Survey of Hybrid Renewable Energy Power Systems

Samah H. H. Mohamed Khair[1] ; Gedani Othman [2]; Abusabah I. A. Ahmed[1]; Mohamed H. H. Mohamed Khair [3]
[1] Department of Electrical and Computer Engineering, College of Engineering, Karary University- Khartoum- Sudan
[2] Electrical Engineering Department, College of Engineering, Khartoum University of Science and Technology, Khartoum, Sudan
[3] College of Engineering, Nile Valey University, Atbara, Sudan

Publication Date: 2025/02/03

Abstract:- In the last decade, the world penetration of renewable energies like Wind and Solar is clear everywhere specially at the hot and mountainy countries. Wind Energy Conversion Power Systems (WECPSs) and Photovoltaic Power Systems (PPSs) are most clean and economic renewable sources. The WECPS energy and PPS energy are dependent on some natural and geographical coordination around the planet. Due to the limitation on power generation for PPS, Hybrid system is optimum solution. combining wind and solar sources with the national grid will lead to sustainable power supply. Beside saving money and enhancing environment, WECPSs also provide sustainable and reliable electricity. Hybrid Renewable Power System (HRPS) mixing Wind energy with Solar is yet complex integrated power system. The main aim of the current survey is to highlight the importance of the WECPSs and PPSs for the National Electrical Grids. The diversity of power generation means help to make a robust National Electricity Grid (NEG). Wind and Solar energies depend on the position coordination and terrain relief to be constructed. Hybrid Renewable Power Systems (HRPS) are the best solution for the continuous and reliable electricity supplying.

Keywords: *Hybrid Renewable Power System (HRPS); Wind Turbine Generation (WTG); PhotoVoltaic Systems (PVS); Battery Energy Storage; Converter Control System.*

How to Cite: Samah H. H. Mohamed Khair ; Gedani Othman ; Abusabah I. A. Ahmed; Mohamed H. H. Mohamed Khair (2024). Survey of Hybrid Renewable Energy Power Syste. *International Journal of Innovative Science and Research Technology*, 9(12), 3096-3104. https://doi.org/10.5281/zenodo.14769417

I. INTRODUCTION

The climate and terrain variation represent great chance for Sudan to make a considerable national wealth and robust power stations system. Wind Energy Conversion Power System (WECPS) and Photovoltaic Power System (PPS) have gained more attention in the last decade because of their efficient and clear power generation [1]. In the recent years, the power generation planner concentrates in renewable energy supplies because of its attractive solution, non-polluting for environment, and highly adapted to decentralized generation. This technology now being developed everywhere if climate is suitable to use on a daily generation basis. The power generation and supply by the mean of renewable source is economic and profitable. Absolutely clear that, the wind turbine power generators are the best choice specially for mountainy areas to supply the designed loads. These renewable energy generators as example apply Induction Machines for power generation which are widely used because of their robustness. The Wind Turbine Generators and PPS systems in hybrid way their overall performance is a function in weather changes, when they are used in Stand-alone topology. The hybrid operation of these renewable power generation systems is considered as big step towards national grid stabilization and power supply sustainability [2,3]. Both WECPS and PPS have the essential working and subjected to many disturbances resulted in some instability. The hybrid generation despite the stabilization difficulties, the advantages are dominant and profitable [4,5]. The governmental grid-connected HRPS projects constructed from WECPS and PPS have seen significant increment over world in recent years. Taking Sudan as example the suitability for Wind Turbine Generation (WTG) is optimum at the north as seen in Fig.1. Identifying suitable locations for installing WTG stations called Wind Farms (WFs). There are a lot of techniques applied for planning locations based on Wind map and Geographic Information Systems (GIS).

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14769417

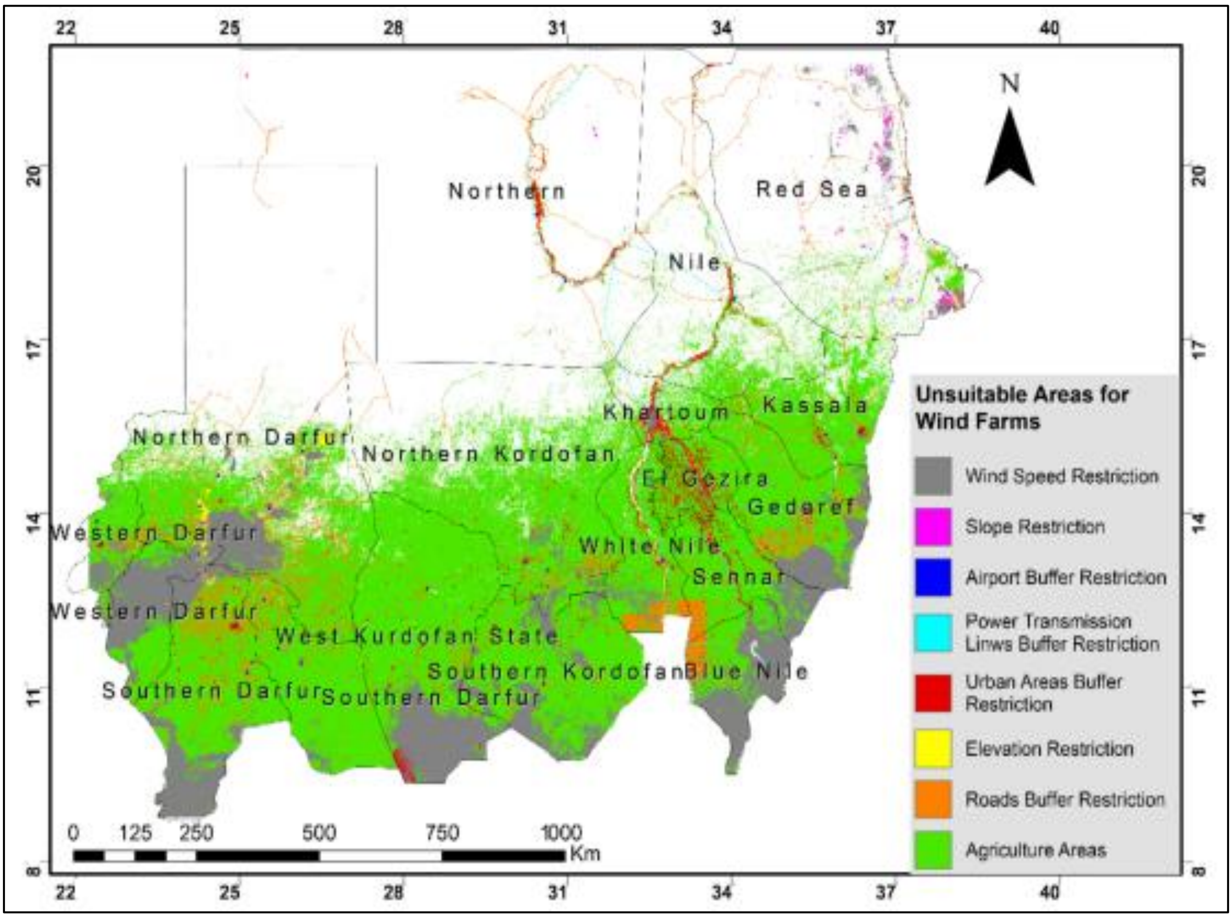

Fig. 1 Map of Wind Farm Locations Suitability in Sudan

Wind speed as most important criterion for WTG planning and constructing varied from 5 m/s to 15 m/s as mentioned in literature. The problems of HRPS in National Electricity Grids can be avoided with good planning, and continuous development researches [5]. In real time operation, HRES suffer from variety of problems such as load variation and grid synchronization. The Renewable Power Source (RPS) itself has some malfunctioning situations, such as wind speed variation and motion transmission backlash. The backlash nonlinearity will lead to rotating speed spikes and generation Frequency mismatch. The spikes and overshoot resulted in wind turbine power system can be canceled or treated applying Adaptive LOcally WEighted Scatterplot Smoothing (ALOESS) as in [6]. For the HPS main parts, the weather conditions such as position's terrain, helps designer to set proper HRPS. During experimental run and even when goes for practical operation performance optimization must be performed to extend the plant's life time. The continuous researches and developing for the installed plant are an important issue for successful and reliable power supply and stable grid. The most recent HRPS researches taking in consideration an important axis such as sizing (designed watts), optimization technique, on site planning and control methodology. The plant control to guarantee smooth injecting of the RPS in to the NEG can be centralized, distributed, hybrid, or new control method. Khan et. al introduced new sizing technique for optimum HRPS design, emphases the new designed grid-connected HPSs in last 5 years and established in practical, as well as the generators used in these systems [7]. For PPS plants the cite temperature represents the focal issue for successful plant construction. Fig. 2 shows the temperature map for Sudan country.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14769417

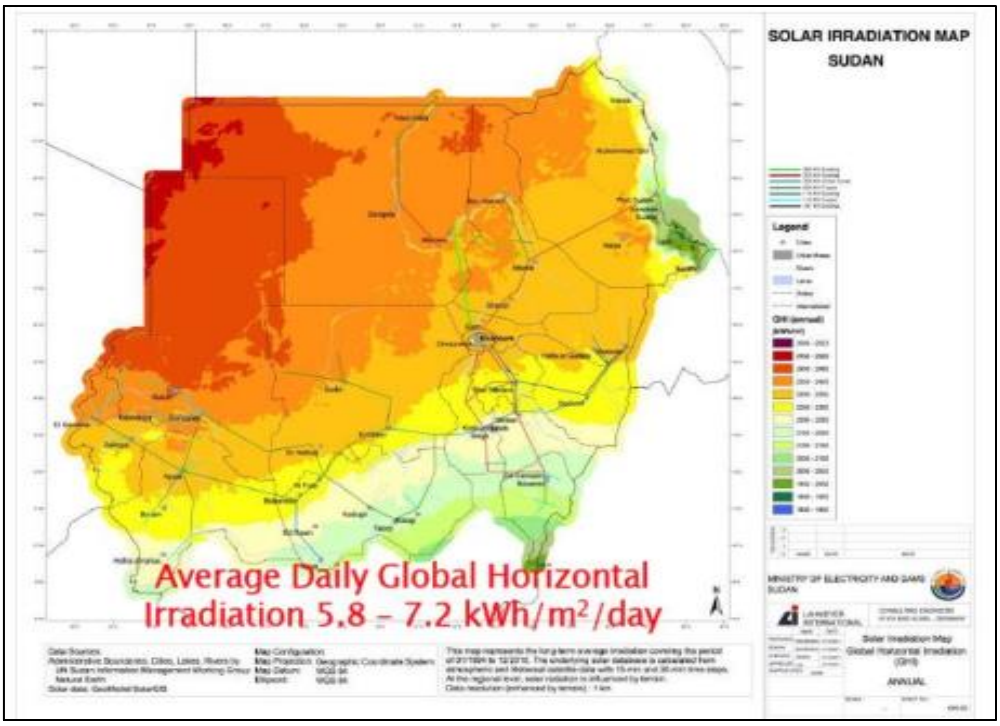

Fig. 2 Map of Temperature Distribution in Sudan

II. PHOTOVOLTAIC ENERGY POWER SYSTEM

Electrical energy directly generated from the sun's radiation by PV array is kind of clear and environment friendly power. These kind of power systems have high outcome when implemented, despite the high initial cost they have approximately zero running cost. Power converters are applied for supplying smooth and regulated DC or AC power by different transformation of the voltages [8]. Single HRPS PPS, as grid-connected topology supplies the excess power and after that share the load with NEG. The solar power generation is highly depended on the site and the capacity beside the connection to the NEG or being stand-alone power system. Solar energy for NEG enhancement and strengthen is available in country like Sudan, but need good planning and smart implementation. Running grid-connected PPS, in single form or hybrid with another renewable power source is good decision to guarantee economic and reliable power supply. Photovoltaic modules when undergone a test at 25^0C temperature about 77^0 F according to the Standard Test Condition (STC), and according to the installation area, Temperature can grave the output efficiency by 10 - 25%. As the surface temperature of the solar panel increases, the output current increases exponentially, while the voltage is reduced linearly.

In fact, the output voltage reduction is predictable, that it can be used to accurately measure temperature. So, panel's heat can severely reduce the solar panels production of power.

In the built environment, there are a number of ways to deal with this phenomenon. PV arrays for PPS are placed with designed inclination to absorb much quantity of radiation as depicted in Fig. 3.


Fig. 3 PV Arrays of Solar Panels

When you think about renewable energy for residential or agricultural applications the first choice is the solar panels, especially in hot countries like Sudan [9], also Sudan Located in northeastern Africa, has a unstable and complex weather varies from very hot, to hot, moderate cool weather and drizzling.

III. WIND TURBINE ENERGY POWER SYSTEM

Wind Turbine Energy Power System (WTEPS) specially for country like Sudan is one of the most promising renewable sources of energy to meet the growth of commercial and domestic loads. This power source is environmentally friendly and economic source, despite its high initial cost. The suitability of Permanent Magnet Synchronous Generators for the WTEPS application proposed it to serve in WTEPSs [10, 11]. The governing relation determines the generated output power of the WTEPS is given as in (1):

$$P_{wind(t)} = \begin{cases} P_r \times \frac{v_{(t)}-v_c}{v_r-v_c}, & v_c \le v_{(t)} \le v_r \\ P_r, & v_c \le v_{(t)} \le v_f \\ 0, & v_{(t)} < v_c or v > v_{f,} \end{cases} \quad (1)$$

where $v_{(t)}$represents the hourly wind speed and P_r and v_r are the rated wind power and rated wind speed, respectively. v_c and $v_f$are the cut-in and cut-off wind speed, respectively [12].

The variable wind speed is arbitrarily chosen with calculated variation using the powerful and specialized software PSCAD to investigate the power generation stability. The simulations trails are focused only on the effective system's parameters which directly given an indicator of the system stability during long and real runs. The problem of stand-alone or grid-connected WTEPSs is air speed fluctuations, affects the frequency and contributed voltage quantity. The continuous developing and planning will lead to extend the life time of these systems and augment its outcome. The general block diagram of WTEPS model is depicted in Fig. 4.

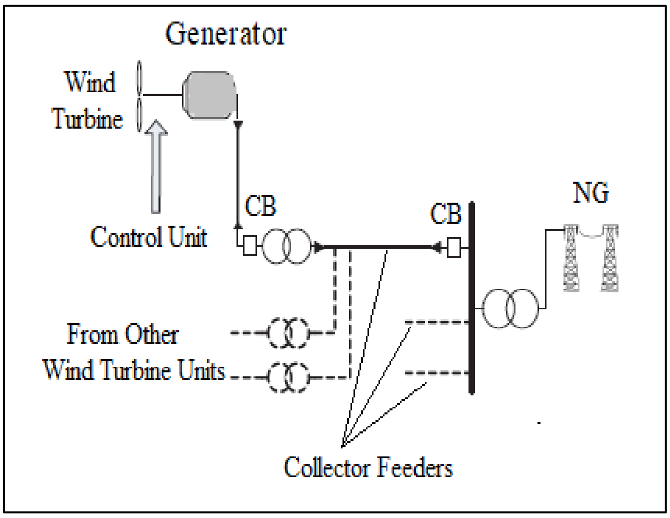

Fig.4 Wind Turbine model diagram

The wind farms as named in literature have considerable effect on the NEG operation cost and cost, stability, beside reliability and efficiency. The wind farm's locations are dependent on the wind map and distance from the NEG. Experimental trails on PSCAD for varying wind speed shown in Fig. 5.

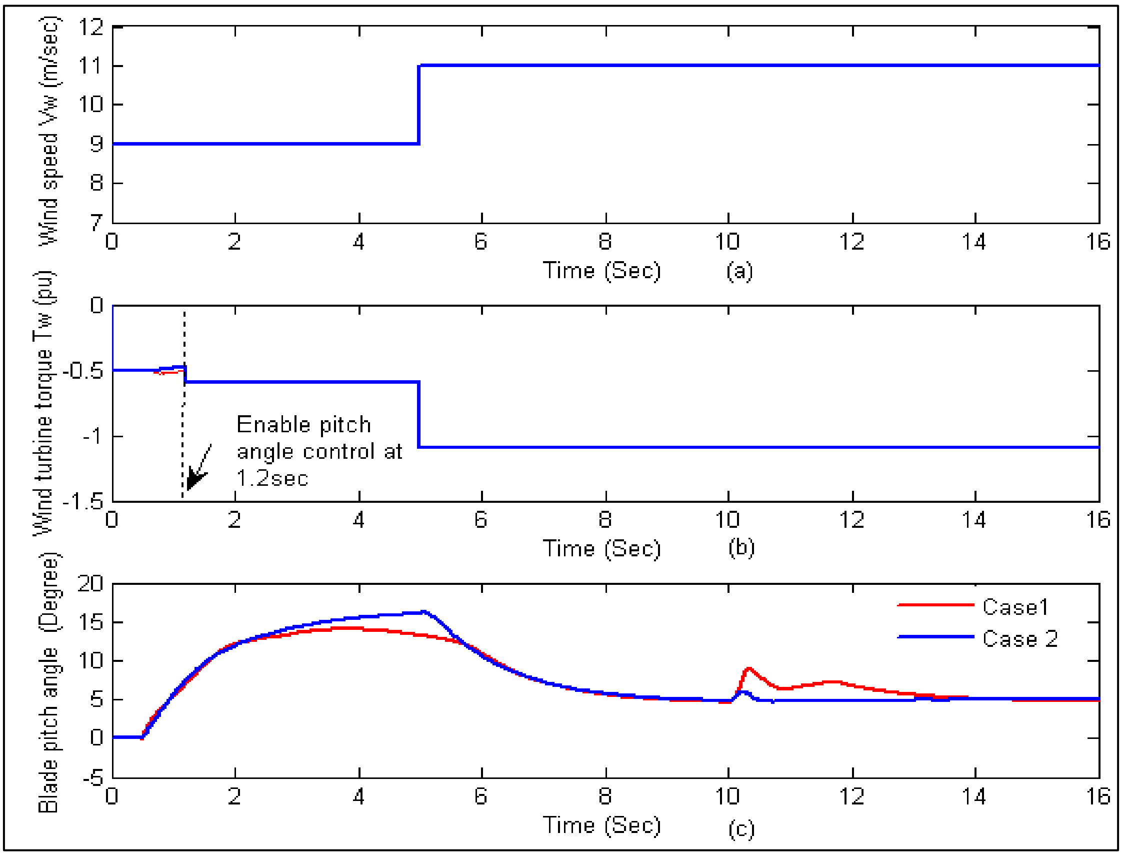

Fig.5 WTEPS response :(a) Wind speed; (b)Turbine torque; (c) Pitch angle.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14769417

IV. HYBRID ENERGY POWER SYSTEM

HRPS collected of two or additional types of renewable electricity generation mean, usually WTG and PPS when connected to NEG added many advantages [11]. The grid-connected HRPSs are now representing most famous power generation issues for sustainability because they are now most advanced and economic power generator mean. These renewable power systems are fruitful and useful because the individual power sources suffer from malperformance. In other words, combining two or more renewable power source in a hybrid way grid-connected or stand-alone will add more advantages to power supplying mechanism. To ensure the best conditions for continuity and sustainability of power delivery of the NEG, to supply designed loads, it is essential to make WTEPS and PV systems compatible with additional energy storage systems as depicted in Fig.6.

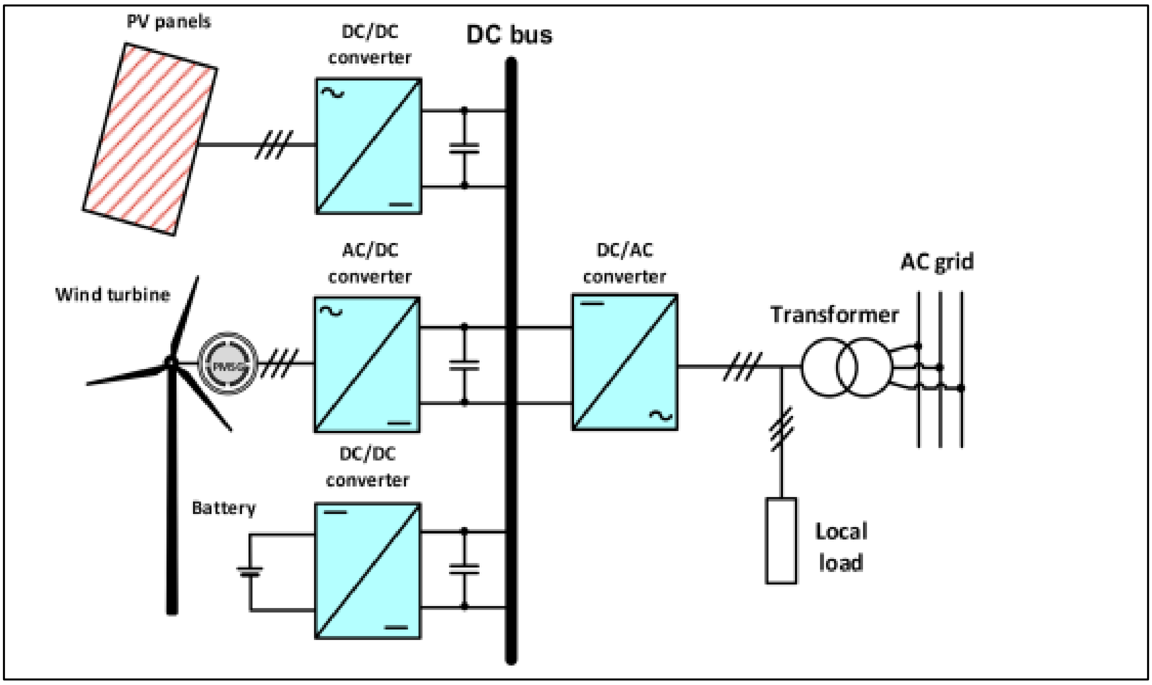

Fig. 6. Scheme of Grid-Connected Hybrid Renewable Energy System (HRES) with Common DC Bus.

Description of HRPS is shown as block diagram in Fig.6, includes Solar panel, wind turbine, control panel, battery Bank, and inverter. This connection between the different generation means and the NEG is satisfying synchronous conditions and contributed voltages. Power generation of PPS and WTEPS connected to NEG forming advanced HRPS save time and money for governments. Either PPS or WTEPS cannot generate electricity in a continuous way, so they found always as grid-connected power sources. The operation of HRES depends on the individual elements, the capacity of every power generation means and the designed load. The evaluation of the outcome from each component, the single component is modeled and subjected to simulation operation trails, then the whole system can be evaluated to ensure the required reliability [12]. HRESs are consists of two or more renewable energy sources, connected to grid or stand-alone integrated with power control equipment and an optional storage system [13].

The general HRPS mainly containing the following stages [14]:

- Electricity generation
- power conversion
- Load supplying

HRPS contains multiple renewable energy sources connected to NEG to provide sustainable and reliable energy production as well as economic and efficient generation [15, 16]. When HRPSs networks are integrated with the NEG to provide designed power, NEG will gain more robust and reliability. Furthermore, the MPPT control technique is required to maximize the generation and control the most unusual power sources [17].

The battery storage system is an essential for power system to compensate for loads variation and serve as equalization technique to ensure the NEG efficiency. The battery efficiency can be evaluated as in (2) depicted from [12].

$$C_{bat} = \frac{E_I \times AD}{DOD \times \eta_{inv} \times \eta_b} \tag{2}$$

where, E_I is the daily load (kWh); AD is the autonomy days number; DOD is discharging depth (80%); and η_{inv} and η_b are the inverter and battery efficiencies, respectively. The grid-connected HRPS produced energy and its consumption depend on the performance efficiency and weather conditions at any given time. When the battery is charging, power generation exceeds the load demand [18, 19]. The net power delivered to the NEG flow equation is expressed as:

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14769417

$$P_{pv(t)} + P_{wind(t)} + P_{battery(t)} - P_{load(t)} = 0 \qquad (3)$$

where P_{pv}, P_{wind}, P_{batery}, and P_{load} represent the output power of the PV array, the output power of the wind turbine, the output power of the battery, and the electrical load power, respectively. The performance of the HRES is analyzed by the modeling of the individual component [20]. In the WTEPS, wind is used to generate electricity by driving wind turbines, which converts the kinetic energy in wind into mechanical power. Also includes generator, which can convert mechanical power into electricity. WPS is the renewable, widely distributed and clean energy source [21]. It's environment friendly, will not produce any chemical gas emission, also consumes no water and uses little land. It will not affect the environment as nonrenewable power sources. The output of WPS is not stable, it is variable so some measures must be taken for optimum power transfer. The wind turbines in the wind energy systems are connected to gear box. The gear box is the electrical- mechanical interface. The output of the gear box is given to the Permanent Magnet Synchronous Generator (PMSG), which produces AC output

V. POWER ELECTRONIC CONVERTERS

Generally, low quality of power may result in additional losses in power, change in behavior of the machines in industries, abnormal operations (especially effect on voltage and frequency parameters), harmonic distortion, and possibility of interference in communication systems at the transmission lines etc. This results in the need of power converters in different levels of power systems for maintaining power quality with proper control strategies [22]. The wind speed is main factor for reliable WTG system, the relation between wind speed and generated power is shown in Fig. 7.

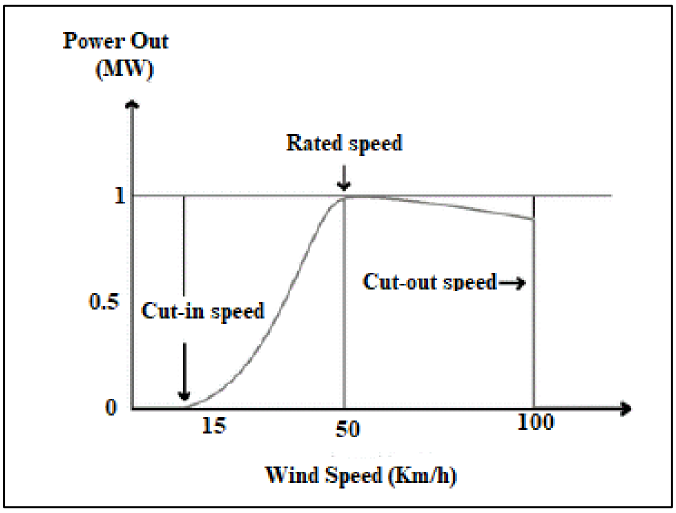

Fig. 7 Wind speed vs. generated power curve

Last decade advances in semiconductor materials and energy-conversion efficiencies of power electronic converters (PECs) have resulted in efficient technologies and widespread adoption of PECs at various levels of the power system and power generation systems. At the consumer level, PECs are generally deployed in the form of DC-to-DC converters for general electronic devices, or AC-to-DC converters for laptops, computers, and televisions, to name a few. Large-scale PECs, such as rectifiers and inverters, are generally used to control the flow of tens of kilowatts to hundreds of megawatts (or the reactive power equivalent) of power. At the power transmission level, PECs typically interface variable and uncertain renewable sources, such as solar PV, with the AC power system, resulting in an asynchronous generation source. The increased integration of renewable energy sources into the power system consequently leads to increased PEC penetration, both from an annual energy and instantaneous perspective. PECs have a wide range of applications [23].

The number and type of required power electronics are determined based on the system configuration. Among these possibilities, the DC-bus configuration is commonly realized due to its robustness and power stability. The energy from DC-bus is inverted into AC form, in order to supply the load power[24].

VI. ADVANCED CONTROL APPROACHES

Control stsrtegy for HRPS stability is main issue to ensure harmony of operation of different power generation mean. Recent control strategies now are used for the control of the PWM converter based on current regulation having the direct axis current to regulate the DC link voltage and the quadrature axis current for the reactive power. The advantage of the electrical form of energy is that the elacticity and it can be transported and controlled with relative ease and with a high degree of efficiency and reliability, new techniques applied to reduce the overshoots on the designed powerflow for sustainable power supply [25, 26].

The presented control approach combines the virtual inertia concept and pitch angle control to dynamically shift the maximum power tracking curve ofWind drived DFIG wind generation system. The voltage control, rotor speed control, and pitch angle control are coordinated in hierarchical manner to reduce the impact of uncertainties due to wind speed variation. Most of the control approaches do not deal with multi disruption and unknown parameters. However, the Model Predictive Control (MPC) approach has the ability to consider both of them[27]. The high penetration of HRPSs combined with their alternating nature can unfavorably affect the stability of the NEG because of their intermittent nature and difficulty to forecast with good accuracy. This disadvantage can be moderated by applying suitable controls strategy. For example, most RESs are inverter-based. The start-up times of these sources can be significantly shorter than the conventional generating plants. The grid forming inverter control can provide black-start functionality and frequency and voltage regulation. Also, fault current contribution and inrush current can be managed [28].

Renewable energy systems, particularly those using power electronics such as inverters, introduce harmonic distortions into the power system [29]. The presence of harmonics can lead to overheating of equipment, increased losses in transmission lines, and interference with communication systems. The proliferation of non-linear loads and the use of power electronic converters in RES are primary sources of these harmonic distortions [30, 31]. The control methodology must consider the variation of the generation by different mean, WTG and PPS, as example the day time PPS is dominant and at the night the WTG and HRPS batteries are dominant as depicted in Fig. 8.

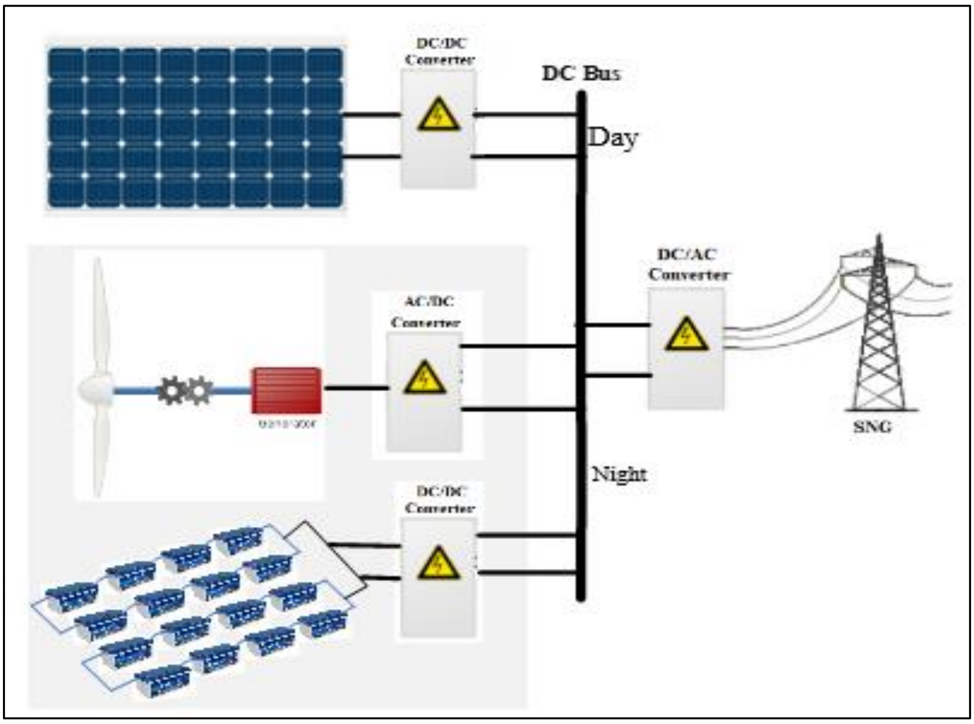

Fig. 8 The Proposed Switching Technique for MPPT

HRPSs stability can be generally defined as, its ability to remain in operation equilibrium and supplying designed load under normal operating conditions and to regain an acceptable state of equilibrium after subjecting to some disturbance. Automatic recovery after grid fauilt is an important factor the HRPSs have, if the grid-connected power system is run in stable way, it will recover fast. The designed automatic control method and possibly human operators will eventually restore the system to normal state as soon as possible. On the other hand, if the system is unstable, it will result in a run-away or run-down situation (Black out), or equivalently a progressive increase in angular separation of generator rotors, or a progressive decrease in bus voltages.

VII. CONCLUSIONS

Grid-connected HRPSs are essential generating means for reliable NEG and sustainable power supply. Computer simulations on MATLAB and PSCAD must be carried out to confirm the successful power system implementation. Optimization of grid-connected HRPS begins from design stage and need recent control strategy beside considering the subsystems parameters during day and night. Grid-connected HRPSs could benefit greatly from recently developed technologies in many fields as semiconductors and sensory techniques.

This survey paper introduces the importance of HRPS and discusses the complexity of these system's control and highlight the importance of such systems. The robust and reliable power supply is essential for developed countries to ensure some level of life comfort. The recent technology race backbone is the electricity, so governments should seek some way to enhance electricity generation and distribution techniques.

REFERENCES

[1]. Ibrahim; N.; Ibrahim; El.; *Optimization and Stability Analysis of Offshore Hybrid Renewable Energy Systems*: International Middle East Power Systems Conference (MEPCON), 978-1-7281-5289-9/19/31.00 ©2019 IEEE.

[2]. Roy, P.; He, J.; Zhao, T.; Singh, Y.V. Recent *Advances of Wind-Solar Hybrid Renewable Energy Systems for Power Generation*: A Review. IEEE Open J. Ind. Electron. Soc. 2022, 3, 81–104

[3]. Touti, E.; Zayed, H.; Pusca, R.; Romary, R. *Dynamic Stability Enhancement of a Hybrid Renewable Energy System in Stand-Alone Applications*. Computation 2021, 9, 14. https://doi.org/10.3390/ computation9020014.

[4]. Mugarura, A; and Guntredi, V; *Modeling and Simulation of Hybrid Solar-Wind Energy System Using MPPT Algorithm*, IDOSR JOURNAL OF EXPERIMENTAL SCIENCES 9(1) 72-83, 2023.

[5]. Ramaz A. M. Alzubeer, Elfadil Zakaria Yahia , Abusabah I. A. Ahmed1 , Samah H. H. Mohamed Khair"*Design of 50 MW Grid Connected Solar Photovoltaic Power Plant in Dongola City, Sudan*" International Journal of Innovative Science and Research Technology,Volume 9 , Issue11 , pp.2203-2208 , 2024.

[6]. Abusabah I. A. Ahmed, Hong Cheng, Hu aping Liu, Xichuan Lin, Mary Juma Atieno. Interaction force convex reduction for smooth gait transitions on human power augmentation lower exoskeletons. Third International Conference on Cognitive Systems and Information Processing (ICCSIP 2016), Beijing, China

[7]. Khan, A.A.; Minai, A.F.; Pachauri, R.K.; Malik, H. *Optimal Sizing, Control, and Management Strategies for Hybrid Renewable Energy Systems*: A Comprehensive Review. Energies 2022, 15, 6249. https://doi.org/10.3390/en15176249.

[8]. Arjun, K.; Shivashankar, K.; *Design and control of autonomous hybrid wind solar system with DFIG supplying three-phase four-wire loads*. https://doi.org/10.1016/j.asej.2020.11.027 2090-4479/ 2021 THE AUTHORS. Published by Elsevier BV on behalf of Faculty of Engineering, Ain Shams University.

[9]. Alzubeer, R., Zakaria Yahia, E. ., Ahmed, A., and Mohammed Khir, S.. "*Analysis of Temperature effect on Power Productivity of Solar Panels in Residence Area*", Journal of Karary University for Engineering and Science, 3(2). (2024).

[10]. Zhiwen, D; and Chang, X, Frequency *Regulation of Power Systems With a Wind Farm by Sliding-Mode-Based Design.* IEEE/CAA JOURNAL OF AUTOMATICA SINICA, VOL. 9, NO. 11, NOVEMBER 2022.

[11]. Nogoye, D.; Lamine ,T.; Oumar ,B.; Thi ,T. S.; Swathi.A and G. Giridhar, *Techno-Economic Feasibility of Wind-Solar Hybrid Systems For Rural Electrification of Sioure Village in Sahel*, 2019 IEEE 2nd International Conference on Renewable Energy and Power Engineering.

[12]. Karunakaran, V; Uma, G. *Optimal power flow control of hybrid renewable energy system with energy storage*: A WOANN strategy: Citation: Journal of Renewable and Sustainable Energy 11, 015501 (2019);

[13]. Gajewski, P.; Pie ́nkowski, K. *Control of the Hybrid Renewable Energy System with Wind Turbine, Photovoltaic Panels and Battery Energy Storage*. Energies 2021, 14, 1595. https://doi.org/10.3390/ en14061595.

[14]. Ligade, G. V.; Pawar V. R.,9 *Solar-Wind Hybrid Energy System Using MPPT* : International Conference on Intelligent Computing and Control Systems ICICCS 2017 78-1-5386-2745-7/17/$31.00 ©2017 IEEE.

[15]. Almutairi, K.; Hosseini Dehshiri, S.S.; Hosseini Dehshiri, S.J.; Mostafaeipour, A.; Issakhov, A.; Techato, K. *Use of a Hybrid Wind–Solar–Diesel–Battery Energy System to Power Buildings in Remote Areas: A Case Study*. Sustainability 2021, 13, 8764. https://doi.org/ 10.3390/su13168764.

[16]. Zakieldeen M. E. Elhassan, Abusabah I. A. Ahmed and Othman Hassen Abdalla, "*Approach Control of DFIG Rotor Side Converter Based on Grid Frequency Coordinated Control*", Journal of Karary University for Engineering and Science, 2021, vol. 1, (1), pp. 1-9.

[17]. Amir M, Prajapati AK and Refaat SS , *Dynamic Performance Evaluation of Grid-Connected Hybrid Renewable Energy-Based Power Generation for Stability and Power Quality Enhancement in Smart Grid*. Front. Energy Res. 10:861282. doi: 10.3389/fenrg.2022.861282, 2022.

[18]. Mohammed H. H. Musa; Abdelaziz Y. M. Abbas and Abusabah I. A. Ahmed, *Cross-Country, Evolving, and Inter-Circuit Relaying Scheme for Double-Circuit Transmission Line*", 2020 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE), Khartoum, Sudan, pp. 1-5, 2020.

[19]. Mohammed H.H.Musa and Abusabah I.A. Ahmed, "*High Impedance Fault Identification in TCSC-Compensated Power Transmission Lines*",FES Journal of Engineering Sciences vol.10 (1), 2021, pp. 6-12.

[20]. Vishakha, V.; Vardwaj, V.; Jadoun, V.K.; Jayalaksmi, N.; Agarwal, A. *Review of Optimization Techniques for Hybrid Wind PV-ESS System*. In Proceedings of the 2020 International Conference on Power Electronics & IoT Applications in Renewable Energy and its Control (PARC), Mathura, India, 28–29 February 2020; pp. 202–207.

[21]. Krishan, O.; Suhan, S. *A novel control strategy for a hybrid energy storage system in a grid-independent hybrid renewable energy system*. Int. Trans. Electr. Energy Syst. 2020, 30, e12262.

[22]. Bandla, P. , Indragandhi ,V. *Analysis of Back To Back (BTB) Converter Control Strategies in Different Power System Applications*: Materials Science and Engineering 906 (2020) 012016 IOP Publishing doi:10.1088/1757-899X/906/1/012016.

[23]. Rick Wallace Kenyona,b , Matthew Bossarta , Marija Markovića , Kate Doubledaya,b , Reiko Matsuda-Dunna,b , Stefania Mitovaa , Simon A. Juliena , Elaine T. Haleb , Bri-Mathias Hodgea,b,⁎ a *Renewable and Sustainable Energy Institute, Department of Electrical, Computer, & Energy*, University of Colorado, Boulder, CO 80309, United States b National Renewable Energy Laboratory, Golden, CO 80401, United State.

[24]. Lee, K.; Kum, D. *The Impact of Energy Dispatch Strategy on Design Optimization of Hybrid Renewable Energy Systems*. In Proceedings of the 2019 IEEE Milan PowerTech, Milan, Italy, 23–27 June 2019; pp. 1–6.

[25]. Robba, M.; Rossi, M. *Optimal Control of Hybrid Systems and Renewable Energies*. Energies 2022, 15, 78. https://doi.org/ 10.3390/en15010078.

[26]. Abusabah I. A. Ahmed, Hong Cheng, Hu aping Liu, Xichuan Lin, Mary Juma Atieno. *Interaction force convex reduction for smooth gait transitions on human power augmentation lower exoskeletons*. Third International Conference on Cognitive Systems and Information Processing (ICCSIP 2016), Beijing, China

[27]. SHAFIUL, A;, FAHAD ,S; ABOUBAKR, S; MOHAMMAD, A. *High-Level Penetration of Renewable Energy Sources Into Grid Utility: Challenges and Solutions*, Digital Object Identifier 10.1109/ACCESS.2020.3031481, 2020.

[28]. Magzoub, M.A.; Alquthami, T. *Optimal Design of Automatic Generation Control Based on Simulated Annealing in Interconnected Two-Area Power System Using Hybrid PID—Fuzzy Control.* Energies 2022, 15, 1540. 2022, 15, 1540.

[29]. Anatole, B; *Regulatory stability and renewable energy investment*: The case of Kazakhstan. https://doi.org/10.1016/j.esr.2020.100484 Received 4 May 2019; Received in revised form 27 February 2020; Accepted 18 March 2020.

[30]. Sabo, A.; Kolapo, B.Y.; Odoh, T.E.; Dyari, M.; Abdul Wahab, N.I.; Veerasamy, V. Solar, *Wind and Their Hybridization Integration for Multi-Machine Power System Oscillation Controllers Optimization*: A Review. Energies 2023, 16, 24.

[31]. Pradeep.; Dr Suresh, C.; Rohit, Ku. G.; Amar ,B. S.; *Impact of Renewable Energy Integration on Power Quality Challenges and Solution* International Journal of Innovative Research in Engineering and Management (IJIREM) ISSN (Online): 2350-0557, Volume-11, Issue-4, August 2024 https://doi.org/10.55524/ijirem.2024.11.4.12 Article ID IJIRD-1338, Pages 95-99.