Optimal Controller Tuning for P&O Maximum Power Point Tracking of PV Systems using PSO Algorithm

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Abstract

Energy production and transmission have had to increase ruthlessly in recent years due to resource and environmental constraints, while demand for electric power has surged significantly. As a result of several transmission lines being substantially loaded, power system stability became a limiting factor in electric power transmission. It's vital to keep the electrical grid safe and stable. Thus, it's not a simple assignment. The FACTs devices are used to manage power and attenuate oscillations. This study explains how to use Matlab Simulink to benefit from the modified particle swarm optimization (PSO) approach to stabilize MPPT with UPFC by employing the PI-C and MATLAB Simulink parameters that build optimal proportional-integral controllers. When a power system failure occurs, the UPFC investigates by emulating the power system's operating characteristics using the two recommended approaches. Compared to existing techniques, the proposed PSO technicality improves the system's reactivity and reduces the amount of undershoot and overshoot in transitions. The results suggest that using this strategy significantly enhanced the simulation model's transient stability.

Keywords:PSO, PI-C, UPFC

Introduction

The FACTs controller can make quick changes to the network's conditions. Line interruptions are unnecessary because the current network can be utilized efficiently. In [1], many FACT devices used to improve the dynamic stability of MMPS were calibrated and modeled to their best performance. Currently, FACTS equipment is regulated individually. The electrical system now has more control due to new concepts and technology that have enhanced power transmission dependability and capacity. The controller provides more convenient and quieter current coefficients, boosting system robustness. The upstream power factor corrector controls the transmitter voltage, line impedance, and phase angle (UPFC). When favorably or interactively regulated, the UPFC can create both positive and negative power injections. The increased power flow management and stability provided by the super control system may improve system performance [2]. This strategy has previously been used to improve short-term and long-term performance while also lowering starting noise. This study proposes an enhanced M-PSO with linearly decreasing inertia weights (new) and acceleration factors (latest) using unknown inertia weights and acceleration factors (Cnew1, Cnew2). With two PI scenarios to choose from (PI-C-PSO and PI-PSO), it is clear how the PI is managed (PI-CM-PSO). During the transition, these techniques reduced stability and undershoot, demonstrating its long-term efficacy. [3]

The controller tuning technique was tested on a conventional PV array and MPPT controller utilizing a topological DC-DC boost converter circuit. The increased DC connection voltage of the DC-DC converter increases the maximum output capacity of the solar array. Instead of using a boost converter, leaving the array voltage at its maximum power point is preferable. The working cycle of the boost converter switch can be changed to accomplish this. The P&O MPPT method is commonly used to generate the reference voltage. MPPT requires increasing the matrix voltage to a predefined level. Using data from the system itself is one technique to optimize the system controller. Using the PV voltage supplied by the supervisor, the P&O MPPT algorithm establishes a reference voltage (Vref) (Vpv). The system instantly corrects any signals that should not be there. The PWM operation cycle for a DC-DC boost converter is generated by comparing the controller output signal to a high-frequency carrier signal. The boost converter is put to the ultimate test throughout this operation cycle. By altering the controller's parameters in either mode, you can switch between them. Using naturally inspired optimization approaches, many optimized controller parameter sets with pre-specified performance indicators are created, and the ideal parameter set is then picked.

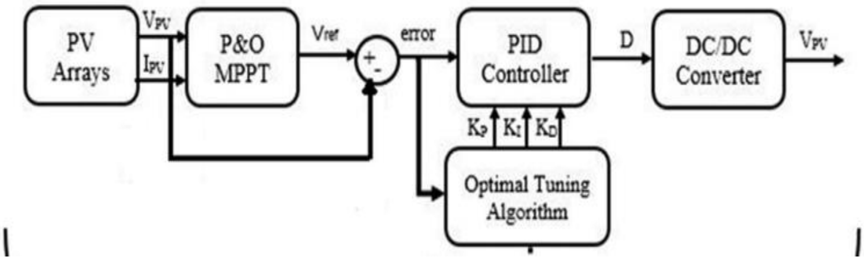

Figure 1: Block Diagram of PV Panel with Optimum Tuning

1 Different Sources of Renewable Energy

1. Wind Power

Wind turbines can be used to harness the power generated by the airflow [7]. The power of turbines used per day is around 600 kW to 5 MW. Because power output is a function of wind speed, it amplifies hastily as wind speed increases. Recent advances have become wind turbines, which are more resourceful than better aerodynamic construction.

2 Solar Power

When British astronomer John Herschel [8] traveled to Africa, he cooked with sun collectors to heat water. There are two primary methods for utilizing solar energy. First, using solar energy, the gathered heat can generate power or heat the atmosphere. Solar radiation, the essential energy source, can also be transformed into electrical energy. This is a possibility. This can be accomplished using solar photovoltaic cells or solar power stations.

3 Small Hydropower

High-power generators, such as power plants with up to 10 MW, are regarded as renewable energy sources [9]. Hydraulic turbines convert the stored energy in dam water into usable electricity. Water kinetic energy must be gathered without the use of dams in order to use flood power.

4 Biomass

Photosynthesis is the process by which plants obtain energy from the sun. When these plants are burned, a large amount of energy is released. Solar energy can be stored and used when needed by using biomass as a natural battery.

5 Geothermal

A geothermal power plant converts waste heat into thermal energy by storing it in its crust and mantle. The gradient formed allows heat to be continually transmitted from the ground's surface to the base. This fuel can generate electricity by heating water to extremely high temperatures and then driving a gas turbine with the steam. Even though current technological breakthroughs have gained popularity [10], places near tectonic plate boundaries frequently experience considerable losses in geothermal energy.

2 Renewable Energy Trends across the Globe

As a result of the current economic trend, renewable energy is on the rise. Figure 1.3 shows that renewable energy and biomass energy have accounted for a significant share of existing renewable energy consumption during the last three years. As new solar photovoltaic information or reliable project introductions have developed in countries/regions like Germany and Spain, the solar photovoltaic market has grown dramatically. The solar photovoltaics market is expected to increase faster than that of other renewable energy sources. The number of countries that have set political targets to use renewable energy to fulfill their assigned duties has grown from 45 in 2005 to more than 115 in 2019. It is an ambitious ambition to use renewable energy to power 30–90% of its overall output.

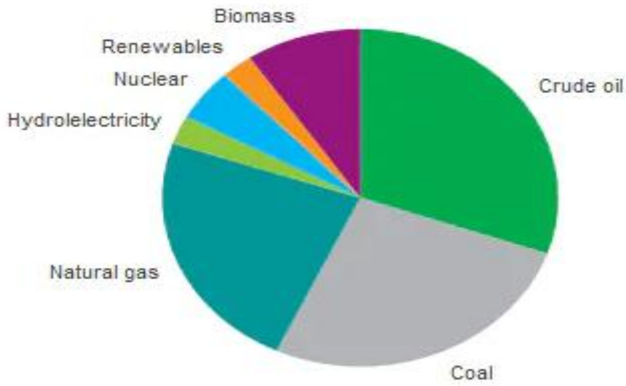

Figure 2: Global Energy Consumption in The Year 2020

LITERATURE SURVEY

Jinjiao Lin et al. (2018) FACTS devices, such as the Unified Power Flow Controller (UPFC), can control system voltage and power flow in a timely, precise, and continuous manner, providing a viable means to circumvent present city-scale power grid expansion constraints. This paper examines the approach for UPFC system control because it is a direct link and a critical difficulty for the application. In this research endeavour, a multi-mode coordination system control technique is also developed for optimizing power flow distribution under various power grid operating conditions. Furthermore, the strategy's actual control effect on the power grid is demonstrated by completing the Western Nanjing Power Grid's UPFC project. This provides hands-on experience for popularizing and deploying UPFC [42].

A. Hamache et al. (2019) synthesize a UPFC (unified power flow controller) device controller using the Decentralized Discrete-Time Quasi Sliding Mode Control (DDTQSMC) technique to track actual and reactive power references over an EHV link. The DDTQSMC control intends to improve on existing linear continuous controls in terms of durability and transient precision. This application makes use of discrete state dynamics and a discrete sliding mode approach developed at UPFC. Before building the DDTQSMC controller, which employs plant dynamics and discrete-time sliding mode theory, a discrete state-space model of the UPFC's dynamic behaviour is required. Numerical simulation reveals that the suggested controller is accurate, effective, and long-lasting when direct an EHV interconnection using the DDTQSMC approach [43].

G. Shahgholian et al. (2017) unified power flow controller, often known as the FACTS, is a popular alternative for increasing transmission capacity and improving power system stability. This article examines the impact of UPFCs on power flow regulation in electrical power networks. The UPFC phasor model is what we employ. This study's simulations were all performed in MATLAB/SIMULINK [44].

Lin Jinjiao et al. (2018) The ability of the UPFC project to manage and perform is dependent on how it is used. The UPFC project control system of the Southern Suzhou 500kV power grid is being examined and analyzed. To begin, we'll go over the UPFC project's position on several problems. The primary control performance index and function requirements are then discussed. Following that, a UPFC fundamental control system is proposed in accordance with the application criteria of the Southern Suzhou UPFC grid. When a power grid has a substantial defect, the commissioning procedure examines the project control system's steady-state and dynamic control performance for each primary electrical quantity, as well as the system's ability to ride through failures. It investigates the impact of the control system on the UPFC of the southern Suzhou 500kV power grid, gathering critical references and data for the development of follow-up engineering and standardization [45].

P. Rajivgandhi et al. (2019). Transmission networks are critical in regulating reactive power in a utility grid that supplies energy to a system. With the advancement of wind storage technology, wind-connected turbines will be required to generate reactive power during periods of high demand and under temporary conditions. Production of reactive power. This study investigates the effect of UPFC modulation on wind power system strength. To ensure the UPFC's efficacy in regulating the wind resource utility grid system, component tuning of the UPFC compensators is critical in the regularization process. For the first time, the DFIG system is detailed in detail in this publication. Following that, UPFC-connected systems, as well as wind farms and electrical grids, are explored. As a result, the compensation technique for the UPFC network's Levy fly Gray wolf optimizer is clarified. Finally, methods for regulating reactive and true power are discussed. Simulations are used to explain the results of implementing each control strategy. The performance of the proposed compensator is associated with the results of MATLAB/Simulink simulations [46].

Xiangping Kong et al. (2018) transmission line power flow control technique is one of the various control strategies available in the control system that the UPFC must use to regulate power flow. One of the most critical aspects of this research is the modular multilevel converter-based UPFC project in the power system of western Nanjing. Furthermore, the method of managing the power flow of the transmission line is thoroughly analyzed. The control approach described above can be used to quickly, separately, and safely alter active and reactive power on a transmission line. Finally, field test findings reveal that the previously proposed control mechanism is effective [47].

Wu-wei et al. (2017) According to the study's findings, UPFC in Suzhou's southern grid can be managed using a multi-target adaptive system control technique. Suppose there is an N-1 failure or conditions change during operation. In that case, the adaptive module should only be used if a transmission line is running at or near its target power level under typical circumstances. The simulations demonstrate that the proposed UPFC multi-target adaptive system control can provide the necessary control effect in normal operating conditions and failure scenarios [48].

Smit Kumar D et al. (2018) To handle today's increased load, more generation capacity is required. External and internal unbalance cause voltage instability, causing the bus voltage to change. FACTS devices, such as the UPFC, maintain transmission line voltage while increasing the amount of power flowing through it. This paper investigates and contrasts UPFCs with other FACTS devices for active and reactive power control. Other FACTS devices, such as STATCOM, which only controls the voltage, and TCSC, which controls impedance, cannot compete with UPFC's capacity to handle phase angle, voltage magnitude, impedance, and several line parameters concurrently or selectively. It also describes the UPFC transmission line structure in great detail [49].

Jinjiao Lin, Peng Li et al. (2017) The UPFC structure and approach to rapid fault isolation are presented first, followed by a coordination technique between the UPFC control protection system and the power grid protection system to improve fault ride-through capabilities. Following an in-depth analysis to identify which operating modes for the UPFC are most suited, the AC protection system is coordinated to carry it out. The strategy determines which operational ways are most appropriate, after which the AC protection system coordinates their implementation, and the power grid state and switch position are thoroughly analyzed. The method goes into great depth about discrimination theory and application techniques. The technique was validated throughout the system commissioning and operation of the Western Nanjing 220kV UPFC project and the control protection system's closing-loop test in the Southern Suzhou 500kV UPFC. A positive outcome indicates that this technology has the potential to improve UPFC's fault-tolerance capabilities further[50].

Hong Ji et al. (2018) UPFC (unified power flow controller) can be used to manage the voltage on the bus, the flow of power along the line, and the system's dynamic stability. The auxiliary damping controller may have an effect on the dynamic stability of the system. This paper incorporates UPFC into the linearized system model before performing DTA (damping torque analysis) to determine how responsive it is. So, using the DTA-time-delay frequency domain model, a DTA model for adjusting UPFC supplemental controller settings can be created, which can then be used in conjunction with the phase compensation method. Finally, the proposed model's validity and viability are proven using two real-world scenarios. Simulation results suggest that reducing oscillations improves system stability.

Xiaomei Yang et al. (2017) Since December 14, 2015, the Nanjing unified power flow controller (UPFC) project has been operating in the Nanjing Western Power Grid. It is the world's first MMC-based UPFC (MMC-UPFC). This project, which is connected to a 220 kV ac grid, utilizes three 60 MVA converters. This document outlines the installation of the project, including the most efficient structure and organization. Additionally, the approach for controlling the UPFC at the system level is described. Under normal operating conditions, the proposed system-level control technique will maintain the preset operating point of a crucial transmission segment of the Nanjing Western Power Grid. While in the event of a fault, the transmission section's power flows can be managed within the line loading constraints.

METHODOLOGY

FACTS can improve the controllability and stability of an alternating current system while increasing its power transfer capacity (Flexible Alternating Current Transmission System). FACTS devices produce their plans and designs by combining essential power framework components (such as transformers, reactors, switches, and capacitors) with power electronics parts. Because thyristor ratings have increased in recent years, power electronics can handle loads of tens, hundreds, or even thousands of megawatts. Because FACTS devices are fast, they can help the transmission framework in various ways, such as enhanced transmission ability, improved transient stability, regulation of power flow, reduction of power oscillations, and voltage constancy. FACTS components can enhance transmission capacity by 40–50 percent, depending on the device type and rating, voltage level, and network circumstances in a particular location.

Similarly to mechanically determined devices, FACTS controllers are less prone to wear and require less maintenance than mechanically selected devices. Costs, complexity, and reliability concerns are now the significant barriers to integrating these promising developments from the perspective of the TSOs. Promote FACTS penetration will be contingent on innovators' ability to overcome these barriers due to increased institutionalization, interoperability, and economies of scale. To increase the performance of the standard PSO formulation, The PSOs in real number space are explained in full, including their gbest and lbest topologies, associated mathematical equations, and details of the PSO outcomes. When some (or all) of the decision variables are integers, a better particle swarm optimizer is projected, along with a detailed description of its theory.

PROPOSED MODEL

Using a wind-solar hybrid system with UPFC, the proposed model uses a PID controller to regulate the fact device and a PSO approach to establish the Kp and ki parameters. Mismatches in power generation and load power produce fluctuations in power supply voltage and frequency because renewable energy is intermittent. Grid-connected hybrid renewable energy systems, such as photovoltaic-wind, can be controlled using the unified power flow controller (UPFC). The proposed tuning technique is intended to address some of the shortcomings of the typical P&O MPPT tuning algorithm, such as oscillations at the maximum power point (MPP) and delayed convergence. Investigate MPP behavior in response to a variety of unpredictable and fast-changing environmental conditions. The parameters of P&O MPPT controllers can be optimized utilizing a PSO-based technique.

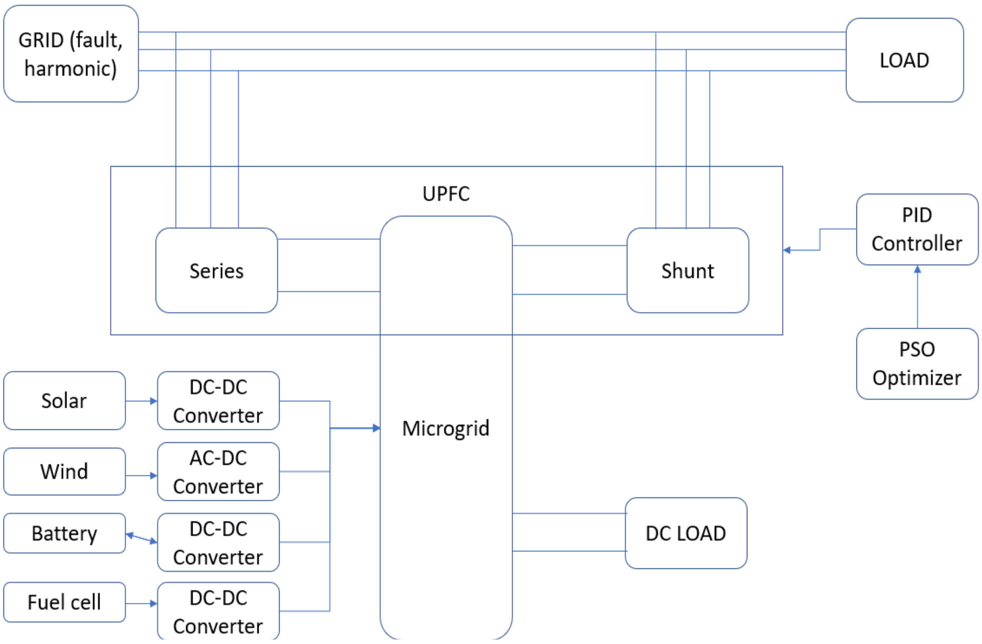

Figure 3: Proposed Block Diagram

RESULTS

The proposed way of incorporating the UPFC in the power system's transmission line outperforms older technologies such as the power system stabilizer and automated voltage controller. Implementing a UPFC increases transient stability since it can compensate in both series and shunt modes. A UPFC provides higher transient stability performance. According to the power flow management strategies developed for the systems and power consumption by load, the controller performs well and also achieves the system's power balance, as proved by the simulation of a UPFC-equipped hybrid renewable energy system in this thesis. According to the simulation results, the power generation of the photovoltaic-wind system always matches the demand of the system's load. According to the results of the MATLAB simulation, the proposed technique was viable and had a lot of potentials. We discovered a solution to the significant power fluctuation in a grid-connected system. As a result, the algorithm's complexity can be lowered while still identifying the best solution.

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