A Robust Control of D-STATCOM for Voltage Stability

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Abstract

Power Quality enhancement is a major topic among researchers as the usage of non-linear loads has increased vastly. The purpose of this work is to maintain constant DC link voltage in hybrid energy system which contains Doubly Fed Induction Generator (DFIG) based Wind Energy Conversion System (WECS) and Photovoltaic (PV) system. Among the various available Flexible AC Transmission System (FACTS) devices, Distribution Static Compensator (D-STATCOM) provides better voltage stability with Voltage Source Converter (VSC). LUO converter is used as it has excellent voltage-gain ratio. The utilization of Adaptive Neuro-Fuzzy Inference System (ANFIS) as Maximum Power Point Tracking (MPPT) assures controlled output and supports the extraction of complete power from the PV panel. This work evaluates the performance of the proposed inverter through MATLAB simulation.

Keywords: Hybrid energy system, DFIG-WECS, PV system, D-STATCOM, ANFIS based MPPT, Voltage stability

1. Introduction

In this paper, to improve performance of a hybrid system with PVs and WECS against wind gusts, as well as ability to keep Renewable Energy Sources (RES) running during three-phase faults at Point of Common Coupling (PCC) between RESs and grid, static synchronous compensator (STATCOM) is implemented [1]. By choosing the optimum reference value of DC-side voltage of D-STATCOM to reduce switching losses and harmonic content of its output current without sacrificing its dynamic performance [2]. An improved Proportional Normalised Least Mean Square (iPNLMS) control technique for the D-STATCOM is

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suggested to achieve the appropriate grid currents quickly and efficiently. The voltages at point of common coupling (PCC) and THD of grid currents measured are within the IEEE-519 standard's limitations [3]. Simple Sub-Synchronous Resonance Control (SSRC) approach based on orthogonal proportional action is used which efficiently estimates the actual rotor position and the obtained steady state performances are satisfactory [4]. A novel ZETA converter is used to create transformer-less buck boost converter. This converter has only one main switch which is used to decrease switching losses, it provides low voltage stress and improves the efficiency of the switches [5]. During fault occurrences in the system, hybrid power systems based on WECS and PV systems are unable to provide the requisite reactive power. As a result, the voltage profile between the RESs and the grid at the PCC will vary. The performance of power system, including system stability, power factor, and power quality, is harmed by these voltage oscillations. This project focuses on the construction of a D-STATCOM model in a test distribution system, with an emphasis on the influence of capacitance on ripple voltage and regulation.

2. Working Principle

In this proposed system hybrid power system DFIG-WECS and PV system is implemented. PWM rectifier is used for the conversion of AC-DC in the DFIG-WECS and pulses for the PWM rectifier is generated using the PI controller. The voltage stability of power system is enhanced by implementation of D-STATCOM [2]. PV power is applied to the D-STATCOM along a LUO converter. Fig 1. shows block diagram of system under investigation.

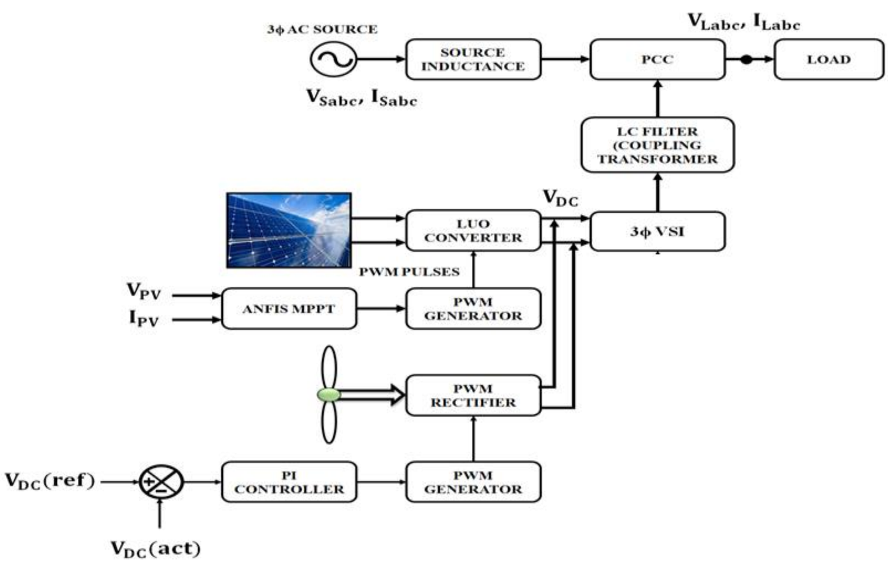

Figure 1. System under investigation

2.1 DFIG-WECS

DFIG-WECS is used to convert energy of wind movement into mechanical power using PI controller to stabilize power oscillations. Since wind is an inconsistent source of energy, the generator's output voltage and frequency will change depending on the wind speed. The cut-in speed, which is between 4 m/s, at which the turbine starts to revolve and create electricity. The forces on the turbine construction continue to rise when the speed exceeds the rated output wind speed of around 12 m/s, and the rotor may be damaged at some point. The cut-out speed is generally around 25 m/s, which is used to bring the rotor to a rest as a result of the braking system. The rectifier converts the fluctuating AC output voltage from the generator into DC voltage. The modulation index of the inverter is controlled to feed the available dc voltage to the load at the desired constant voltage and frequency. Fig 2. shows the power output of typical wind turbine. Pulses are generated for regulating the PWM rectifier using a PI controller.

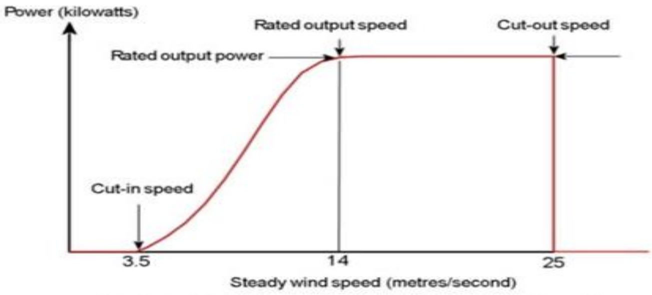

Figure 2. Typical wind turbine power output

2.2 PV System

PV system for power conversion is made up of many series and parallel PV modules, a tracking controller, and power converters such as DC-DC converters and inverters. LUO converter is used as it has excellent voltage gain ratio ANFIS based MPPT assures controlled output and enables total power extraction from the PV panel. Thus, the PV power is applied to the STATCOM inverter along the LUO converter.

2.3 LUO Converter

In the circuit, power switch is S, and the freewheeling diode is D. Inductors are the passive energy storage elements. The load resistance is represented by L1, L2 and capacitors C1, C2. Fig 3. LUO Converter Circuit Diagram. There are two modes to the LUO converter circuit.

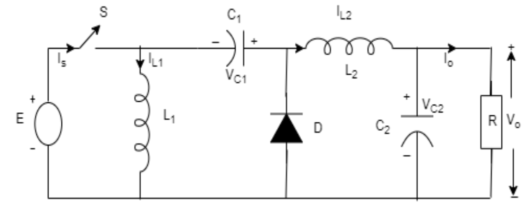

Figure 3. LUO Converter Circuit diagram

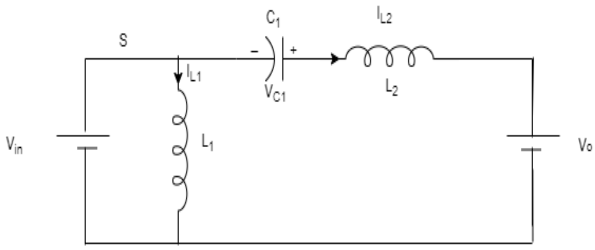

Figure 3(a). Mode 1

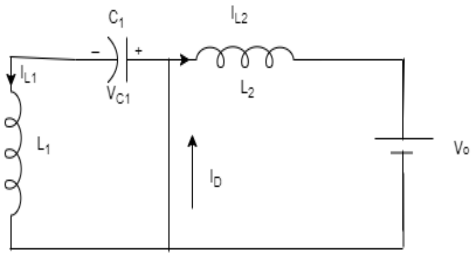

Figure 3(b). mode 2

Inductor L1 is charged by the supply voltage E when switch is on. Simultaneously, the inductor L2 draws energy from source and capacitor C1. The capacitor C2 provides power to the load. Fig 3(a). LUO converter mode 1 operation. When switch is turned off, current pulled from source is zero, as illustrated in the Fig 3(b). Current iL1 flows through freewheeling diode to charge capacitor C1. Current iL2 goes through the C2 –R circuit and freewheeling diode D to keep the circuit running continuously.

2.4 ANFIS based MPPT

To extract maximum power of the PV module under changing weather circumstances, an ANFIS-based MPPT approach is proposed. Solar voltage (Vpv), solar current (Ipv), and solar cell temperature are the proposed input variables (Tpv). The duty cycle is an output variable that is used to control the LUO converter and ensure that maximum power tracking is maintained. Since traditional Fuzzy Logic Control modelling depends on trial and error, there's a limited probability of obtaining ideal performance. As a consequence, fuzzy rules and membership functions may be obtained by ANFIS. First and foremost, the training data should be gathered. The data had to be trained in order to get it. The following are the steps required in obtaining the training data:

- Typical MPPT techniques were used to simulate the system under various solar radiation and ambient temperature.
- Data was gathered, updated using MATLAB that was designed especially in order to get the relevant data.
- Revised data was swapped. The data is then processed once more to generate data collection's distinct rows.

The data used to train the ANFIS are V_{pv} , I_{pv} and T_{pv}. Fig 4 shows the general structure of the five-layer network ANFIS model. Fig 5. is the PV voltage (Vpv) generated by ANFIS' membership function. Fig 6. shows the PV current (Ipv) generated membership function, whereas Fig 7. shows the PV cell temperature generated membership function (Tpv). For each input, there are three general bell-shaped membership functions: low, medium, and high. The duty cycle is compared to saw tooth to provide appropriate pulse generation to the switching boost LUO converter. The solar system voltage differs from the starting voltage, which is the voltage at maximum power under various circumstances. The photovoltaic current, on the other hand, changes, as does the area of the current at maximum power under various circumstance. Under varied environmental circumstances, the PV current, as well as the current at maximum power, fluctuates. Moreover, the PV cells' temperatures range around 298 and 323 degrees Fahrenheit. As previously stated, the ANFIS controller creates membership functions based on information obtained previously from training data. During training step, form of membership function changes, and once training is done, final shape is obtained. When learned with a minimum number of cycles, ANFIS is capable of establishing the matching training data sets. ANFIS provides a collection of fuzzy rules to generate suitable output for various input values by modifying the values of membership functions.

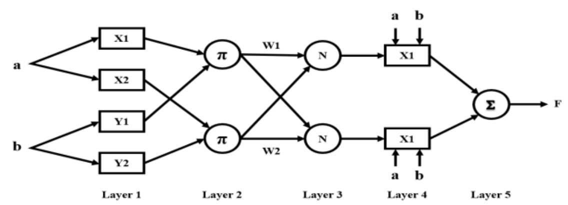

Figure 4. ANFIS model structure

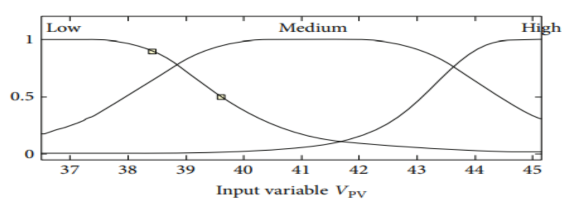

Figure 5. Membership function of the input variable (Vpv)

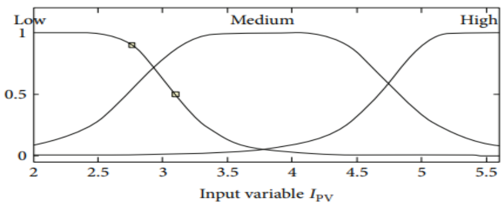

Figure 6. Membership function of the input variable (I_{pv})

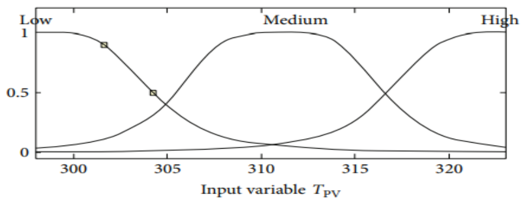

Figure 7. Membership function of the input variable (Tpv)

2.5 Three Phase VSI

It is feasible to change the amplitude of the inverter output voltage by effectively controlling the inverter controlled rectifier device. Lower frequency harmonics can be significantly reduced or eliminated using this method of control. As a result, a suitable output waveform may be achieved throughout a large inverter voltage control range with minimal filtering. The switches Q1, Q2, Q3, and so on are quick and easy to control. Fast recovery diodes D1, D2, D3, and so on are placed anti-parallel to the switches. The output terminals of the inverter are labelled 'A, B, and C,' and are connected with ac load. The load-phase terminals on a three-phase inverter is three, while the load-phase terminals on a single-phase inverter is one. To minimize current harmonics, a simple L-filter is commonly used for the inverter. Low pass filters can be replaced by LC or LCL filters, which have very small inductor and capacitor values. Due to two inductors, the LCL filter requires additional space and cost. Depending on the filter type, the efficiency, cost, losses, weight, and size vary. Thus, the pulses for controlling the VSI is generated by hysteresis current controller, thereby reactive power compensation is provided, and harmonics are eliminated.

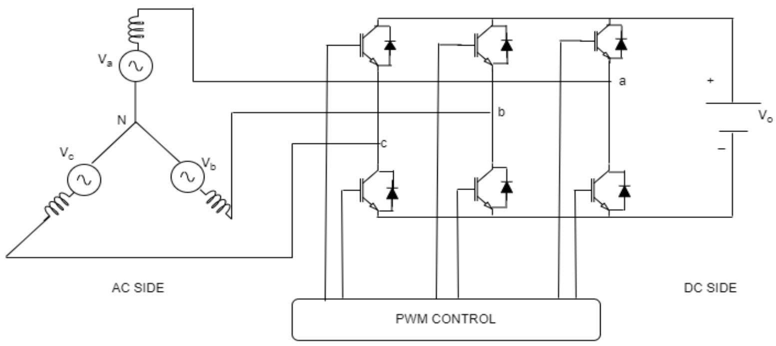

Figure 8. Three Phase PWM Rectifier

If the comparator's error value is positive, the capacitor attached to the DC link will be discharged then the converter operates as a rectifier. I_0 will have a positive DC current. The control block will emit pulses to each power semiconductor devices in order to achieve this configuration. It also provides the necessary phase shift, allowing power to flow from variable AC to DC. When the output current becomes negative, the capacitor is overloaded, and the reference voltage is compared, and the capacitor discharge is regulated by the control system to keep the AC within limits. The supply voltage and phase can be used to regulate the rectifier. As a result, the magnitude of control voltage and its phase will change with respect to supply. As a result, it may be used as a rectifier and an inverter in two quadrants, with leading and lagging power factors, for a total of four quadrant operations. PWM regulates active power and reactive power, allowing the rectifier to draw current at greater power factor. PWM generator's main purpose is to generate gate pulse signals to control the VSI through a hysteresis current controller.

3. Simulation Results

In this section, the dc link voltage stability is evaluated through simulations.

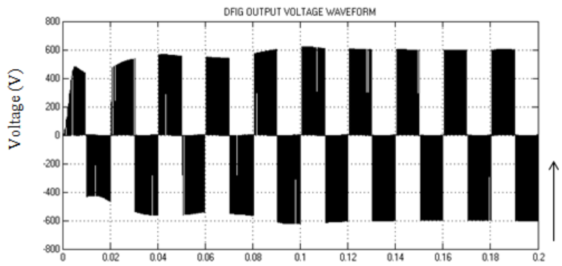

Figure 9. Output voltage for DFIG

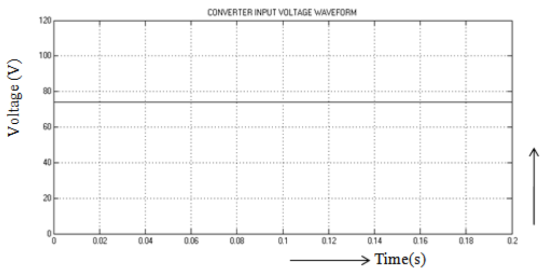

Figure 10. Input voltage of LUO converter

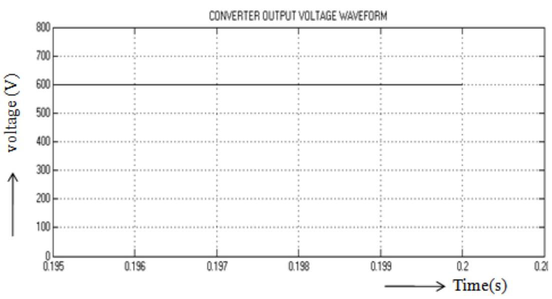

Figure 11. Output voltage of LUO converter

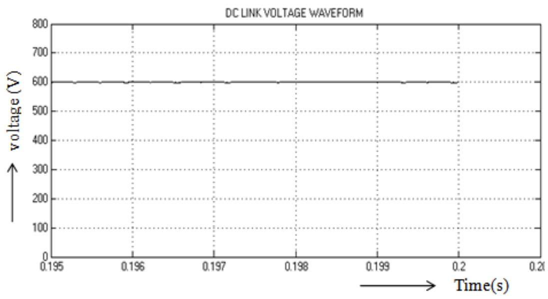

Figure 12. DC link voltage waveform

Table 1. DC link voltages under various test conditions

Wind (speed) (m/s)	Solar (temperature) (°C)	DC link Voltage (V)
4	25	599.3
8	31	599.3
10	28	599.5
12	30	599.1
15	35	599.5

4. Conclusion

In this work, an efficient way of regulating voltage stability is addressed by using a PV fed D-STATCOM. D-STATCOM is basically shunt connected, which provides reactive power compensation and voltage stability. DC-DC converters have been incorporated with PV systems and LUO converter has been utilized in this project along with ANFIS MPPT for tracking the maximum power from the PV, along with dc-link voltage regulation. The chosen converter provides better efficiency and voltage-gain ratio when compared with other converters. The proposed work is validated using MATLAB simulation.

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Author's biography

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