Power Quality Improvement using Three-Phase Pulse Width Modulated Rectifire and MPPT

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Abstract— This paper proposes a novel and simple direct power control of three-phase PWM rectifiers with constant switching frequency using space vector modulation (DPC-SVM). The active and reactive power is used as the pulse width modulated (PWM) control variables instead of the three-phase line currents usually used. Moreover, line voltage sensors are replaced by a virtual flux (VF) estimator. The theoretical principle of this method is discussed. The steady state and dynamic results of DPC-SVM that illustrate the operation and performance of the proposed system are presented. It is shown that DPC-SVM exhibits several features as: simple algorithm, good dynamic response, constant switching frequency and particularly provide sinusoidal line current when supply voltage is not ideal. Results have proven excellent performances and verify the validity of the proposed system. The control of modulation index(m) and phi has been shown in the closed loop system. This paper presents the state of the art in the field of regenerative rectifiers with reduced input harmonics and improved power factor. The influence of the discussed modulation methods on the line current distortion and the switching frequency has been examined. The simulation results of the presented techniques have been demonstrated and concluded for various load resistance.

Keywords— Pulse Width Modulation Rectifier, THD, PV Cell, Wind Power, MPPT , Battery, Voltage Source Inverter, LCL Filter.

I. INTRODUCTION

Accompanied by the previous twenty years the enthusiasm for amending units has been rapidly developing in the principle the expanding worry of the electrical utilities and complete clients concerning the adapted Contamination in the power framework. As a result, pulse width- modulated (PWM) rectifiers are of explicit interest and that they became engaging particularly in industrial variable-speed drive applications within the power vary from one or two of kilowatts up to many megawatts. This is partly due to the reduced costs and improved performance of both the power and control electronics components but most of all due to the numerous benefits the using of the PWM rectifiers offers.

There has been a requirement to regulate disturbances to the provision network virtually since it had been initial made within the late nineteenth century the primary of these was British Lighting Clauses Act of 1899 that kept uncontrolled curve lights from causing flash on radiant lights.

With the development of gear at interims the 1970's, it ended up important to deal with the unsettling influences caused by this expanding instrumentation. The development of customer physical science has implied that the normal home contains an excess of mains driven electronic gadgets and not just televisions. Continually these electronic gadgets have mains correction circuits that is existing purpose for mains consonant twisting. most up to date electrical and electronic hardware utilize some sort of air conditioning to dc control supply among their plan and it's these provisions that draw beats of current from the air conditioner organize all through each 0.5cycle give waveform.

The amount of reactive power drawn by one equipment (a domestic tv for example) could also be little, however at intervals a typical street there could also be a hundred or a lot of TVs drawing reactive power from constant offer part leading to a big quantity of reactive current flow and generation of harmonics. Power electronic converters have become a lot of common in industrial and residential applications for reducing size and weight, likewise as for increasing performance and practicality. The domestic tariff meters do not notice this reactive current and also the match between the ability generated which used ends up in a loss of revenue to the utilities.

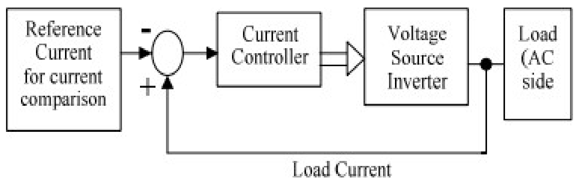

Fig.1.1 Basic block diagram of current controller for VSI

1.2 OVERVIEW OF VOLTAGE SOURCE PWM RECTIFIER

A typical voltage source PWM rectifier configuration is shown schematically in Fig. 1.2. It consists of three parts: line filter, Rectifier Bridge and DC voltage link. Series inductors, which are so-called L-filters, are the most commonly used line filters. Also the LCL-topology, illustrated in Fig. 1.3, has lately become popular due to its higher attenuation above the resonance frequency and better line voltage disturbance rejection capability compared to the L filter. The purpose of the line filter is to attenuate the current ripple produced by PWM switching and, at the same time, to act as energy storage for voltage boost operation. The inductance of the line filter inductor is denoted with 1.The bridge circuit, which is identical to a conventional inverter bridge, is constructed of six controllable power switches and anti parallel diodes. In low- voltage applications the power switches are typically IGBTs with switching frequency from a few kilohertz to a few tens of kilohertz. At medium-voltage levels GTOs or IGCTs are often used. The switching frequency of these devices is typically a few hundred hertz.

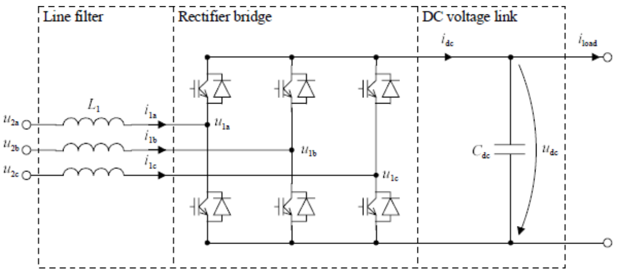

Fig. 1.2: Main circuit of a voltage source PWM rectifier with L-filter

It is additionally conceivable to orchestrate the channel capacitors in delta association. L1 and L2 indicate the inductance of the converter side and line side inductors, individually. i2a, i2b and i2c are the line side stage streams and UCa, UCb and UCc are the voltages of the channel capacitors C.

II. LITERATURE REVIEW

George C. Konstantopoulos et al. [1] —Nonlinear Control of Single-Phase PWM Rectifiers With Inherent Current-Limiting Capability‖, in this paper, a nonlinear controller with an innate current constraining capacity was proposed for single-stage rectifiers. The created methodology ensures nonlinear asymptotic solidness and combination to a novel arrangement consistently, while accomplishing the principle errands of the rectifier activity, i.e., precise yield voltage control and solidarity control factor task. A diagnostic depiction of the controller parameters choice was given to ensure that the info current will be constrained underneath a given an incentive amid drifters regardless of whether the network voltage fluctuates. Contradicted to the current control strategies, the proposed current-restricting controller is completely free from the framework parameters and does not require a PLL or the quick estimation of the network voltage, prompting a rearranged usage. Expansive test outcomes were given to help the speculative establishment of the proposed approach and check its practical movement.

George C. Konstantopoulos et al. [2] —Current-Limiting Non-linear Controller for Single-phase AC/DC PWM Power Converters‖, a current-constraining non-direct controller was proposed to accomplish PFC and yield voltage direction for single-stage air conditioning/dc control converters. The proposed CLNC acts autonomously from the framework parameters and can ensure shut circle framework solidness and a given limit for the information current. Since the CLNC has a straightforward structure and does not require the prompt estimation of the framework voltage or a PLL, its execution turns out to be exceptionally basic. Reenactment results utilizing Matlab/Simulink and a constant computerized test system appropriately checked the hypothetical examination for a few changes of the yield voltage reference.

Omar stihi et al.[3] —A Single-phase Current Controlled PWM rectifier‖, it is shown that by incorporating a butterworth filter in its voltage feedback loop, the single phase controlled current PWM rectifier can be made into a fast response stand alonee system drawing near sinusoidal current waveform at unity power factor with bidirectional power flow capability. The possibility of feedback instability is identified and an experimentally verified approximate theoretical analysis is presented.

Wensheng Song et al. [4] —A Simple Model Predictive Power Control Strategy for Single-phase PWM Converters with Modulation Function Optimization‖, show prescient direct power control (MP-DPC) with the balance work enhancement for the prompt power control of single-stage PWM rectifiers is proposed in this paper. Based on SOGI, the momentary dynamic and responsive forces arrangement of single-stage converters is talked about in two-stage stationary organize outline. The streamlined regulation capacity of the received rectifier is gotten from the cost work minimization in MP-DPC. The proposed MP-DPC conspires joined with the PWM arrange comprises the general control arrangement of the embraced rectifier. What's more, the affectability of the MP-DPC conspire is researched, because of the air conditioner side inductor parameter confound. Based on this, the inductance parameter on-line estimation plot is proposed to wipe out its impact on the responsive power. The execution of the proposed MP-DPC plot is assessed dependent on a solitary stage PWM rectifier downsize test. Besides, it was contrasted and that of ordinary PI-based prompt current control (ICC) approach broadly embraced in the railroad footing application, and the limited control-set (FCS) MP-DPC plot. Also, Table IV demonstrates an execution correlation of these three control plots based on test results and hypothetical examination.

Yongchang Zhang et al. [5] ―Performance Improvement of Two-Vectors-Based Model Predictive Control of PWM Rectifier‖, this paper proposes an improved two-vectors-based MPC (MPC2) for PWM rectifier. Different from prior MPC with duty cycle control (MPC1), which applies a nonzero vector and a zero vector during one control period. The proposed method relaxed the restriction on the second voltage vector, which is possibly a nonzero vector. In other words, in the proposed MPC2, it is possible to apply two nonzero vectors during one control period to achieve better steady-state performance. The principle of the selection of the first vector and the second optimal vector is explained in detail and the theoretical study confirms that the optimal second vector is not necessarily a zero vector. By using the negative conjugate of complex power as the control variable, both the first and second voltage vector in the proposed MPC2can be obtained in a very efficient way, which is favorable for the practical implementation. The vector duration is such derived that the power error is minimized at the end of one control period. The proposed MPC2 is compared with MPC1, DB-SVM, and andDB- 3VV. Both the simulation and experimental results prove that, compared to MPC1 at the same sampling frequency, the proposed MPC2 not only achieves better steady-state performance in terms of reduced power ripples, less current harmonics, and lower THD, but the switching frequency is also reduced by up to 29.5% in average. Furthermore, the current THD of the MPC2 is also lower than those of DB-SVM and DB-3VV.Finally, the merits of MPC1 in terms of quick dynamic response and concentrating the current harmonics on the multiples of sampling frequency are maintained. Hence, it is concluded that the proposed MPC2 is an effective alternative to prior MPC1, DB-SVM, and DB-3VV.

Qing-Chang Zhong et al. [6] ―Nonlinear Current-Limiting Control for Grid-tied Inverters‖, A nonlinear controller with a current-limiting property was proposed for single-phase grid-tied inverters with an LCL filter. The proposed controller can achieve the desired real and reactive power regulation with guaranteed closed-loop stability in the sense of boundedness. In light of the nonlinear elements of the framework and utilizing contribution to-state solidness hypothesis, a given limit for the inverter current is constantly demonstrated autonomously from the power reference esteems. Direction for choosing all the controller parameters was additionally introduced to get the total controller usage technique. The desired performance of the proposed current-limiting controller and the theoretical analysis were verified through extensive simulations.

Deepak Sharma et al. [7] ―The principle techniques of current harmonics reduction and power factor improvement for power plants and the utilities: A review‖, Many new PWM control schemes are being developed which improve the performance of the converter. The indirect current control without the need of current sensors is an improvement over the hysteresis current control scheme as the switching frequency remains constant and all the advantages of HCC are retained. Computerized reasoning systems are being produced for the execution of control procedures in power hardware. A portion of these are fluffy rationale control, fake neural systems. Space vector balance execution is a lot simpler utilizing neural system preparing strategy when contrasted with the one that utilizes the d-q change.

S. P. Gawande et al.[8] ―Current Controlled PWM for Multi level Voltage-Source Inverters with Variable and Constant Switching Frequency Regulation Techniques: A Review‖, This paper

presented a comprehensive review of the distinctive current control PWM strategies utilized for traditional and staggered voltage source inverters. The traditional current control regulation, its enhanced forms and ongoing methods have been abridged. It has-been seen that more elevated amount VSIs require further alteration in the control plan and control calculation of executed strategy. Controller grouping based on factor and steady exchanging recurrence is appeared. The fundamental standards, most recent improvement and a quantitative examination of these strategies have been methodically portrayed. The advantages and impediments have been plot, and the application field, where a specific strategy is suited has been depicted. Taking into consideration the problem of a variable switching frequency in case of hysteresis, which increases the switching losses, the various latest constant switching frequency techniques are discussed and recommended.

III. PROBLEM FORMULATION

The existing method describes AC/DC converters are inherently nonlinear systems because of their change operative perform. Among these devices, the single-phase full-bridge or H-bridge rectifier represents a typical greenhouse emission device operative in pulse-width modulating (PWM) mode and its model is generalized within the three-phase device case.

The three-phase hysteresis current control has an extremely simple and robust structure and excellent dynamic performance. Nevertheless, this control scheme has also disadvantages such as varying and load-dependent switching frequency, wide line current spectrum, poor utilization of the converter zero voltage vectors and interaction between the phases in three-phase three- wire systems. A number of proposals have been put forward to overcome these problems. An adaptive tolerance band can be applied to achieve nearly constant switching frequency

(Bose, 1990). To decrease the switching frequency and to compensate the phase interaction effect, the hysteresis current control based on space-vector approach, three-level comparator and lookup table can be used.

IV. PROPOSED METHODOLOGY

The planned methodology describes a nonlinear controller with a current-limiting property is planned to ensure correct dc output voltage regulation and unity power issue operation forthree-phase pulse-width modulating rectifiers while not the requirement of a phase-locked-loop (PLL). To possess harmonic current alleviation of the provision voltage and also the grid current harmonics, a compensation technique utilizing expedited management of 2 parallel interfacing converters is planned during this section. To boost the ability quality and system performance and reduces the overall harmonic distortion mistreatment the 3 section pulse breadth modulating rectifier and MPPT ways.

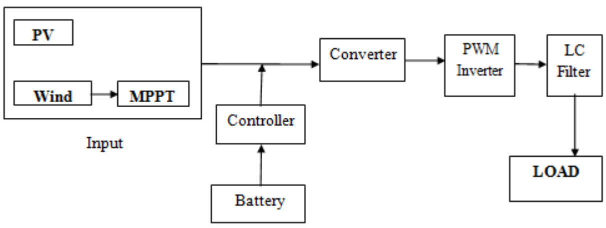

Fig.4.1 Block Diagram of Proposed System

3.1 PHASE CONTROLLED RECTIFIERS

The electric energy conversion created by semi conductive converters is getting used additional and additional. This had diode to the expansion of negative development that appeared negligible, once solely a couple of converters square measure used. But the event of semiconductor structures has enabled higher power to be transmitted and has additionally diode to wide unfold of converters. During this method, converters have a negative impact on the provision network. The regressive effects of overloads with harmonics and reactive power consumption have become major disadvantages of section controlled (mostly thyristor) rectifiers. These facet effects have to be compelled to be remunerated by extra filtering circuits with capacitors or inductances. However, such circuits raise the prices and additionally increase material and house necessities for the device.

Phase management and commutation of semi conductive devices impact the part displacement between 1st|the primary} harmonics of the consumed current and also the first harmonics of the provision voltage. This displacement ends up in power issue degradation and to reactive power consumption. The consumed current harmonics because non-sinusoidal voltage drops on provide the availability the provision} network impedances and cause supply voltage deformation. This could cause malfunctions of alternative devices that area unit wise to the curving form of the provision voltage (e.g. mensuration apparatuses, communication and management systems). The reactive power raises with longer management angle delays that the rectifier acts as time variable ohmic resistance that's nonlinear and causes ill-shapen current consumption.

3.2 THREE PHASE PWM RECTIFIER

The three-phase PWM rectifier/inverter consists of a three-phase bridge (implemented victimization six high speed electronic switches like IGBTs), a three-phase filter, line inductors, current and voltage sensors, and a current management loop (the current management loop allows the three-phase PWM electrical converter to control as a grid-tied rectifier or a grid tied inverter). The road inductors are necessary so as to limit the speed of modification of the present IAC flowing through the ac facet of the three-phase PWM rectifier/inverter, therefore raising the steadiness of the present management loop. Note that three-phase filters, though conditionally necessary to the operation of 3 part PWM rectifiers/inverters, are usually additional to the circuit to eliminate the distortion within the voltage wave shape created at the ac facet of the three-phase PWM.

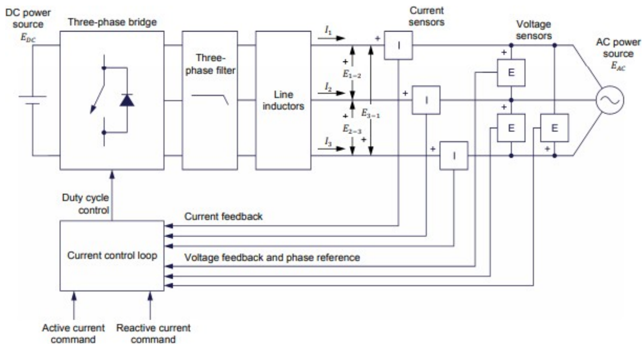

Fig. 4.2 Block diagram of a three-phase PWM rectifier/inverter connected to a dc power source and an ac power source

The higher the worth of the three-phase ac voltage EAC across the ac aspect of the three-phase PWM rectifier/inverter, the upper the voltage EDC that the dc power supply should manufacture. identical suggests that accustomed eliminate or scale back this limitation in single-phase grid- tied inverters are employed in three-phase PWM rectifiers/inverters (e.g., connecting batteries asynchronous to extend the dc power supply voltage, adding a three-phase transformer to decrease the voltage at the ac aspect of the rectifier/inverter).

V. SIMULATION RESULTS

Simulink contains all-inclusive library of sink, source, linear and nonlinear, and connecting blocks. If the blocks cannot meet your needs, however, you may create your own blocks. The intuitive condition improves the displaying procedure, taking out the need to detail differential and distinction conditions in a dialect or program. Simulink is a chunk outline environment for multi territory renovation. It generally bolsters confirmation of inserted frameworks, reproduction, and programmed code age. Constant test and Simulink gives a graphical editorial manager, adaptable square libraries, and solvers for demonstrating and mimicking dynamic frameworks. It is coordinated with MATLAB®, empowering you to consolidate MATLAB calculations into models and fare recreation results to MATLAB for further investigation.

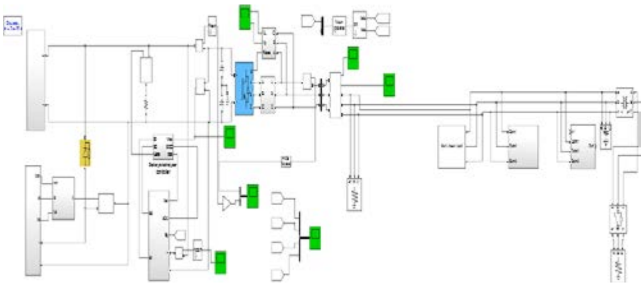

Fig. 5.1 Proposed Model

Figure 5.1 shows the proposed model, to have concurrent relief of the supply voltage and the matrix current music, a pay strategy utilizing composed control of two parallel interfacing converters is proposed in this area. The hardware and control outlines of the proposed framework are appeared in Fig.

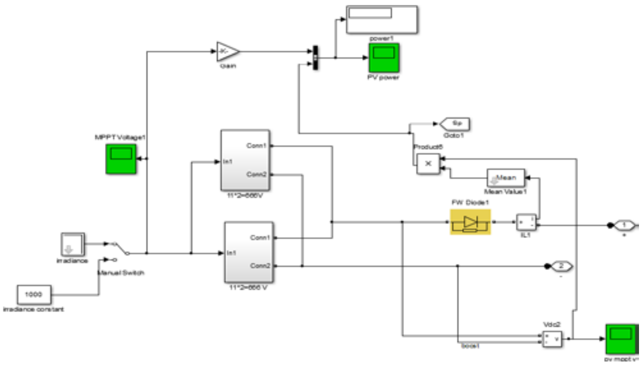

Fig. 5.2:- Subsystem of PV Systems

Proposed model has three sections. Section1 is wind, second is PV cell (Photovoltaic Cell) and last section is battery block. In wind section basic focus is on pitch angle and wind speed. This wind model contains wind turbine that is related to static magnet synchronous generator that is directly driven by turbine while not exploitation case varity of PV panels connected in serial and/or in parallel giving a DC output out of the incident irradiance. Orientation and tilt of those panels are square measure vital style design parameters, furthermore as shading from close obstructions.

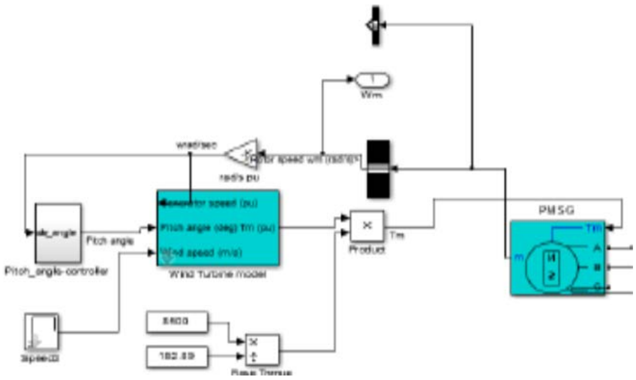

Fig. 5.3: Scheme of Wind Energy System Part 1

The output voltage of the PV and Wind power generation area unit quite low as compared with the required in operating level. Wind turbine that is put in on high of a tall tower, collects mechanical energy from the wind and converts it to electricity that’s compatible with a home’s electrical system. Figure 5.3 shows the wind turbine model half part & Figure 5.4 shows the half of wind Turbine section.

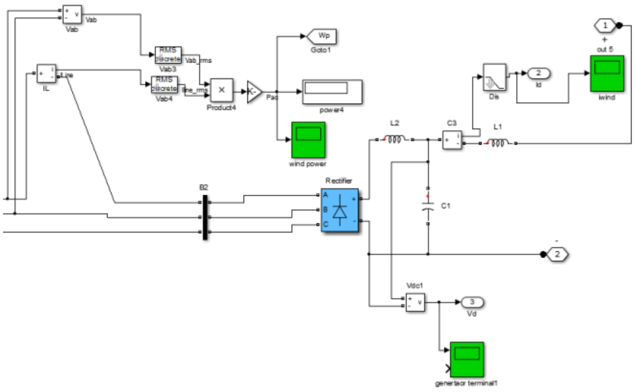

Fig. 5.4: Subsystem of Turbine Energy System Part 2

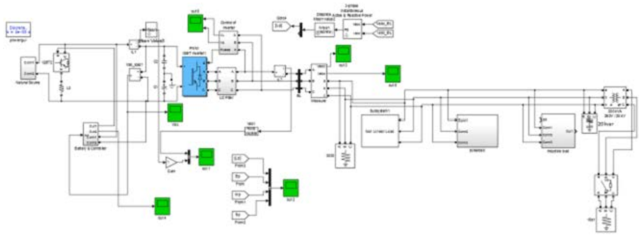

Fig. 5.5: Subsystem of merge PV and Wind, Battery and Controller

Above Figure 5.6 shows the PV cell and load voltage output in which labels shows power and applied voltage level diagram. In this three color wave form blue color shows battery power,

pink color shows wind power, and yellow color show PV power. The MPPT section describes the maximum power point tracking algorithm used to extract the maximum power available to wind hybrid – battery system for load requirement and charging the battery.

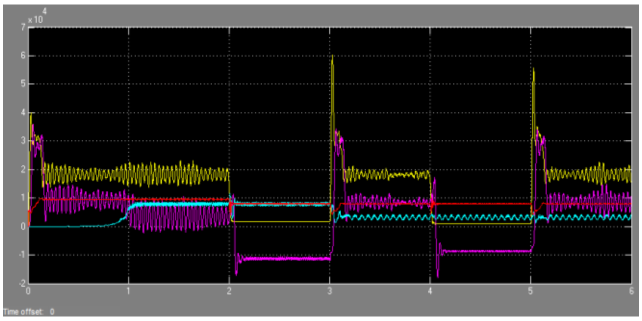

Fig.5.7 Simulation result of the power management when PV and Wind supplies load

In Figure 5.7, the power produced by PV and wind is high; the load demand is also high. In this case the PV alone is sufficient to run the load; the excess power from the wind is used to charge the battery through. In this four color wave form cyan color shows battery power, pink color shows wind power, yellow color show PV power, and red color shows load power.

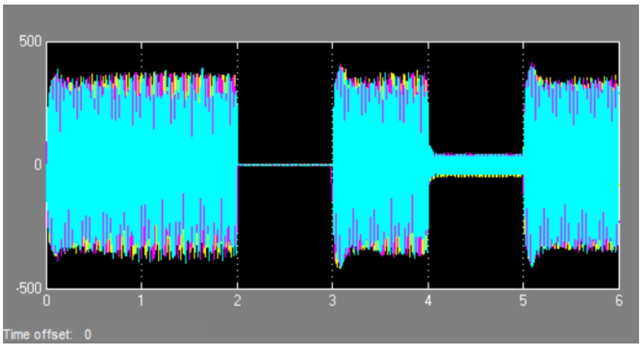

Fig.5.8 Simulation result of the FLC power management when battery alone supplies load

In Figure 5.8 the power produced by the PV is very high, approximately to its maximum power of, the power produced by wind is very low, less than load demand is high. In this case the FLC activates the PV selector switch, the wind selector switch and battery charging switches. Fuzzy rule which satisfies. In this three color wave form blue color shows battery power, pink color shows wind power, and yellow color show PV power.

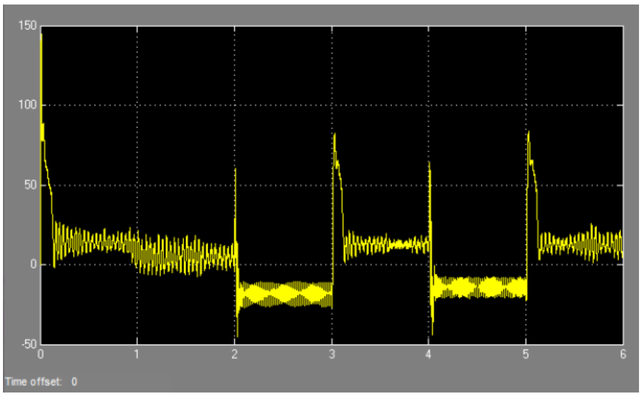

Fig.5.9 Rotor speed with respect to Time

Figure 5.9 shows the variation of the speed of rotor. It is seen that according to the wind speed variation, the generator speed varies and that its power to rotating speed of rotor is produced corresponding to the wind speed variation.

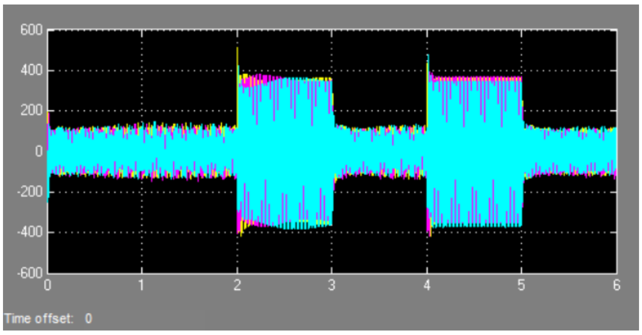

Fig. 5.10 PV output power

Figure 5.11 shows the dynamic response of the PV output power at constant isolation level of and at constant temperature. In Figure 6.6, the power produced by PV and wind are very low, the load demand is medium and the battery state of charge is high enough to run the load. In this three color wave form blue color shows battery power, pink color shows wind power, and yellow color show PV power.

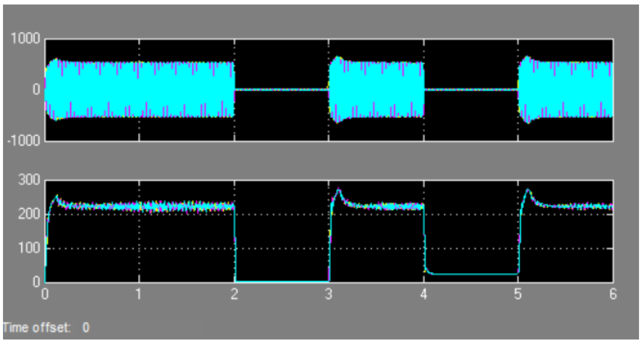

Fig. 5.11 Output Voltage levels of load and PV Cell

Above figure 5.11shows the load voltage & PV cell and output in which labels shows power and applied voltage level diagram. In this three color wave form blue color shows battery power, pink color shows wind power, and yellow color show PV power.

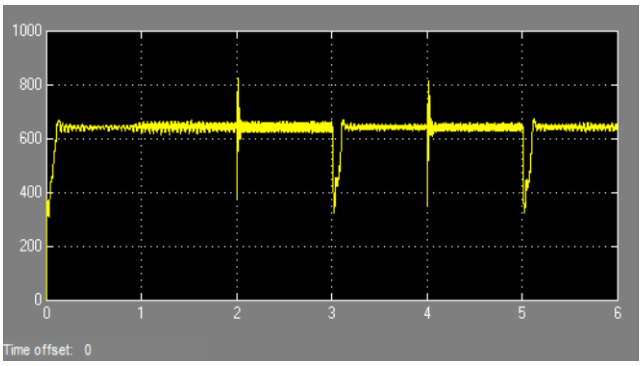

Fig.5.12 DC Voltage

Dc Voltage of the proposed model for the input section has been shown in the figure which shows some speckle in it. The pmsg generates power, in terms of current and voltage with reference speed. Reference speed basically is employed for pitch angle of the rotor blade.

Table 6.1: Input parameters of PV under STC

Input parameters	value
Short circuit current (I_{sc}) {A}	0.709
Voltage at open circuit (V_{oc}) {V}	21.0
Current at maximum power point(I_{mp}) {A}	0.093
Voltage at maximum power point(V_{mp}) {V}	46.59

Table 6.2: The resulting model parameters for single cell of 60-cell in panel

Parameters	Calculated value
Shunt current, I_{sh}(A)	0.1295
Reverse bias saturation current,I_o(uA)	0.026
Band gap energy,E_g,eV	1.16
Phase current, I_{ph} (uA)	0.709

Table 6.3: Comparison among PI and FLC controllers

MPPT Controller	Setting time	Maximum overshoot	Steady state error
PI Controller	42.31s	56%	16.35%
FLC Controller	24.08s	24%	2.35%

VI. CONCLUSION & FUTURE WORK

6.1 Conclusion

Proposed work reduces the total harmonic distortion and the system power quality is improved using maximum power point tracking, wind power, PV cell and three phase pulse width modulated. In the meantime, the harmonic current brought on by the nonlinear load and the principal converter is repaid by the second converter. Consequently, the nature of the network current and the supply voltage are both essentially progressed. To lessen the computational heap of DG interfacing converter, the organized voltage and current control without utilizing load current/supply voltage harmonic extractions or stage bolt loops is produced to acknowledge composing control of parallel converters. At the point when a single multi-useful interfacing converter is received to compensating generation the harmonic current from nearby nonlinear burdens, the nature of supply voltage to neighborhood load can barely be enhanced in the meantime, specific once the basic network voltage is blended.

6.2 Future Work

Further investigation is required to obtain a generic structure that may be applied to both types of ac/converters with different operating conditions (e.g. constant power, constant current loads) and satisfy some additional practical limitations (e.g. saturation of the management input) with an improvement of the ability quality. These issues represent interesting topics for future research.

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