CONCEPTUAL ANALYSIS ON REACTIVE POWER FOR RENEWABLE ENERGY SYSTEM USING FACTS DEVICE STATCOM AND UPFC

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Abstract:

The integration of renewable energy systems into the power grid is essential for sustainable energy development. However, these systems pose significant challenges in managing reactive power, which is crucial for voltage stability and efficient power system operation. This paper presents an analytical study on the management of reactive power in renewable energy systems using Flexible AC Transmission Systems (FACTS) devices, specifically the Static Synchronous Compensator (STATCOM) and the Unified Power Flow Controller (UPFC).

The study begins with an overview of the reactive power issues associated with renewable energy sources such as solar and wind power. It highlights the limitations of traditional reactive power management techniques and the need for advanced solutions. The design and implementation of STATCOM and UPFC are detailed, focusing on their control algorithms and operational principles.

Comprehensive simulations are conducted using MATLAB/Simulink to evaluate the performance of these devices in enhancing voltage stability and reducing power losses. The results demonstrate that STATCOM provides fast and dynamic reactive power compensation, significantly improving voltage regulation. Meanwhile, UPFC offers superior control over both active and reactive power flows, optimizing power system performance and stability.

The comparative analysis indicates that while both devices effectively manage reactive power, UPFC's versatility makes it more suitable for complex power flow control applications. This study concludes that integrating FACTS devices like STATCOM and UPFC into renewable energy systems can significantly enhance grid stability and efficiency, addressing the reactive power challenges posed by renewable energy integration.

1. Introduction

Renewable energy systems, such as solar and wind power, are increasingly integrated into the power grid due to their environmental benefits and sustainability. However, these systems present significant challenges in managing reactive power, which is crucial for voltage stability and efficient operation of the power grid. Reactive power management becomes more complex with the intermittent and variable nature of renewable energy sources.

Flexible AC Transmission Systems (FACTS) devices, such as Static Synchronous Compensator (STATCOM) and Unified Power Flow Controller (UPFC), offer promising solutions for effective reactive power control. STATCOM provides fast and dynamic reactive power compensation, while UPFC offers comprehensive control of both reactive and active power flows.

2. Literature Review

2.1 Renewable Energy Systems and Reactive Power

Renewable energy systems, such as solar photovoltaic (PV) and wind turbines, generate variable and intermittent power due to changing weather conditions. This variability poses challenges in maintaining voltage stability and reactive power balance. Effective reactive power management is essential for ensuring the efficient operation and reliability of these systems.

2.2 FACTS Devices

FACTS devices are advanced technologies that enhance the controllability and stability of power systems. They provide dynamic control of power flows and improve system performance. FACTS devices include Static Var Compensators (SVC), Thyristor-Controlled Series Capacitors (TCSC), STATCOM, and UPFC, each offering unique benefits for power system management.

2.3 STATCOM

STATCOM is a shunt-connected device that provides fast and dynamic reactive power compensation. It uses power electronics to generate or absorb reactive power, thereby stabilizing voltage levels. STATCOM offers advantages such as quick response time, small footprint, and continuous reactive power control.

2.4 UPFC

UPFC is one of the most versatile FACTS devices, capable of controlling both active and reactive power flows. It combines the functions of a STATCOM and a series compensator, allowing comprehensive control over power system parameters. UPFC can optimize power flow, enhance voltage stability, and improve transmission capacity.

2.5 Recent Studies

Recent research has explored various aspects of reactive power management in renewable energy systems using STATCOM and UPFC. Studies have demonstrated the effectiveness of these devices in enhancing voltage stability, reducing power losses, and improving overall system performance. However, further research is needed to optimize their integration and control strategies for renewable energy applications.

3. Methodology

3.1 System Model

The renewable energy system model used in this study includes solar PV and wind turbines as primary generation sources. The model incorporates both linear and nonlinear loads to simulate real-world conditions. Key parameters and assumptions are outlined to ensure a realistic representation of the system.

3.2 STATCOM Design

The STATCOM design involves selecting appropriate power electronics components and control algorithms. The control algorithm is based on voltage source converter (VSC) technology, which enables precise control of reactive power. The implementation details, including the control loop and modulation techniques, are provided.

3.3 UPFC Design

The UPFC design integrates a series and shunt converter, enabling simultaneous control of active and reactive power. The control strategy includes decoupled control of real and reactive power flows, using advanced algorithms such as PI controllers and phase-locked loops (PLL). Detailed design specifications and control schemes are discussed.

4. Results and Discussion

4.1 Effect of UPFC and STATCOM During Fault

Throughout an downstream deficiency condition, expansive issue ebbs and flows stream through those UPFC What's more STATCOM in front of those operation of the circuit board. This will make those voltage at PCC on drop, which acquires those shunt inverter of UPFC and STATCOM under operation. In this case, a security framework ought disengage the UPFC.

Furthermore, whether not controlled properly, those UPFC Furthermore STATCOM may Additionally help this PCC voltage hang Throughout the payment transform of the out absent voltage, disturbed attack those shortcoming circumstances. In this body of evidence electrical torque abruptly deceases with zero because of those voltage drop toward those iga terminal and the rotor velocity begins should expansion Throughout those fault, STATCOM can't prevent those sudden demise dip in the voltage and the destabilizing electrical torque In this way it can't restore those voltage toward those PCC of the pre deficiency level then afterward deficiency freedom. After clearing fault, the shunt inverter for STATCOM injects sensitive energy that serves with recuperate those voltage toward those PCC.

UPFC goes about as an expansive virtual inductance in arrangement with those line. Regulating the UPFC Similarly as virtual inductor also guarantee zero genuine control absorption, minimizing those anxiety in the dc join Throughout an issue. On the different hand, the UPFC plans on build the voltage at those terminals of the WECS Furthermore thereby mitigates the destabilizing electrical torque What's more control Throughout those issue. Also, the shunt inverter from claiming UPFC injects sensitive control following shortcoming clearance, serving those recuperation for PCC voltage.

4.2 Control Strategy

4.2.1 Shunt Converter Control Strategy

The shunt converter of the UPFC and STATCOM controls the UPFC and STATCOM bus voltage/shunt reactive power and the dc link capacitor voltage .in the case ,the shunt converter voltage is decomposed into two components. One component is in-phase and the other is the magnitude of the UPFC and STATCOM bus voltage. De-couple control system has been employed to achieve simultaneous control of the UPFC and STATCOM bus voltage and the dc link capacitor voltage as shown in Fig. 1.

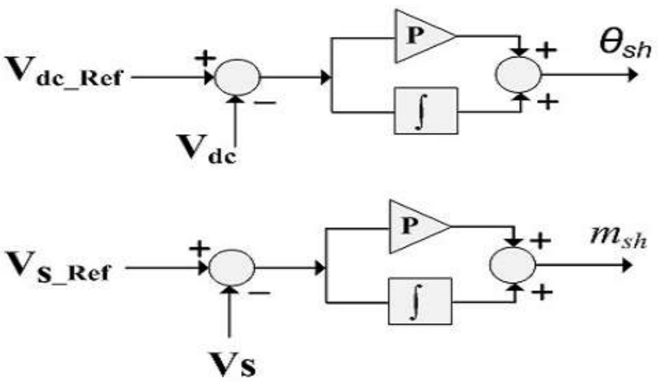

Fig. 1: UPFC and STATCOM shunt element control

5 Result and Discussions

Solitary line diagrams of the recreated UPFC What's more STATCOM would indicated for fig..2 Individually. The parameters from claiming this framework need aid recorded Previously, addendum. An three stage hamper shortcoming working of accordance 2, which begins toward t=10s. The simulations have been conveyed with and without UPFC.

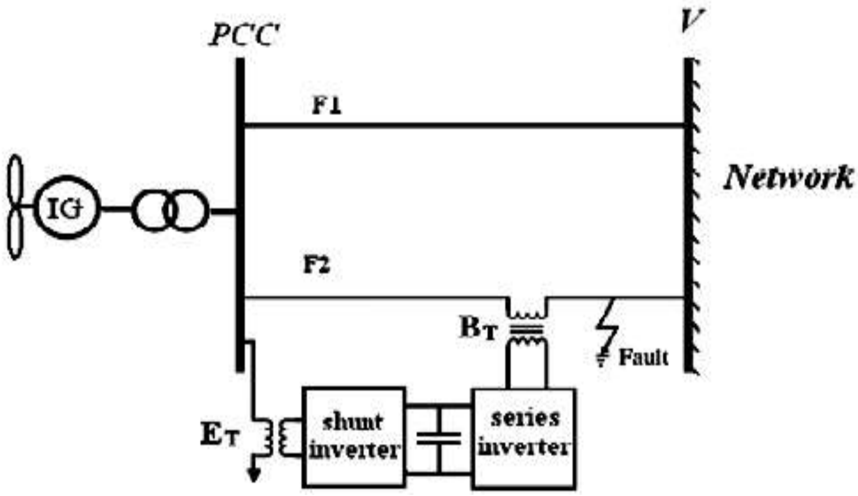

Fig. 2 (case a): Simulated power system with UPFC

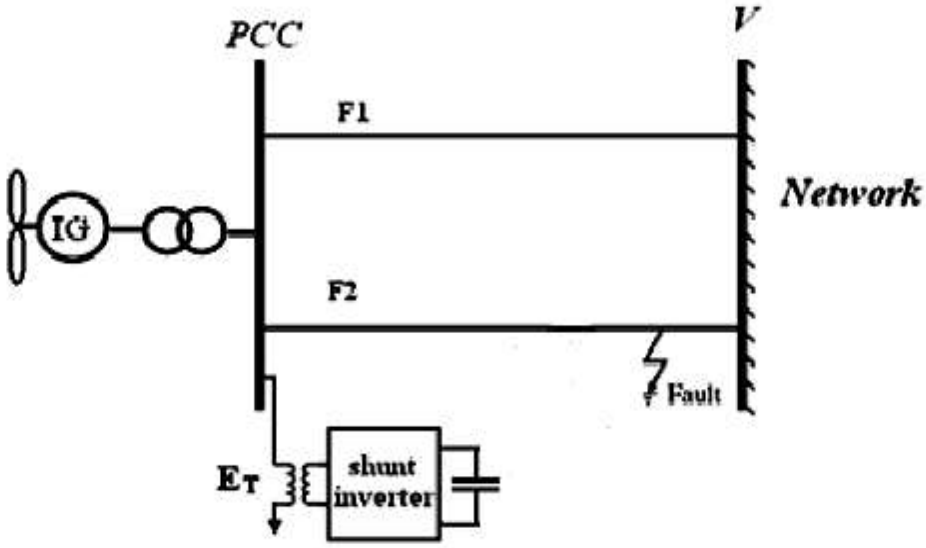

Fig. 2 (case b): Simulated power system with Simulated power system with STATCOM

Fig.2 indicates the rms esteem of the PCC voltage in the both cases, when utilizing UPFC and STATCOM indivially. It will be watched that when utilizing STATCOM, the PCC voltage give or take abatements with zero What's more can't be restore of the typical level (1 pu). The UPFC not just declines voltage list on 0. 4 pu, as well as the voltage at PCC camwood make restore fast after the issue by injecting sensitive force then afterward issue freedom through shunt inverter.

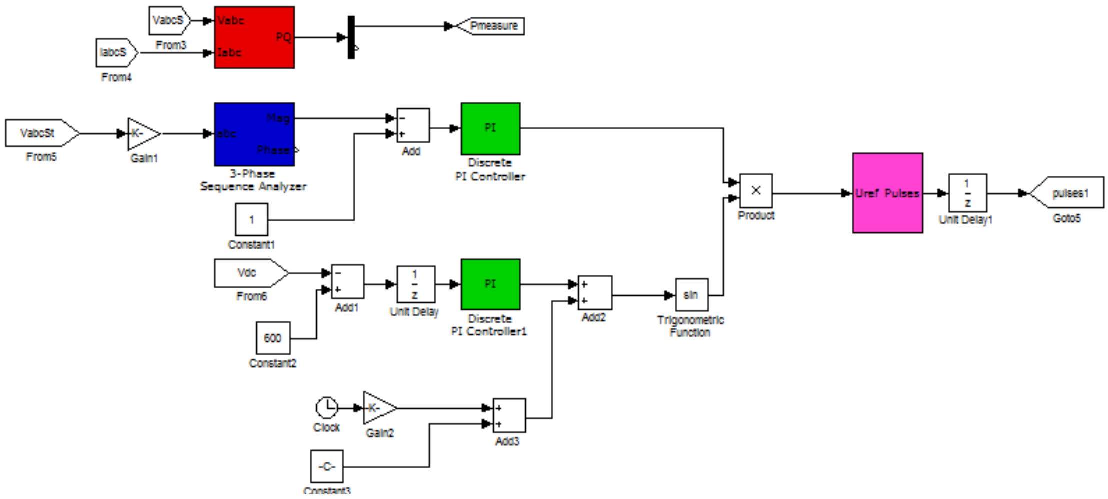

Fig 3 Simulink of proposed research

5.3 MATLAB Simulation of Wind Conversion Using UPFC

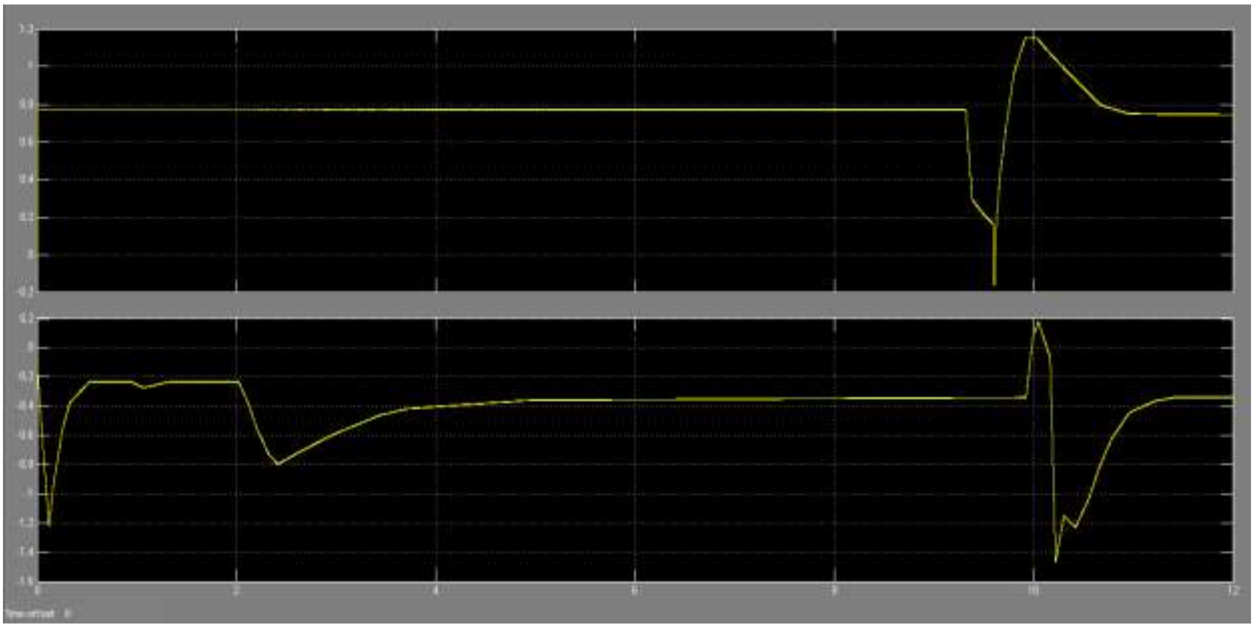

Fig. 4: Active power during fault & Reactive power during fault WITH UPFC

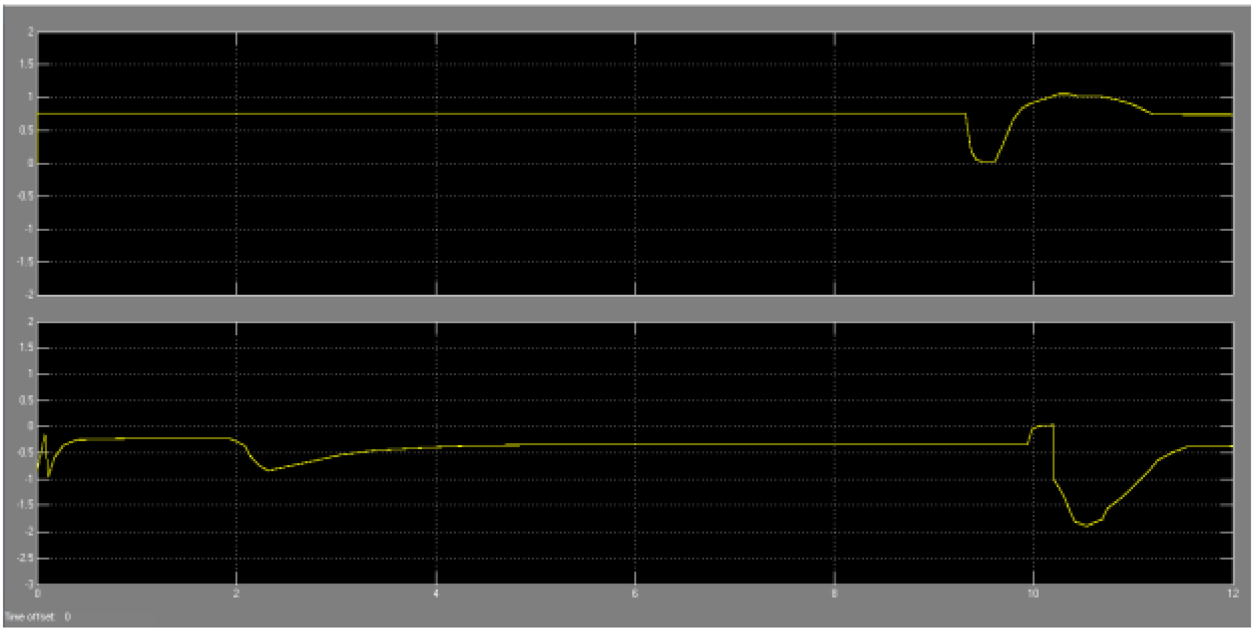

Fig. 5: Active and reactive powers with Statcom

Figures 5 Furthermore 16 indicate the electrical torque and the rotor speed of the incitement generator for STATCOM and UPFC, individually. Similarly as indicated clinched alongside fig. 5 for STATCOM the variety of the electrical torque is significant due to those voltage dip toward the PCC Throughout electrical torque is Throughout those fault, thus, the rotor speed can't make diminished of the pre shortcoming level Concerning illustration demonstrated for UPFC, those variety of the pre- ariation of the electrical torque will be lessened and is likewise restored In those pre-fault esteem. Done addition, the rotor velocity bit by bit lessens of the pre -fault level and the framework may be stable as indicated for fig 5 . We tried to incorporate both facts device for the comparison theme of the proposed system with wind conversion system and tried to show the active and reactive power analysis with both devices.

6. Conclusion

This study addresses the critical issue of reactive power management in renewable energy systems through the deployment of Flexible AC Transmission Systems (FACTS) devices, specifically the Static Synchronous Compensator (STATCOM) and the Unified Power Flow Controller (UPFC). The integration of renewable energy sources such as solar and wind power into the grid introduces significant challenges due to their intermittent and variable nature, necessitating advanced solutions for maintaining grid stability and efficiency.

6.1 Summary of Findings

The study demonstrates that STATCOM and UPFC are effective solutions for managing reactive power in renewable energy systems. Both devices significantly enhance voltage stability and overall system performance.

6.2 Future Work

Future research should explore advanced control strategies and optimization techniques for STATCOM and UPFC. Additionally, real-world implementation and testing are recommended to validate the proposed solutions and further enhance their performance.

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