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Hybrid wind-solar power deployment in India: Green Energy Open Access (GEOA) and Renewable Energy Certificates (REC)

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Abstract. The hybrid wind-solar energy concept has a big influence on the spread of wind and solar power projects in India since it combines the benefits of both industries while also providing extra benefits such as resource sharing such as land, infrastructure, and power evacuation systems. Furthermore, while the hybrid policy may reduce certain barriers to the installation of wind and solar energy in India, there are still some issues that must be resolved rapidly in order to ensure a sustainable installation. According to the study's findings, the installation of wind and solar power plants is significantly influenced by energy policy. The wind-solar hybrid energy strategy will also be crucial in the near future for growing the usage of renewable energy sources. Aside from that, the establishment of Green Energy Open Access (GEOA) and the restart of the trading of Renewable Energy Certificates (REC) would promote the quick deployment of standalone and hybrid renewable power projects throughout the nation, enabling it to reach 500 GW of installed non-fossil energy capacity by 2030.

Keywords: green energy open access; policy; renewable energy certificates; solar energy; wind energy

1. Introduction

Solar and wind power are now the most popular and dependable renewable energy (RE) sources. Government laws and regulations are in place, and they have a significant influence on the development of wind and solar energy. The establishment of a hybrid wind-solar policy has transformed the dynamics of individual wind and solar power projects by authorizing the building of hybrid power plants that use both wind and solar energy concurrently. The techno-economic framework and current projections of the marginal contributions of the wind and solar sectors will have a significant impact on the expansion of hybrid power plants. This research looks at how specific wind and solar energy legislation, as well as India's recently disclosed hybrid energy

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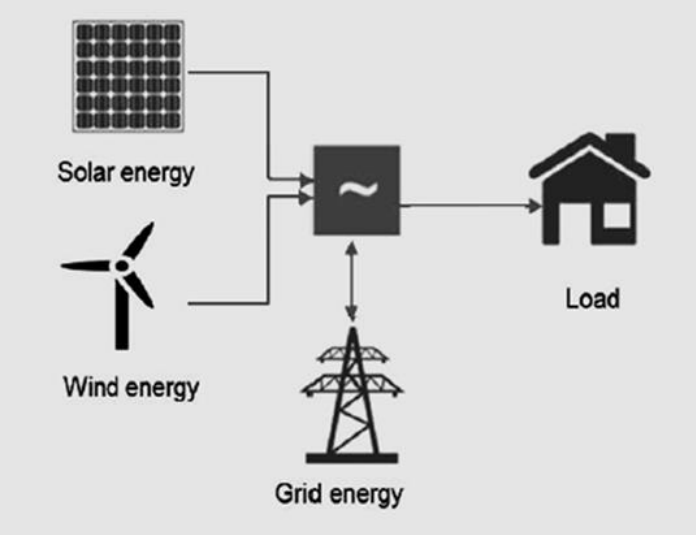

Fig. 1 Representation illustration of hybrid wind-solar energy system

strategy, impact the techno-economic structure of current and future power plants. There are also some challenges that project developers must overcome while creating renewable energy-based power plants. The implementation of wind and solar power generating may be sped up and made easier by addressing these issues.

The availability of intermittent energy sources like wind and solar energy is based on the surrounding environment. However, there are a number of variables that affect how much energy may be captured, including resource variability over time (seasonal and yearly changes), access to technology, funding, and policy support from the government. The government or any one project developer cannot directly control the availability of technology or funding. However, the supporting policy environment encourages improved financial inflow and the freedom to select the best power production technology (Das *et al.* 2019, 2020b). Thus, the framework of governmental policy has an impact on how wind and solar power projects are implemented.

Countries develop their unique renewable energy policy frameworks depending on a range of factors, including the power potential of various energy sources, financial conditions, technological accessibility, and the state of existing power generating systems. India's Ministry of New and Renewable Energy (MNRE) publishes the country's national renewable energy policy. Perhaps the only country with a ministry solely focused on alternative energy sources is India. For both RE- and non-RE-based electricity generations, the Ministry of Power (MOP) and MNRE publish tariff-related rules. According to the power potential, technical status, and financial cash flow scenario that are unique to each state, the state governments also release their own RE programs. Federal and state renewable energy programs include the Feed-In Tariff (FIT) and Renewable Purchase Obligation (RPO). The FIT was originally formed at the state level in the early 2000s, then at the federal level in 2009. The tariff rate at which the project developer will be compensated for electricity is decided by the FIT value of the power purchase agreement. RPO focuses on the minimal proportion of total power generation that must be produced from renewable energy sources in various jurisdictions and across the country. The state and federal governments each established their own RPO objectives for the next year.

2. Need and status of hybrid power

The utilization of renewable energy-based power generating has considerably expanded as a result of the perceived shortcomings of conventional power production methods (depletion of fossil fuels and environmental pollution etc.). In 2019–20, India generated 114 TWh of electricity from solar and wind energy (64.64 TWh and 50.10 TWh, or 4.7% and 3.6% of total electricity output, respectively) (IRENA 2019a, b). Because of their stochastic character, wind and solar energy sources fluctuate throughout time (Jani *et al.* 2020). Both of these energy sources are combined and developed as hybrid wind-solar energy systems (HWSES) across the world to correct such variations and harness them. By employing the same infrastructure, HWSES is an effective way to lower power generation variations, smooth out the total output power, and lower system costs (Das *et al*. 2020a). The salient features of HWSES across the globe are tabulated in Table 1. Therefore, the performance of the hybrid system has to be assessed exhaustively to ensure the suitability and reliability of the project. The wind-solar PV systems exhibit greater performance in terms of energy and exergy than the wind-solar thermal systems, according to the comparative performance evaluation.

3. Hybrid wind-solar energy policy

In May 2018, the Ministry of New and Renewable Energy (MNRE) unveiled the National Wind-Solar Hybrid Policy to encourage the hybridization of wind and solar energy generation in India. Wind and solar energy resources complement each other nicely in India. Combining wind and solar power plants improves grid stability and allows for more efficient use of available resources such as infrastructure, land, and power evacuation systems. This policy applies to all new and current initiatives. The strategy's principal purpose is to provide a framework for the construction of large, grid-connected renewable energy projects. Wind Turbine Generator (WTG) and Solar PV (SPV) systems must be built to a single point of grid connection, according to the regulation. Each wind and solar energy installation's power and efficiency are optimized *(Modi et al.* 2020).

The kind of wind turbine influences the integration of the WTG and SPV systems. The integration will take place on the High Tension (HT) side of the AC output bus for fixed-speed wind turbines. The device will be connected to the AC-DC-AC converter's intermediate DC bus for variable-speed wind turbines. According to the regulations, which indicate that the technology ratio should be less than 75:25, a system must have at least a 25% stake to be classified as a hybrid project. The CERC will create the standards and guidelines, which will include, among other things, the REC system, power transmission permits, metering, forecasting, and scheduling techniques for the hybrid project. In addition to these regulations, the government should develop technical recommendations for WTG and SPV systems. The hybrid plants will be qualified for all incentives provided to solar and wind power plants.

The hybrid wind-solar energy concept is critical to the spread of wind and solar power projects in India since it combines the benefits of both industries while also providing other benefits like as resource sharing, infrastructure, power evacuation systems, and land. Other challenges to the use of wind and solar energy remain in India as well, and while the hybrid method may assist to lessen some of these barriers, they must still be addressed rapidly to ensure the long-term viability of these energy sources.

Table 1 Worldwide hybrid wind-solar power plants (MW scale capacity power plant only)

Country	Type	Company	Capacity (MW)				Status
			Total	Wind	Solar	Battery	
India	Wind-solar	SB Energy, Adani Green Energy, and ReNew Power	2400	No info	No info	No info	Auction completed
India	Wind-solar	Premier Mills	2.2	2	0.2	0	Operational since 2007
India	Wind-solar	Hero Future Energies / Siemens Gamesa	78.8	50	28.8	0	Operational
India	Wind-solar-storage	Solar Energy Corporation	No info	No info	No info	No info	Approved
India	Wind-solar-storage	L&FS Energy Development Company Limited – GE	51	16	25	10	Contracted
China	Wind-solar-storage	Luneng Haixi	No Info	400	250	No Info (100 MWh)	Approved
United States	Wind-solar-storage	GE	2.5	2	0.5	0	Operational
United States	Wind-solar-storage	NextEra Energy Resource & Portland general Electric Co.	380	300	50	30 (120 MWh)	Contracted
United Kingdom	Wind-solar	Vattenfall	8.98	4	4.95	0	Operational since 2017
Netherlands	Wind-solar-storage	Vattenfall	65	21	32	12	Under construction (commissioned in 2020)
Spain	Wind-solar	Acciona energia	3.1232	2	1.1232	0	Operational since 2019
Spain	Wind-solar-storage	Siemens Gamesa	1.674	1	0.245	0.429 (0.5 MWh)	Operational since 2016
Portugal	Wind-solar-storage	Younicos	12	5	1	6 (3.2 MWh)	Operational since 2016
Australia	Wind-solar	Apa Group	147.5	130	17.5	0	Under development
Greece	Wind-solar	Vestas / Terna Energy	25	24	1	0	Operational since 2012
Greece	Wind-solar-storage	Aiolian land	3.3	1	0.86	1.44 (7.2 MWh)	Under licensing (commissioned in 2018)
Greece	Wind-solar-storage	Research consortium	1.24	1	0.16	0.8 (2.4 MWh)	Under licensing (commissioned in 2017)
Greece	Wind-solar-storage	Aiolian land	1.821	1	0.101	0.72 (3.6 MWh)	Under development
Brazil	Wind-solar	Iberdrola	27	22	5	0	Operational since 2014
Brazil	Wind-solar	Enel Green Power	91	80	11	0	Operational since2015
Chile	Wind-solar-storage	Enel	0.455	0	0.205	0.25 (0.8 MWh)	Operational

4. Green Energy Open Access (GEOA)

Another significant change made by the Government of India (GoI) to support renewable energy is called Green Energy Open Access (GEOA). It makes it possible for industrial and commercial users to go green. Customers can request green power from discoms under this provision. By doing this, every customer becomes a stakeholder who can help India meet its goal of using 500 GW of non-fossil fuel by 2030.

Green Open Access Rules, 2022 were announced on June 6, 2022, with the intention of accelerating our ambitious renewable energy projects and guaranteeing that everyone has access to inexpensive, dependable, sustainable, and green energy(PIB Delhi, 2022). The purpose of these regulations is to encourage the production, acquisition, and use of green energy, including energy from waste-to-energy facilities. A streamlined process for open access to green electricity is made possible by the notified Rules. It will make it possible for Green OA, Uniform Banking, and the voluntary purchase of RE electricity by commercial and industrial users, the Applicability of OA fees, and other initiatives to be approved more quickly. Commercial and industrial users are permitted to voluntarily purchase green power. Under Green Open Access, captive users are permitted to use power with no minimum requirement. Discoms customers have the option to request and receive green power.

The key elements of the Rules are as follows:

- The Green Open Access is available to all customers, and the Open Access Transaction Limit for Green Energy has been decreased from 1 MW to 100 kW to allow for the purchase of renewable energy by smaller users as well.
- Provide clarity about the open access fees that will be assessed to consumers of green energy, including transmission fees, wheeling fees, cross-subsidy surcharges, and standby fees. The removal of extra surcharges and the restriction on cross-subsidy surcharge increase not only encourage customers to buy environmentally friendly products but also solve the problems that have hampered the expansion of open access in India.
- Openness in the open-access application's approval procedure. If approval is not given within 15 days, it will be assumed to have been authorized, subject to technical conditions being met. Through a national gateway, that is.
- The Appropriate Commission will decide on the green energy tariff separately. It will include the average pooled power purchase cost of renewable energy, any applicable cross-subsidy fees, and service fees that cover the distribution licensee's reasonable costs associated with providing green energy to customers.
- In order to increase the predictability of revenue flows for renewable energy providers, the Rules will serve to expedite the whole approval process for providing Open Access, including quick approval. Additionally, it will make the application process uniform.
- It is required that extra green energy is deposited with the distribution licensee.
- All obliged entities in the territory of a distribution licensee should be subject to a common renewable purchasing obligation. For the completion of its RPO, it has additionally added the green hydrogen/green ammonia.
- If customers use green power, they will receive green certifications.
- If green energy is used to produce green hydrogen and green ammonia, cross subsidy surcharge and extra surcharge are not applicable.

5. Renewable Energy Certificates (REC) trading

The "Terms and Conditions for Renewable Energy Certificates for Renewable Energy Generation Regulations, 2022" have been published by the Central Electricity Regulatory Commission (CERC) (Mercom India, 2022a). Renewable energy generating facilities, captive producing facilities using RE sources, distribution licensees, and open access clients are now entitled to issue renewable energy certificates (REC), according to the amended regulations. The organization in charge of putting these rules into effect has been named the national load dispatch Centre (NLDC). The CERC published a draught of the REC rules in February 2022 and requested feedback from interested parties.

5.1 Eligible entities

A RE producing station cannot issue certificates unless it satisfies the following requirements:

- For an obliged entity to comply with an RPO, the energy generated by such a RE producing plant must either not be sold directly, through an electrical trader, or in the power exchange, or its tariff has not yet been created or authorized.
- The RE project hasn't benefited from any exemptions from paying the concessional transmission or wheeling costs.

Certificates from captive generating stations may be issued if permitted for self-consumption. The amount of surplus renewable energy that an obligated organization has acquired above and beyond the RPO requirements, such as an open access consumer or a distribution licensee, qualifies them to issue certificates.

5.2 Granting of certification accreditation

The qualified enterprises linked to the intrastate transmission system will get accreditation from the state agency. Accreditation provided to organizations prior to the implementation of these requirements shall be considered valid at that time. If the qualifying entities were accredited before these laws went into effect, they will be allowed to link to the interstate transmission system (ISTS).

5.3 RECs issuance

A qualified entity that has been registered or is presumed to have registered may submit an application to the central agency for the issuing of certificates. Within six months after the entity's corresponding generation, a captive generating station that uses energy sources or a station that produces renewable energy may submit an application to the central agency for the issuance of RECs. Within three months of the fiscal year's end, the distribution licensee or an open access user must submit the application. The central agency must either produce certifications or reject the application within fifteen days of receiving it.

5.4 Certificate exchanges and redemptions

The certificates must be traded via electricity merchants or power exchanges. The quantity of certificates proposed for sale through electricity traders must be disclosed to the central agency by

the qualified companies. The Trading License Regulations, 2020, which treat each certificate as being equivalent to one MWh of electricity, shall govern the trading margin for the exchange of certificates through electrical traders. The certificates must be regarded redeemed when swapped through electrical exchanges or dealers and utilized for RPO compliance by the obliged organizations. The central organization will take the certificates out of the registry when they are redeemed.

5.5 Certificate denominations

One MWh of electricity produced from RE sources and contributed to the grid, or assumed to be added, should be shown on each certificate issued in accordance with these regulations.

5.6 Certificate multipliers

For three years, the central agency set the certificate multiplier for onshore wind and solar at 1, hydro at 1, municipal solid waste at 2, non-fossil fuel-based cogeneration at 2, and biomass and biofuel at 2.5. After the effective date of these regulations, the relevant certificate multiplier will be applied to captive generating stations that use renewable energy sources and renewable energy producing stations. After being allocated to a renewable energy facility, the certificate multiplier is valid for 15 years.

5.7 Certificate pricings

The cost of certificates shall be established by the power exchanges or jointly agreed upon by eligible companies and the energy traders, provided that both parties submit monthly reports to the central agency detailing all transactions.

5.8 Certificate validities

The issued certificates are only valid until they are utilised. If an eligible organisation received accreditation or registration based on fraudulent information and had it later revoked, all previously awarded but unredeemed certificates must be extinguished from the date of issuance. The Commission may pick the fees that qualified entities must pay for accreditation, registration, certificate issuing, and other related things based on the central agency's recommendation.

6. Execution of RECs trading

On November 24, 2021, the Indian Energy Exchange (IEX) once again began trading RECs (Mercom India 2022b). The Appellate Tribunal for Electricity issued a stay order in response to petitions submitted by many renewable energy organizations against adjustment of the floor and forbearance rates, which prevented the trading of RECs. In the first quarter of 2022, IEX exchanged 22,49,517 renewable energy certificates (RECs). They consist of 6,12,544 solar RECs and 16,36,973 non-solar RECs.

In January, 1,93,121 solar RECs and 9,33,359 non-solar RECs were traded. The exchange determined that solar RECs cost $2,300 (about $30) each and non-solar RECs cost $1,000 (about

Table 2 RECs traded at IEX during Quarter 1 of 2022

Month	Type	Buy bids	Sell bids	Cleared volume	Cleared price		No. of participants
					₹/REC	~$/REC	
Jan.	Solar	5,19,327	6,03,289	1,93,121	2300	30	414
	Non-solar	9,33,359	16,71,523	9,33,359	1,000	13	496
Feb.	Solar	5,48,271	4,80,891	1,67,447	2,300	30	410
	Non-solar	4,44,295	11,92,954	4,44,259	1,000	13	520
March	Solar	9,87,573	4,22,776	2,51,976	2,250	29	430
	Non-solar	2,59,319	11,90,196	2,59,319	1,000	13	546

$13) each. 414 entities traded solar RECs in January, whereas 496 traded non-solar RECs. For solar RECs, there were 5,19,327 purchase offers and 6,03,289 sale bids, compared to 9,33,359 buy bids and 16,71,523 sell bids for non-solar RECs.

In February, IEX exchanged 1,67,447 solar RECs and 4,44,295 non-solar RECs. The exchange determined that solar RECs cost $2,300 (about $30) each, whereas non-solar RECs cost $1,000 (about $13). While 410 businesses had traded solar RECs in February, 520 entities had traded non-solar RECs. For solar RECs, there were 4,80,891 sale offers and 5,48,271 buy bids. There were 4,44,295 buy bids and 11,92,954 sale bids for non-solar RECs.

In March, 2,51,976 solar RECs and 2,59,319 non-solar RECs were traded. It found that solar RECs cost $2,250 (about $29) per certificate while non-solar RECs cost $1,000 (about $13). 430 solar RECs and 546 non-solar RECs were exchanged in March. For solar RECs, there were 9,87,573 purchase offers and 4,22,776 sale bids. There were 11,90,196 sale bids and 2,59,319 buy offers for non-solar RECs.

7. Recent advances in wind-solar hybridization

The transition of power sectors towards clear and renewable energy is catching attention across the globe since Glasgow climate summit. Combining diverse energy sources through hybridization can mitigate the barriers to integrating renewable energy projects with the national grid. Performance assessment with respect to resource availability is an important part while planning an energy system.

An study was recently completed on a conceived hybrid wind-solar energy project of 5.6 MW rated power (a SUZLON-S128 wind turbine and 2.8 MW solar photovoltaic system) at a coastal area in Gujarat, India (20.75° N, 71.25°'E) (Jani et al., 2021). The capacity factor and exergy efficiency ranges were discovered to be 9.58-35.51% and 4.74-10.40%, respectively, while extended exergy efficiency ranged from 3.39-5.79%. The hybridization improves system performance by lowering uncertainty and reducing volatility throughout the year.

Further, simultaneity assessment of energy resources is essential and crucial for the planning of any hybrid power project. In the wake of environmental requirement and government policy implementation, deployment of hybrid renewable energy projects are attaining decent momentum. In a recent study, the simultaneous availability of energy resources was assessed using various correlation techniques (Pearson, Spearman, and Kendall), and the study region was divided into a

number of clusters using machine learning classification technique to determine the priority level of various clusters for the establishment of hybrid power projects (Jani et al., 2022, 2021). The present study is completely innovative in that it uses high-resolution ERA5 reanalysis data with a 41-year (1979–2019) period (1 hour temporal and 0.1°–0.1° spatial) to examine the simultaneity of wind-solar energy resources for India using several statistical methods and a machine learning methodology. Among the three correlation techniques, Kendall correlation has been identified and more suitable one with reference to its superior principal component variance and cluster inertia.

8. Conclusions

An overview of wind-solar hybrid energy strategy is given in the current study, along with a brief description of solar and wind energy. The study's conclusions indicate that the deployment of wind and solar producing plants is significantly influenced by energy laws. Future growth in the utilization of renewable energy sources will also be significantly influenced by the wind-solar hybrid energy plan. Furthermore, the declaration of Green Energy Open Access (GEOA) and resumption of Renewable Energy Certificates (REC) trading would induce a swift deployment of standalone and hybrid renewable power projects across the country, enabling the achievement of 500 GW installed capacity from non-fossil energy by 2030.

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