Performance Enhancement and Minimization of Total Harmonic Distortion Using Spwm Based 3-Phase Inverter For 250 Watts Wind Energy System

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Abstract: The analysis of industrial, utility and commercial electrical power system for frequency regulation is one of the important issues that this study presents a comprehensive research of the underlying principles of the renewable energy technology (RET) using 3 phase SPWM with the objective of ensuring a consistent and commercial energy solution for a sustainable development in the rising world. The grid-connected amalgam renewable energy system integrates a power conversion and battery storage space unit has been proposed based on the availability, dynamism, and techno-economic viability of energy resources within the region are used for voltage and inner current control loop as a global and local best value for applying to the turbine generator. Our work focuses on frequency control of wind for 3phase inverter using SPWM isolated micro-grid using traditional control technique and minimizing computational efficiency compared to existing simulated system using MATLAB.

Index Terms: PWM, SPWM, wind turbine, energy, cost-effective, 3-phase inverter etc.

I-INTRODUCTION

1.1. Three phase inverter for PWM
These techniques require sophisticated gating circuits or controls. Sinusoidal pulse-width modulation (SPWM) and space vector modulation (SPWM) are two of these techniques. During the past decades, many different PWM techniques have been developed and with these techniques; wide linear modulation range, less switching loss, less total harmonic distortion (THD) in the spectrum of switching waveform, easy implementation and less totaling time have been achieved. In the previous, in maximum applications, carrier-based PWM methods were commonly used. The initial modulation signals for a carrier-based PWM are sinusoidal. However, with sinusoidal three phases PWM, the linear modulation range cannot be extended for line-to-line voltages. To conquer this restriction, the non- sinusoidal carrier-based PWM methods, which use zero- succession signals, has emerged.

1.2. Pulse Width Modulation
PWM is the most important control method for the SMs of the Various Pulse Width Modulation plans for regulatory Modular multilevel converter have been planned in works. These growths the dc bus operation which reasons alteration on the ac sideways output waveforms. In its place, it is likely to comprise a 3rd harmonic component in the position to grow the dc bus operation [59].

Figure 1.1: Ideal output waveforms for one carriers, lower: resulting waveform.

Figure 1.2: Demonstration of the level shifted PWM. Upper: Of a three-phase converter
1.3. Sub Modules

The most shared SM topology, the half bridge, is shown in figure 1.3. It involves two insulated-gate bipolar transistors with anti-parallel diodes and a fluctuating capacitor and low component count. With the capacitors comprised in the SM, the overall capacitance of the Modular multilevel converter is usually greater than which of topologies with a single capacitance.

![Sub-module topology](image)

Figure 1.3: Sub-module topology

Though, the merits of untwisting the capacitive elements in which the converter has no essential mechanisms such as the large dc connection capacitor of conservative voltage source inverters.

1.4. Wind Power as Energy Source

The Earth’s wind is a manifestation of the sun’s renewable energy for US Department of Energy has estimated that the world’s wind could theoretically supply the equivalent of 5 800 quadrillion BTUs of energy each year, which is more than 15 times the current world energy demand (American Wind Energy Association 2009). In another study from Stanford University, an estimation of five times the current world energy demand was calculated as the world’s wind theoretical supply if modern 80 m, 1500 W turbines were to be used in feasible locations worldwide (Archer and Jacobson 2005). Fortunately, worldwide the growth rate of wind power capacity has significantly increased since 2009 reaching nowadays about 2% of the world’s electricity production (WWEA 2010).

1.5. Wind Power Technologies for 3 phase inverter

Wind Turbines are generally classified into two types based on their structure: horizontal axis turbines and vertical axis turbines. In horizontal axis wind turbines (HAWT) the blades rotate along the horizontal axis, i.e., analogous to the ground. In contrast, in the vertical axis wind turbines (VAWT) the blades rotate along the vertical axis, i.e., vertical to the ground. Both HAWT and VAWT types can be split into subcategories according to whether they primarily make use of lift force or drag force to turn the rotors (Mannwell, McGowan & Rogers 2009). There are a number of technologies for each type. Both having reward and drawback currently, the most common wind turbines are the horizontal axis ones.

II-RELATED WORK

A large amount of exploring is agreed out in the field of convention power. A brief literature review related to the SPWM wind energy system is presented as follows:

**Bhim Singh**, et al. [1] focuses on power quality development of power electronic technology which climbs to a characteristic like power-factor correction, voltage regulation and load harmonizing of the linear load. Dstatcom is realizing using a three-leg IGBT static and dynamic presentation. A hysteresis small voltage FACTS machine discuss which can help to get better power-law based carrier-less PWM current controller is used to derive quality problems in the distribution system. Gating pulses for the IGBTs.

**H. Nasiraghdam**, et al. [2] introduces a new control method for balanced and unbalanced voltage sag mitigation regulates compensator current and load voltage. Delayed signal termination has been used for sequence separation. The compensator should look after perceptive loads against dissimilar types of voltage sag. Presentation of the proposed method is investigated under many types of voltage sags for linear and nonlinear loads.

**J. Sun**, et al. [3] explain Voltage flicker, a phenomenon of annoying light intensity fluctuation, which is the reason by huge rapid industrial load changes, it has been a foremost anxiety for both Power Company and customers in the region of power excellence. Distribution Static Compensator (DSTATCOM) has a rapid reaction which makes it the proficient solution for improving power quality in distribution systems.

**G. Molina**, et al. [4] investigates the dynamic performance of a distribution static compensator coupled with energy
source system (ESS) for improving the power quality of distribution systems. Also existing integrated DSTATCOM/ESS compensator is analyzing as a voltage organizer, a power factor controller, and an active power controller. Modeling and control loom are proposed, together with a detailed modeling of the DSTATCOM/ESS.

Pierre Giroux, et al. [5] presents a study of the modeling of a STATCOM (Static Synchronous Compensator) used for reactive power compensation in a distribution network. The power circuits of D-STATCOM, Static and dynamic presentation of an E3 Mvar D-STATCOM on a 25-kV system is evaluated. A “standard modeling” advance is proposed to make simpler the PWM inverter process and to accelerate the simulation for control parameters regulate purpose. Simulation presentation found with both modeling methods are presented and compared.

Afshin LASHKAR ARA, et al. [6] presents the power electronic devices and technical review on various power engineering levels. Flexible AC Transmission System is an efficient type of equipment on power management in energy transmission systems. In addition, the power electronics-based equipment, which is called power conditioners are used to solve power quality problems.

Zhang Dongliang, et al. [7] analyzed the circuit of DSTATCOM. The dynamic model of DSTATCOM based on three-level voltage inverter is recognized by way of lead-in switch function. The Control method of DSTATCOM is the main point of this research. The paper determines the exposure means based on instantaneous reactive power. PWM control by tracking the current expertise accomplish to direct control. The simulating consequence proves the DSTATCOM put forward in the paper can realize dynamic var compensation effectively.

III-SYSTEM MODEL

3.1 PRINCIPLE OF SPWM

A mathematical diagram of a static compensator (SPWM) is shown in Figure 3.1. The SPWM shown in this figure consists of self-commutated converters using Gate Turn-Off (GTO) thyristors, a dc voltage source, a converter transformer, a step-up transformer, and a checker. Note down that the step-up transformer is not normally required for the lower system voltage appliance.

![Figure 3.1 Single line diagram of SPWM](image)

Every GTO converter produces a voltage that is stepped up by a line-side-series-linked multi-stage converter transformer. The converter transformer permits the construct of a sine-wave voltage in cooperation magnitude and phase. However, if the system voltages exceed a low-voltage (V1) or high-voltage limit (V2), the STATCOM operates as a constant current source by controlling the converter voltage (Vi) properly. Its voltage limits, the amount of reactive power compensation provided by the SPWM is more than the most-common competing FACTS controller, namely the Static Var Compensator (SVC).

Wind energy conversion systems consist of a wind turbine, an electrical generator, power edge and control systems. Each of these components has a specific role. The wind turbine changes the wind kinetic energy into mechanical energy. The kinetic power presented in the wind transient through an area Aw with velocity wind ($v_{wind}$)

$$P_{wind} = \frac{1}{2} \rho A_w v_{wind}^3$$  (3.11)

Where $\rho$ is the air density. The Only part of this power (3.11) is extracted by the wind turbine. Its speculative maximum limit is 59% and it has been established by the German physicist Albert Betz [57]. This segment of useful mechanical power is generally named as power coefficient (Cp). Commercial wind turbines have lower power coefficients due to inherent losses [58]. Therefore, the useful wind turbine mechanical power is:

$$P_{mech} = c_p \frac{1}{2} \rho A_w v_{wind}^3$$  (3.12)

The power coefficient $c_p$ is a nonlinear function of the blade pitch angle $\theta$ and the tip speed ratio $\lambda$ [59]. The concluding is the ratio involving the blade tip speed and the wind speed:

$$\lambda = \frac{\omega R}{v_{wind}}$$  (3.13)

Anyway, $R$ is the rotor radius and $\omega$ is the velocity (angular) of the rotor.
A representative power coefficient curve is presented in Figure 3.8, supercilious a fixed-pitch angle wind turbine. There is the highest value for the power coefficient at an exact value of the tip speed ratio which exploits the mechanical power removed from the wind.

### 3.2 PMSG Model

Assuming that there is no saturation, a sinusoidal back emf, and negligible eddy current and hysteresis losses, the PMSG voltage equations in the synchronously rotating reference frame (dq) [65] are:

\[ v_d = R_{st}i_d + \frac{d\lambda_d}{dt} - \omega_s\lambda_q \]  
(3.14)

\[ v_q = R_{st}i_q + \frac{d\lambda_q}{dt} + \omega_s\lambda_d \]  
(3.15)

Where, \( R_{st} \) is the stator winding per-phase resistance, \( \omega_s \) is the synchronous angular speed, \( \lambda_s \), and \( \lambda_q \) are the dq axis stator flux linkages and their equations are:

\[ \lambda_d = L_di_d + \lambda_f \]  
(3.16)

\[ \lambda_q = L_qi_q \]  
(3.17)

\( L_d \) and \( L_q \) are the d, q axis inductances, respectively, and \( \lambda_f \) is the rotor magnets flux linkage.

The electrical form of the PMSG uses its currents equations articulated in the rotor indication:

\[ \frac{di_d}{dt} = \frac{1}{L_d}v_d - \frac{R_{st}}{L_d}i_d + \frac{L_q}{L_d}\omega_s i_q \]  
(3.18)

\[ \frac{di_q}{dt} = \frac{1}{L_q}v_q - \frac{R_{st}}{L_q}i_q + \frac{L_d}{L_q}\omega_s i_d - \frac{\lambda_f\omega_s}{L_q} \]  
(3.19)

The velocity (angular) of the rotor is given by:

\[ \omega_s = p\Omega_m, \]  
(3.20)

With \( p \) is the number of pole pair and \( \Omega_m \) as the speed (rotor).

The mechanical and electrical positions of the PMSG rotor are, respectively:

\[ \theta_m = \int \Omega_md t, \]  
(3.21)

\[ \theta_e = p\theta_m, \]  
(3.22)

\[ \frac{d\omega_s}{dt} = \frac{1}{J}(T_e - D_p\omega_s - T_L) \]  
(3.23)

Finally, the electromagnetic torque equation of the PMSG is [70]:

\[ T_e = \frac{3}{2}p[\lambda_f i_q + (L_d - L_q) i_d i_q] \]

### 3.3 Discrete Time Fourier Transforms (DTFT)

The Discrete-Time Fourier Transform (DTFT) is one of the Fourier transforms family that operates on a periodic and discrete signal. DTFT can be simply implicit if you narrate it to the DFT. used for, example, assume you obtain an N sample signal and want to find the frequency spectrum of these signals. In DTFT, the Fourier transform that narrates and an intermittent, discrete signal, with a periodic, uninterrupted frequency spectrum.

When a discrete set of real or complex numbers is \( x[n] \), for all integers, the discrete-time Fourier transform (or DTFT) of \( x[n] \) is frequently written as:

\[ X_{2\pi}(\omega) = \sum_{n=-\infty}^{\infty} x[n] e^{-j\omega n} \]  
(3.31)

Within conclusion, the four types of Fourier transforms are different, but they are really close and virtual to each other.
IV-RESULTS AND DISCUSSION

4.1 SIMULINK MODEL OF THE TEST SYSTEM WITH STATIC LINEAR LOAD

Simulink model of the test system is given in below Figure (4.1). The system consists of two parallel feeders with similar loads of the same rating. One of the lines is connected to the wind turbine and the other line is kept as it is. This system is analyzed under different fault conditions. Basically, MATLAB is cast-off as experimental and simulation software for the configuration of the system established up & for location up the data transmission among various nodes existing in the set-up. MATLAB is an important software design & commands are used as a reproduction device.

4.2 SIMULATION RESULT

Increasing automation in the modern industry and deregulation has changed the requirements on Power Quality. Computer and process control apparatus, as well as drive converters, are sensitive to the difference of the line voltage from the ideal sinusoidal. Voltage sags, harmonic distortion, glimmer and disturbance of power supply are the most general problems.

4.3 Input parameter

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In this section, we provide simulation results for energy cooperation of renewable energy in the telecommunication industry. First, the traffic load profiles of the entire workstation data are trained using a neural network, which depicts the instantaneous energy demand of each workstation. Then we simulate the energy generated at each Base Station from its own RES (SPWM + wind).

**Figure-4.1:** Simulink model of a test system with the nonlinear load SPWM wind energy system
Above figure in an increasing number of cases, where conventional equipment cannot solve these problems, SPWM converter-based shunt connected Power with energy storage added to the Power Conditioner even extra flexibility in system procedure and planning is provided for conveniences and industry. In this experimental model, two related loads with dissimilar feeders are considered. Above figure, the control technique implements a wind turbine controller which starts from the difference between the injected current and reference current (identified current) that determines the reference voltage of the inverter.

Figure (a), (b), (c) and (d): Figure specification wind energy efficiency as with Vref and Iref characteristics.

V-CONCLUSION

The proposed controller configuration is reproduced and assemblage segment is tried effectively through the MATLAB continuously prepare. Under the state of unequal cell dc voltages, the ordinary SPWM can able to do low-recurrence of harmonic and Wind energy has been the focus of a number of feasibility studies for renewable energy in India, however, it is considered that a thorough examination of the hydropower potential will reveal a number of locations which could increase hydropower’s contribution to electricity generation in India. The proposed method for telecom site is proven to show 100% reliability on a 24-hour basis, high performance, extended lifetime (20 years) and more cost-effective than conventional power sources. MATLAB software was able to provide these results based on several input data (available solar and wind resources, size and costs of system components and load PWM additionally lessens the negative result of the unequal dc voltages, in this way enhancing the nature of unequal voltage waveform, upgrading the quality accepting ability of the MMC inverter and amplifying a scope of its application.
VI- FUTURE SCOPE

In this research work, it is shown that DSTATCOM can compensate for harmonics in the current. This work can be extended in the following area:

1. Other advanced controllers like a fuzzy controller, the adaptive fuzzy controller can be employed with DSTATCOM to increase the effectiveness of DSTATCOM in distribution networks.
2. In future work, the dynamic loads can be considered and the effect of DSTATCOM with them can be studied.

VII-REFERENCES