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Survey Paper on Fractional Order and Optimal Control for Wind Energy Conversion Systems

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ABSTRACT: -

Wind energy is progressively gaining awareness as a viable alternative to satisfy expanding power needs while also being cost-effective and environmentally friendly. Because wind is intermittent, an asynchronous generator is required for enhanced power extraction efficiency, and an induction generator (IG) is ideal for this purpose. Wind energy is one of the most rapidly growing renewable energy sources. As a result, the performance of wind energy is improved in this article by employing a new adaptive fractional order PI (AFOPI) blade angle controller. The fractional calculus is used to assign both the integrator order and the fractional gain in the AFOPI controller. The Harmony search algorithm (HSA) hybrid Equilibrium optimization algorithm is used to improve the controller parameter initialization and integrator order (EO). The controller gains (Kp, Ki) are then auto-tuned after that. The suggested new controller is validated by comparing it to classic PID and adaptive PI controllers under normal and fault situations. The fractional adaptive PI enhanced the electrical and mechanical characteristics of the wind turbine. To demonstrate its robustness, the adaptive fractional order PI controller was exposed to various high variation wind speed profiles.

Keywords: - Wind Energy, AFOPI, IG, Fractional Order

INTRODUCTION

The supply of fossil fuels is depleting. In the current situation, power generation must meet not just demand but also the needs of the environment. Wind energy conversion is regarded the most favorable renewable energy source in this scenario. This is because wind energy is non-polluting, efficient, and cost-effective when compared to its competitors, such as solar power systems. A wind energy conversion system (WECS), which comprises of a wind turbine and a generator that generates AC power, can convert the kinetic energy contained in wind to electrical power.

The growing use of wind energy has resulted in the creation of a number of dynamic WECS models. In response to the desire for growing usage of renewable energy, wind turbine technology has also advanced rapidly [1]. The output power of a wind generator, on the other hand, varies with wind speed. This has major consequences in a stable power distribution network. Wind turbines can run at a constant speed or at a variable speed. The generator of a fixed-speed wind turbine is directly connected to the electrical grid. Fixed-speed wind turbines have a rotor speed that is nearly constant at all times. Although the rotor blades are securely attached to the hub, they are designed to get aerodynamically stopped at high wind speeds, typically greater than 25 m/s.

The generator output of a variable speed wind turbine, on the other hand, is controlled by power electronics equipment. As a result, it is favorable as the amount of energy captured increases as a result of power extraction at various wind speeds [1]. Variable speed operation of wind turbines has been chosen for a variety of reasons, including the reduction of mechanical structure strains, acoustic noise, and the ability to adjust active and reactive power.

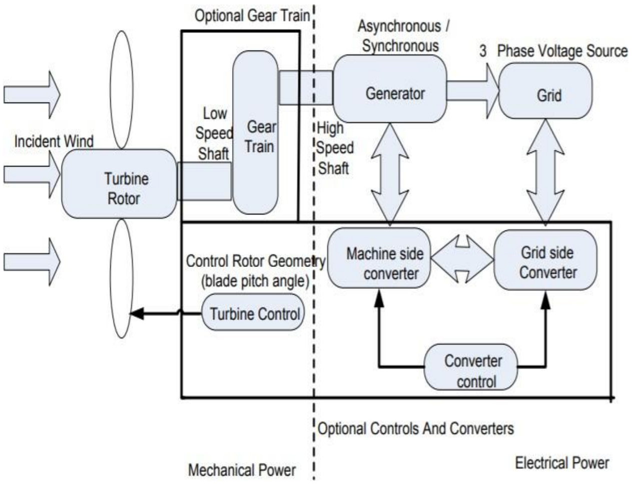

Fig. 1: A typical schematic diagram of a grid connectedWECS

A WECS is primarily an electromechanical system that includes a wind source, a turbine, a generator, and a sink (grid/local load). In hilly terrain or near the coast, wind speed distribution is often high. It's possible that it's off the grid in such a remote place. WECS has two primary topologies based on economic viability and convenience. The following are the details. WEC systems connected to the grid have a significant installed capacity for capacity use rather than storage. Figure 1 shows a schematic diagram of a grid-connected wind energy conversion system. In association, isolated systems have a limited capacity to provide local load

TOPOLOGIES OF WECS

Different types of generators, as well as an appropriate power electronic converter, are employed in the electrical system. Various topologies are described in this article. Induction generator with a fixed speed [3] As shown in Fig. 2, the first type of turbine employs an asynchronous squirrel cage induction generator [4]. By adjusting the slip slightly, the power produced remains constant. They can be grid linked without the need of power electronic equipment and are self-exiting without the use of sliprings. They are extensively used in power systems due to several advantages including as simple design, low cost, and ease of maintenance. A capacitor bank is required to enhance the induction generator's reactive power.

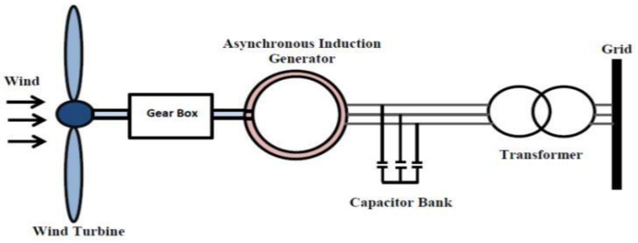

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Fig. 2: Fixed speed induction generator

Full-scale power electronic equipment is used in these WECS. A permanent magnet synchronous generator (PMSG) or a wound rotor type synchronous generator can be used. Rather than connecting the stator directly to the grid, they are connected via rated power electronic converters. The voltage source converter is a back-to-back converter (VSC). Pitch angle control can be used to change the power control. They are more expensive since they use fully rated power electronic converters. A synchronous generator with a full-rated converter is shown in Figure 3.

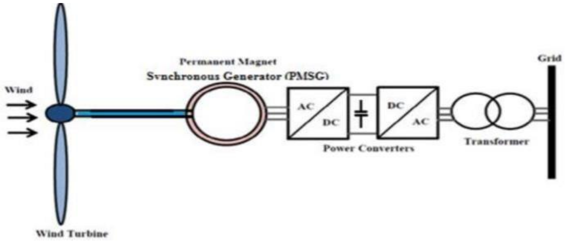

Fig. 3: Synchronous generator with full rated converter

LITERATURE REVIEW

Wind power facilities are known to exhibit nonlinear dynamics and carry various uncertainties such as parameter uncertainties and unknown nonlinear disturbances, according to Frikh Mohamed Lamine et al. [1]. As a result, designing a reliable controller for this system is a difficult challenge. The maximum power point tracking (MPPT) control of a permanent magnet synchronous generator (PMSG)-based wind energy conversion system is proposed in this study using a robust fractional-order proportional integral (FOPI) controller.

Under the same number of parameters design and tuning limitations, a comparison with the classic integer order proportional integral (IOPI) controller was made. This may ensure the planned controllers' robustness to loop gain variations and the necessary control performance. Simulation investigations comparing the two controllers (IOPI and FOPI) reveal that the IOPI controller cannot always be stabilized to reach flat-phase constraint, but the FOPI controller is always stabilizing.

To reduce the apex EMI in SMPS, Shailendra Kumar Tiwari et al. [2] developed an important congested heartbeat position guideline. To boost the profitability of DC-DC support converters, the authors developed an essential confounded carrier time method that lowered trading adversities and EMI enough. It has developed a randomization process that solidifies randomized PWM and Sigma Delta PWM propels for a 10 to 20 dBV EMI reduction in flyback converters over RPWM modulators. To supply customized dynamic vacillating to remove undesirable stand by tones in the yield of the SDM, a pseudo-subjective progression generator is implemented.

Miloud Rezkallah and colleagues [3] demonstrated and examined the consonant security of a three-phase inverter in a force structure. This method can be used to investigate consonant precariousness in a force electronic-based force system. The results of non-straight time territory reenactments, as well as a theoretical assessment in the repetition space using linearized models of inverters with internal control circles, show that this structure is feasible. The showing, reenactment, and control approach of an HPS coordinating a WECS, a solar orientated SPV, and a BDG as a capacity battery meant to ensure power dependability under all climate situations is presented in this study.

The model includes wind turbines, solar boards, PMSG, power converters, and most MPPT regulators, according to José Antonio Aguado et al. [4]. For the WECS, a P&O calculation is used to remove the most force from the PV and TSR regulators. The suggested HPS's distinctive behavior is investigated under a number of situations, including wind speed variation and sun orientated radiations. When the SOC is less than 45 percent, the BDG is added only for reinforcement. The BDG startup is controlled using a hysteresis method that is based on the battery SOC range. A 50 W photovoltaic board, a 300 W wind turbine, a 400 W biodiesel generator, and a 200 Ah/24 V battery make up the HPS. The resulting model provides a reasonable mechanism for ensuring power reliability under all scenarios while employing renewable energy sources.

Sun-based electric or photovoltaic innovation, according to Mostafa Farrokhabadi et al. [5], is one of the greatest sustainable power assets for producing electrical force and the fastest developing force age on the globe. The presentation of the PV framework is influenced by natural factors such as temperature, illumination, distinctive properties of daylight, soil, shadow, and so on. Changes in insolation on boards as a result of rapid environmental changes, such as a gloomy climate or an increase in surrounding temperature, can reduce PV cell yield power. Because the PV framework has helpless usage productivity, it may be used at a wide range of MPPs. The main goal of this research is to look into the photovoltaic framework's interface with the heap, the force hardware device, and the technique for following the MPPs of the sun-powered board.

However, according to Aquib Jahangir et al. [6], the most bulk of PV power generation comes from framework-related establishments, where the force is managed by the power organization. Indeed, it is a growing industry in developed countries, such as Germany, which is the world leader in PV power generation, followed by Spain, Japan, the United States, and Italy. PV power generation, on the other hand, is more expensive than other assets due to the hardware required.

Governments are promoting it by sponsorships or feed-in tariffs, anticipating that the innovation would grow and become major sooner rather than later. Expanding PV plant proficiency in order to increase the force created is a crucial perspective, as it will increase livelihoods while lowering the cost of the force created, with the cost shifting toward the cost of the force given from various sources. The basic components of photovoltaic boards are solar-powered cells. Despite the fact that other materials are used, silicon is used in the majority of cases. Solar cells take advantage of the photoelectric effect, which is the ability of certain semiconductors to convert electromagnetic radiation directly into electrical current. A appropriate plan of the construction of the sun orientated cell helps to isolate the charged particles created by the episode radiation in order to make an electrical flow

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,

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

Where,

A = Circular Area

V_w = Wind speed

$\boldsymbol{\rho}$ = Air density

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

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

Where,

C_p = Power coefficient

B = Pitch angle

ʎ = Speed ratio

$$\lambda = \frac{wR}{Vw} \qquad (3)$$

Where,

w = Turbine rotor speed

R = Turbine Radius

C_p can be expressed by

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

Where,

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

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

The aerodynamic torque is determined by

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

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

The fundamental dynamic equation is described with the following equation

V METHODOLOGY

The term "phase-locked loop" refers to a control device that generates an output signal whose phase is related to that of an input signal. It's best to think of it as an electronic circuit made up of a variable frequency oscillator and a phase detector, however there are many variations. When the phase of the output periodic signal differs from the phase of the input periodic signal, the phase detector adjusts the oscillator to maintain the phases equal. Bringing the output signal back toward the input signal for comparison is referred to as a feedback loop because the output is "fed back" toward the input, producing a loop.

A looped feedback device with a VCO, phase detector, and low pass filter is known as a PLL. The VCO is required to reproduce and monitor the frequency and phase at the input while it is locked. The phase lock loop (PLL) is a control device that allows one oscillator to monitor the output of another. A phase discrepancy between the input and output is possible, but the frequencies must track perfectly when locked.

Benefits of PLL

- Eliminates the problem of frequency drift.
- Increase battery life of product
- Less manufacturing cost
- PLL System are very important in generating accurate and stable frequency.

A sequence-based controller with a reactive power compensation mechanism is presented to control the voltage at PCC.This approach uses DC-link voltage, filter capacitor value, PCC voltage, and current as inputs to construct the dq component of sequence current references. The DC-link voltage of the inverter is initially regulated to generate the d part of positive sequence current. The filter capacitance and positive sequence voltage at PCC are used to compute the reactive power and voltage (Q–V) characteristic of the reactive power compensator. The q component of positive sequence current is determined by comparing the measured reactive power to the reference. The negative and zero series current references are measured using the PCC voltage controller. The negative and zero sequences' voltage references are all set to zero. In the sequence current controller, the created individual sequenced reference current is compared to the inverter output current and processed in the compensator. The control signal is made by combining the adjusted signal with the feed-forward compensation signal. Similarly, the control signals of all sequence controllers are divided by half the DC-link voltage and transformed to abc type. To generate switching pulses for the inverter, the abc type of the generated signal is supplied into a pulse width modulator (PWM).

VI. CONCLUSION

A new adaptive fractional order PI was proposed in the paper. The controller benefits from adaptive PI as well as standard fractional order PI. A validation case study was conducted to demonstrate the novel controller's differentiation from classic PID and adaptive PI controllers. The new controller ensured its dependability and robustness by outperforming existing controllers with more steady and oscillation-free performance. In comparison to the traditional adaptive PI, it was also successful in allowing defects to pass through with fewer steady state errors

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