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D-STATCOM DESIGN AND IMPLEMENTATION FOR POWER QUALITY IMPROVEMENT

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Abstract: :- This paper presents the use of a traditional PI (Proportional-Integral) controller in a Distribution Static Compensator (DSTATCOM) to improve power quality and compensate for reactive power in electrical distribution systems. It compares five different methods for generating reference currents needed by the DSTATCOM. The method chosen to extract these currents significantly affects the DSTATCOM's performance. When nonlinear loads are connected to a three-phase system, they cause voltage and current imbalances, making the supply system go out of phase. The DSTATCOM is used to correct this by aligning the phase of voltage and current and rebalancing the three-phase supply. The proposed PI controller-based DSTATCOM is implemented and tested using MATLAB/Simulink. Simulation and experimental results demonstrate the effectiveness of this control approach.

keywords - - DSTATCOM, d-q theory

I. INTRODUCTION

In modern electric power distribution network is subject to various challenges such as fluctuating loads, voltage sags and swells, Harmonics, Reactive power imbalance, Flicker, Unbalanced load and integration of renewable energy sources. These challenges can lead to power quality issues that disrupt industrial processes and degrade the performance of sensitive electronic equipment. The need for reliable voltage control and reactive power compensation has led to the development of devices like the Distribution Static Synchronous Compensator (D-STATCOM). D-STATCOM, a flexible and efficient FACTS (Flexible AC Transmission Systems) device, is specifically designed for low-voltage distribution networks. It provides fast-acting reactive power compensation and voltage regulation, enhancing power quality and reliability. This provides a comprehensive overview of D-STATCOM, discussing its architecture, control strategies, and real-world applications. Consequently, the voltage magnitude of a certain phase may suffer a severe decrease, breaching the lower voltage limit or unbalanced three-phase voltages at a remote bus may violate the percentage voltage imbalance accepted in the standards. In this we a case study is conducted on the motor to demonstrate how the proposed methods can be applied to analyze an unbalanced network and to improve its performance.

II. SYSTEM DESIGN/METHODOLOGY

1. Problem Identification and Objective Setting

Analyze common power quality issues (voltage sag, swell, flicker, harmonic distortion) in distribution systems. Set clear objectives for mitigating these issues using a Distribution STATCOM (D-STATCOM).

2. System Modeling

Develop a model of the distribution network including loads, sources, and disturbances. Model the D-STATCOM circuit: Voltage Source Inverter (VSI), DC-link capacitor, coupling transformer, and necessary control circuits.

3. Design of D-STATCOM

Select suitable power electronic devices (like IGBTs, MOSFETs). Design DC-link voltage and inverter ratings based on system requirements. Design filters (LCL filter) for harmonic reduction.

4. Control Strategy Development

Implement control algorithms like: Voltage Control Strategy (for voltage regulation) Current Control Strategy (for reactive power compensation) PWM Techniques (like Sinusoidal PWM, Space Vector PWM). Design controllers (PI, fuzzy logic, or advanced controllers) for maintaining DC-link voltage and reactive power compensation.

5. Simulation and Validation

Simulate the designed system using software like MATLAB/Simulink or PSCAD Inject disturbances (e.g., voltage sag, harmonic load) and observe the D-STATCOM's performance. Validate the improvement in power quality indices.

7. Results and Analysis

Compare system performance with and without D-STATCOM. Measure voltage profile, THD (Total Harmonic Distortion), reactive power compensation. Analyze improvements in system stability and power quality.

8. Conclusion and Future Scope

Summarize the effectiveness of D-STATCOM in enhancing power quality. Suggest improvements like integrating renewable sources or adaptive control strategies.

II.1 BLOCK DIAGRAM

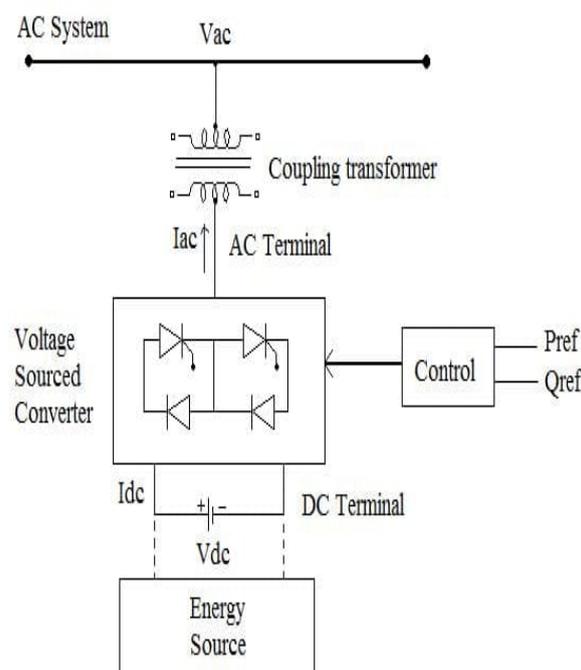


Figure 1: Block Diagram of D-STATCOM

D-STATCOM (Distribution Static Synchronous Compensator) is a power electronic device used in the distribution network to improve power quality by compensating for voltage fluctuations, reducing harmonic distortion, and maintaining voltage stability. It is commonly used in power systems to provide dynamic reactive power compensation, helping to address common power quality issues like voltage sag, voltage swell, flicker, and unbalanced loads.

Working Principle of D-STATCOM

The working principle of D-STATCOM is based on the following key concepts:

- 1. Power Electronic Converter:** D-STATCOM employs a voltage-source converter (VSC) that is connected to the distribution network via an inductive coupling element (typically a transformer or a series inductor). The VSC is made up of Insulated Gate Bipolar Transistors (IGBTs) or other semiconductor devices that can rapidly switch to control the amount of reactive power injected or absorbed into the system.
- 2. Voltage Source:** The VSC generates a controllable AC output voltage that is in phase or out of phase with the line voltage, depending on the reactive power requirements. By controlling the magnitude and phase angle of the output voltage of the converter, the D-STATCOM can either absorb or inject reactive power into the grid.
- 3. Capacitive or Inductive Operation:**
- 4. Capacitive Mode:** When the D-STATCOM's output voltage is in phase with the line voltage, it injects reactive power into the system, helping to raise the system voltage (compensating for voltage sags).
- 5. Inductive Mode:** When the output voltage of the D-STATCOM lags behind the line voltage, it absorbs reactive power from the system, helping to reduce the voltage level (compensating for voltage swells).
- 6. Control Mechanism:** The reactive power injection or absorption is controlled through a feedback control system that senses the voltage at the point of common coupling (PCC) with the grid. The controller adjusts the firing angles of the power electronic switches in the VSC to maintain the desired voltage profile at the PCC. Various control algorithms can be employed, including.

D-STATCOM is inserted in transmission line to suppress voltage variation due to deviating load conditions and control reactive power. Basically it is connected in shunt to transmission line with Point of Common Coupling (PCC) in phase with system voltage. It can compensate for inductive and capacitive currents linearly and continuously.

II.II SIMULATION MODEL OF THE PROJECT

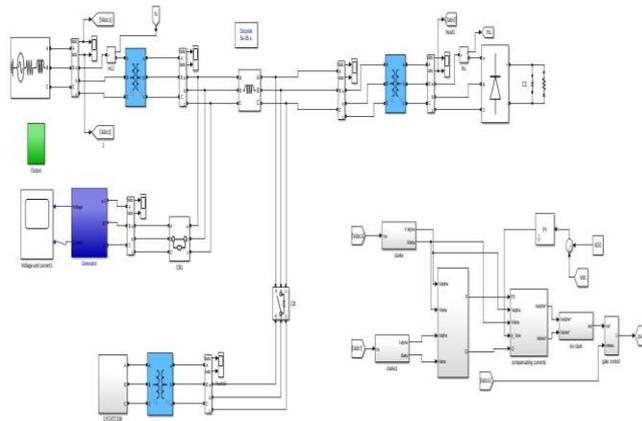


Figure 2: Working simulation model of the project

The D-STATCOM operates by injecting or absorbing reactive power to maintain voltage levels at the PCC within acceptable limits. It utilizes a Voltage Source Converter (VSC) connected in shunt to the distribution line through a coupling transformer.

1. **Measurement and Monitoring:** Voltage and current at the PCC are measured using sensors. The measured three-phase signals are transformed into two-phase orthogonal (α - β) components using the Clarke Transformation, which simplifies control in the stationary reference frame.
2. **Control System:** The α - β components of voltage and current are processed to calculate instantaneous power components (P, Q) based on instantaneous reactive power theory (p-q theory). These values are compared with reference values, and the errors are processed through PI controllers to generate the required compensation signals (i.e., the reference compensating currents).
3. **Inverse Clarke Transformation:** The reference currents in the α - β domain are transformed back to three-phase (abc) values using an inverse Clarke Transform. These currents are used to produce PWM switching signals through a PWM generator, controlling the IGBT-based inverter in the D-STATCOM.
4. **Reactive Power Compensation:** Based on whether the system needs to inject or absorb reactive power, the VSC generates voltage in-phase or out-of-phase with the system voltage. This maintains voltage stability, reduces harmonics, and improves the power factor.

Load and Disturbance Simulation

The presence of a non-linear load (such as a diode bridge) introduces distortions in the voltage and current waveforms. These distortions manifest as:

- Harmonics
- Voltage sags/swells
- Reduced power factor

The D-STATCOM compensates for these disturbances by generating an opposing waveform, essentially "canceling out" the undesired components, thereby restoring sinusoidal voltage and current waveforms at the PCC. This section provides a detailed simulation results under different cases to investigate the performance of DSTATCOM. To validate the performance of DSTATCOM cases considered as: performance under nominal load, unbalance and distorted source voltage, sag-swell, sudden load interrupt. Required harmonic components are delivered by All Simulink parameters.

III. RESULTS AND ANALYSIS

Simulation results

This section provides a detailed simulation results under different cases to investigate the performance of DSTATCOM. To validate the performance of DSTATCOM cases considered as: performance under nominal load, unbalance and distorted source voltage, sag-swell, sudden load interrupt. Required harmonic components are delivered by All Simulink parameters.

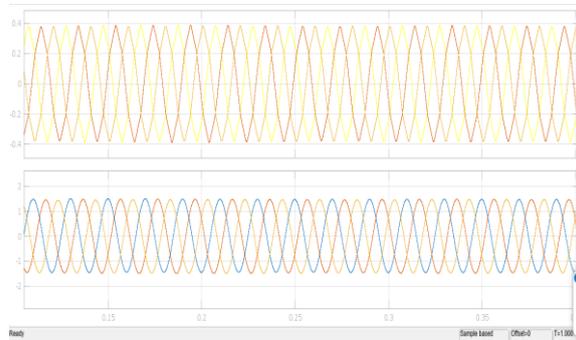


Figure 2: Simulation result

CONCLUSION

This project presents the detailed modeling of one of the custom power products, D-STATCOM is presented using instantaneous P-Q theory and phase shift theory used for the control of D- STATCOM are discussed. These control algorithms are described with the help of simulation results under linear loads and nonlinear loads.

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