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Simulation & Controlling of 3- Phase Grid Integrated Solar PV System

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Abstract: This paper proposes the use of a simulation and controlling of three-phase grid integrated SPV (Solar Photovoltaic) system. It consists of SPV array, VSC (Voltage Source Converter), three-phase grid and linear/nonlinear loads. This system has a SPV array coupled with a VSC to provide three-phase active power and also acts as a static compensator for the reactive power compensation. It also conforms to an IEEE-519 standard on harmonics by improving the quality of power in the three-phase distribution network. Therefore, this system serves to provide harmonics alleviation, load balancing and regulating the terminal voltage. In order to increase the efficiency the SPV array at varying environmental conditions, a single stage system is used along with P&O (Perturb and Observe) method of MPPT (Maximum Power Point Tracking) integrated with the LMF based control technique. The proposed system is modeled and simulated using MATLAB/Simulink with available simpower system (SPS) toolbox and the behavior of the system under different loads and environmental conditions are verified experimentally on a developed system in the laboratory.
Key words: Solar panel, VSC, MPPT, Battery, LCD, Adriano UNO, Current sensor, Voltage sensor, DC motor

I. INTRODUCTION

Renewable energy (RE) is being gazed upon as the ultimate panacea for tackling global warming, changing climate and controlling the continued depletion of fossil fuels. We are trying to integrate RE systems into the power grid and distribution networks. In the current scenario, the solar energy is the best form of RE in terms of its clean nature, noise-less, non-polluting and available in abundance even in remote locations. Some of the major potential challenges to be faced when integrating solar photovoltaic (SPV) system with the grid are voltage instability, reliability, weak grid system and degraded power quality. The proposed grid integrated SPV configuration is designed, modeled and simula ted in MATLAB/Simulink environment and experimental tests carried on a developed laboratory prototype for unity power factor (UPF) mode along with mitigating harmonics, load balancing and reactive power compensation. The presented system applies a single stage SPV with P&O MPPT for supplying required voltage to VSC dc link.

A. Existing Method

The LMF method is one of the algorithms from the family of the adaptive filters. LMF has been first proposed by Wallach and Widrow in 1984 as a modification to the LMS (Least Mean Square) algorithm. The LMF method has significantly lesser noise in the weights than the conventional LMS algorithm when the time constant values for both the methods are set to be equal. The main goal of this algorithm is to provide a reduced steady state of maladjustment for the assumed rate of learning as compared to the LMS technique. It has been observed that the LMS technique cannot attain good steady state performance in environments having low SNR's (Signal to Noise Ratios) as it works like a lower order adaptive filter.

B. Proposed Method

The proposed method describes to overcome the problem of existing method and to improve the steady state performance of the system, a fourth-order power optimization has been applied which can eliminate noise interferences even in low SNR regions. Hence, the LMF method acts as a higher order adaptive filter in which the updating equation involves fourth-order power optimization. It has been observed that adaptive algorithms like LMF with high order moments of errors perform better MSE (Mean Square Error) than conventional LMS algorithms which has been proved. MSE is a parameter which gives an idea about the performance of error involved with the algorithm. Moreover, proof of the stability of the LMF method over different ranges of step-sizes/adaptation constants are also reported in the literature. The proposed LMF based control algorithm has never been implemented for the harmonics extraction from the sinusoids.

Block diagram of proposed method:

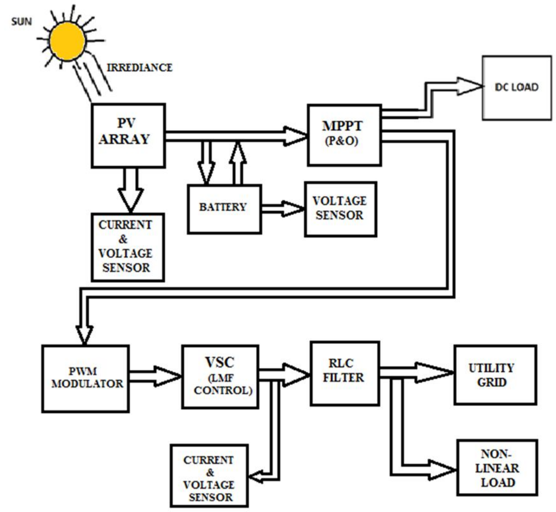

Fig (1), block diagram of proposed method.

C. *Proposed Simulation Model*

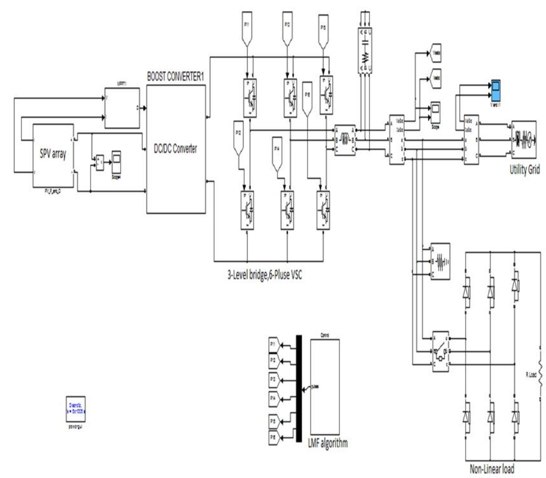

Fig (2), Proposed simulation model.

D. *LMF Control Algorithm*

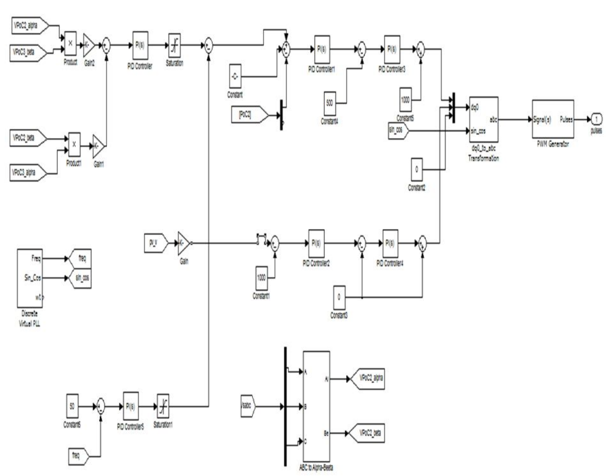

Fig (3), LMF control algorithm.

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II. HARDWARE COMPONENTS:

A. Solar panel

A solar panel (photovoltaic module or photovoltaic panel) is a packaged interconnected assembly of solar cells, also known as photovoltaic cells. The solar panel is used as a component in a larger photovoltaic system to offer electricity for commercial and residential applications. Because a single solar panel can only produce a limited amount of power, many installations contain several panels. This is known as a photovoltaic array. A photovoltaic installation typically includes an array of solar panels, an inverter, batteries and interconnection wiring. Solar panels use light energy (photons) from the sun to generate electricity through the photovoltaic effect. The structural (load carrying) member of a module can either be the top layer (super state) or the back layer (substrate). The majority of modules use wafer-based crystalline silicon cells or a thin-film cell based on cadmium telluride or silicon. Crystalline silicon, which is commonly used in the wafer form in photovoltaic (PV) modules, is derived from silicon, a commonly used semi-conductor. A solar cell or photovoltaic cell is a wide area electronic device that converts solar energy into electricity by the photovoltaic effect. Photovoltaic is the field of technology and research related to the application of solar cells as solar energy. Sometimes the term solar cell is reserved for devices intended specifically to capture energy from sunlight, while the term photovoltaic cell is used when the source is unspecified. Assemblies of cells are used to make solar modules, or photovoltaic arrays.

B. Arduino

Arduino is a single-board microcontroller to make using electronics in multidisciplinary projects more accessible. The hardware consists of a simple open source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM. The software consists of a standard programming language compiler and a boot loader that executes on the microcontroller.

C. Specifications of Arduino

1) Microcontroller: ATmega32
2) Operating Voltage: 5
3) Input Voltage (recommended):7-12
4) Voltage (limits): 620
5) Digital I/O Pins: 14 (of which 6 provide PWM output

6) Analog Input Pins: 6
7) DC Current per I/O Pin: 40 Ma
8) Clock Speed: 16 MHz

D. MPPT Charge Controller

Ideal for Solar Street Light: This charge controller is used to charge a battery from a PV power source. The Maximum Power Point Tracking (MPPT) algorithm is used in advanced solar charge controllers to track the peak power delivered by a solar panel and maximize the energy harvested by the panels. MPPT varies the electrical operating point of the modules and enables them to deliver maximum available power. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage)

1) Specifications:
2) Automatic MPPT tracking.
3) It can track multiple peak power points.
4) Diming control signal (for LED Lamps) for energy saving during non peak hours.
5) Dusk to dawn or continuous output.
6) Suitable for Lead Acid, SMF or VRLA batteries.
7) Automatic periodic equalize charging.
8) Temperature compensated charging

E. LCD

LCD stands for Liquid Crystal Display. LCD is finding wide spread use replacing LEDs (seven segment LEDs or other multi segment LEDs) because of the following reasons:

1) The declining prices of LCDs.
2) The ability to display numbers, characters and graph-ics. This is in contrast to LEDs, which are limited to numbers and a few characters.
3) Incorporation of a refreshing controller into the LCD, thereby relieving the CPU of the task of refreshing the LCD. In contrast, the LED must be refreshed by the CPU to keep displaying the dat
4) . Ease of programming for characters and graphics.

These components are "specialized" for being used with the microcontrollers, which means that they can-not be activated by standard IC circuits. They are used for writing different messages on a miniature LCD.

III. CONTROL ALGORITHM

The proposed system employs a single stage converter topology to effectively extract the maximum power from the SPV array and to regulate the dc link voltage at the VSC. The control algorithm consists of two components: MPPT algorithm and the control algorithm of VSC. The purpose of the MPPT algorithm is to extricate maximum power from the SPV array at all conditions and also to provide a reference VSC-DC link voltage which is used to sustain the dc bus voltage to its desired level.

A. MPPT Control

Out of various MPPT algorithms reported in the literature, the most often used one is the P&O technique due to its generic nature and the simplicity. This technique is based on the fact that at the MPP (maximum power point) the derivative of power w.r.t. the voltage is zero. At any point of operation on the power versus voltage curve, if the voltage at that point is perturbed in any direction and the change in power is positive, then it is said that the perturbation has moved the SPV array's operating point towards the new MPP and the perturbation is then continued in same direction. Another case would be if the change in power is negative, then it is said that the perturbation has moved the SPV array's operating point away from the MPP which means the next perturbation has to be in the reversed direction. Last case is if the change in power is zero, which means the array's operating at its MPP. Here the MPPT inputs SPV array voltage (*Vpv*) and current (*Ipv*) and it processes to give dc reference voltage *V dc* as its output.

B. Control Algorithm for Switching of VSC

Fig.3 covers the structure of the LMF based control technique for the estimation of reference three-phase grid currents. As seen from Fig., the control algorithm is sub- divided into small sections such as estimation of in-phase and quadrature unit templates from sensed PCC voltages, the extraction of the active and reactive fundamental components of the load currents as well as their weights, generating the three phase reference grid currents and generating gate signals for switching of the converter via pulse width modulation (PWM) controller.

IV. MATLAB MODELING

The proposed model of three phase SPV power generating system integrated with the grid is modelled and simulated in MATLAB/Simulink with the help of simpower system toolbox. The LMF based control algorithm proposed here serves to extricate maximum power from SPV array as well as improving the power quality parameters of the distribution network. To demonstrate these functions of the proposed system, its behaviour is observed and studied under different load conditions (linear or nonlinear loads) and environment conditions (variable insulation).

V. SIMULATION RESULTS

The behaviour of the model of SPV grid interactive system is implemented in MATLAB/Simulink with UPF and ZVR modes of operation under different conditions. For assessing the behaviour of the proposed system, results involve significant signals such as grid voltages (*v*sabc), grid currents (*i*sabc), load currents (*iLabc*), reference grid currents (*i s*), VSC voltages (*vspv*), VSC currents (*ispv*), VSC-DC link voltage (*Vdc*), SPV array dc current (*Ipv*), SPV array dc voltage (*Vpv*), and SPV array dc power (*Ppv*).

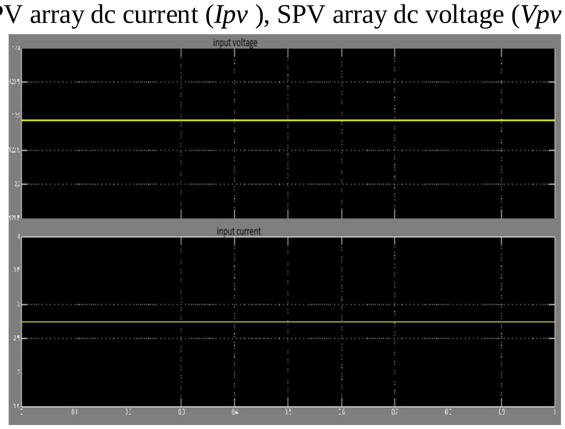

Fig.5(a)

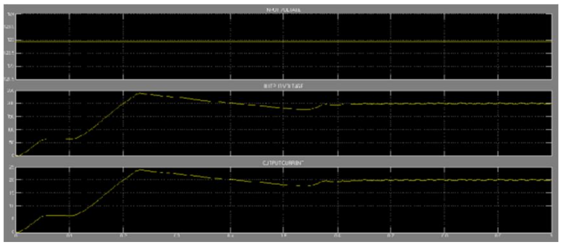

Fig.5(b)

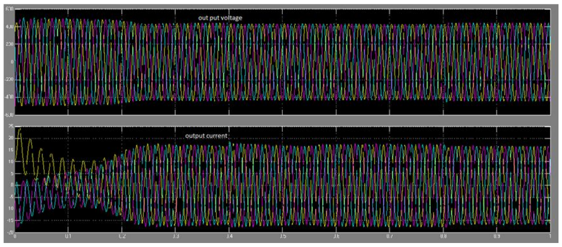

Fig.5(c)

Fig (5) (a) Solar PV array voltage and currents.(b) DC boost converter I/O voltage &currents.(c) Grid voltage and currents with study state condition

VI. CONCLUSION

The proposed control algorithm has been based on a LMF adaptive filtering technique. This technique has been designed for grid integration of SPV system. The simulation results have depicted that THD (total harmonics distortion) of the grid currents is within limits and maximum power is extracted from the SPV system. The response of the proposed system configuration has proved to be effective and reliable in comparison with existing conventional control algorithms. Moreover, the experimental results have shown that the single stage SPV system has less loss in the converter system giving rise to high efficiency as compared to the double stage SPV system. The performance of proposed LMF based control algorithm has been found with less oscillation in the weight signals than the conventional LMS control algorithm. The static error as well as MSE involved with the LMF control is lower than the MSE involved with LMS control. In comparison with other conventional control algorithms, LMF is less complex, stable and has a high DSP speed of about 0.26 million operations per second. Eventually, it reduces the harmonics on the grid side below 5% which is the IEEE-519 standard limit for THD.

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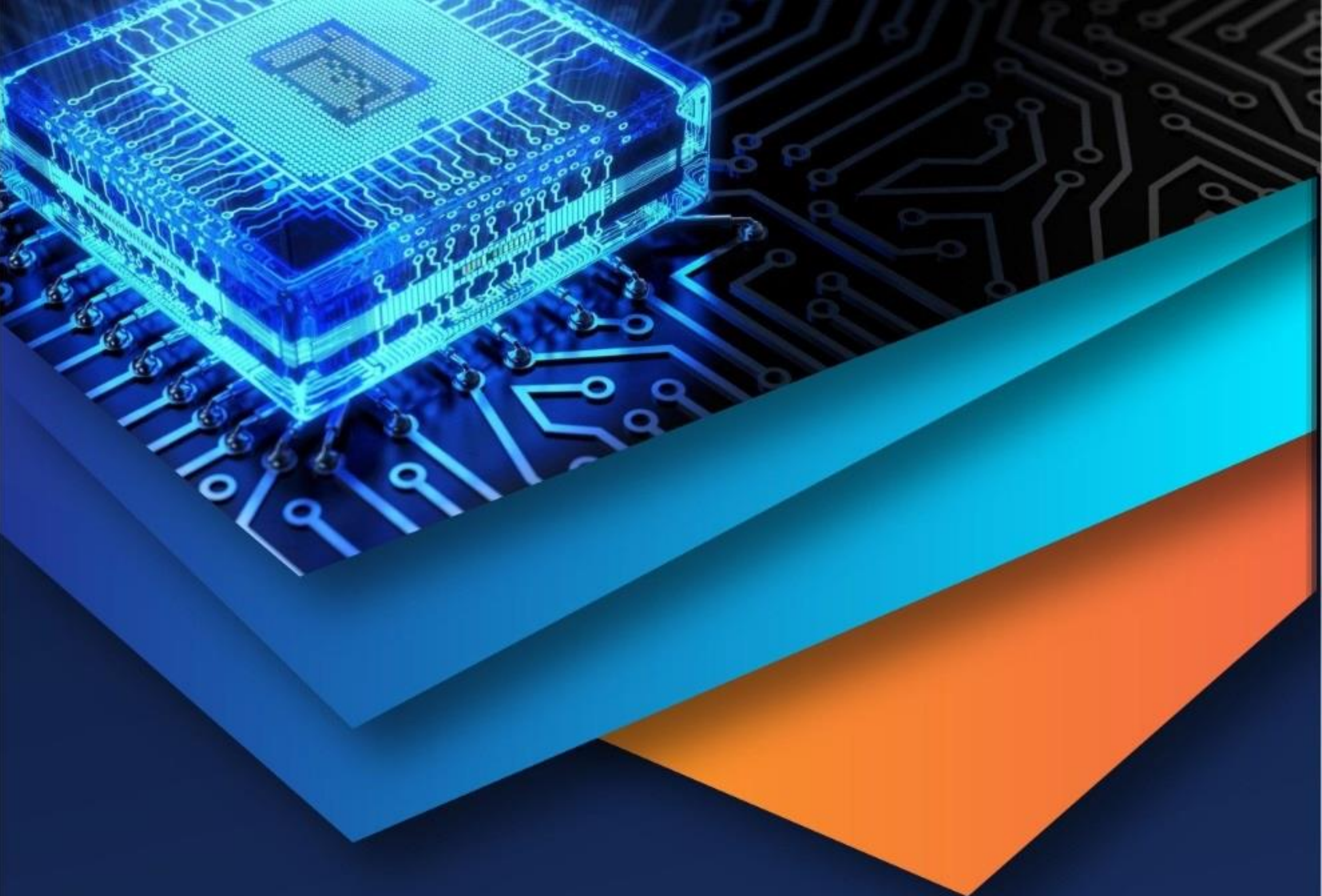

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