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An Improved DC-Link Voltage Control Strategy for Grid Connected Converters

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ABSTRACT: This paper presents a robust control strategy to improve dc-link voltage control performances for Grid connected Converters (GcCs). The proposed control strategy is based on an adaptive PI controller and is aimed to ensure fast transient response, low dc-link voltage fluctuations, low grid current THD and good disturbance rejection after sudden changes of the active power drawn by the GcC. The proportional and integral gains of the considered adaptive PI controller are self-tuned so that they are well suited with regard to the operating point of the controlled system and/or its state. Several simulation and experimental results are presented to confirm and validate the effectiveness and feasibility of the proposed dc-link voltage control strategy.

KEYWORDS: DC-link voltage control, adaptive PI controller, Grid connected Converters

I.INTRODUCTION

Nowadays, power converters have an important role in a large scale of industrial applications since they allow efficient power transmission between the grid (on one side) and loads or energy sources (on the other side). The commonly used power converters topologies use a dc-link as an intermediate stage for the power conversion process in addition to a Grid connected Converter (GcC) and a filter based on passive (inductive and/or capacitive) elements. For example, this is the case of adjustable speed drives, renewable energy sources active power filters, UPS systems and back-to-back systems. Efficient dc-link voltage control is very important for such applications to reduce voltage fluctuations in the dc-link which are mainly caused by random changes (particularly sudden and sever changes) in the power drawn by the GcC. When these fluctuations cross their limits, the protection devices are activated leading to a system shut-down. Thus, the control objectives pertaining to the dc-link voltage can be summarized in the following key points: 1) the voltage across the dc-link capacitor must be kept at a constant value by controlling the power flow in the AC side of the GcC so that two objectives are satisfied: the first one is the upkeep of the capacitor charge, while the second one is the supply of a load connected to the dc-link (for the rectifying mode case) or the transfer of the power provided by a DC source (for the inverting mode case), 2) the dc-link voltage fluctuations must be minimized, 3) the generation of high grid current harmonics must be prevented and 4) The deviation from the unity power factor operation caused by the grid current ripples must be prevented. The most frequently used dc-link voltage controller is the PI controller Different PI controller design techniques were described in literature. Among them, we can cite the pole zero cancellation method, the pole placement method and the optimum criterion method. For these methods, the PI controller is usually adjusted with respect to different constraints: *C*1) stability; *C*2) dynamic performances; *C*3) disturbance rejection; and *C*4) step responses with low overshoot. In order to satisfy all these constraints, some research works presented the design of adaptive PI controllers. Other ones combine between the benefits of the PI controller and the feed forward compensation method. For that case, despite the excellent improvement of dynamic performances, such a method increases the coupling between the controlled dc-link voltage and the grid currents. Consequently, any noise or fast oscillation in the grid currents can create ripples at the output reference of the dc-link voltage controller. Other works have presented a Direct Power Control (DPC) combined with the boundary control to improve the dynamic performances of the dc-link voltage. Compared to the conventional DPC, the dc-link voltage is considered for selection of the switching states through a switching table. As a result, no outer loop is needed and the dynamic performances are highly improved. However, this method results into a variable switching frequency, which is limited to the half of the used sampling period and which depends on the system parameters, dc-link voltage and ac-side voltage. So, the DPC combined with boundary control cannot be used for applications that require constant switching frequency, like the case of LCL-based GcCs since it will lead to resonance problems. Moreover, this control will lead to high grid current THD values during steady state operation if low mean switching frequency is achieved.

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II.SYSTEM MODEL AND ASSUMPTIONS

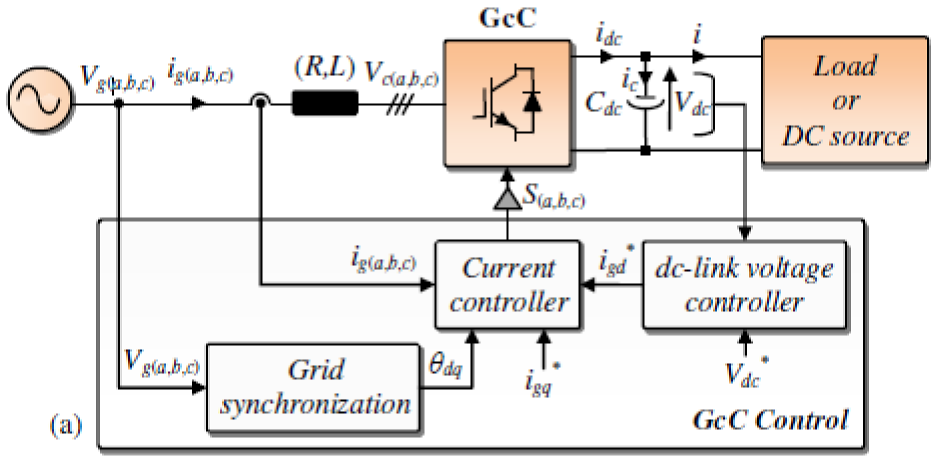

Fig.1 Commonly used control structure for Grid-connected Converters

This paper proposes an efficient adaptive PI controller for the dc-link voltage control. The adaptive nature of the proposed PI controller guarantees the different control constraints *C*(1.4) mentioned in the previous paragraph in addition to the reduction of grid current THD during steady state operation, which is mainly caused by dc-link voltage controller's output signal. The proportional and integral gains of the considered adaptive PI controller are self-tuned according to the operating point of the controlled system and/or its state (*i.e*. transient or steady state). For that, a band around the dc-link voltage reference is defined. When the measured dc-link voltage is outside this band, the PI gains were selected constants so that a very good dynamic is achieved. Otherwise, the PI gains become variable so that the previously mentioned constrains remain still satisfied. Also, an anti-windup process is added in order to prevent large overshoot after step jumps of the dc-link voltage reference. The rest of the paper is organized as follow. Section II presents a simplified modeling, analysis and design of the dc link voltage controller. Then, section III describes the proposed adaptive dc-link voltage controller. Accordingly, section IV shows and discusses the obtained experimental results with the proposed adaptive PI controller. Finally, section V summarizes the main conclusions of this work.

III. SYSTEM DESCRIPTION

A. Modeling and design of the dc-link voltage controller

The studied system is depicted on Fig.8.1, where L(respectively R) is the filter inductor (respectively the filter resistor); C is the capacitor of the dc-link; $V_{g(a,b,c)}$ refer to the components of the grid voltage vector in the natural reference frame; $i_{g(a,b,c)}$ refer to the components of the grid current vector in the natural reference frame; $S(a,b,c)$ are the GcC switching states; V_{dc} is the dc-link voltage; V_{dc*} is the dc-link voltage reference; i_{dc} is the current coming out from the power converter; i_c is the current flowing into the capacitor C; i is the current consumed/generated by the load/the DC source connected to the dc-link; and $i_{g(d,q)*}$ are the d and q components of the grid current reference in the synchronous reference frame (d,q), where the d axis is linked to the grid voltage vector.Fig.8.1 shows also that the control structure of a GcC includes three main functions: the grid synchronization [2], the current controller [3] and the dc-link voltage controller [5].

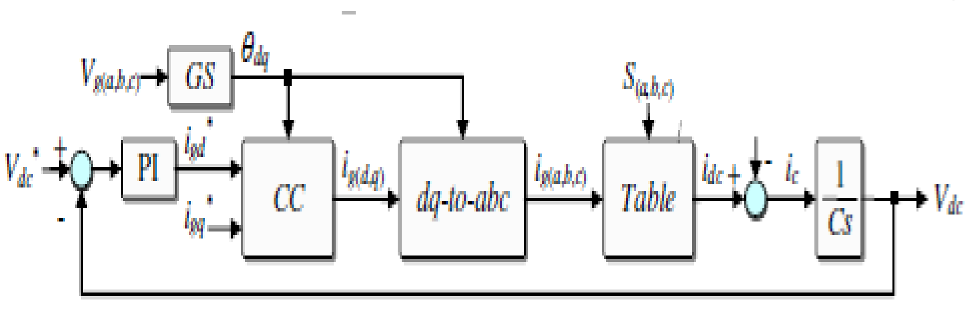

Fig.2 Model of the dc-link voltage control system

$$\left.\begin{array}{l} P_{AC}=\frac{3}{2}V_{gm}i_{gm}\approx\frac{3}{2}V_{gm}i^{*}_{gd} \\ P_{dc}=V_{dc}i^{mean}_{dc} \end{array}\right\} \rightarrow I_{dc}^{mean}\approx\frac{3}{2}(V_{gm}/V_{dc}^{*})\,i^{*}_{gd}=G\,i^{*}_{gd} \quad (1)$$

Above Fig. shows the model of the dc-link voltage control system. In this figure, *GS* and CC stand for grid synchronization and current controller, respectively. It can be noted that the dc-link voltage control is not in the form of a LTI system. This is mainly due to nonlinearities introduced by the i_{dc} table that computes i_{dc} current based on grid currents $i_{g(a,b,c)}$ and applied switching signals $S_{(a,b,c)}$. To simplify the model, the relationship between the mean value of i_{dc} (i_{dc}^{mean}) and i_g^* currents is firstly determined. This relationship is deduced according to equation (1) [20]. In this equation, $P_{AC}$is the active power fed in the AC side of the GcC, V_{gm} is the magnitude of the phase voltage, i_{gd} is the *d* component of the grid current and P_{DC} is the active power fed in the DC side of the GcC. Supposing that $V_{dc}\approx V_{dc}^*$ and neglecting the power losses on the GcC and on the internal resistor of the inductive filter ($P_{AC}\approx P_{DC}$), the relationship between i_{dc}^{mean} and i^* currents can be deduced as shown in equation(1).

IV. RESULT

A PI controller can be used to control the DC link voltage effectively. This indicates that PI controllers can be applicable to any type of load like linear, non-linear or its combinations. Also, it works under variable load conditions with basic shunt active filters and an analysis is conducted using a MATLAB simulation under various load conditions.

Table 1 Parameter table

Symbol	Description	Value	Unit
S	GcC rated power	20	KVA
L	Inductive filter	40	mH
C	Dc-Link Voltage capacitor	1100	µF
Z_{load}	Load Impendence	120	Ω
I_{max}	Maximum load current	1.25	A
V_{dcintl}	Dc link Voltage initial value	100	V
V_{dc}	Dc link voltage Reference value	150	V
G_{dc}	Ratio of the DC-link voltage band	10	%
Λ	Used coefficient for ω_n *computation*	1	-
ω_{nmax}	Maximum natural frequency	2π22.73	rad/s
$\omega nopt$	Optimal natural Frequency	2π5.35	rad/s
$\omega nmin$	Minimal natural Frequency	2π3.5	rad/s
Ξ	Damping ratio	0.7	-
K_c	Anti- windup coefficient	0.02	-
T_s	Sampling period	50	µs

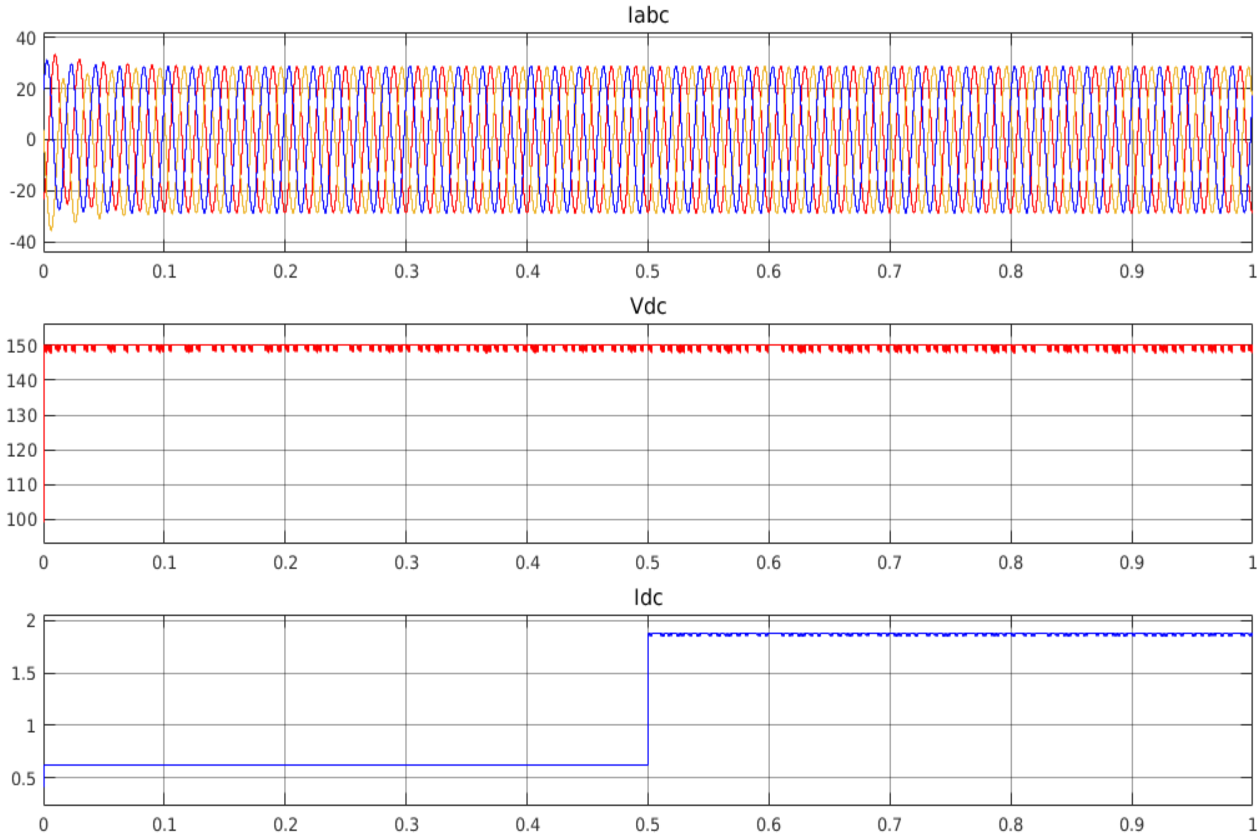

Fig.3 Result waveform

V.CONCLUSION

This system presented an improved dc-link voltage controller based on an adaptive PI controller with an anti-windup process. The proportional and integral gains of the proposed PI controller are self-tuned so that the following constraints are satisfied: 1) no overshoot after step jumps of the dc-link voltage reference input; 2) fast dynamic response after step jumps of the dc-link voltage reference; 3) fast dynamic response after step jump of the input current *i* and 4) low grid current THD value during steady state operation. The considered control was experimentally tested on a prototyping platform. The obtained experimental results are quite similar to simulation results and show the effectiveness and reliability of the adopted control strategy.

REFERENCES

[1] Meriem Merai, Mohamed Wissem Naouar, "An Improved DC-Link Voltage Control Strategy for Grid Connected Converters" IEEE Trans. Power Electron.

[2] M. Karimi-Ghartimani, S.A. Khajehoddin, P. Jain, A. Bakhshai, "A systematic approach to dc-bus control design in single phase grid connected renewable converters," IEEE Trans. Power Electron, vol. 28, no. 7, pp. 3158–3166, July.2013.

[3] Sayed Ali Khajehoddin, Masoud Karimi-Ghartemani ,"DC-Bus Design and Control for a Single-Phase Grid-Connected Renewable Converter with a Small Energy Storage Component" IEEE Transactions on Power Electronics, VOL. 28, NO. 7, JULY 2013.

[4] Chi-Seng Lam, Man-Chung Wong was present "Adaptive DC-Link Voltage-Controlled Hybrid Active Power Filters for Reactive Power Compensation". IEEE Transactions on Power Electronics, VOL. 27, NO. 4, APRIL 2012.

[5] Daniel Salomonsson, Ambra Sannino was discuss and analysis "Comparative Design and Analysis of dc-Link-Voltage Controllers for Grid-Connected Voltage-Source Converter". Royal Institute of Technology SE-100 44 Stockholm, Sweden