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Review Paper on Wind Energy Conversion Systems Using DC-DC Converter

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ABSTRACT: In order to prevent the natural environment on the earth, the development of clear energy without pollution has the major representative role in the last decade. By accompanying the of Kyoto protocol, clear energies, such as Fuel Cell (FC), photovoltaic (PV), wind energy, etc., have been rapidly promoted. Nowadays wind energy systems have been used for electricity generation from small house hold consumers to large factories. Investors have started to prefer the establishment of large wind energy systems due to cost, performance and power requirements advantages. Thus, in this paper the wind energy performance is enhanced through using a new adaptive fractional order PI (AFOPI) blade angle controller. The AFOPI controller is based on the fractional calculus that assigns both the integrator order and the fractional gain. The initialization of the controller parameters and the integrator order are optimized using the Harmony search algorithm (HSA) hybrid Equilibrium optimization algorithm (EO). Then, the controller gains (K_p , K_i) are auto-tuned. The validation of the new proposed controller is carried out through comparison with the traditional PID and the Adaptive PI controllers under normal and fault conditions. The fractional adaptive PI improved the wind turbine's electrical and mechanical behaviors. The adaptive fractional order PI controller has been subjected to other high variation wind speed profiles to prove its robustness.

KEYWORDS: Wind Energy, AFOPI, IG, Fractional Order

I. INTRODUCTION

Electricity generation and distribution arrangement came into life since September 1882. The first power plants were run on water or coal. The electricity production sources are classified as conventional and nonconventional energy sources. Conventional energy sources cannot be compensated after their utilization. These energy sources are thermal power, hydropower, nuclear energy and natural gases. The conventional energy sources are exhaustible and highly expensive. These energy sources are not sufficient to fulfill the increasing power demand in the world and also leading to atmospheric pollution. The World needs an alternative solution to meet the power demand. The non-conventional energy sources are used to meet out the power demand. These energy sources are solar power, wind power, tidal power and bioenergy. Among these energy sources, wind is the plentiful and safest non-conventional energy source in the environment which is available freely and friendly. Worldwide it has high attention because the operating cost is low after installing the wind turbine generator [1, 2].

However the output power of wind generator fluctuates due to wind speed variations. This causes serious problem in a stable power distribution network adversely. Wind turbines can either operate at fixed speed or variable speed. For a fixed speed wind turbine, the generator is directly connected to the electrical grid. Fixed-speed wind turbine operate at a near constant rotor speed at all times. The rotor blades are rigidly fixed to the hub, however, they are designed to become aerodynamically stalled at high wind speed, and typically above 25 m/s. Variable speed wind turbine on the other hand have the generator output controlled by power electronics equipment. Thus, it is advantageous as energy harvested increases due to extraction of power at different wind speeds [1]. Several reasons, such as the reduction of the mechanical structure stresses, the acoustic noise and the possibility to control active and reactive power have driven the choice for variable speed operation of wind turbines.

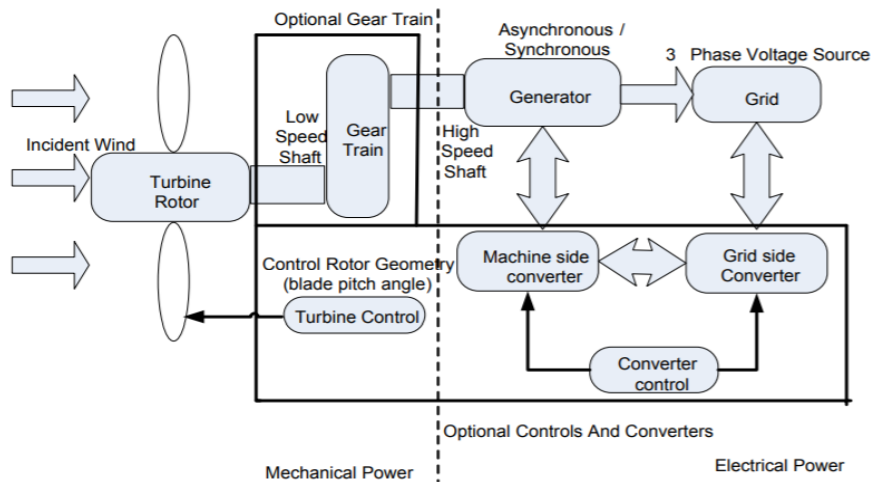


Fig. 1: A typical schematic diagram of a grid connected WECS

Mainly a WECS is an electromechanical system which consists of wind as the source, the turbine, a generator and sink (grid/local load). Wind speed distribution is generally high in hilly areas or near the shore. For such remote locations it may be far off the grid. Economic viability and convenience has given rise to two basic topologies of WECS. These are as follows. Grid connected WEC systems have large installed capacity for its capacity utilization rather than the storage. A schematic diagram of a grid-connected wind energy conversion system is shown in Fig. 1. Isolated systems have small capacity to supply local load in association.

II. TOPOLOGIES OF WECS

The electrical system mainly differs in different types of generators used along with a suitable power electronic converter. Different topologies are described here. Fixed speed induction generator [3] The first kind of turbine uses asynchronous squirrel cage induction generator [4] as shown in Fig. 2. The power produced is kept constant by varying the slip slightly. They are self-exciting without sliprings and can be grid connected without the need of the power electronic devices. Due to some advantages such as simple design, lower cost and easy maintenance, they are commonly used in power system. Capacitor bank is necessary to supplement reactive power of induction generator.

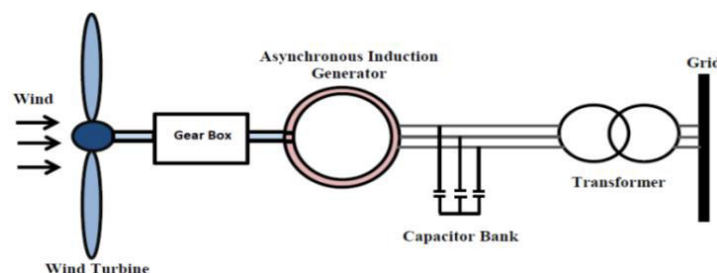


Fig. 2: Fixed speed induction generator

These types of WECS use full scale power electronic equipments. The generator may be permanent magnet synchronous generator (PMSG) or wound rotor type synchronous generator. Instead of directly connecting the stator to the grid, they are connected through rated power electronic converters. The converter is a back-to-back voltage source converter (VSC). The power control can be adjusted by pitch angle control. Due to fully rated power electronic converters they are more costly. Fig. 3 shows synchronous generator with full rated converter.

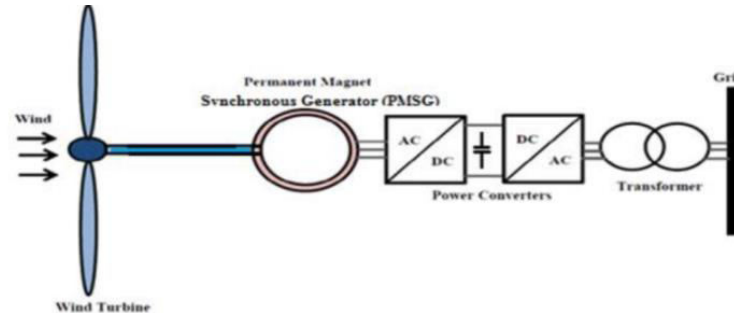


Fig. 3: Synchronous generator with full rated converter

III. LITERATURE REVIEW

Ahmed M. Shawqran et al. [1], one of the most rapidly developing renewable energy systems is wind power. Consequently, a brand-new adaptive fractional order PI (AFOPI) blade angle controller is utilized in this paper to improve wind energy performance. The fractional calculus that determines both the integrator order and the fractional gain serves as the foundation for the AFOPI controller. The Harmony search algorithm (HSA) hybrid Equilibrium optimization algorithm (EO) is utilized in order to optimize the integrator order as well as the initialization of the controller parameters. Then, the regulator gains (K_p ; K_i) are pre-tuned. Under both normal and fault conditions, the new proposed controller is compared to conventional PID and adaptive PI controllers for validation. The electrical and mechanical behaviors of the wind turbine were enhanced by the fractional adaptive PI. To demonstrate its robustness, the adaptive fractional order PI controller has been subjected to additional profiles with high variation in wind speed. The controller demonstrated resistance to system nonlinearity and variations in wind speed profile. Additionally, the proposed controller (AFOPI) ensured uninterrupted generation of wind power in the face of these extreme variations. Also, the dynamic power factual examination of the AFOPI showed expansion in energy caught of around 25 %, and decrease in the standard deviation and root mean square mistake of around 10% contrasted with different regulators.

Frikh Mohamed Lamine et al. [2], Wind power plants are known to have nonlinear dynamics and carry many uncertainties as parameter uncertainties and unknown nonlinear disturbances. So, it is a challenging task to design a robust controller for this system. This paper proposes a robust fractional-order proportional integral (FOPI) controller for maximum power point tracking (MPPT) control of permanent magnet synchronous generator (PMSG)-based wind energy conversion system. A comparison with the classical integer order proportional integral (IOPI) controller has been handled under the same number of parameters design and tuning constraints. This may guarantee the robustness to the loop gain variations of the designed controllers and the desired control performance. Comparison of the two controllers (i.e., IOPI, FOPI) via the simulation tests show that, the IOPI controller designed cannot always be stabilizer to reach flat-phase constraint while FOPI controller designed is always stabilizing.

Shailendra Kumar Tiwari et al. [3], have made an essential cluttered heartbeat position guideline to decrease the apex EMI in SMPS. The proposed an essential confounded carrier time strategy to improve the profitability of DC-DC support converters, and reduced the trading adversities and EMI sufficiently. It has made a randomization procedure solidifying randomized PWM and Sigma Delta PWM propels for drove EMI decline in fly back converter in the extent of 10 to 20 dB μ V over RPWM modulators. Pseudo-subjective progression generator is used to give customized dynamic vacillating to clearing undesired stand by tones in the yield of the SDM.

Miloud Rezkallah et al. [4], have exhibited and analyzed the consonant security of three phase inverter in a force structure. This methodology is useful for the examination of consonant precariousness in a force electronic based force system. The outcomes of non-straight time territory reenactments and theoretical assessment in the repeat space considering the linearized models of inverters with internal control circles affirm the feasibility of this arrangement. This paper presents the displaying, reenactment and control technique of a HPS coordinating a WECS, a sun oriented SPV and a BDG just as a capacity battery intended to guarantee power dependability under all different climate conditions.

José Antonio Aguado et al. [5], the model incorporates wind turbine, photovoltaic boards, PMSG, power converters and most MPPT regulators. P&O calculation is utilized to remove the greatest force from PV and TSR regulator for the WECS. The unique conduct of the proposed HPS is analyzed under various conditions dependent on wind speed variety and sun oriented radiations. The BDG is included uniquely for reinforcement when the SOC is under 45%. A Hysteresis strategy is utilized to control the BDG startup on dependent on the variety of the battery SOC. The created HPS comprises of a 50 W photovoltaic board, 300 W wind turbine, 400 W biodiesel generator and 200 Ah/24 V battery. The resultant model offers a decent system to guarantee power dependability under all conditions utilizing sustainable power sources.

Mostafa Farrokhhabadi et al. [6], sun based electric or photovoltaic innovation is one of the greatest sustainable power assets to produce electrical force and the quickest developing force age on the planet. The natural impacts like temperature, illumination, unique qualities of daylight, soil, shadow, etc influence the presentation of the PV framework. Changes in insolation on boards because of quick environment changes, for example, overcast climate and expansion in surrounding temperature can diminish the PV cell yield power. The PV framework has helpless use productivity so it works at the most MPPs. The fundamental point of this work is to investigate the interface of photovoltaic framework to the heap, the force hardware gadget and the strategy to follow the MPPs of the sun powered board.

Aquib Jahangir et al. [7], nonetheless, the vast majority of the PV power age comes from framework associated establishments, where the force is taken care of in the power organization. Indeed, it is a developing business in created nations, for example, Germany which is world pioneer in PV power age followed by Spain, Japan, USA and Italy. Then again, because of the hardware required, PV power age is more costly than different assets. Governments are advancing it with sponsorships or feed-in taxes, expecting the advancement of the innovation so that sooner rather than later it will get serious. Expanding the proficiency in PV plants in order to build the force created is a key perspective, as it will build the livelihoods, decreasing the expense of the force created, cost moving toward the expense of the force delivered from different sources. Sun powered cells are the fundamental segments of photovoltaic boards. Most are produced using silicon despite the fact that different materials are additionally utilized. Sunlight based cells exploit the photoelectric impact: the capacity of certain semiconductors to change over electromagnetic radiation straightforwardly into electrical flow. The charged particles produced by the episode radiation are isolated helpfully to make an electrical flow by a suitable plan of the construction of the sun oriented cell.

IV. MODELING OF WIND TURBINE

The wind energy captured by the blades was transformed by the wind turbine into mechanic energy. The aerodynamic energy of the wind can be represented as,

$$P_w = \frac{1}{2} \rho A V_w^3 \quad (1)$$

Where,

A = Circular Area

V_w = Wind speed

ρ = Air density

Using the wind aerodynamic energy, aerodynamic power can be produced by the turbine. It can be expressed as

$$P_t = \frac{1}{2} \rho A V_w^3 C_p(\beta, \lambda) \quad (2)$$

Where,

C_p = Power coefficient

β = Pitch angle

λ = Speed ratio

$$\lambda = \frac{wR}{V_w} \quad (3)$$

Where,
w = Turbine rotor speed
R = Turbine Radius
 C_p can be expressed by

$$C_p(\lambda, \beta) = C1\left(\frac{C2}{\lambda_i} - C3\beta - C4\right)e^{-\frac{C5}{\lambda_i}} + C6\lambda \quad (4)$$

Where,
C1 to C6 = Constant on the wind turbine rotor and blade design

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \quad (5)$$

The aerodynamic torque is determined by

$$T_t = \frac{P_t}{w} \quad (6)$$

$$T_t = \frac{0.5\rho\pi R^3 V^2 C_p}{\lambda} \quad (7)$$

The fundamental dynamic equation is described with the following equation

$$J \frac{dw}{dt} = T_t - T_{em} - f_w \quad (8)$$

Where,
 T_{em} = Electromagnetic torque
f = Turbine rotor friction

Then, the wind turbine generator drive that represents the mechanical block can be given by:

$$T_t - T_{em} = J \frac{dw}{dt} + f_w \quad (9)$$

V. METHODOLOGY

Figure 4 shows the multilevel converter modulation methods. The modulation control schemes for the multilevel inverter can be divided into two categories, fundamental switching frequency and high switching frequency PWM such as multilevel carrier-based PWM, selective harmonic elimination and multilevel space vector PWM. Multilevel SPWM needs multiple carriers. Each DC source needs its own carrier. Several multi-carrier techniques have been developed to reduce the distortion in multilevel converters, based on the conventional SPWM with triangular carriers. Some methods use carrier disposition and others use phase shifting of multiple carrier signals. By generalizing, for an 'n' level multilevel inverter, (n-1) carriers are needed. The implementation of the various carrier PWM techniques that is possible for multi-level inverters are [5, 6]:

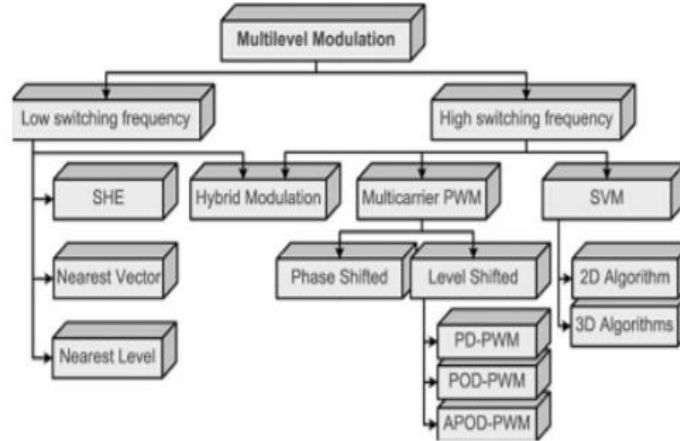


Figure 4: Multilevel converter modulation methods

Level Shifted PWM (LSPWM)

This modulation method is especially useful for NPC converters, since each carrier can be easily associated to two power switches of the converter. LSPWM leads to less distorted line voltages since all the carriers are in phase compared to PSPWM [7]. In addition, since it is based on the output voltage levels of an inverter, this principle can be adapted to any multilevel converter topology. However, this method is not preferred for CHB and FC, since it causes an uneven power distribution among the different cells. This generates input current distortion in the CHB and capacitor unbalance in the FC compared to PSPWM [8, 9]. Figure 5 shows the LS-PWM carrier arrangements.

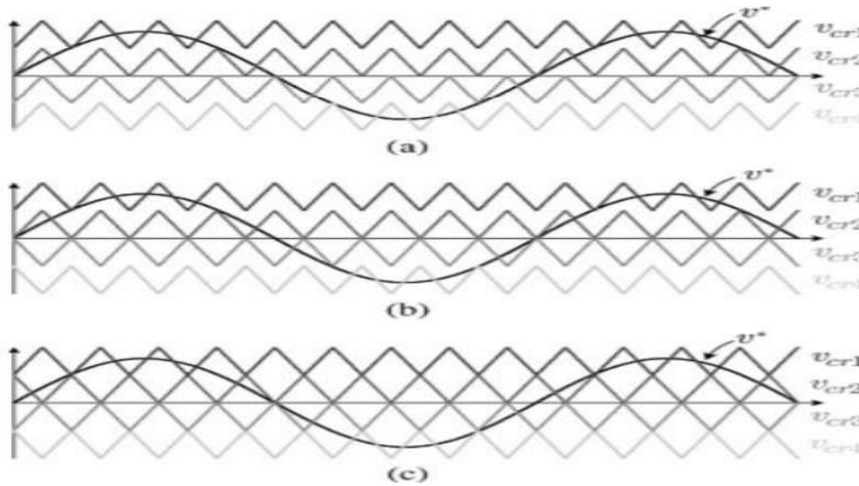


Figure 5: LS-PWM carrier arrangements: (a) PD, (b) POD, and (c) APOD.

Phase Shift Pulse Width Modulation

PWM signals are pulse trains which are applied to the gate of switches to perform the operation of converter. The pulse trains are fixed frequency and magnitude and variable pulse width [10]. There is one beat of settled extent in each PWM period. In any case, the width of the beats changes from period to period as indicated by a regulating signal.

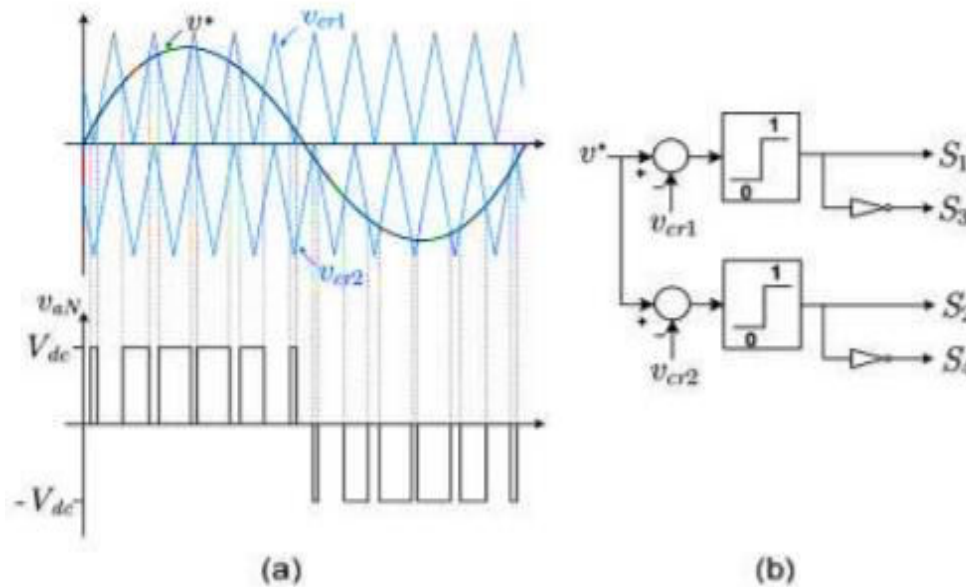


Figure 6: Phase Shift PWM

At the point when a PWM flag is connected to the entryway of a power transistor, it causes the turn on and kills interims of the transistor to change starting with one PWM period then onto the next PWM period as indicated by the same regulating signal and thus working of converter begins. The recurrence of a PWM flag must be substantially higher than that of the regulating signal, the major recurrence, with the end goal that the vitality conveyed to the heap depends generally on the tweaking signal. The control of yield voltage is done utilizing beat width balance [11, 12]. This technique uses a set of carriers that are all phase-shifted. The four triangular carriers are phase-shifted by 90° . Using the same sampling period, it has four times larger switching frequency than that of other techniques. This technique is specially conceived for FC and CHB converters. Since each FC cell is a two-level converter, and each CHB cell is a three-level inverter, the traditional bipolar and unipolar PWM techniques can be used, respectively. Due to the modularity of these topologies, each cell can be modulated independently using the same reference signal [13].

VI. CONCLUSION

The paper presented a new proposed adaptive fractional order PI. The controller acquires the advantage of both: adaptive PI and classical fractional order PI. A validation case study has been carried out to prove the distinction of the new controller with respect to the traditional PID and adaptive PI controllers. The new controller assured its reliability and robustness through surpassing the other controllers with its more stable behavior that is free of oscillations. It also succeeded in making faults ride through with lower steady state errors compared with the conventional adaptive PI.

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