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Challenges and Opportunities of Industrial Revolution 4.0 in Renewable Energy Sector of Pakistan: Case Study

Muhammad Hamza* and Ahmed Muddassir Khan

Department of Electrical Engineering, Indus University Karach i - 75300, Sindh, Pakistan
Corresponding author: Muhammad Hamza (Email: hamzamastoi@ymail.com).

Abstract- Industry 4.0 digitalized the manufacturing units and energy sources through the built-in sensors virtually in various components, equipment, and products of different power sectors and manufacturing industries. It merges the digital data and the physical objects to analyze the real data which is present in the system and transform industrial units with much greater impact and provide fast services. The necessity of industry 4.0 is to rework the consciousness of constant steady machines into self-learning machines by which it can improve efficiency and maintenance regulations. A smart energy sector is the vision of industry 4.0 to construct the industrial network with information applications. Tracing the fault's real-time encryption and following the directions to command the production system are the goals of industry 4.0. However, influenced by meteorological and environmental terms and conditions the efficiency of renewable power generation often switches randomly, which disturbs the balance of power and voltage tenacity of the power system. Industrial revolution 4.0 main factors are eco-friendly and free gas emissions energy. Due to the renewable energy regulation introduced by the government under the Alternative Energy Development Board to generate electricity from natural resources rather than fossil fuel. In this framework industrial revolution 4.0 facilitates for extensive integration of renewable power into the network which is a massive task for power system operators and also for renewable energy farms to dispatch the power and taking critical actions. Industrial revolution 4.0 provides different pillars to overcome these issues likewise interoperability connects machines, objects, and humans through the internet of things to make smart grids. Uncertainty is the biggest challenge in renewable energy which can't be eliminated, but it can be manageable by virtualization. Through cyber-physical systems, computational proficiency and physical assets are interconnected for transformation advancement in the system; smart decisions acquire to form reliable and accurate data.

Index Terms-- **Industrial revolution 4.0, Renewable energy, Cyber physical system, big data.**

I. INTRODUCTION

The fundamental idea of Industry 4.0 was first coined in Germany. It was presented in the year 2011 at the Hannover Fair. In Germany Industry 4.0 is a common discussion theme in research, scholastic, and industry networks at numerous diverse events. To achieve the potential new innovations and ideas was the principal thoughts like usage and availability of internet and IoT. Real-world will be digitalized and virtualized by industry 4.0 [1]. Slackening renewable energy is a key indicator to boost industrial production and transportation, overcome poverty, diminishes health issues, and developed rural support by enhancing sustainability and ecosystem quality. Renewable energy global demands increase 8% per year and global energy consumption of renewable sources is 20%. By estimation, the demand for energy consumption rises by 56% by 2040 [3]. Industrial revolution 4.0 is efficient to get higher generation results and less energy consumption. Favorable weather is required to install renewable energy plants for maximizing power output that leads to spatial discrepancy in generation and consumption. Small renewable energy plants are connected with grids as compared to fossil fuels. So small connected plants are large in numbers as compare to conventional plants. Three Points, temporal-spatial discrepancies, variability and certainties of power, and inclining generator numbers to lead to certain challenges for operation and control. To overcome these challenges, a lot of literature is suggested, but the smart grid is leading. The smart grid provides the solution for a stable system and controlling renewable energy sources [4]. Recently nationwide electricity blackout sinks into darkness. Pakistan power system provides 21 Million people are rarely complex delicate web. If the troubleshooting comes in one grid or generation plant then it falls out the entire system. The complex web of power distribution leads to cascading breakdowns. This blackout was the curse as it plunges whole big cities into darkness [5]. The shortfall of power effect individual but also affect the Stability of economic development of the nation. Due to the shortage of electric power, many organizations and different business sectors are affected including transportation, agriculture, and manufacturing industries which cause direct loss and affect the economies of the country. The total integration of renewable sources is very less in Pakistan. In power generation Pakistan mostly dependent on fossil fuels. Fossil fuel cost is high, and it highly affects the poor economy of Pakistan, but also it causes some environmental issues regarding CO2 emission and the greenhouse effect. Our natural resources are decreasing due to overuse. A new energy economy is required to overcome these issues. Renewable energy sources utilized to power generation which declined the overuse of

costly fuels and burden on economic growth will be reduced [6]. Pakistan's President Initiative to implement Artificial intelligence in the academic. The president said innovative technology and good governance lead Pakistan towards success in different sectors. The world is going to digitalize, so Pakistan also needs to enhance its capability in Artificial intelligence and the internet of things to solve the complex system in the health, agriculture, manufacturing, and power sectors [7]. The industrial revolution has created its own motive "smart thinking" in industries. The smart factory interconnects every component established on the Internet of things and benefits economic growth which can change into intelligent infrastructure. Smart grids and intelligent infrastructures enhance energy utilization for economic growth.

- Big data, wireless connectivity, and computational power.
- Analytics intelligence
- Human and machine interface.
- Cyber-physical system [8].

A. UTILIZATION OF INDUSTRIAL REVOLUTION 4.0 IN RENEWABLE ENERGY

Pakistan's transmission network got many challenges for the smart grid due to unreliable sources. Smart grids perform well under constant voltage with synchronized phase conditions by the distributed sources of energy. The performance of reliability in the transmission line can be calculated by the number of outages and time duration. Pakistan faces many forced outages and unplanned sources in power grids. So it is necessary to focus on the integration of renewable energy in the energy mix. The detailed description shows that by overcoming distributed generation Pakistan's energy economy can be handled [9].

B. GUIDELINES AND POLICIES

The principal's explanation of the energy crisis is faced through improper energy integration, political instability, policy failure, low investment in renewable energy sectors, non-utilization of different energy sources, and high costing of energy units. Mega energy projects are sidelined by political wills due to the corruption on both sides. The infrastructure of transmission and distribution becoming old [10]. The Smart Grids in Pakistan are not fully functional, but the generation of electricity through renewable energy is merging. So, smart meters and tariff guidelines for demanding customers have been issued since 2015 by the government through NEPRA. End-user can sell and purchase electricity by generating their own energy from different kinds of renewable energy like solar wind or biomass. Incoming and outgoing record of electricity is saved in smart meters to calculate the usage of power and surplus. These guidelines will encourage the end-user to generate their own energy and overcome the shortage of power through renewable energy. Power is calculated in different kinds of parameters, so Smart meters calculate different data from ranging minutes to hours and any misshape can be captured through screenshots. Unfortunately, manual readings of energy meters are still in practice in Pakistan, so that is also a cause of energy theft and corruption. Inappropriate data from the manual readings of the system cause defective load consumption. Smart meters are credible it generates an alarm in various critical situations therefore there is mishandling of data which cause corruption and theft in energy readings and also mislead information and defective load consumption. Approaches to demand management also because misleading information. The government took initiative by motivating people to install smart meters which is more credible. Smart meters have more features related to alarms to monitor and identify grid losses. A smart meter is capable to store data and retrieve by poor communication. Theft issues can be handled by installing smart meters. Quantifying bidirectional energy flow meters used by industrial consumers. Prepaid energy meters are in pipeline which calculates timely identification and power theft diminish. Incorporating smart meters can be made in the energy mix to overcome the losses [11].

To examine the potential of manufacturers for the transformation of industry 4.0, these design principles are;

• Interoperability: The Internet of things gathers machines, humans, and components to communicate. This principle is most useful to make the industry smarter.

• Virtualization: Virtualization of real-time simulate with the cyber-physical system (CPS) with a virtual copy of the system and also detect uncertainty in weather.

• Decentralization: The potential cyber-physical systems work separately. It provides troubleshooting of customized products and gives a flexible environment for a generation. If any collapse and issue happen it resolve its higher level.

• Real-Time Capability: Real-time data will be stored in the cloud and analyze for decision-making. This capability will help not only in the external systems but also internal systems failure and troubleshooting examined. Production optimization and flexibility gained by tracing out defects and assigned tasks to another machine.

• Service Orientation: Customer choice product production. Smart devices and people connected by the internet of services for customer satisfaction product. It is also essential for customer relations.

• Modularity: In a fast-growing market. Market adaptability is essential for smart factories. It takes a long time to research the market product for production. Speedy and smoothly seasonal changes adopted by smart factories [12].

Apparently, the development and impact of the industrial revolution 4.0depends on exceeding automated manufacturing processes that need less conventional manufacturing jobs and high modernized ones for developing and expansion, the economy. Excessive expectations flourish for industry 4.0 with a view to affect key partners favorably: Client would experience manufacturing applications run by artificial intelligence, automated technologies, and machine learning interconnected with data science back for gauging customer necessities [13]. Various forecast software's resources within the field of resource planning by industry 4.0 to find out the better quality analyze better predictive algorithms and better programs used for more optimized. Easy to manage, control, maintain, and cost-effective production process to minimize process defects [14].

II. PAKISTAN RENEWABLE ENERGY SECTOR

"Pakistan socio-economic development with inclining its energy generation by renewable energy. Traditionally Hydropower is a permanent source of energy that integrates 7.1 Gigawatts (GW) electricity to the national grid. IRENA assessment shows that Pakistan has the potential of 50GW theoretical in wind generation and has a potential to increase its generation by adopting renewable energy because Pakistan has energy resources and report illustrate that after reducing the cost of photovoltaic (PV) it's growing by 400 Megawatts of solar project in 2015-2016 which helped to create jobs as well [15].

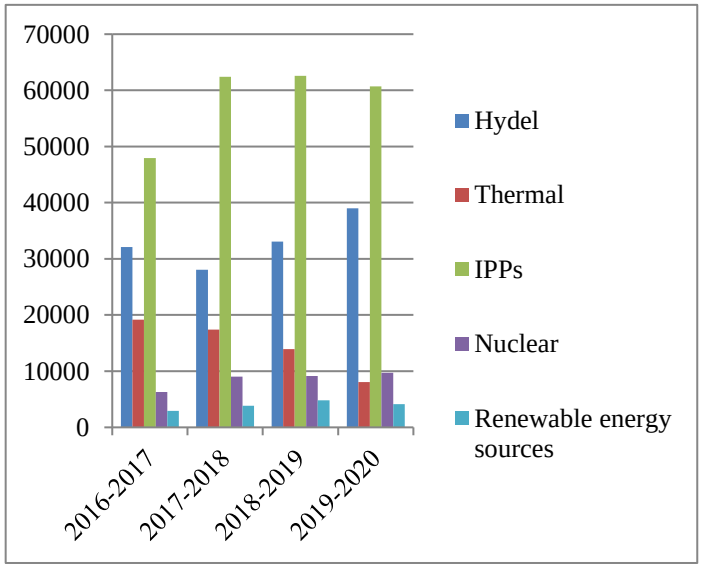
A. TOTAL INSTALLED CAPACITY OF DIFFERENT SOURCES IN PAKISTAN

Pakistan mainly depends on thermal power to complete its demand, but the natural reservoir of oil is lessening day by day, so Pakistan imports most of its oil from friendly countries like Saudi Arabia. Wind power capacity is increasing every year [16].

Table I: Electricity generation in Pakistan excluded K- Electric from 2017-2018 to 2019-2020 regarding their sources [17][19][20].

Total Installed Capacity Of Pakistan Generation in GW/h from 2017 to 2020			
Description	2017-2018	2018-2019	2019-2020
Hydel	28069	33095.89	38987.96
Thermal	17400	13945.8	8078.9
IPPs	62434	62597.73	60720.33
Nuclear	9051	9135.67	9704.89
Renewable energy source	3869	4840.59	4151.91

Table 2: Shows the inclining of wind power generation in Pakistan



Pakistan primarily relies on oil and gas assets to satisfy its necessities. Domestic assets of oil are deficient to extinguish the vitality thirst of a developing economy. Subsequently, Pakistan has to import enormous oil from Middle East and notably from Saudi Arab. So Pakistan is diverting its energy demands from oil to renewable energy [21].

B. WIND ENERGY POTENTIAL IN PAKISTAN

Power is the mainstream of electricity which assumed a huge part of socio-economic development and social prosperity of any state. The world is intensively needy of non-sustainable assets for completing its power need. Indications of these assets are going to be finished shortly. In that capacity, the paradigm of the ongoing energy consumption cycle is not changed obviously the power insufficiency occurs. So, that's why there is a need to choose a different kind of possibilities to overpower the electricity deficit situation by choosing sustainable power generation and reserve the remaining assets for the future generation. Generating electricity from sustainable resources likes wind and solar is the only solution to meet the increasing needs of electricity [22]. While the national objective is to achieve 9700MW from renewable energy generation by the year 2030. It is clear that wind farms can play an important role in increasing the country's energy in the future [23]. Pakistan is blessed with a massive wind source. Figure 2 represents the airflow which is indicated by color to know the exact potential of air in any area of Pakistan for wind power plants. It is generated by World Bank and Alternative Energy Development Board. This map will help in the future to developed more wind plants and attract foreign investors to invest in Pakistan [24].

C. SOLAR ENERGY IN PAKISTAN

Geographically Pakistan has a tremendous potential of renewable energy because of its weather conditions and hot places which are beneficial for solar energy. It is very important to utilize natural resources. Public-private partnership for investment is a very crucial component to utilize the resources in solar energy [25]. Pakistan reclines in a locale of high sun power irradiance, all things considered, it is appropriate for sun-oriented energy projects [26].

III. CHALLENGES

By the estimation of (AEDB) Pakistan has the potential of (2900GW) solar energy but the main obstacles which have a face are the lack of technology, government policy conflicts, and socio-political behaviors contradict [27].

A. COST AND MATERIAL CHALLENGES

Relying on solar energy (PV) cells also need storage due to the cycle of sunlight if we install the capacity of a 14 MW solar energy plant as an example, we are going to assemble one each hour for the following 81 years which is a huge amount to pay [18].

B. POWER INTEGRATION ISSUES

Solar and wind source of energy is uncertain and unpredictable and recently a surge of penetration into grids has declined, the concept of power flexibility in the system can be redefined. Unpredictable weather causes uncertainty on the supply side which also causes Uncertainty on the load side. Flexibility in the power system prescribed the potential of generation on both the demand side and supply side in a variable generation [19]. Transmission congestion increased by variable loads which are

connected by privatization and deregulation in renewable energy generation. Power grid loaded up quickly with unstable loads and wide-area power trading at same time cause disturbance. As the demand increases there are more chances of blackouts, instability in voltage, power quality, and frequency. Additionally, expanding numbers of distributed generation, especially wind energy cause uncertainty of load on grids and power flow distribution which contribute strain on the power system [20]. Power quality issues happened in renewable energy power generation connected with the power grid. The uncertain nature of renewable energy generation causes non-dispatchable and discontinuous with high variation which causes power quality issues in the system as the penetration level increases. From the power grid side, voltage sags caused a short circuit and load variation in supply and generation change that interact with the interconnected systems and create more complex and uncertain conditions. Overall power quality aspect is major that can affect the system reliability and stability [21]. There are three main components which plays important role in power system, Power generation plants, Power grid, and end-user. The whole system runs dynamically if none of them is out of order if any of the three components failed to perform it will affect positive or negative on the whole three components of the power system. When a large capacity power plant is installed with a new transmission line it has an impact on the power system which is managed. Like fully operational nuclear plant at full power at the night has a chance of surplus energy supply when demand is minimum [22].

C. MANAGEMENT AND DATA CHALLENGES

Integration of renewable energy into the grid station is a complex issue for power plant operators and planners. Photovoltaic cell cost is also a factor that is high in comparison with conventional power sources [13]. Daily and weekly predictions are made to predict the availability of solar and wind power, if the power demand does meet the supply thus standby power is needed [14].

D. ECOLOGY AND ENVIRONMENTAL CHALLENGES

Wind turbine impact on humans and wildlife especially (avifauna) is at risk. In developed countries bats are lethal. Bat temporality is very high due to the construction of wind turbine blades globally. Due to the installation of wind turbine blades, the danger of birdlife is the main issue of criticism. By collisions of wind turbine blades, bird death is leading. Wind turbine blades are lethal for passerine species as passerine species are migratory and preserved by (MBTA) Migratory Bird Treaty Act. During the survey's construction of wind turbine blades causes fatality to passerines [15]. Environmental impact assessments are considered as the main tool to be used to predict the positive and negative impact of ecology in renewable energy development. EIA is authentic and enshrined in legislation for making decisions and evaluations [16]. During the maintenance of wind turbines, it can exploit the oil contamination into the water which is against inhabitants and poor peasants [17]. The origin of cloudy and damage to plants into seabed into the base of wind turbines and structure of wind turbine tower. The structure of wind turbines under the ocean floor can block the sunlight and damage biodiversity [18].

E. TECHNICAL CHALLENGES

In this modern technological era, technical challenges are complicated like operation, design installation, and maintaining renewable energy.

- Limited source of local production of quality equipment.
- Deficiency of standardized technology
- Very less information about the market potential
- Very costly in installation from generation to end-user.
- There is risk and instability variation [19].

F. EFFECT OF UNEMPLOYMENT

The impact of unemployment is the main issue in renewable energy by replacing conventional energy sources and also resulting in decreasing energy consumption and high energy prices. In fact, studies show the decline of employment due to decreasing in conventional energy, and increasing of renewable energy, and high energy prices. It also affects employment because of reducing consumption of services and other materials [20].

IV. OPPORTUNITIES

AEDB has got the task to ensure the total electricity generation of 5% through renewable energy by 2030 by the directive of the Government of Pakistan. Additionally the electrifying of 7874 remote villages through renewable energy in Baluchistan and Sindh are included [21]. Metropolitan territories are often subjected to regular load shedding of 8-10 hrs, while the typical load shedding of 20 hrs occurs in urban areas. While the typical load shedding of 20hrs away in rural areas. Renewable energy plays a vital role to overcome this scenario. The contribution of renewable energy in Pakistan is approximately 1 % in 2010. By Government initiative, it will contribute to enhancing the renewable energy generation to 5% until 2030. Researching the main factors between economic growth, energy consumption and fiscal development plays an important role as economic cooperation and development and non-economic cooperation development regions investigated the association. It founded that energy consumption of renewable energy and economic growth incline together. Recently Pakistan's growth of energy consumption is increasing by approximately 9% annually. Energy demand is expected to incline 8 times by 2030 and 20 times by 2050 in Pakistan [24].

A. WIND POWER OPPORTUNITIES

Wind energy included an important source of renewable energy. The speed of air and direction effect when the earth moves. The waves of heat also play a major role in wind speed as the sea has different speeds of air and land has different. Apparently, the region which lies on the sea has more speed of wind which means more wind power and compare to land region. Various reviews have been collected by Pakistan meteorological Department from various spots in Pakistan to calculate the capacity of wind energy. Data collected from 20 spots of about 9700 km2 coastal belts has determined that approximately 43000Mw can be generated through wind power sources.

Pakistan is suitable for wind energy sources and an estimated 9% of land can be utilized to generate 349000MW energy [22].

B. WORLDWIDE STATUS OF WIND ENERGY

Wind source of energy is leading in installation and utilization. Recently in 2019, the installation capacity of wind farms was 60.4GW which is a 10% increase from the previous year. The total global wind power generation capacity stood at 651GW. Wind energy has two pathways one is offshore and the second one is onshore. Onshore wind market installed capacity raised up to 54.2GW which is 17% as compared to the previous year.60% addition of newly installed onshore wind energy farms belongs to the USA and China. The world's largest onshore market belongs to the USA and China. On the other side, Germany shrink from its onshore generation to 55% last year. The onshore rise in Europe by 30% due to slackening in Spain, Greece, and Sweden. Last but not least 4.5GW combined installation in Africa, Latin America, Middle East, and Southeast Asia [23].

C. SOLAR POWER OPPORTUNITIES

Pakistan has got many blessings of God as it is ideally located in the un-drenched line and able to use the solar irradiance technologies. In most areas of Pakistan solar generation is possible. As per calculation about 200-250Watt per m2 global irradiation scattered on a horizontal surface per day which is 6840-8280 MJ/m2 per year. In Pakistan, Sindh, Punjab, and Baluchistan are bountiful in solar energy. Especially in Baluchistan the average 19-20 MJ/m2 global irradiation scattered per day which is the highest in the universe [25]. Alone Pakistan has the second-highest areas to gain solar irradiation 1900-2200kWh/m2. Solar irradiance scattered in Pakistan per year [26].

D. WORLDWIDE STATUS OF SOLAR ENERGY

Recently renewable energy sector has got slacken position in a global market with the rise of installed capacity, by leaving behind nuclear energy and also fossil fuel-based energy. In 2019 global power generation capacity through renewable energy inclined by 200 GW the biggest rise ever, mostly in solar energy. Five years in series the renewable energy have left behind nuclear energy and fossil fuel energy generation which shows a lack in capacity installation. Renewable energy is most effective and cost-effective in many countries than generating electricity from a source of electricity. The global market capacity of installed renewable energy is approximately 27.3% in 2019. Achieving larger share of renewable energy is facing challenges because of the large investment have been done in nuclear and fossil fuels [27].

V. CONCLUSION AND FUTURE DIRECTIONS

Pakistan has a great potential for generating electricity from renewable energy sources. Renewable energy sources complete their demands of generation on weather conditions. There is a lot of uncertainty in renewable energy sources. Industrial revolution 4.0 provides different pillars to overcome these issues likewise interoperability connects machines, objects, and humans through the internet of things to make smart grids. Uncertainty is the biggest challenge in renewable energy which can't be eliminated but can be manageable by virtualization. Through the cyber-physical systems, computational proficiency and physical assets are interconnected for transformation advancement in the system, smart decisions acquire to form reliable and accurate data. Human decisions are based on their previous experience but the industrial revolution assists in the self-optimizing system which helps to make a decision by follow up the virtualization and decentralized system. Big data processing by advanced instruments is applied in the smart system at different stages of product life, like machine operation, quality control, warranty duration and product utilization is analyzed and stored. This big data analysis enhances the abilities to acquire strategies for flexible and reliable operation. Internet of things, big data analysis, and artificial intelligence simultaneously applied in industrial revolution 4.0 to increase the efficiency of renewable energy.

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