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Obstacles in integrating variable renewable energy in Pakistan's power gird

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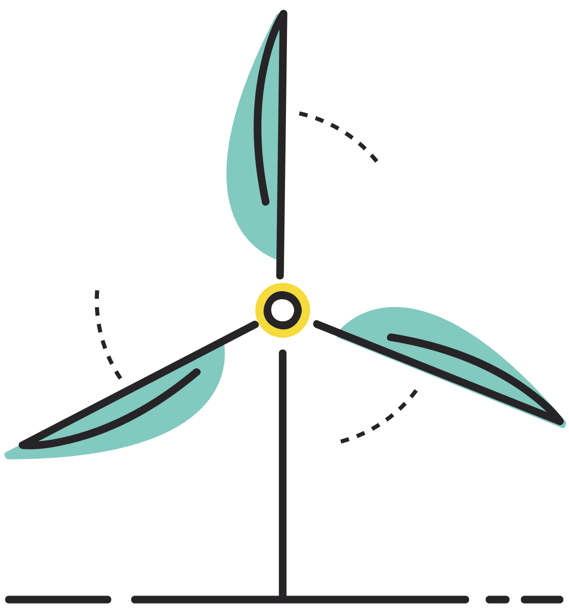


Contents

List of Figures and Tables

List of Figures:

List of Tables:

Introduction

In Pakistan solar and wind energy emerges as abundant, freely available, and widely distributed renewable energy resources. However, these ample resources have not been exploited to their true potential. Despite the huge potential of renewable energy resources, only a fraction of it has been harnessed to date. As per an estimate of U.S. National Renewable Energy Laboratory (NREL), the theoretical potential of wind in Pakistan stands at 340 GW, whereas the economic potential stands at around 43 GW[1,2] . Similarly, Pakistan receives on average eight to ten hours of sunshine in most parts of the country and the solar potential is estimated to be as high as 2900 GW. Despite this huge potential, solar and wind energy presently account for only 1% (530 MW) and 5% (1845MW) of the national grid. [3]

While solar and wind energy, also known as variable renewable energy (VRE), are feasible sources of power generation in Pakistan because of their availability—they also present economic viability. In the past decade the levelized cost of energy generated from VRE has averaged at 3.5 cents/kWh for Pakistan. In contrast, the per unit of electricity to different categories of consumers ranges between 13 cents/kWh to over 18 cents/kWh This stark difference in cost positions VRE as a compelling option for displacing expensive energy within the system and also for any future expansion given any increase in demand. VRE is also an environmentally safe source of energy procurement. They reduce the amount of carbon emissions significantly as compared to the amount produced in procuring and transporting conventional fossil fuels. [4] Pakistan being one of the most vulnerable countries to climate change needs a rapid energy transition. Overall, despite the promising economic and environmental potential—the associated intermittency challenges and need for additional reserve requirements is cited as a key concern for the slow uptake of these resources.

In dynamic power systems with growing electricity demand such as in the case of Pakistan, wind power and solar photovoltaic (PV) are ideal to meet incremental demand while facilitating system transformation. In this energy monitor, we endeavor to delve deeper into this 'skepticism surrounding VRE accommodation in the power system' owing to its intermittent nature. We first look at the state of existing grid and transmission infrastructure and its capacity to uptake higher shares of VRE. This will further serve as a starting point in understanding whether the nature of the generation resource is linked with impediments of Pakistan's electricity grid or the grid in itself requires an overhaul which will be beneficial for the overall system stability. This is particularly important, because VRE shares have significantly increased around the world. In countries such as Uruguay, Denmark, and Lithuania, the share of VRE in the final electricity consumption has reached over 30%. [5]Understandably, the power system of any country needs to be catering to the energy needs of its citizens and economic machinery without disruptions. Thus, reliability and stability of power supply is a necessity. So, how countries accelerating VRE are addressing these system challenges while increasing their share and how those solutions can be applicable in the context of Pakistan, are vital questions. In this energy monitor, we will be addressing these aspects so that the needed renewable transition could also be achieved timely.

[6]11 GW out of this actual potential could be harnessed alone from the Gharo-Jhimpir wind corridor in the Sindh province.

State of Existing Power Grid Infrastructure

Pakistan has an aged power grid and transmission infrastructure. The increasing frequency of country wide power blackouts in recent years is a testament of its deteriorating state. Built prior to Pakistan's independence in 1947 and major updates in the 1960s, [7]the grid faces challenges in reliable evacuation of power. The design of the centralized grid that connects power generation units far in the north and south with major load centers in the middle of the country through long transmission lines is also a contributing factor to its demise. These long transmission lines are a major factor contributing to energy losses that occur due to resistance in the transmission lines. Transmission lines travel many miles in different territories with variable and some very extreme weather conditions, giving rise to certain engineering challenges with higher voltages. At the point when a source is associated through a "long" transmission line, the line's own characteristic impedance rules over load impedance in deciding circuit conduct therefore an electrically "long" line acts as the principal component in the circuit, its own characteristics overshadowing the load's.[8]

National Transmission and Dispatch Company (NTDC), which is responsible for power transmission in the country as well as acting as the System Operator (SO), has been maintaining following resources as of June 30th 2022:

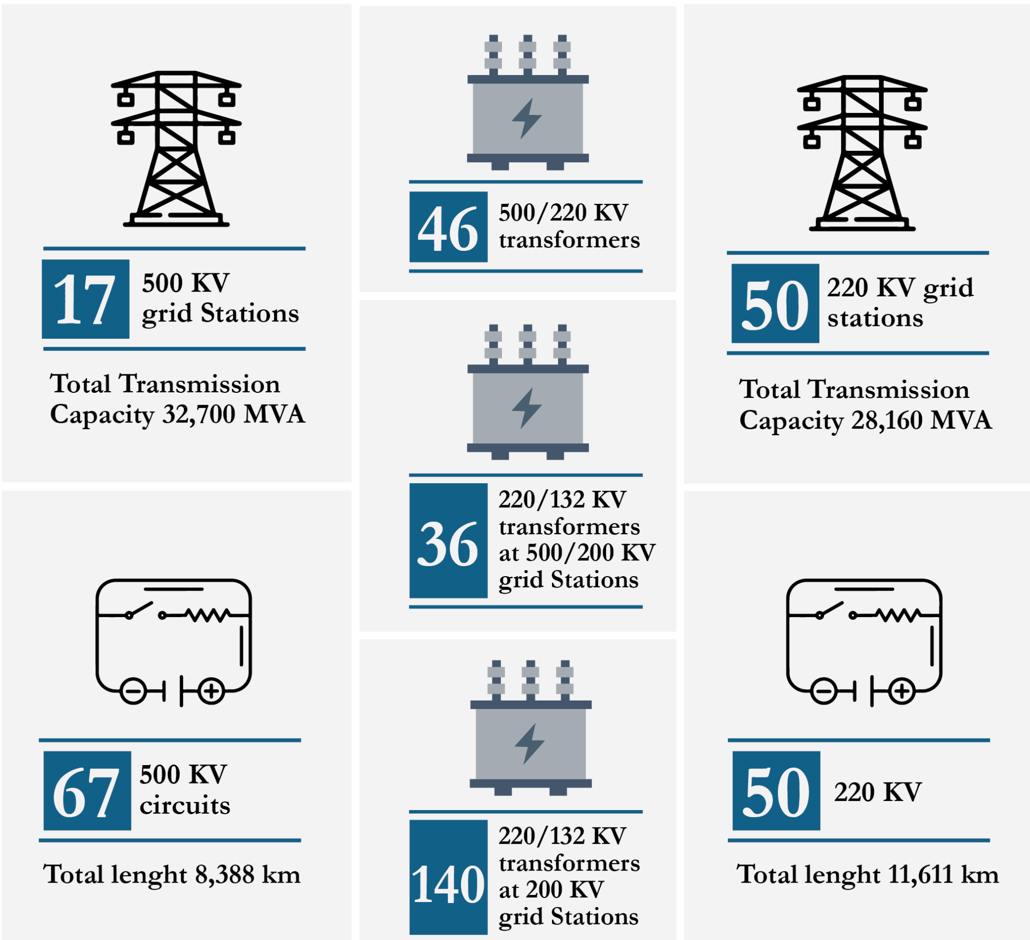


Figure 1 NTDC System as of June 30th, 2022
Source: State of Industry Report 2022, NEPRA

One of the reported causes of NTDC system's degradation is its underutilization. For example, about 15% of 500 kV transformers and 14% of 220 kV transformers have been loaded less than 30% of their rated capacity in the financial year (FY) 2021-2022, and 64% of the 500 kV transmission lines and 44% of the 200 kV transmission lines have been underutilized during the same period. The result has been the reduced efficiency of the system. [9]

Another reason for system degradation is the overloading position of 500 kV and 220 kV transmission networks. On average, 36% of the total power transformers have been overloaded in the financial year 2021-2022, with the highest value reaching 65% in the month of July 2021.[10] The result is increased copper losses, more heating effect and insulation failure in equipment used to transmit electric power.

Apart from system's underutilization and overloading, the power grid often experiences breakdowns that either result in partial or complete blackouts across the country, leaving millions without power for an extended period of time. In the past 5 years, following causes have been stated in the State of Industry Report 2022 as the reasons for system wide disruptions:

Table 1: Causes of Disruptions in Power Transmission 2018 - 2023

Year	No. of Incidents	Causes of Disruption			
2018	4	Grid Fault	Partial System Collapse		
2019	7	System Splitting	Shikarpur-HUBCO-KE grid collapse	Nuclear power plant tripping	Tripping of transmission lines at various grid stations connected with thermal plants
2020	4	Frequency Tripping at a power plant	Fire incident at a switchyard at Jamshoro plant resulting in loss of generation from wind power plants		
2021	6	Frequency Tripping at a power plant	Tripping of KAPCO power plant and associated transmission lines	Tripping of transmission lines at various grid stations in the South	Tripping of an Extra High Voltage Line that connects KE and NTDC system

2022	2	Tripping of Mangla and associated 220kV transmission lines	Use of sub-standard, dilapidated conductors at one of the transmission towers at Karachi's nuclear power plant units K-2 and K-3		
2023	1	Voltage variation in the southern part of grid	Voltage variation in the southern part of grid		

In the past 3 years, there have been three major power breakdowns which lasted for at least 8 hours and more than 24 hours in the country. The breakdown in 2021 was caused by an engineering fault at a coal power plant in the South where frequency suddenly dropped from 50 Hz to 0 Hz which led to closure of other power plants as well and caused load interruption of about 10,311 MW for about 20 hours in the country.[11] In 2022, the major parts of the country were out of power for more than 24 hours because of a transmission line fault in the south. [15] In 2023, the situation recurred, when voltage variation in the south cascaded northwards to cause power breakdown in the country for more than 12 hours. Additionally, extreme weather conditions also render the grid dysfunctional in the northern parts of the country. Tourist areas such as Murree in the snow season face extended hours of power outage with no reliable recourse available.

These recurring incidents of grid failure indicate that the power transmission infrastructure has been highly neglected and compromised. Although It requires extensive upgradation work to better respond to frequency and voltage variations, no serious attention is being placed on this aspect. A study conducted by USAID in 2015 also recommended grid system reinforcement for enhanced system sustainability and reliability. [12] The study also highlighted that irrespective of the generation resource being VRE or non-VRE, the need stands as the grid in the current state poses constraints to any additional power evacuation.

DISCOs

Figure 2 : Geographical territories of DISCOs

Distribution Companies (DISCOs), which are responsible for onward sale of electricity to the end consumers, are another major contributor of the power distribution infrastructure degradation. There are total 10 DISCOs which are serving electricity to over 33 million end consumers in their respective territories.

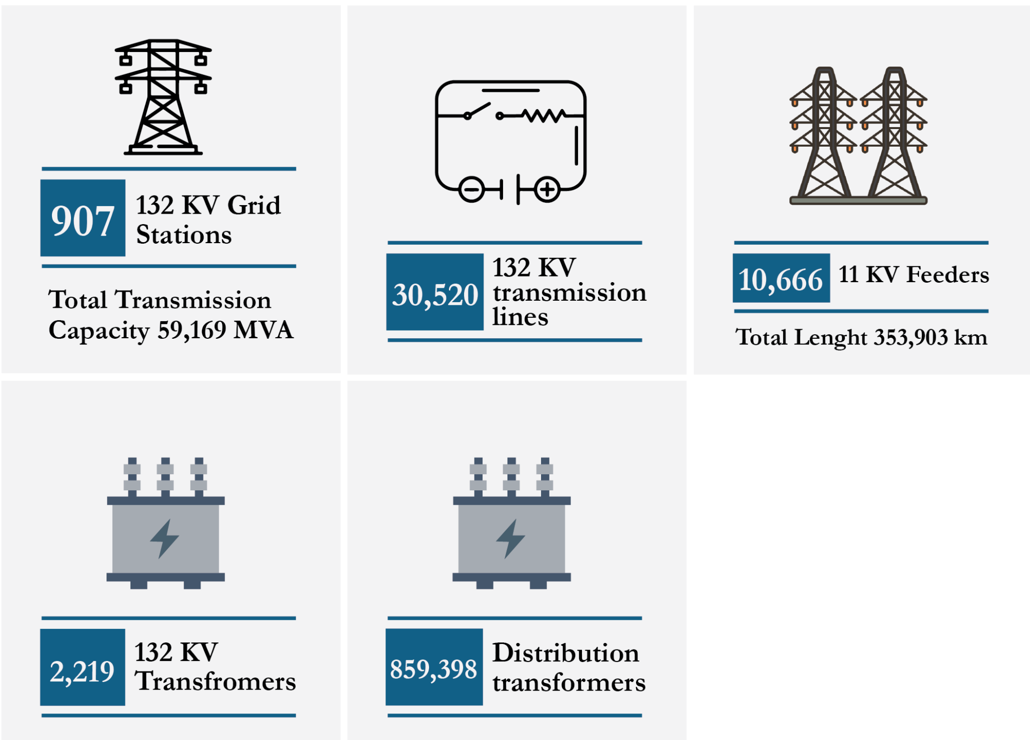


Figure 3: DISCOs Infrastructure as of June 30th, 2022
Source: State of Industry Report 2022, NEPRA

DISCOs infrastructure has also been in a state of decline. Every year they incur technical and distribution (T&D) losses that exceed the allowed/targeted percentage of losses set by NEPRA. Some DISCOs perform worse than the others, but overall impact on the end consumers in terms of unit electricity price is uniform, which disincentivizes the individual DISCOs to improve their performance. In the FY 2021-2022, the average T&D losses of all DISCOs stood at 17.13%, with the highest T&D loss reaching 37% for Peshawar Electric Supply Distribution Company (PESCO). The overloading position of transformers in the FY 2021-2022 is also 19.92% which has increased from 17.76% in the FY 2020-2021. Similarly, the percentage of overloaded 11 kV feeders stood at 19.86% in the FY 2021-2022, and percentage of overloaded distribution transformers stood at 5.38%. The result is an overutilized system with a higher tendency for overheating and system breakdowns, and reduced lifespan of the equipment. Although the DISCOs are allowed a budget for system improvements every year, their actual spending is consistently lower than the allowed budget.

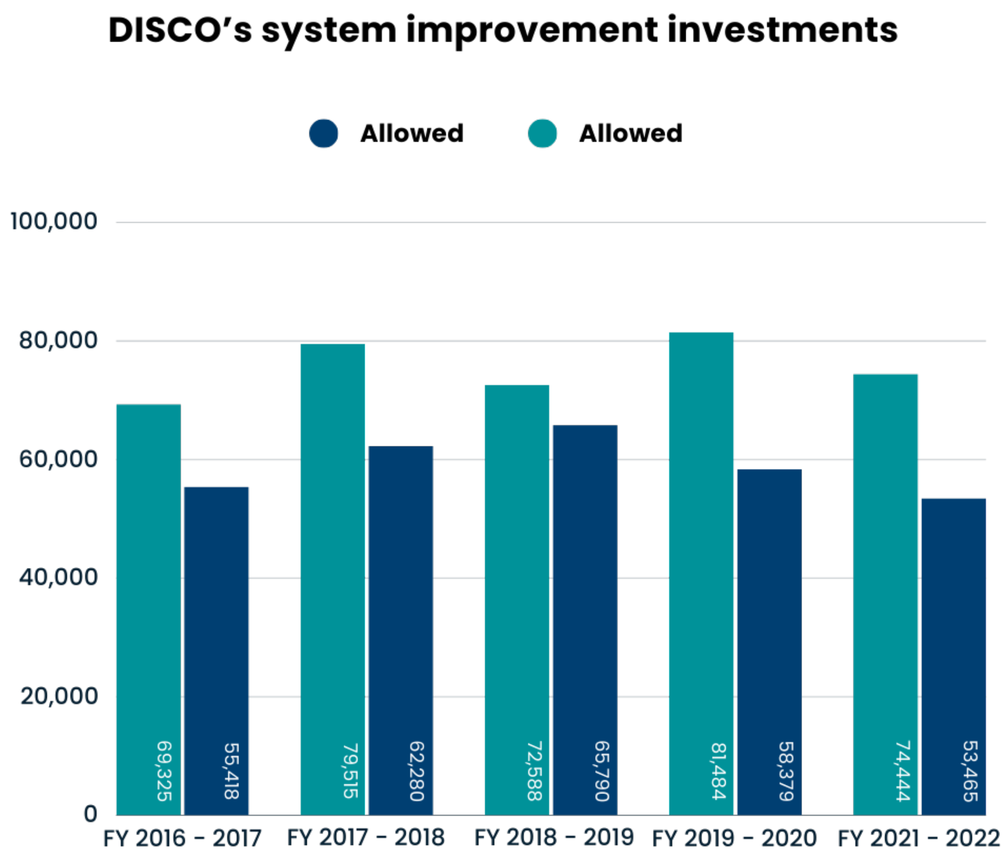


Figure 4: DISCOs Investments Allowed vs. Actual
Source: State of Industry Report 2021 – 2022

Table 2: Wind Power Curtailment in Pakistan

Wind Power Curtailment*

Currently 1845 MW of wind power is part of Pakistan's power generation fleet. Most of these projects lie in the Gharo-Jhimpir wind corridor. The first wind power plant started supplying power to the national grid in 2013. Since then, many wind power projects have been installed in the Gharo-Jhimpir wind corridor. However, their generation has often faced curtailment in Pakistan. Even though their share in installed generation capacity is about 5%, their share in supplied electricity (GWhs) stood at only 3% in FY 2021-2022. Resultantly, these wind power projects received PKR 1.178 billion in FY 2021-2022 for Non-Project Missed Volume (NPMV).[13]In the FY 2019-2020, these wind power plants have received the highest payment for NPMV of PKR 11.90 billion. [14] The electricity that these wind power projects could have supplied to the grid was intentionally not taken into the grid because of constraints in the transmission capacity.

The periods of curtailment have lasted for at least 6 days to months for the wind power projects in the past many years, despite their 'must-run' status in the merit order dispatch list. This has a toll not only on the national exchequer but also on the investors' confidence, as most of these wind power projects have foreign investors as their sponsors.

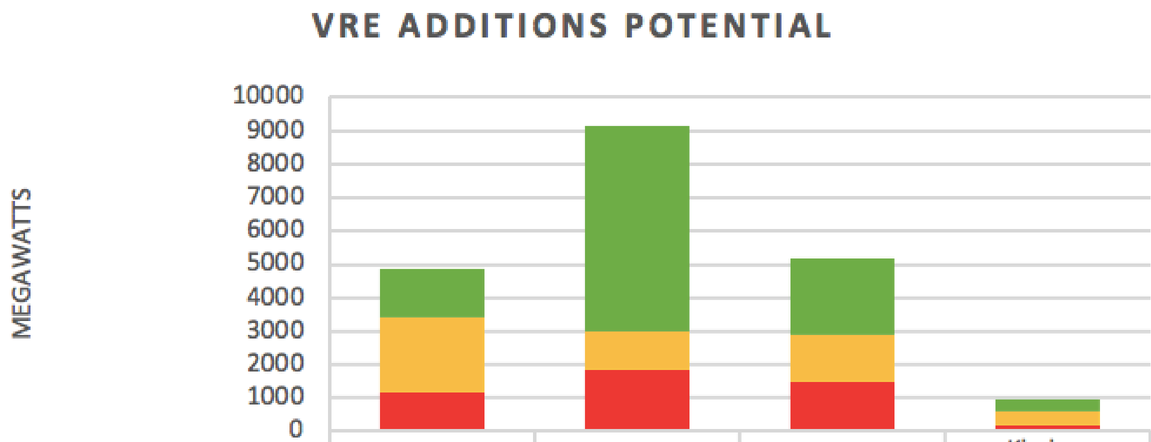
The grid infrastructure is weak in the wind corridor because of which the power plants operating in the corridor often experience curtailment. Underutilization, overloading and exploitation of the worn-out grid causes frequent tripping of transmission lines in the entire wind corridor. Particularly the addition of many power plants in the southern region of the country in the recent years, have led to choking of transmission infrastructure in the south and have caused system stability problems. In addition, during the periods of low demand and high wind generation, the system operator finds it less expensive to shut-down a wind power facility than a fossil fuel based power plant because of contractual power offtake arrangements.

The government should pay attention to increasing transmission capacity in the wind corridor in order to harness the benefits of cheaper wind power generation. Failure to do so will result in lost energy as well as future wind power development in the region despite its abundant availability.

*Curtailment is the intentional reduction of output from a power generation facility.

VRE Integration Potential in the Existing Grid

The Alternate and Renewable Energy Policy 2019 (ARE Policy), sets a target of at least 20% VRE in the system by the year 2025, and at least 30% by the year 2030. A VRE locational study conducted by the World Bank identifies that the 20% VRE target in the system can be largely achieved with minimal grid investment. The approach should be to add small quantities of solar and wind (20MW to 100 MW) close to the existing substations and transmission lines with spare capacity. [15] The target of at least 30% VRE in the system can be achieved by laying some additional transmission lines that connect high VRE potential regions — such as in Balochistan — with the central grid. The study, overall, develops three site scenarios until the year 2030 for integration of VRE in the grid i.e., the short-term scenario until 2023 for the *interconnection ready sites* [1], the medium-term scenario (additions between 2023 and 2025) which requires investments and reinforcements, and the long-term scenario (additions between 2025 and 2030) which requires intensive investment in the sector. [16]



	Sindh	Balochistan	Punjab	Khyber Pakhtunkhwa
Long-term Scenario	1450	6150	2300	400
Medium-term Scenario	2250	1150	1390	375
Short-term Scenario	1180	1850	1510	200

Figure 5: Province vise VRE Integration Potential by Year 2030
Source: World Bank VRE Locational Study 2021

While in the short-term and medium-term, VRE additions could be made in all provinces, in the long-term scenario Balochistan province presents the highest VRE integration potential. A High Voltage Direct Current (HVDC) line of 6 GW in Balochistan is proposed — ±800 kV bi-pole HVDC line connecting Chaghi in western Balochistan to Muzaffargarh in western Punjab — which will bring power from very suitable hybrid locations for wind and solar in the remote areas to the load centers in eastern Balochistan and western Punjab. At an annual power transportation of 22,700 GWh units and an estimated lifetime of 50 years, this leads to a per-unit transportation cost of around 0.13 US$ per kWh. There are 29 interconnection ready sites out of which

1 Locations which do not require any grid reinforcement for the additional feed-in from new power plants. The study identifies a total of 29 interconnection ready sites with the potential of VRE integration of 4,160 MW.

9 lie in Balochistan. The province being less populated than others and having the maximum sites available can be immediately targeted for integration of VRE. Similarly, the other plans for transmission lines available in other provinces are just as capable as this one.

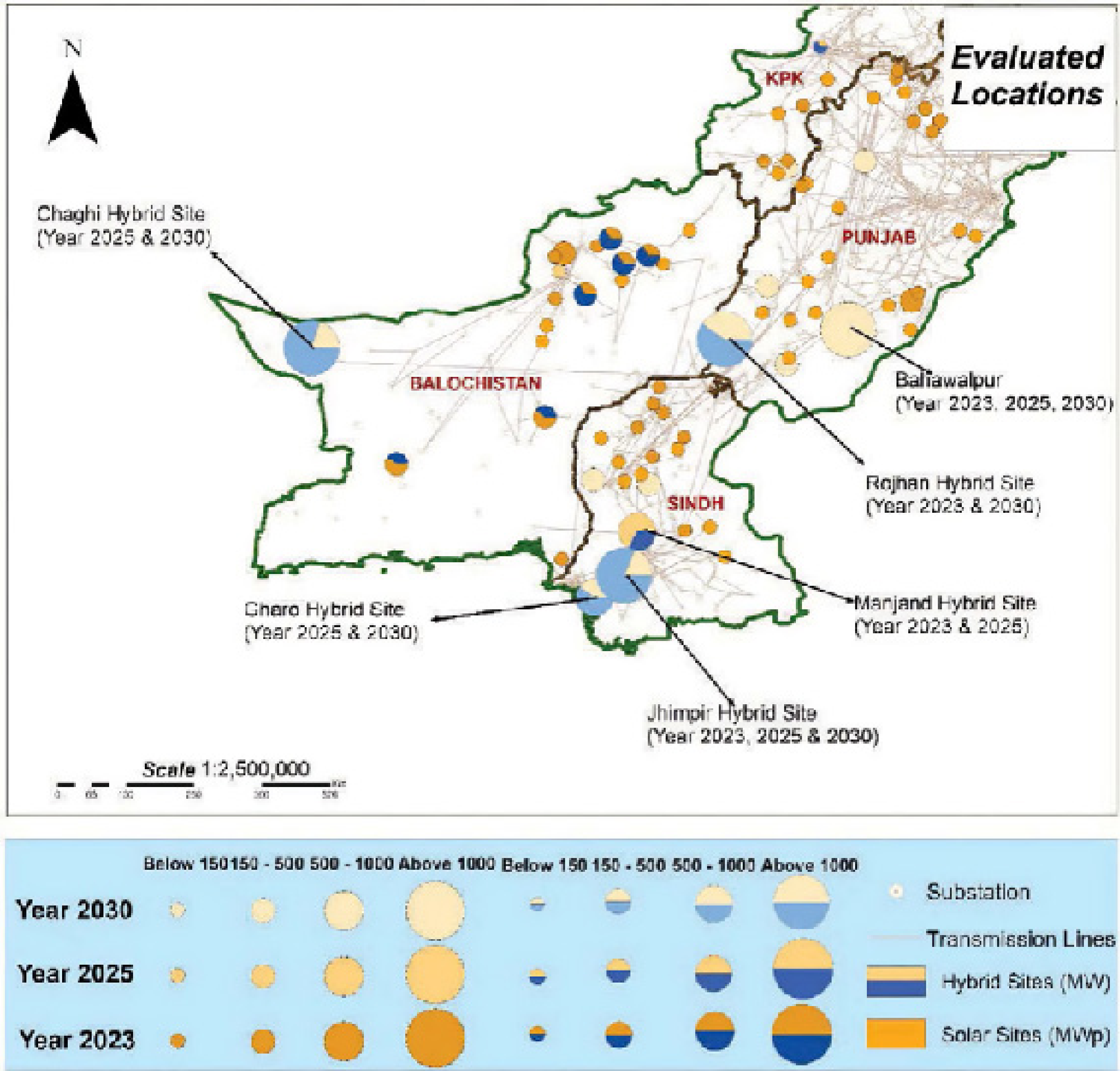


Figure 6: Proposed VRE Development Sites for 2023, 2025, and 2030
Source: World Bank VRE Locational Study 2021

Figure 6 above shows the locations available for VRE integration along and around the national grid in the short-term, mid-term, and the long-term. The transmission infrastructure exists extensively in the regions of Punjab and Sindh, whereas major developments will be required in the provinces of Balochistan and KPK. The potential of hybrid solar and wind power plants also exists tremendously in Balochistan. The benefits of co-development of hybrid plants will be seen not only in the form of less land requirement for the projects but also a more predictable power generation profile from such sites and a better capacity factor of the transmission lines.

Power Grid Constraints

There are some inherent constraints associated with the conventional grids with fossil fuels based power generation sources at the supply side, and some constraints arise because of the declining state of our national grid infrastructure. These constraints, if not addressed, can impede the seamless integration of VRE and thus require strategic attention.

First and Foremost, our national grid is inefficient. The inefficiency emanates from the centralized power generation in the northern and southern parts of the country and load centers being away from the sources of power generation. In addition, there are significant technical losses –aforementioned- that occur while transmission of power through the long transmission lines network. As a result, we frequently experience system breakdowns with cascading effects caused by tripping of transmission lines at one end of the system or the other. [17]

Secondly, the operations of conventional grids align well with the traditional dispatchable power generation sources. The dispatchable power generators provide flexibility to the grid through their ability to ramp-up/ ramp-down in a short time interval as needed in accordance with power demand. Their rotating masses such as turbines and generators are synchronous with the grid which provide stability to the grid. The VRE generation resources are non-synchronous with the conventional grid. Not having a mechanical link with the grid, their ability to quickly respond to the changes in the power demand is limited. Balancing power demand with power supply at every instance thus becomes a challenge for the grid operators. This constraint of the conventional grid needs to be addressed as the VRE shares increase beyond a certain limit in the power system.

Thirdly, the limited transmission capacity can also constrain the grid particularly when VRE resource is available away from the bounds of the existing grid infrastructure.[18] In the case of Pakistan, for example, the national grid is not readily available in the areas with abundant solar and wind resources in the province of Balochistan. In order to capitalize on the abundantly available solar and wind in that region, the transmission network will need to be extended in that region as well its capacity will have to be enhanced. Otherwise, this will present a challenge to the integration of higher shares of VRE in the system.

Finally, if the grid continues to operate without updates as required for the integration of new power generation resources, the cleaner energy transition may not be realized. The accessibility and procurement of required investments to modernize the grid are therefore very crucial. Besides this, any regulatory barriers towards deployment of new technologies (such as advanced grid management systems and smart meters) have to be removed so that the grid can operate flexibly even with higher shares of VRE resources.

Needed Grid Transformations for VRE Integration

VRE integration has the potential to address various aspects of the ongoing energy crisis in Pakistan, but having a flexible grid is an indispensable prerequisite. An efficient grid has to be balancing power demand with power supply instantaneously. However, when higher shares of VRE become part of the power generation system, the need for balancing becomes even more crucial because of temporal and locational variability of solar and wind. A grid which is more flexible, can cater to such variabilities, and is capable of promptly and efficiently adapting to changes in the power supply and demand in a dynamic fashion. Currently Pakistan's grid has power supply coming from majorly baseload power plants and a very few renewable energy plants. The structure of payments to the baseload power plants is also binding in the form of capacity payments that have to be made because of their availability, in addition to the payments made to them for power supplied to the grid. Therefore, decisions to procure energy are more contingent on contractual arrangements rather than the assessment of availability of cheaper and sustainable energy resources. As per the State of Industry Report 2022, the financial impact of violations of merit order by the System Operator is PKR 23.26 billion in FY 2021-2022. The national grid is thus in a dire need of flexibility that in turn alleviates the financial burden of the power sector and allows for an easier integration of VRE.

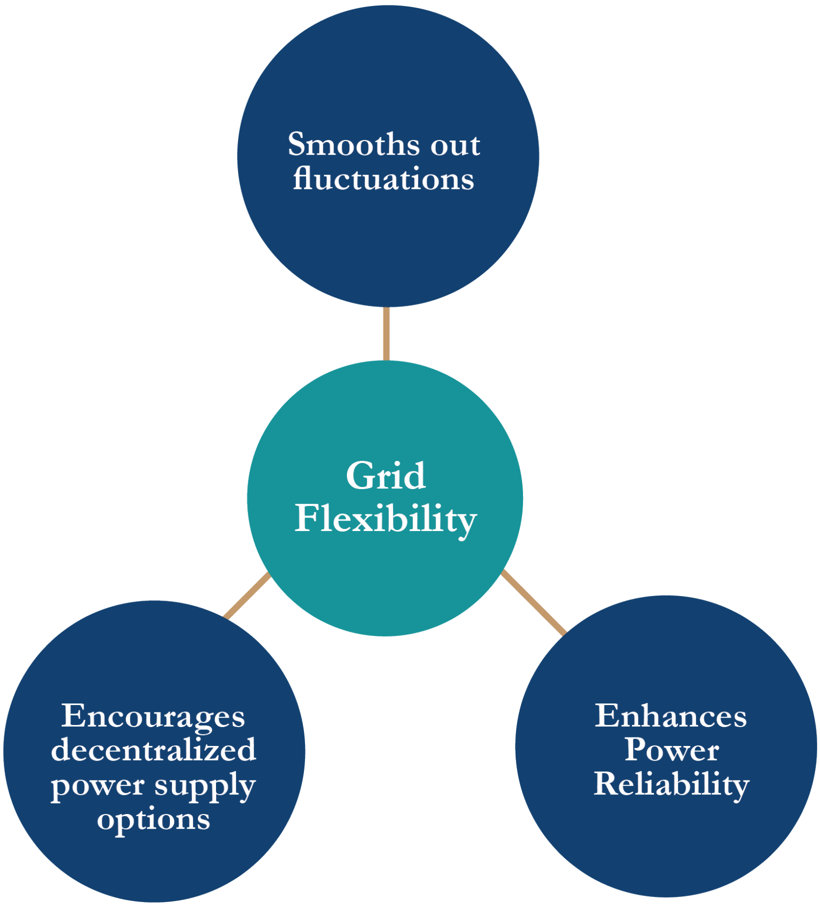


Figure 7: Grid Flexibility

Grid Flexibility

Flexibility in the grid can be introduced through short-term measures as well as long-term measures. In the short-term, grid operations can be managed smartly by introducing shorter dispatch intervals and high precision weather forecasts. Defining smaller dispatch intervals such as hourly dispatches, or sub-hourly dispatches, can help the grid operators to rapidly respond to changes in power supply from VRE resources.[19] In such a manner, the dispatchable renewable energy resources such as hydropower, can also help in balancing the power demand with power supply by ramping up and ramping down (as needed) on an almost real-time basis. Improving weather forecasting mechanisms can further help reduce the balancing needs of the system. With high quality weather forecasting the generation output from VREs can be more accurately predicted on a two-to-six-hour interval and as a result power from VREs become more reliable.[20]

Demand response is another important aspect of grid flexibility which can be used both in the short-term as well as the long-term. Introducing measures to manage energy demand such that the profiles of power utilization/energy needs match the profiles of power generation, is at the core of demand response. Examples may include: shifting of electricity usage to periods of low demand; introduction of time-of-use pricing to encourage electricity usage shifts to periods of lower price; alerting end consumers of peak demand periods and high prices so that they reduce their electricity consumption voluntarily; incentivizing users of electric vehicles to charge as per the grid conditions; and encouraging consumers to adopt net metering so that surplus energy can be stored at times of low demand and supplied at times of high demand to the grid. In the long-term, demand response can be integrated into future grid planning and smart grid technologies can be deployed to ensure bidirectional communication between the consumers and the utility providers.

Transmission Capacity

Moreover, in the long-term, increasing transmission capacity in a supplying region can also make the grid more flexible. Creating inter-regional connections can also help balance demand and supply. For example, currently the power flow from NTDC's system to K-Electric's system is constrained at 1100 MW. However, if demand in the KE's system is in addition to 1100 MW and NTDC's system can balance it, that should be facilitated. Energy storage is another means of enhancing grid flexibility. Systems such as grid-scale Battery Energy Storage Systems, Pumped Hydro Systems, and Compressed Air Energy Storage Systems, can serve as additional sources of power supply at times of high demand and energy storage at times of low demand.

Microgrids

Microgrids can also play a vital role in strengthening the grid operations. A microgrid is defined as an active distribution network in which small-scale power generation facilities, mainly distributed energy sources like solar photovoltaics, wind, biomass energy, etc., are connected either directly to the main grid at the distribution level near the load centers, or operate in island mode independent of the grid. [21]Because of their capacity to operate as either grid connected or in island mode, their installation can reduce the load on overloaded grid assets. In addition, strengthening the grid connections, installation of substations, and automation of feeders are also viable solutions to improve the quality of the existing conventional grid in Pakistan. [22]

It is important to note here that these transformations are essential for increasing the shares of VRE in the system, but also otherwise to modernize the grid as per technological advancements and needed cleaner energy transitions in the wake of climate change. The grid has been facing frequent disruptions and the life span of the grid infrastructure has also reduced because of overloading positions of its various components. The National Electricity Policy 2021 recognizes the need for improving system efficiency, reducing technical losses, and modernizing the grid. The National Electricity Plan ("Plan") further devises ways for modernization of the grid through deployment of systems such as SCADA, Smart Meters, and Advanced Metering Infrastructures. The plan further identifies the need for decentralized induction of renewable energy resources and demand side management. The government also introduced a fast-track Solar PV initiative in 2022, under which it has introduced a program to induct decentralized solar power projects of size up to 4MW into 11 kV feeders in order to resolve issues of technical line losses and voltage variations. These planned measures are promising for a robust grid infrastructure; however, implementation of these measures need to be ensured. The government needs to take steps to attract required investments for the strengthening of grid infrastructure.

Regional Case Studies of Grid Flexibility Measures for higher VRE Uptake

India

The most prominent example of fast renewable energy development is India. Currently, the largest solar plant in the world is located in the India, i.e. The Bhadla Solar Park- a solar power plant located in the Thar Desert of Rajasthan, India. It covers an area of 56 square kilometers and has a total installed capacity of 2,245 megawatts (MW). [23] India has become the third largest producer of electricity in the world. To integrate such a huge potential of VRE in the grid, India has invested huge lumps of capital to modernize their conventional grid system. India's smart grid market was valued at US$309.397 million in 2021 and is projected to expand to reach US$2,279.049 million by 2028 as per the forecasting models. [24] The smart city mission [25] started in India is one of the key driving forces in modernizing the grid system. Many pilot projects were initiated by the government of India alongside — the projects have been launched in collaboration with the local and international agencies. By enabling smart grids India has been able to reduce the electricity cost for both the consumers and the utilities. Alongside, India is keen to address the compliance verification issue and works on grid codes implementation.

California

California leads the way in integrating renewable energy into its existing grid infrastructure, with over 30% [26] of its energy portfolio hailing from sources like solar power. Their ambitious target is to reach 50% by 2050. This rapid adoption owes much to the state's supportive regulations, which have fostered an environment conducive to renewable energy uptake. To effectively address the challenges of integrating renewable energy into the grid, California's state regulator and its affiliated agencies have implemented specific grid operation regulations. These regulations undergo periodic revisions to adapt to the changing dynamics of the power system. In addition to this, a step towards smart grid was a vast spread of smart meters. Pacific Gas & Electric Co company distributed almost six billion advanced meters to consumers in Northern and Central California. [27] In the same year, the United States was among the world's largest investors in grid battery storage, with approximately 2 billion dollars invested in the region. The key lesson learned from these efforts emphasizes the importance of prioritizing flexibility over outdated approaches.

Denmark

Denmark is one of the leading countries fast tracking towards Renewable energy transition. The country has integrated 7GW of wind and solar capacity in the grid with the recent numbers showing that 60% of electricity needs are fulfilled by renewables in the country. [28] Denmark has an experience of over 40 years in using wind energy, and has therefore been the first country to address the challenges posed by the integration of a large degree of wind energy in the power system breaking the myths surrounding the integration of VRE in the grid. To increase the shares of wind energy in their system, they increased the flexibility of existing power plants, expanded cross-border interconnections and trade, invested in heat pumps as well as heat storage to serve as a source of flexibility, improved wind generation forecasting, and made consumer demand more flexible. [29] However, the key factors behind their successful transition is their policy continuity despite changing governments, and focused approach towards innovations and stakeholders' participation in the process. [30] Moreover, one of Europe's most aspiring smart grid projects is currently taking place on the island of Bornholm in Denmark. The full-scale EcoGrid project is aiming to lead the way in establishing the energy system of the future. [31] In the upcoming years, the largest intelligent power supply system in the world will be set up on Bornholm, and the project will test and demonstrate how a region can become fully self-sufficient with renewable energy. The project is aimed to be established by 2030. [32]

Way Forward

VRE integration has become a necessity for a better and sustainable power outlook of our country. Pakistan has an abundant VRE potential available for exploitation. The successful integration of higher shares of VRE into the electricity grid requires a comprehensive and coordinated effort to address the discussed grid constraints. This involves updating grid infrastructure, implementing flexible grid management solutions, overcoming regulatory barriers, and investing in technologies that enhance grid resilience. By proactively addressing these challenges, Pakistan can unlock the full potential of VRE, paving the way for a more sustainable and resilient energy future. Understandably, the grid infrastructure needs to be enhanced for higher shares of VRE integration, but at least the VRE shares that are possible with existing grid infrastructure should be realized on priority basis. Then the investments in the grid strengthening and modernization should be prioritized in order to achieve grid stability for any power generation expansion plans until 2030. The benefits of investment in the grid will extend to better and higher VRE integration, making it less dependent on expensive and dirty imported fuels.

The technical and commercial losses incurred by respective DISCOS have also resulted in significant loss to national exchequer which amounted to billions of rupees. The brunt of this losses is indirectly borne by the consumers in form of their utility bills. By integrating VRE near the load centers and in an underutilized grid, the DISCOs can reduce the technical loss component significantly. It is high time that the DISCOS attend to their poor performance and consistent inefficiencies, and at least utilize their allowed budgets for their distribution infrastructure enhancements. The result will benefit the overall system to achieve stability.

Demand Side Management:

An efficient demand side management is another prerequisite alongside an increased transmission capacity as mentioned earlier for higher VRE integration. The National Electricity Plan 2023-2027 is devised while keeping in consideration many of these impediments, but so were the previous policies introduced in the power sector. The plans when introduced on paper seem flawless, but on practical grounds, implementation of these plans is rarely evident. It is, therefore, important that the practical implementation of the delineated measures in the plans and policies be ensured, and within the stated timelines. Starting with simple measures that can encourage consumers to shift and align their energy consumption patterns with, for example, the daytime generation profile of solar power can help make the most use of it.

Grid Infrastructure:

Besides this, as recommended in the VRE integration study by the World Bank, the shift to advanced and proficient grid operating systems be prioritized such as Supervisory Control and Date Recognition (SCADA) system and Automatic Generation Control (AGC) for numerous conventional plants to improve controllability by the system operator and provide reserves. For the provision of uninterrupted supply, the contractually agreed ramp rates of existing and committed plants must be revised in order to meet the international standards and thereby contribute to different reserve power categories and overall grid flexibility.

The grid reinforcement is required to guarantee steady-state and transient stability. The reinforcement is supported by an integrated generation and transmission expansion plan and respective network model along with a high accuracy central forecasting system for VRE resources. These reinforcements can be considered as “no-regret” measures that would be necessary with or without a higher share of VRE in order to provide the required security and quality of power supply in the future. As a result, they should not be attributed as an additional cost of deploying VRE, but as investments in the grid system that will benefit the overall power sector and all its consumers.

Even developing countries like Bangladesh and India, are fast progressing towards renewables. Given the opportunity of sustainable and affordable electricity that the VRE resources present, their intermittency should be taken as an opportunity to modernize Pakistan's power system in line with the global renewable energy direction, instead of being considered a bottleneck. This direction is also indispensable for Pakistan as the impacts of climate change have already begun to disrupt the social and environmental ecosystems here. We have examples of countries like Denmark who have modernized their grids and now rely majorly on renewables for their electricity needs. Small scale and utility scale energy storage devices are also being developed around the world, and investments in their research and development need to be accelerated in Pakistan as well, in order to fully benefit from solar and wind power generation.

There is no better time than now to focus on our power transmission and grid infrastructure as a part of transition towards a clean energy path. With less than six years left to achieve our committed goals in the ARE policy, Nationally Determined Contributions, and sustainable development agenda, we need to act vigilantly. All that we need are transparent and diligent efforts by the enabling authorities and regulators to grab on this opportunity.

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