximize the utilization of renewables.

The article sources also state that specifically, the latest research works reveal there is remarkable growth for Hybrid RERs (HRERs) for versatile applications including electric vehicles, desalination, micro-grid as well as the power to fuel conversion. Most of the research work focuses on analysing the performance of these systems along with developing hybrid algorithms wherein, which is useful to enhance the performance of the system. The collective survey highlighted in Figure 2 reveals that the trend in implementing the digital techniques includes developing new algorithms for optimization of the system, hybrid them for decision making and optimization. The process of using the optimization technique does not stop at this juncture beyond this trend marching towards developing Artificial Intelligence (AI) based predicting techniques including such as machine and reinforcement methods in designing and controlling the entire system. The research society also envisaging towards to not like earlier stage initial analysis for sizing the system now marching over practical vision from fundamental design to fully functional systems such as predicting the uncertainty, assessing the energy generation, quality check for power, live monitoring and control, forecasting the weather, market size, and load requirement along with storage system deployment for HRERs in the recent times. The impact of digital growth is enormous in all the sectors wherein, which reflects in the growth of practical implementation of HRERs. Whereas, by continuous development over the models to identify the uncertainty, effective prediction, developing smart as well as reliable energy managing system, along with providing better control over the system depicts the remarkable progress of HRERs more efficient than before.

Thus, the future does not depend only in assessing the system size, it moved on further to develop novel system development that is capable of multiple functional and structured holistic visions towards efficient system design leads to having much better HRERs (Li and Wang 2021),

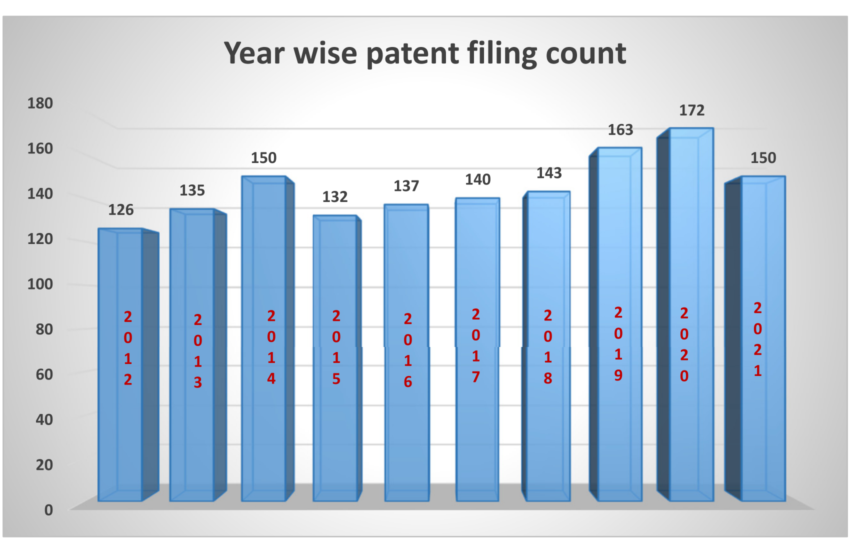

Figure 1: Year-wise growth of RERs (WIPO 2021).

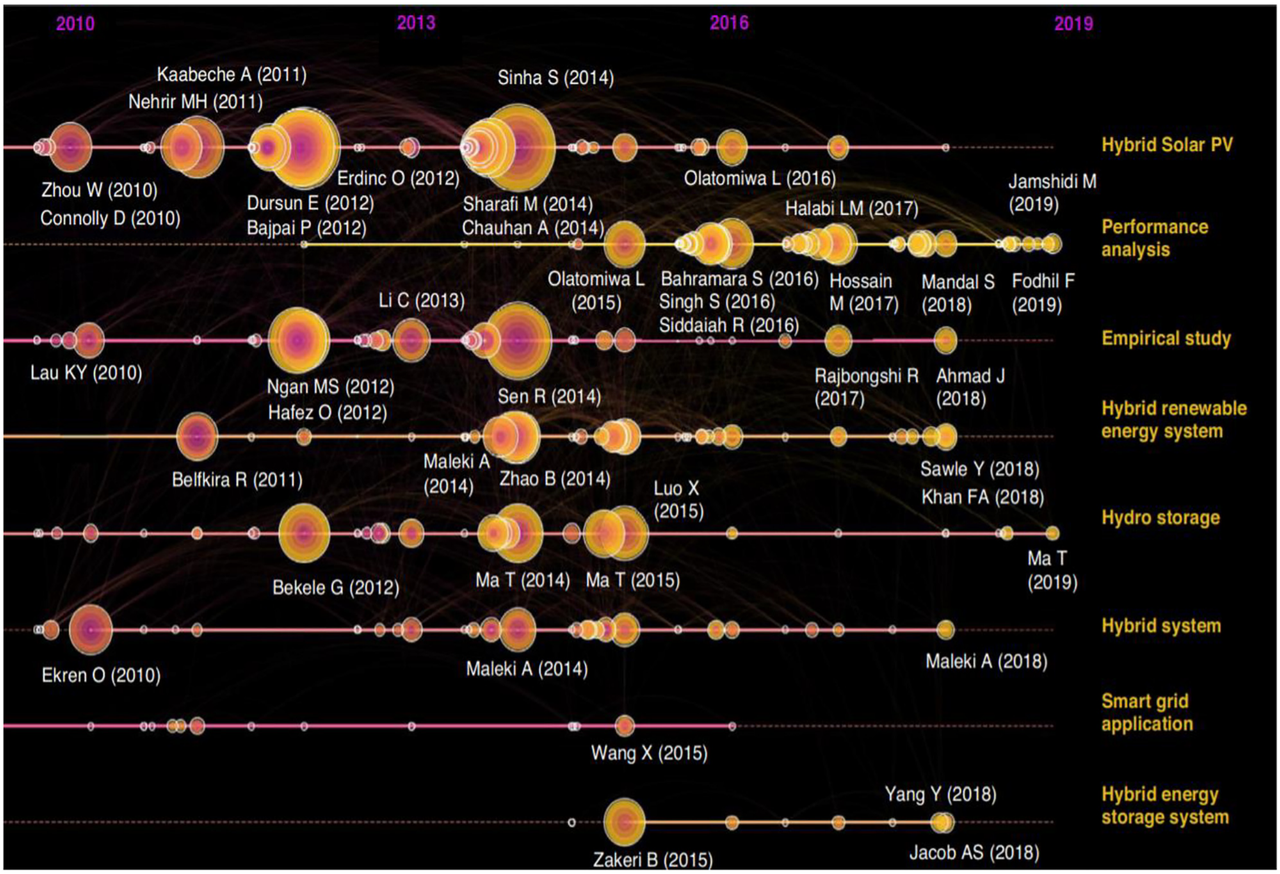

Figure 2: Year-wise researcher's contribution for different energy sources (Li and Wang 2021).

owing to more than 2000 articles being published in the year 2021 converging from the survey is very hard. General search for hybrid renewable energy in google scholar reveals around 22,900 articles with which the following systems are the guess wherein which might have future scope.

GE – hybrid RERs

Figure 3 reveals a system is given to managing a hybrid energy production plant. The device is configured to start receiving current circumstances at a multitude of electric generation resources, which include the first resource type as well as a second resource type, anticipate future for quite a time frame of period relying at least to an extent somewhat on current circumstances, evaluate that this first resource of its first resource type of either the multitude of electric generation resources has an obtainable uprate margin for producing the first quantity of active power, as well as evaluate that somehow the second resource of something like the 2nd resource category seems to have an obtainable uprate edge for producing enhance the generation of power factor throughout the 2nd resource by its first proportion, as well as command the secondary resource to enhance responsive energy production by the 2nd proportion.

Hybrid RERs

The mechanism was developed to generate more power with a combination of different sources, without affecting the atmosphere. The major units used here are the see-saw unit, pneumatic unit, piezo unit, and separately solar panel for power harvesting. Each embodiment supports others for effective utilization and power generation.

Figure 4 reveals, the see-saw which is embedded along with the roller and thereby is connected to the power generation unit. The see-saw possesses two attachments which are comprised of a set of springs along with a set of pneumatic units. Once the roller is started functioning with the initial trigger manually, it compresses the spring and the pneumatic unit both are attached on one side,

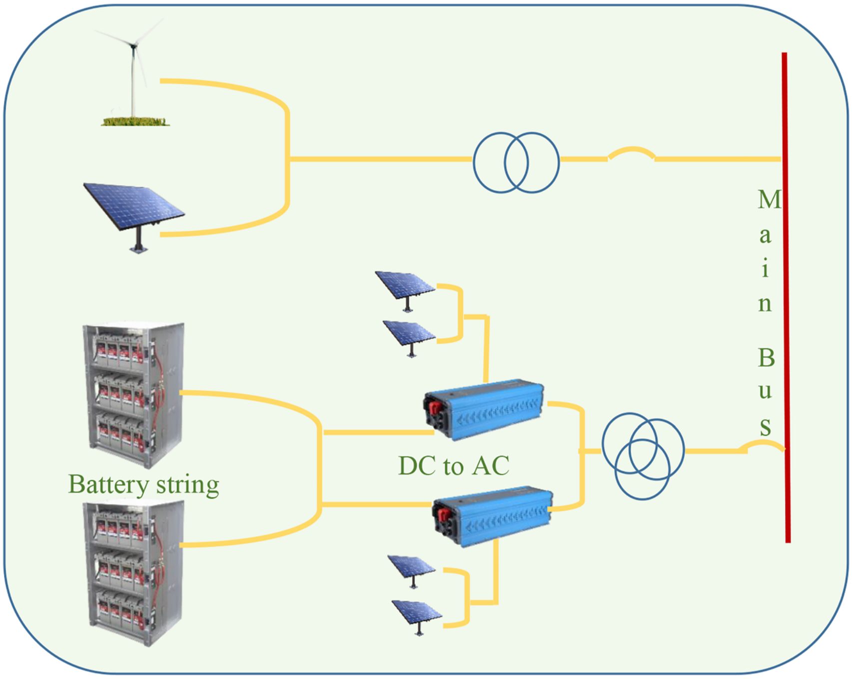

Figure 3: Hybrid RERs system (GE Co 2021).

similarly, while moving to the other end it compresses the other side. The roller is directly connected to the generator for power generation. A piezo unit is attached beneath the roller, while it's in motion those piezo units generate power. In connection with the spring end and the pneumatic unit, the additional plates are attached, it has a few piezo inside that also produces the power all are connected to a rechargeable battery. In addition, the pneumatic unit at the bottom has opened for the inlet and outlet of air. In that exit passage, it has rotating fans one on each side. This fan is connected to the generator for power generation. The additional attachment of the solar panel is connected for further power generation. All the units are combined for better power generation which is not quite feasible by single power sources. The mechanism is effectively combined to make it has an energy-efficient mechanism (Balaji 2019).

Combination of power and heat unit in hybrid renewables

In addition to the uncoupled system as a starting point, two new electro-thermal system architectures have been recommended and also investigated. Electro-thermal systems, when implemented early, can reduce system costs and fossil fuel consumption significantly while retaining the strong reliability of the system. An electro-thermal supply structure is being recommended that makes use of all available waste heat sources to meet the thermal demand. A thermal storage chamber has been incorporated into the system to better match thermal supply with demand. The thermal storage tank has been primarily charged using surplus electricity and waste heat from combined heat and power units (CHP). Only in an emergency was the boiler called upon. With the CHP's excess electricity or heat, 80–90% of the thermal load was covered, resulting in a substantial reduction of diesel energy usage besides the boiler. The results obtained show that excess electricity is the least expensive supply of thermal generation mostly in structure mostly in the greater part of the cases considered. Even with thermal storage as well as combined heat and power (CHP), the amount of extra electricity that must be disposed of in the Base Architecture is still high. Base Architecture (BA) has a 25% surplus, while the total surplus generated in another two architectures is over 50%, with 15% remaining unused. This in turn shows that there is nevertheless a lot of room for enhancement, especially when it comes to power distribution. Adding cooling to HRERs could, for illustration, be a viable option in hotter climates in which cooling is much more of a necessity than heating. Enhanced energy storage methods including such latent heat thermal or thermo-chemical energy containers can also be taken into account.

Hybrid RERs for electric vehicle charging

A new, multi-criteria approach that incorporates an experimental process for verifying the HRERs' arrangement for something like an electric vehicle charging system

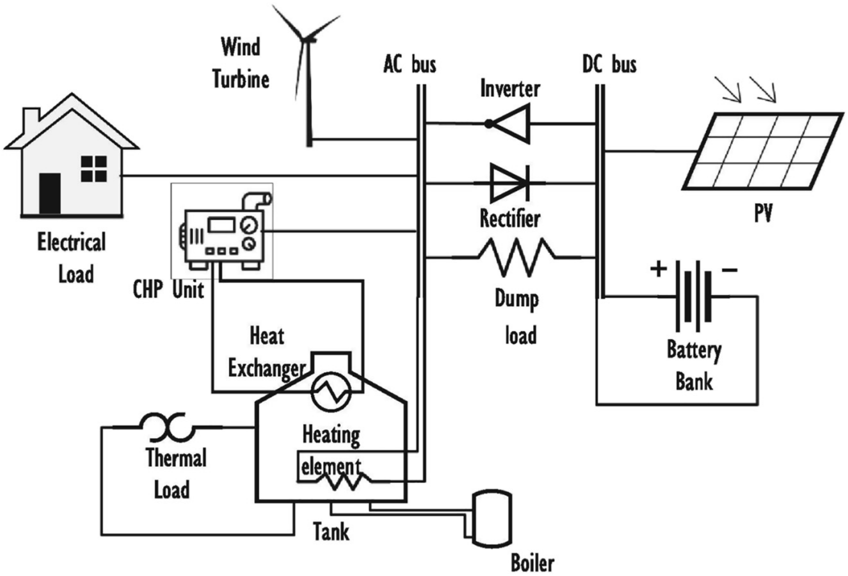

Figure 4: RERs combined with power and heat unit (Kahwash, Maheri, and Mahkamov 2021).

(EVCS). An innovative multi-criteria evaluation is used to prioritize potential HRERs structures, but upon determining the obtainable renewable resources as well as the energy consumption of such EVCS. HOMER tool is used to deduce these same possible HRERs structures. The HRERs through question is evaluated over a yearly period to get an estimate of their behaviour mate test is carried out on the architectures also with top scores to ensure that they are both reliable as well as power efficient. They must be monitored on some kind of daily basis, owing to the nature of their behaviour. The method recommends selecting a mean day among the most unfavourable period in referring to non-dispatchable generation for the investigational authentication phase. Accordingly, the final configuration is selected to guarantee the suitability of HRER for EVCS, aided not hardly numerically and yet also experimentally. It was found that the 270 kW peak demand from these vehicle types in EVCS occurs in the early hours of the morning (between 9:00 and 10:00 a.m.) as well as in the early evening (between 10:00 p.m. and 4:00 a.m). It was found that solar PV, wind resources, were suitable, including current average irradiation of 5 KWh/Sq. meter/day as well as a typical wind speed of 3.6 m per second at 18 m, that the evaluation of generation resources had demonstrated their suitability. Batteries, a diesel generator, and a connection to the grid, were all options considered for backup systems.

A preliminary simulation of the system, which took into account both constraints (the availability of generation resources and the electricity demand) and made use of HOMER, produced a filtered list of 27 possible configurations. These options were then assessed using the multi-criteria methodology presented here, with the same weights assigned to the various constraints. According to the simulations, an off-grid system of renewable generation, as well as battery support, is the most appropriate structure for the case study, followed by an off-grid system of diesel generator support. The on-grid system of renewable energy generation was the 3rd-highest scoring configuration (Figures 5 and 6).

With a factor of 1:250, the resources for both generation and demand have been scaled to match the specifications of the laboratory. A total of 4.5% maximum power losses were observed in all scenarios, and battery state-of-charge (SOC) varied from 35 to 100%. There were only minor differences inappropriate evaluation values in between experimental as well as the modelled result obtained for the preferred configurations. We conclude that our methodology guarantees the viability of HRERs for use in an EVCS, supported by a comprehensive multi-criteria evaluation and empirical testing. Using HRERs to recharge Electric Vehicles at EVCS's in Valencia proves its survivability in terms of technical, economic as well as environmental viability (Bastida-Molina et al. 2021).

Mitsubishi – HRERs

Renewable energy fluctuation is taken into account when driving control is performed upon that rotary energy production device in a hybrid system for power generation. The rotary energy production device's rotation speed is temporarily reduced by something like a load fluctuation, significantly reducing the output frequency if the renewable energy fluctuation amount exceeds a predetermined amount. Solar panels can exhibit this phenomenon when

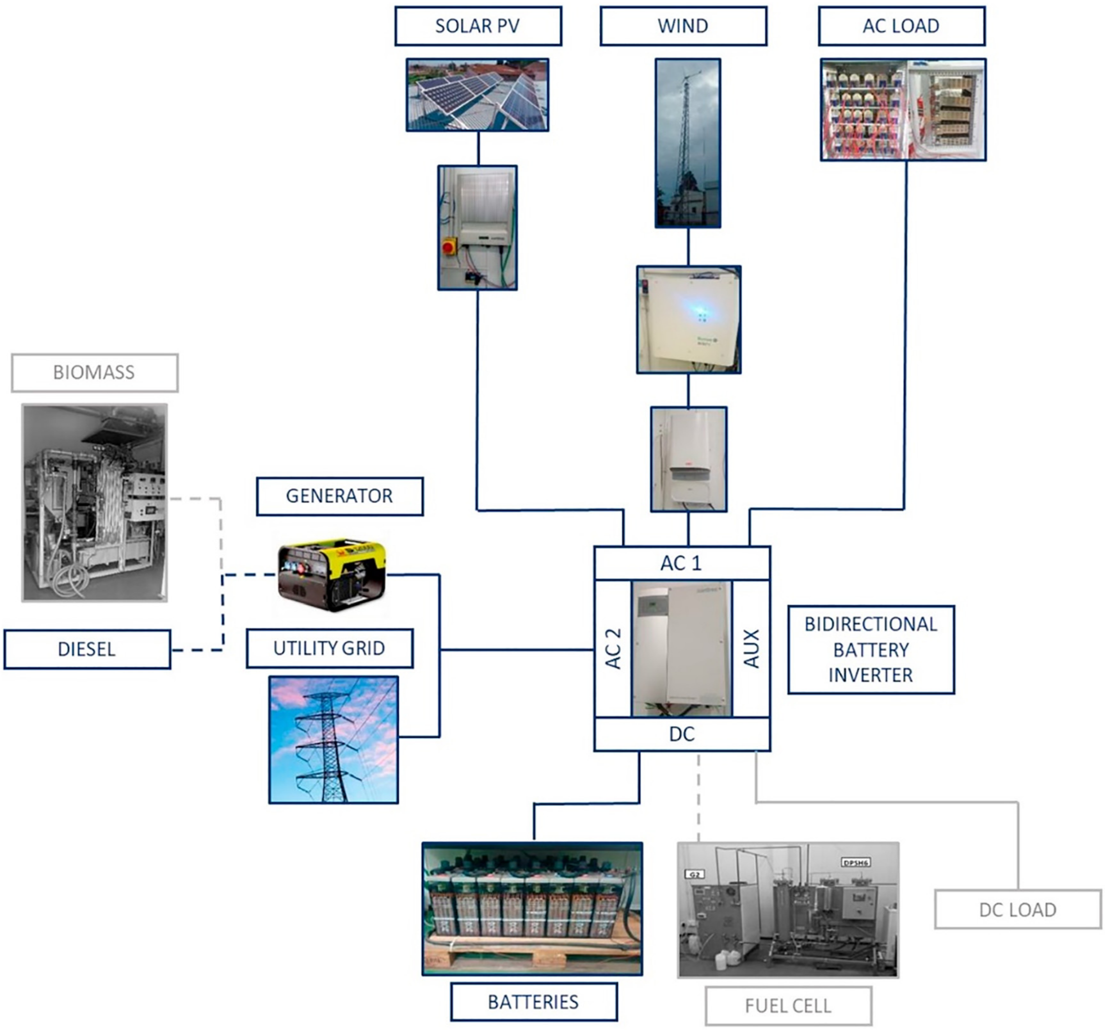

Figure 5: Hybrid RERs for electric vehicle charging (In this work, the only blue colour highlighted portion is utilized.) (Bastida-Molina et al. 2021).

they are used to generate renewable energy power and the availability of solar radiation falling on the panels rapidly decreases as the temperature fluctuations from sunny to overcast.

The rotary energy production device must be disengaged from either the power system because the lower output frequency does have a deleterious impact on the power system, making it unfeasible to stabilize the amount of power generated. A hybrid electricity generation system, which does include power storage equipment capable of connecting to the power system, is known to avoid such a disassociation of the rotary energy production device. When the renewable energy fluctuation amount exceeds a predetermined value, the system's power generation amount is stabilized by trying to connect the electrical energy storage equipment to the power system instead of the rotary generation device. Lithium-ion storage batteries or the like are used to store electricity in advance. Large-scale power generation systems require a large electric storage device, making it extremely expensive to use electric storage devices in large-scale energy production systems. A hybrid power generation system and a control method for the hybrid energy production system are provided to address this by at least one embodiment of the invention. An object of both the existing innovation will provide output stabilization whenever the renewable energy fluctuates (Mitsubishi heavy industries engine and turbocharger and Ltd. 2019).

Hybrid RERs with wind, PV, and tide

Natural resources such as wind, solar, as well as tidal energy can be used to meet the needs of a consistent energy supply in regions where these resources are plentiful. The

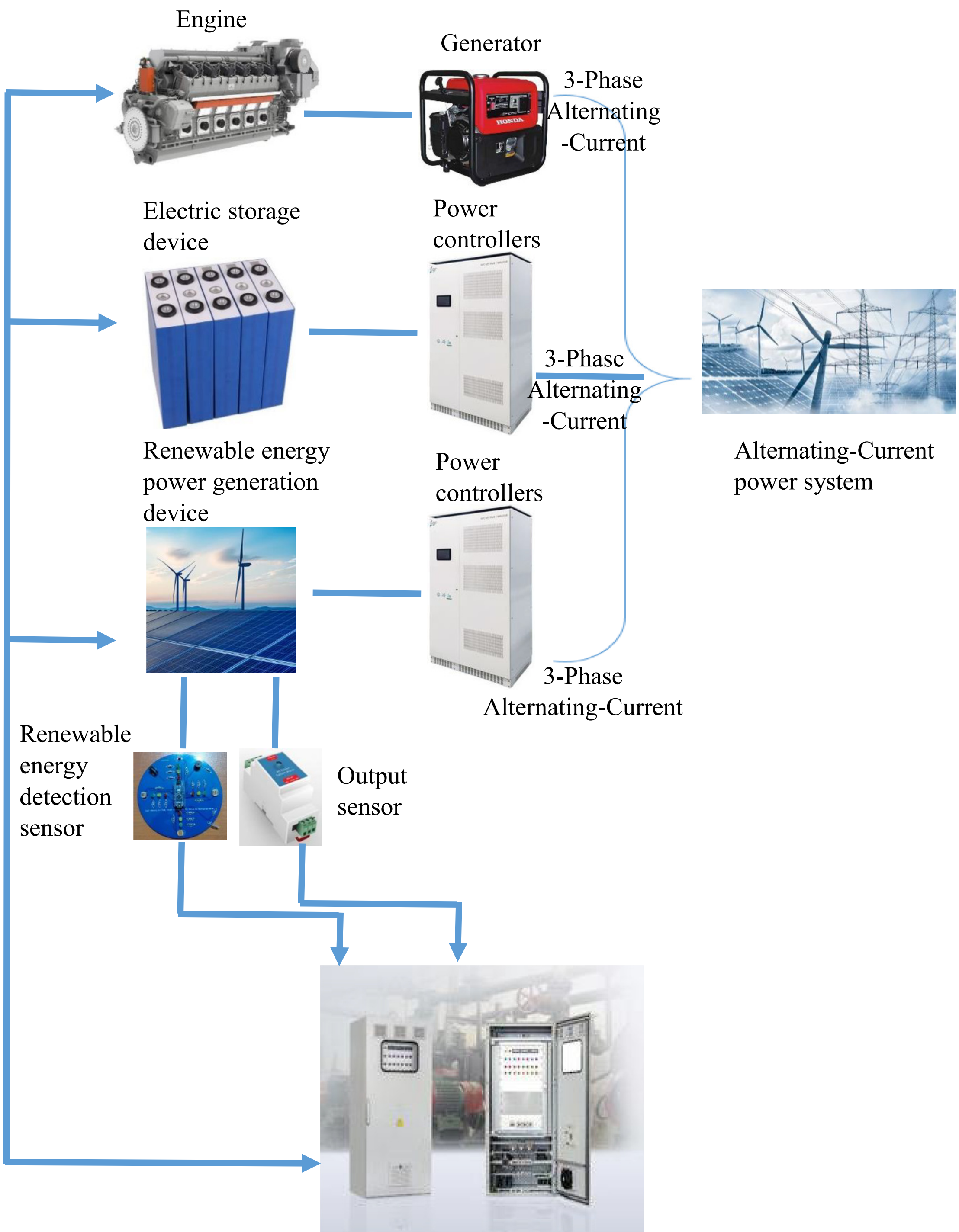

Figure 6: Hybrid RERs system (Mitsubishi Heavy Industries Engine and Turbocharger and Ltd. 2019).

surplus energy is generated by combining the three various renewable conversion methods.

Wind, solar, as well as tide energy generation modules, are all utilized in this invention. At three different points, the three modules have been connected to a hollow member. On the upper side of something like the hollow member, there is a wind turbine, a solar panel, as well as a tidal energy production module that is submerged. When compared to traditional renewable energy systems, this hybrid system has better productivity, higher energy density, enhanced system reliability, as well as a smaller footprint (Dhingra et al. 2021).

The systems described above are the trending system that can obtain remarkable growth shortly owing to their advantages like more power harvesting capabilities, easy to develop system, simplicity, reliability and cost-effectiveness.

The analysed articles have embedded the technological connections with the hybrid RER's. So, those articles with the patent analysis may aid the researchers to bring the better way of bring out the novel outcomes (Arefin 2020; Shezan et al. 2016, 2020, 2021; Shezan and Lai 2017).

Conclusions

The interpretations drawn from the analysis are,

- Hybrid RER is the better way to harvest green energy as well it is the well-known fact due to single resource efficiency is less, further, it has been accelerated by the contemporary techniques including AI, ML, DL, ANN, FL, and so on.
- The specific attention drawn by MPPT – Maximum Power Point Tracking which governs a few things like ensuring the system stability, system fortification, and power balance over the system are the pivotal parameters achieved by the techniques including practical swarm for optimization, artificial neural network along with fuzzy logic.
- The further benefits of usage of modern techniques are that it can go for the maximum level of system efficiency, provide a better forum for system accuracy calculation, and system convergence can be obtained at high speed.
- Hybrid RERs system management demands the objective of the study, optimal selection of techniques, assessment over the other systems accuracy, which technique is most suitable based on the geography and size of the system, based all the facts the system accuracy is taken as a key factor.
- Several researchers work on combining solar PV with wind turbines owing to the effective energy generation which is optimized using some of the trending technologies for maximum power harvesting.
- Further work requires the employment of many approaches within every study to provide the best possible results in accuracy calculation and to manage the system effectively. The comparison of multiple methods ensure the device's optimal effectiveness and accomplishes of the authors.

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