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Survey Report on Single-Phase Pulse Width Modulated Rectifier

Avinash Kumar Rai[1], Deepak Pandey[2], G.P. Rathore[3]
[1]*M.Tech Scholar, Electrical & Electronics Engineering, TIT, Bhopal, avinashrai49@gmail.com, India;*
[2,3]*Assistant Professor, Electrical & Electronics Engineering, TIT, Bhopal, deepakniist@gmail.com,girrajmist@gmail.com, India;*

Abstract *– The equipment connected to an electricity distribution network usually needs some kind of power conditioning, typically rectification, which produces a non-sinusoidal line current due to the nonlinear input characteristic. Pulse width-modulated (PWM) rectifier technology is increasingly used in industrial applications like variable-speed motor drives, since it offers several desired features such as sinusoidal input currents, controllable power factor, bidirectional power flow and high quality DC output voltage. Recently, however, new control approaches analogous to the well-established direct torque control (DTC) methodology for electrical machines have additionally emerged to implement a superior PWM rectifier. This approach is predicated on phase shifting of 2 boost converters connected in parallel and dealing at a similar switching frequency. The PI controller is employed to reshape the input current therefore on reduce the harmonics. The input EMI filter is inserted in the projected strategy thus as to reduce the effects of switching harmonics.*

Keywords*: PWM rectifiers, nonlinear control, current limit, asymptotic stability, grid voltage dip, Single-phase rectifier, model predictive power control, modulation function optimization, parameter sensitivity,*

I. Introduction

In earlier time's rectification accustomed be a far easier concern covering circuits like the peak-detection and inductor-input rectifiers, the phase-controlled bridge, poly-phase transformer connections, and maybe some multiplier factor circuits. But recently, rectifiers have become far more sophisticated and currently complicated systems instead of mere circuits. An intensive research within the area of variable-speed AC drives has been administered over the last four decades. For an extended time the emphasis of the analysis has been put on the motor inverter and its control, whereas the AC to DC rectification has been accomplished by an uncontrollable diode rectifier or a line commutated phase controlled Thyristor Bridge. Although both these converters offer a high reliability and simple structure they also have major inherent drawbacks. The output voltage of the diode rectifier cannot be controlled and the power flow is unidirectional. Furthermore, the input current of the diode rectifier has a relatively high distortion. By controlling the firing angle, the DC voltage of the Thyristor Bridge can be regulated. Also power flow from the DC side to the AC side is possible, but because the polarity of the DC voltage must be reversed for this to occur, a thyristor bridge is not a suitable rectifier for applications where a fast dynamic response is required.

In fact, the DC voltage polarity change is not even allowed due to the electrolytic capacitors typically used in the DC link of a voltage source converter. By connecting two thyristor bridges anti parallel, bidirectional power flow is possible without DC voltage polarity reversal, but, as a result, the number of the power switches is doubled. In addition, the power factor of the thyristor bridge rectifier decreases once the firing angle will increase and therefore the line current distortion may be an even worse drawback than that of the diode rectifier. Current controlled pulse width modulated (PWM) inverters are rather more well-liked due to their smart dynamic response. Since most of the applications for voltage-source pulse width modulated (PWM) inverters have an effective structure involving an internal current feedback circuit, their performance depends on the quality of the applied current control technique. As a result, the current management techniques for PWM voltage supply inverters are one amongst the most important areas of research in modern power electronics. compared with typical open-loop PWM voltage source inverters (VSI), current-controlled PWM inverters have the benefits of extremely smart dynamics, overload rejection, peak current protection, management of the instant current waveforms, high accuracy, compensation of effects because of load parameter changes, compensation of the semiconductor voltage drops and dead time of the converters, compensation of the dc-link and ac-side voltage changes, etc. [1]. At present, thorough analysis is underway on the optimization of modulation techniques for multilevel inverters [2]. The fundamental diagram of a voltage source inverter with PWM current management is shown in Fig 1.

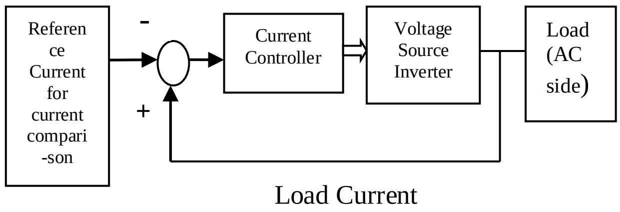

Fig.1 Basic current controller VSI block diagram

II. Literature Survey

George C. Konstantopoulo S et al. [1] "Nonlinear Control of Single-Phase PWM Rectifiers With Inherent Current-Limiting Capability", a nonlinear controller with an inherent current limiting capability was proposed for single-phase rectifiers. The developed strategy guarantees nonlinear asymptotic stability and convergence to a unique solution at all times, while achieving the main tasks of the rectifier process, i.e., truthful amount produced voltage regulation and unity power factor operation. An analytic description of the controller parameters selection was provided to guarantee that the input current will be limited below a given value during transients even if the grid voltage varies. Opposed to the existing control techniques, the projected current-limiting controller is totally freelance from the system parameters and doesn't need a PLL or the instantaneous measuring of the grid voltage, leading to a simplified implementation. Extensive experimental results were provided to support the theoretical background of the proposed approach and verify its effective operation.

George C. Konstantopoulos et al.[2] "Current-Limiting Non-linear Controller for Single-phase AC/DC PWM Power Converters", A current-limiting non-linear controller was proposed to achieve PFC and output voltage regulation for single-phase ac/dc power converters. The projected CLNC acts independently from the system parameters and may guarantee closed-loop system stability and a given limit for the input current. Since the CLNC encompasses a straightforward structure and doesn't need the instantaneous measurement of the grid voltage or a PLL, its implementation becomes very simple. Simulation results using Matlab/Simulink and a real-time digital machine suitably verified the theoretical analysis for many changes of the output 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 alone 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", model predictive direct power control (MP-DPC) with the modulation function optimization for the instantaneous power regulation of single-phase PWM rectifiers is proposed in this paper. On the basis of SOGI, the instantaneous active and reactive powers solution of single-phase converters is discussed in two-phase stationary coordinate frame. The optimized modulation function of the adopted rectifier is obtained from the cost function minimization in MP-DPC. The proposed MP-DPC scheme combined with the PWM stage constitutes the overall control system of the adopted rectifier. And the sensitivity of the MP-DPC scheme is investigated, due to the ac-side inductor parameter mismatch. On the basis of this, the inductance parameter on-line estimation scheme is proposed to eliminate its effect on the reactive power.

Yongchang Zhang et al. [5] "Performance Improvement of Two-Vectors-Based Model Predictive Control of PWM Rectifier", The proposed method relaxed the restriction on the second voltage vector, which is possibly a nonzero vector. 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 MPC2 can be obtained in a very efficient way, which is favorable for the practical implementation. 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", Guidance for selecting all the controller parameters was also presented to obtain the complete controller implementation procedure. 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" The principle of operation and implementation of each scheme is discussed in detail and the advantages and disadvantages of each scheme are stated. A closed loop control system has been designed for each control strategy and the converters are simulated using the MATLAB/SIMULINK program. The performance of the converter under each control strategy is evaluated. Artificial Intelligence techniques are being developed for the implementation of control techniques in power electronics. Some of these are fuzzy logic control, artificial neural networks.

S. P. Gawande et. al.[8] "Current Controlled PWM for Multilevel Voltage-Source Inverters with Variable and Constant Switching Frequency Regulation Techniques: A Review" A multilevel topology approach is found to be best suited for overcoming many problems arising from the use of high power converters. This paper presents a comprehensive review and comparative study of several current control (CC) techniques for multilevel inverters with a special emphasis on various approaches of the hysteresis current controller. Since the hysteresis CC technique poses a problem of variable switching frequency, a ramp-comparator controller and a predictive controller to attain constant switching frequency are described along with its quantitative comparison.

Nancy Visairo et. al. [9] "A single nonlinear current control for PWM rectifier robust to input disturbances and dynamic loads" In this paper, authors propose a simplified approach to address that problem by using a feedback linearization-based nonlinear controller using only a single-loop current control and avoiding d-q modeling to reduce processing stages. To demonstrate the feasibility of this approach, several simulations are presented considering a 1.5 kW PWM rectifier.

Fernando Arturo Ramírez et. al. [10] "A Novel Parameter-independent Fictive-axis Approach for the Voltage Oriented Control of Single-phase Inverters" This paper presents a novel Parameter-Independent Fictive-Axis (PIFA) approach for the Voltage-Oriented Control (VOC) algorithm used in grid-tied single-phase inverters. VOC is based on the transformation of the single-phase grid current into the synchronous reference frame. As a result, an orthogonal current signal is needed. Traditionally, this signal has been obtained from fixed time delays, digital filters or a Hilbert transformation. Nevertheless, these solutions present stability and transient drawbacks. Recently, the Fictive Axis Emulation (FAE) VOC has emerged as an alternative for the generation of the quadrature current signal. FAE requires detailed information of the grid current filter along with its transfer function for signal creation.

III. Method

The method describes a nonlinear controller with a current-limiting property is to guarantee accurate dc output voltage regulation and unity power factor operation for single-phase pulse-width modulating rectifiers without the need of a phase-locked-loop (PLL). The current-limiting controller is fully independent of the system parameters and can guarantee asymptotic stability and convergence to a unique solution for the closed-loop system using nonlinear control theory.

III.1. Phase controlled rectifiers

The electric energy conversion made by semiconducting converters is being used more and more. This had led to the growth of negative phenomenons that appeared negligible, when only a few converters are used. However the development of semiconductor structures has enabled higher power to be transmitted and has also led to wide spread of converters. In this way, converters have a negative effect on the supply network. The regressive effects of overloads with harmonics and reactive power consumption are becoming major disadvantages of phase controlled (mostly thyristor) rectifiers. These side effects need to be compensated by additional filtering circuits with capacitors or inductances. However, such circuits raise the costs and also increase material and space requirements for the converter. Phase control and commutation of semiconducting devices impact the phase displacement between the first harmonics of the consumed current and the first harmonics of the supply voltage. This displacement leads to power factor degradation and to reactive power consumption. The consumed current harmonics cause non-sinusoidal voltage drops on the supply network impedances and lead to supply voltage deformation. This may cause malfunctions of other devices that are sensible to the sinusoidal shape of the supply voltage (e.g. measurement apparatuses, communication and control systems).

III.2. PWM rectifiers

In order to suppress these negative phenomena caused by the power rectifiers, use is created of rectifiers with a additional refined management algorithmic program. Such rectifiers are accomplished by semiconductors that may be shifted IGBT transistors. The rectifier is controlled by pulse width modulation. A rectifier controlled in this approach consumes current of required form that is generally sinusoidal. It works with a given phase displacement between the consumed current and therefore the supply voltage. The power factor also can be controlled and there are minimal effects on the supply network.

PWM rectifiers are often divided into 2 groups in keeping with power circuit affiliation – this and therefore the voltage type.

For proper operate of current a kind rectifier, the maximum value of the availability voltage should be more than the value of the rectified voltage. The main advantage is that the corrected voltage is regulated from

zero. They're appropriate for work with DC loads (DC motors, current inverters) for proper operate voltage kind rectifiers need higher voltage on the DC side than the maximum value of the supply voltage. The rectified voltage on the output is smoother than the output voltage of the current type rectifier. They also require a more powerful microprocessor for their management. The function of the rectifier depends on the availability form of network. There are 2 styles of offer network – "hard" and "soft".
Ordinary rectifiers that work on a relatively "hard" supply network don't affect the shape of the supply voltage wave form. Harmonics produce electromagnetic distortion, and also the network will be loaded with reactive power. The PWM rectifier aims to consume curved current and to work with given power factor.

III.3. Grid-Tied Single-Phase Inverter

The layout of a single-phase grid-tied VSC is depicted in Fig. 2. The VSC is connected to electric mains through an inductive current filter, although it may be substituted with other filter topologies such as the LC, LCL, LLCL and (LCL) 2 filters. The VOC controller is based on treating the grid as a virtual electrical machine. Accordingly, the filter inductance and resistance become analogous to stator parameters, while the grid voltages are treated as the voltages induced in the virtual electric machine. The grid voltage and current are assumed to be aligned along the α-axis. A fictitious quadrature axis, β, is created to transform the system into the synchronous reference frame.

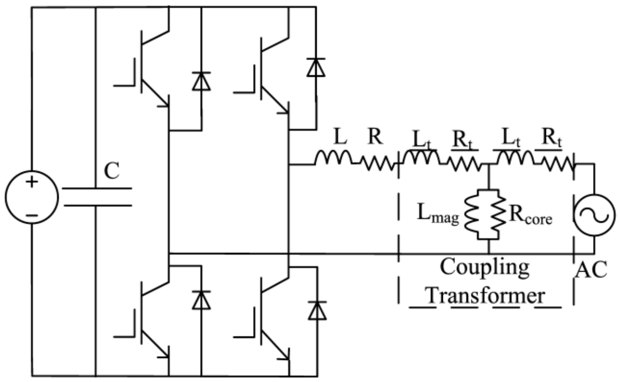

Fig. 2. Single-phase grid-tied inverter.

IV. Conclusion

This paper gives a review of previous work related to Nonlinear Control of Single-Phase PWM Rectifiers With Inherent Current-Limiting Capability. In which many different method should be applied and explained briefly in literature survey section. In [1] nonlinear controller with an inherent current limiting capability was proposed for single-phase rectifiers. The developed strategy guarantees nonlinear asymptotic stability and convergence to a unique solution at all times, while achieving the main tasks of the rectifier operation, i.e., accurate output voltage regulation and unity power factor operation. In [2] proposed CLNC acts independently from the system parameters and can guarantee closed loop system stability and a given limit for the input current.

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