Improve performance of DFIG based WECS system with ABC algorithm based STATCOM

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ABSTRACT: This paper proposes a method to improve the performance and voltage stability of a grid connected doubly fed induction generator (DFIG) based wind energy conversion system (WECS) using a static synchronous compensator (STATCOM). The efficacy of the STATCOM predominantly depends on the precise tuning of its PI control loops. However, due to the nonlinear and time-varying nature of modern power systems, conventional PI tuning techniques often yield suboptimal performance. To address these limitations, the artificial bee colony (ABC) algorithm is implemented in this work. The ABC algorithm is an intelligent optimization technique it optimally tunes the PI parameters that precisely operate the voltage source converter (VSC) control structure within the STATCOM. Due to stochastic search capabilities the ABC algorithm can adapt to dynamic grid conditions more effectively than traditional methods.In this framework, each "food source" represents a candidate set of controller gains, while the objective function specifically the Integral of Time-Weighted Absolute Error (ITAE)evaluates the STATCOM's performance regarding PCC voltage regulation, reactive power support, and DC-link voltage stability. By effectively balancing exploration and exploitation, the ABC algorithm is uniquely suited for such nonlinear, multimodal optimization problems. The proposed strategy significantly enhances reactive power compensation and low-voltage ride-through (LVRT) capability during transient grid disturbances.

KEYWORDS: LVRT, STATCOM, DFIG, ABC, VSC.

I.INTRODUCTION:

The flexible AC transmission system (FACTS) gadgets are used to beautify the LVRT within the electricity gadget and reduce electricity oscillation. Because of its high performance and ability to inject reactive power, the STATCOM-based FACTS device is essential to increasing the LVRT of the DFIG [1]. Electrical energy systems use the STATCOM, a electricity electronic-primarily based FACTS device, to manipulate reactive electricity and enhance voltage stability. Its function as a shunt-linked device is to fast regulate for reactive power and reduce voltage fluctuations introduced on by numerous disturbances inclusive of switching operations, network faults, and load versions [2]. Fig. 1 shows the grid integration of DFIG and STATCOM. By presenting reactive energy to the grid, the STATCOM employs excessive-strength electronics such insulated gate bipolar transistors (IGBTs) to manipulate the voltage level [3]. The STATCOM's VSC makes use of diverse styles of regulators to improve the grid-connected wind farm's efficiency. For the STATCOM to improve the DFIG's performance, fuzzy logic and proportional-quintessential by-product controller (FLC-PID) are recommended. Nevertheless, the gadget's complexity is multiplied with the aid of the PID-FLC [4]. The grid-related DFIG-WECS's performance is greater through the STATCOM's synthetic neural network (ANN)-based manage topology [5].

However, the ANN's implementation of this technique may want to take a while. PI controllers had been utilized by severa authors inside the STATCOM voltage supply converter (VSC) to enhance the grid-linked wind farm's robustness, low parameter putting, and electricity excellent [6], [7]. Nevertheless, the PI controller can not function in a nonlinear dynamic system and is extraordinarily touchy to changes in parameters. In order to as it should be tune the PI controller in grid-linked wind generators, numerous optimization topologies, such as particle swarm optimization (PSO), sunflower optimization strategies, and genetic algorithms (GA), are used [8], [9]. Furthermore, the golden eagle optimization method is used to regulate the PI controller to be able to enhance the overall performance of the wind turbine (WT) that employs a everlasting magnet synchronous generator (PMSG). Additionally, the STATCOM makes use of the shuffled frog leaping (SFLA) set of rules to improve the exceptional of electricity in the grid-connected wind farm. In addition, the PSO-based totally hybrid PI-FLC is employed to beautify the micro grid-connected STATCOM's performance [10].

However, those optimization strategies' major drawbacks are (1) their sluggish fee of convergence, (2) their extended processing attempt, (3) their decreased accuracy at a regular-state, and (four) their computational complexity [11]. Adaptive filtering algorithms (AFAs) are therefore used in the electricity device due to their truthful design, low computing complexity, and excessive convergence velocity [12].

II.LITARATURE SURVEY:

1) Model reference adaptive control of STATCOM for grid integration of wind energy systems

In order to enhance the combination of pushed wind turbine-based totally self-excited induction generators (SEIG) into electric grids, this take a look at shows a version reference adaptive manipulate (MRAC) of static synchronous compensator (STATCOM). Grid-incorporated SEIG's reactive electricity glide is controlled through an MRAC-based Massachusetts Institute of Technology adaptive mechanism. The extraordinary operating situations within the wind strength conversion device are addressed by using the STATCOM's voltage-supply inverter sinusoidal pulse width modulation. As a quit end result, the low-voltage journey thru (LVRT) capacity is advanced. Faults at the thing of not unusual coupling many of the generator and the grid are the reason of the unusual working conditions. The counseled MRAC is contrasted with genetic set of guidelines (GA)-tuned proportional-necessary (PI) controllers. A a part of the Egyptian 220 kV network integrated with the Zafarana Wind Energy System is used to evaluate the cautioned STATCOM control for enhancing grid-covered SEIG. In assessment to a static PI controller whose parameters are adjusted by using way of GA in the voltage, cutting-edge, and wind generator velocity responses, the findings show an effective and reliable advised adaptive manipulate common performance. Additionally, the suggested controller improves each the LVRT functionality and the wind mills' functionality to perform continuously below numerous bizarre working situations.

2) Transient Stability and Voltage Regulation in Multimachine Power Systems Vis-à-Vis STATCOM and Battery Energy Storage

In order to enhance the brief stability of massive-scale multimachine strength structures the usage of synchronous and doubly-fed induction mills (DFIGs), this research investigates the usage of

STATCOM and battery power storage. For multimachine energy structures, a passivity-based manipulate layout method known as interconnection and damping undertaking passivity-based totally manipulate (IDA-PBC) is created. Its effectiveness is classified on a -place device that includes two synchronous turbines (SGs), DFIG, and a STATCOM/battery strength garage system. This paper's 3 primary contributions are: 1) utilising a battery power storage gadget and STATCOM to improve temporary stability and supply voltage control with SG and DFIG; 2) showcasing using nonlinear manage theory (extra especially, the IDA-PBC method) for the layout of a stabilizing remarks controller in large-scale strength systems to enhance temporary gadget performance; and three) growing a technique that can employ the greater levels of freedom in big-scale power structures to similarly decorate system overall performance, especially the dynamic temporary performance of the gadget and the transient stability margin [measured through critical clearing time (CCT)]. The overall performance of the cautioned control scheme following the prevalence of considerable disturbances is assessed and contrasted with a traditional electricity device stabilizer and a comments linearizing controller for you to gain power angle balance alongside the simultaneous law of frequency and voltage.

III.PROPOSED SYSTEM: Fig.1 illustrates the schematic structure of the grid interfaced DFIG based WECS. A WECS primarily consists of aerodynamic, mechanical, and electrical components.

- Aerodynamic Components: Include the wind tower and turbine blades.
- Mechanical Components: Comprise the gearbox and generator assembly.
- Electrical Components: Consist of power electronic converters and control systems.

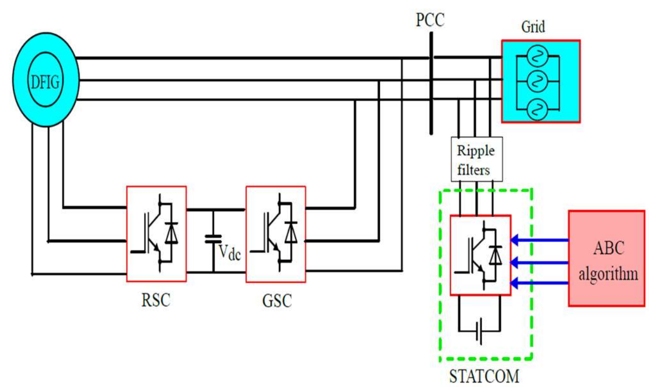


Fig.1 Block diagram of grid connected DFIG based WECS

Wind power generation efficiency is significantly influenced by environmental and structural variables, such as wind availability and tower height. These systems typically operate in two modes: Islanding Mode, the system operates independently to satisfy local load demands. Grid-integrated mode, The WECS is synchronized with the utility grid, allowing for power exchange and balancing of the total load demand. Due to intermittent nature of wind, the power produced by the wind is unstable. The DFIG architecture addresses this by connecting the stator directly to the grid while the rotor is interfaced through back-to-back power converters.

The GSC is primarily responsible for regulating the DC-link voltage by adjusting the active power exchanged with the grid. The GSC converter regulates the power factor at the PCC by providing reactive power support. The RSCcontrols the rotor current to decouple and control the generator's active (P_s) and reactive (Q_s) power. It allows the DFIG to remain synchronized with the grid even as wind speeds change.During normal operation, the power injected by the RSCinto the DC link is balanced by the power transferred to the grid by the GSC, thereby keeping the DC-link voltage at its reference value.

DFIGs are broadly classified into four types: Standard, Cascaded, Single-frame Cascaded, and Brushless. Among these, the Brushless DFIG is frequently utilized for high-reliability WECS applications. The mathematical model of a DFIG in the dq synchronous reference frame is expressed as follows:

$$V_{sd} = Ri_d - w_s Øs + \frac{dØs}{dt}$$

$$V_{rq} = Ri_q - w_r Ør + \frac{dØr}{dt}$$

Where V_{sd} and V_{sq} are the stator voltages in the dq axis, and i_{sd}, i_{sq} are the stator currents. The active (P_s) and reactive (Q_s) power produced by the DFIG are mathematically expressed as:

$$Ps = 0.6\,(V_{sd}i_d + V_{sq}i_{sq})$$

$$Qs = 0.6\,(V_{sq}i_d - V_{sd}i_q)$$

As indicated by the power equations, P_s and Q_s are directly dependent on the stator and rotor current components. This paper proposes an ABC algorithm-based STATCOM to enhance system stability. During periods of wind intermittency, the STATCOM optimized by the ABC algorithm act as a fast-acting compensator at the PCC. This ensures voltage stability and improves the power quality delivered to the grid.

3.1 Proposed ABC approach:

In a VSC-based STATCOM, multiple PI controllers are employed in cascaded control loops to regulate PCC voltage, reactive power injection, grid current, and DC-link voltage under nominal and grid fault conditions. The performance of these controllers is highly dependent on appropriate tuning of controller gains. Conventional tuning approaches are often inadequate due to the nonlinear, time-varying nature of power systems and grid disturbances. Hence, metaheuristic optimization techniques such as ABC are adopted to determine optimal controller parameters that minimize a selected objective function.

Fig.2 illustrates the proposed ABC control scheme for operating the STATCOM. The three-phase PCC voltage $V_{PCC}$is processed to extract the grid frequency and electrical angle ωt using a PLL. This transformation enables independent control of active and reactive power, as the dq components are decoupled under grid-voltage-oriented control. The outer control loops generate current references in the abc framework through two parallel control paths. This loop ensures power balance between the AC and DC sides of the converter. Hence, regulation the PCC voltage and DC link voltage at constant is achieved.

In the ABC framework, each food source represents a candidate solution vector

$$\mathrm{X}_i = [K_{p1}, K_{i1}, K_{p2}, K_{i2}, \dots]$$

corresponding to the STATCOM control parameters. The quality of each food source is evaluated using an objective function, typically the ITAE, defined as

$$J = \int_0^T t \ | \ e(t) \ | \ dt,$$

where $e(t)$denotes the control error (dc-link voltage deviation).

During the employed and onlooker bee phases, new candidate solutions are generated using neighborhood perturbation,

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj}), \phi_{ij} \in [-1,1],$$

and are accepted based on a greedy selection mechanism that favors lower ITAE values. Stagnated solutions are replaced in the scout bee phase to enhance global exploration. The globally optimal controller parameters,

$$\mathrm{X}_{\mathrm{best}} = \arg\min_{\mathrm{X}_i} J(\mathrm{X}_i),$$

The outputs of the ABC controllers are then converted into dq current references and compared with the actual dq currents. The resulting current errors are processed through discrete PI controllers, which generate the reference dq voltages required for the converter operation. These dq voltage references are subsequently transformed back into abc quantities using the inverse dq0 transformation synchronized with the grid angle ωt.

The ABC-optimized STATCOM provides faster voltage recovery, improved reactive power support, and enhanced LVRT capability, thereby significantly improving the dynamic performance of the grid-connected DFIG-WECS during nominal and grid disturbances operating conditions.

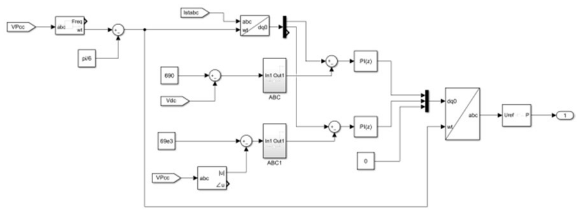
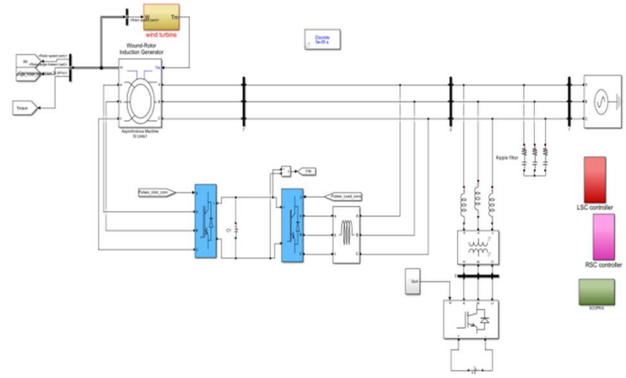
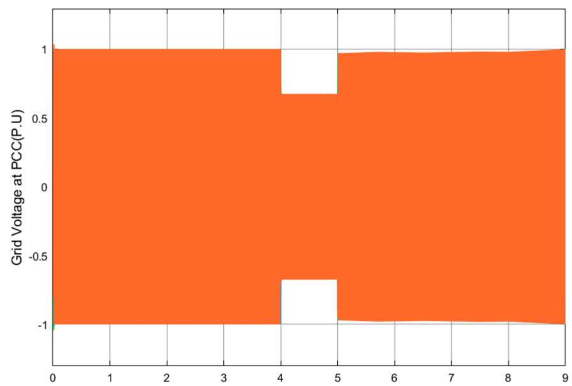


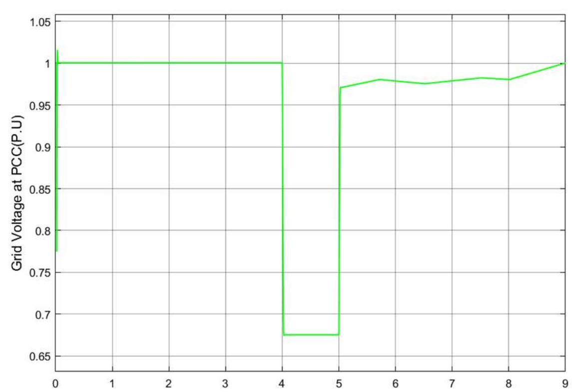
Fig.2 Proposed ABC control scheme.

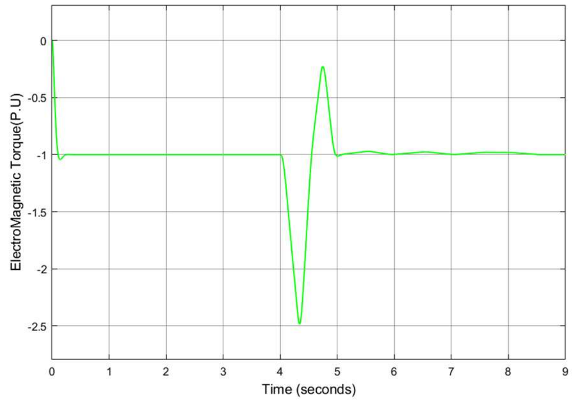
IV.SIMULATION RESULTS:

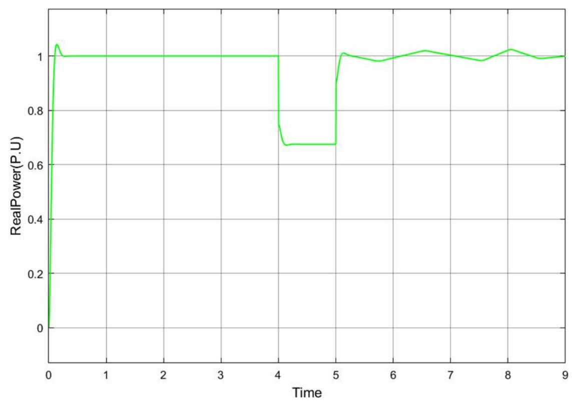
Fig. 3 presents the MATLAB/Simulink model of the proposed ABC-based STATCOM compensator for a grid-connected DFIG-WECS system. To evaluate the effectiveness of the control scheme, the system was subjected to severe disturbances, including symmetrical grid faults. The results demonstrate that the proposed ABC controller effectively manages the power flow between the wind farm and the utility grid while maintaining the DC-link voltage at its steady-state value. Regulating a constant DC-link voltage is critical, as it ensures seamless power transfer, stable converter operation, and the decoupled control of the RSC and GSC within the WECS.

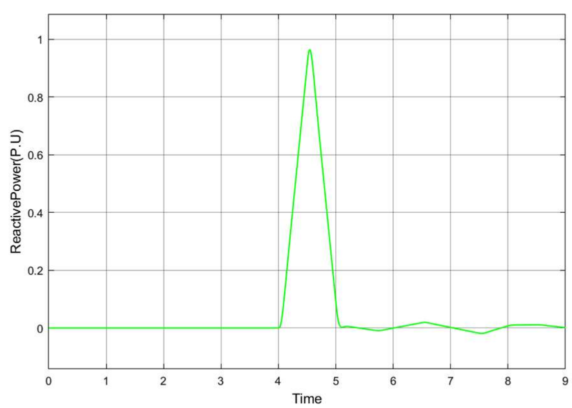


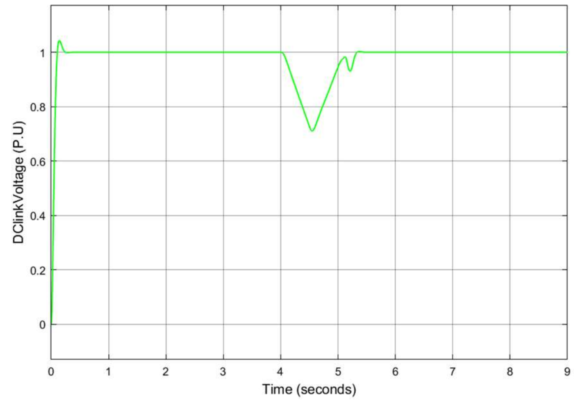












V.CONCLUSION: The integration of an ABC-optimized STATCOM into the DFIG-based WECS provides a robust solution for maintaining grid stability under transient conditions. By dynamically adjusting reactive power compensation, the controller effectively mitigates the adverse effects of symmetrical grid faults, ensuring that both electrical and mechanical parameters remain within safe operational limits. The simulation results confirm that the proposedABC controller based STATCOM provides superior dynamic response and enhances the LVRT capability. Besides, the proposed method stabilizes the DC-link voltage quickly, suppresses electromagnetic torque oscillationsand robust LVRT performance of the DFIG-based WECS under severe grid disturbances.Ultimately, this approach improves the overall reliability and transient power quality of wind energy systems interfaced with the utility grid.

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