Vol 10, Issue 11, Nov /2019
ISSN NO:0377-9254

A ROBUST CONTROL STRATEGY TO IMPROVE DC-LINK VOLTAGE CONTROL PERFORMANCES FOR GRID CONNECTED CONVERTERS (GCCS)

[1]E. RAVINDRA BABU, [2]Dr.P.SANKARA BABU
[1]M.Tech Student, [2]PROFESSOR
DEPT OF EEE
SVR ENGINEERING COLLEGE, Nandyal

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.

Index Terms—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 [1-2], renewable energy sources [3-4], active power filters [5-6], UPS systems [7] and back-to-back systems [2],[8]. Efficient dc-link voltage control is very important for such applications to reduce voltage fluctuations in the dc-link [9], 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 [3],[9]. 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 [10],[11]. 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 [8],[11]. For these methods, the PI controller is usually adjusted with respect to different constraints: C1) stability; C2) dynamic performances; C3) disturbance rejection; and C4) step responses with low overshoot [12]. In order to satisfy all these constraints, some research works presented the design of adaptive PI controllers [13-17]. Other ones combine between the benefits of the PI controller and the feed forward compensation method [18-20]. 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 [26] to improve the dynamic performances of the dc-link voltage.

Vol 10, Issue 11, Nov /2019
ISSN NO:0377-9254

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 [23], [27]. 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 [23], [26].

II. PI CONTROLLER

The general block diagram of the PI speed controller is shown in Figure

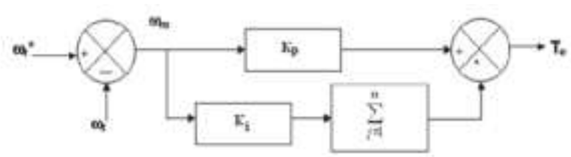

Fig1 : PI Controller

The output

Of the speed controller (torque command) at *n*-th instant is expressed as follows:

$Te(n)=Te(n-1)+Kp\_\omega re(n)+Ki\omega re(n)$ (10)

Where $Te(n)$ is the torque output of the controller at the *n*-th instant, and *Kp* and K*i* the

proportional and integral gain constants, respectively. A limit of the torque command is imposed as

$$T_{e(n+1)} = \begin{cases} T_{emax} & \text{for } T_{e(n+1)} \geq T_{emax} \\ -T_{emax} & \text{for } T_{e(n+1)} \leq -T_{emax} \end{cases}$$

The gains of PI controller shown in (10) can be selected by many methods such as trial and error method, Ziegler–Nichols method and evolutionary techniques-based searching. The numerical values of these controller gains depend on the ratings of the motor.

III.DC-DC CONVERTERS

A DC-DC converter with a high step-up voltage, which can be used in various applications like automobile headlights, fuel cell energy conversion systems, solar-cell energy conversion systems and battery backup systems for uninterruptable power supplies.Theoritically, a dc-dc boost converter can attain a high step-up voltage with a high effective duty ratio.But,in practical, the step-up voltage gain is restricted by the effect of power switches and the equivalent series resistance(ESR) of inductors and capacitors.

Generally a conventional boost converter is used to get a high-step-up voltage gain with a large duty ratio. But, the efficiency and the voltage gain are restricted due to the losses of power switches and diodes, the equivalent series resistance of inductors and capacitors and the reverse recovery problem of diodes. Due to the leakage inductance of the transformer, high voltage stress and power dissipation effected by the active switch of these converters. To reduce the Voltage spike, a resistor-capacitor –diode snubbed can be employed to limit the voltage stress on the active switch. But, these results in reduction of effiency.Based on the coupled inductor; converters with low input ripple current are developed. The low input current ripple of these converters is realized by using an additional LC circuit with a coupled inductor.

BUCK CONVERTER

The buck converter is the most broadly utilized dc-dc converter topology in force management and chip voltage controller applications. They can change over a voltage source into a lower controlled voltage. For instance, side a machine frame work, voltage needs to be ventures down and a lower voltage needs to be kept up. For this reason buck converter can be utilized.

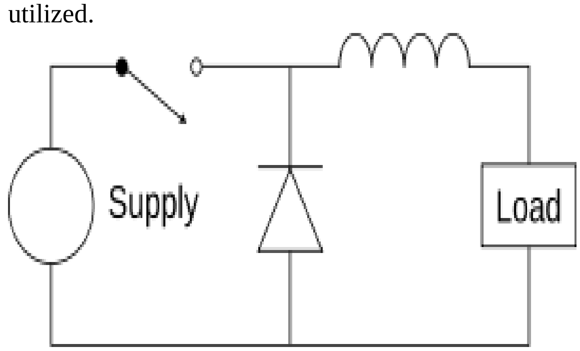

Fig2 : The basic schematic of a buck converter

Besides buck converters give longer battery life to versatile frameworks that invest the vast majority of their time in “stand-by”. Buck controllers are regularly utilized as switch-mode

Journal of Engineering Sciences
Vol 10, Issue 11, Nov /2019
ISSN NO:0377-9254

Power supplies for base band computerized centre and the power speaker.

BOOST CONVERTER

A boost converter is DC-to-DC steps up converter which can be improving the output voltage more than its input voltage. The class of switched-mode power supply consists of at least two switches (a diode and a transistor) and at least one energy storage element, like inductor, capacitor or the two combinations.

DC sources are used supplying power to the boost converter, like batteries, solar panels, rectifiers and DC generators. The process of converting a level of DC voltage in to a different level of DC voltage is known as DC to DC conversion. The boost converter is a step-up DC to DC converter with an output voltage greater than the source voltage.

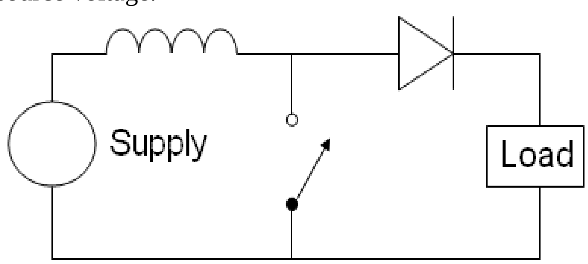

Fig.3 The basic schematic of a boost converter

IV.PROJECT DESCRIPTION AND CONTROL DESIGN

4.1 MODELING, DESIGN AND ANALYSIS OF THE DC-LINK VOLTAGE CONTROLLER

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

The studied system is depicted on Fig.1.a, where L (respectively R) is the filter inductor (respectively the filter resistor); C is the capacitor of the dc-link; Vg(a,b,c) refer to the components of the grid voltage vector in the natural reference frame; ig(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; Vdc is the dc-link voltage; Vdc * is the dc-link voltage reference; idc is the current coming out from the power converter; ic 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 ig(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.1.a shows also that the control structure of a GcC includes three main functions: the grid synchronization [21], the current controller [22] and the dc-link voltage controller [11]. Fig.1.b 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 idc table that computes idc current based on grid currents ig(a,b,c) and applied switching signals S(a,b,c) . To simplify the model, the relationship between the mean value of idc (idc mean) and igd * currents is firstly determined. This relationship is deduced according to equation (1) [20]. In this equation, PAC is the active power fed in the AC side of the GcC, Vgm is the magnitude of the phase voltage, igd is the d component of the grid current and PDC is the active power fed in the DC side of the GcC. Supposing that Vdc≈Vdc * and neglecting the power losses on the GcC and on the internal resistor of the inductive filter (PAC≈PDC), the relationship between idc mean and igd * currents can be deduced as shown in equation (1).

$$\left.\begin{aligned}P_{AC}&=\frac{3}{2}V_{gm}i_{gd}\approx\frac{3}{2}V_{gm}i^{*}_{gd}\\ P_{DC}&=V_{dc}i^{mean}_{dc}\end{aligned}\right\}\rightarrow i^{mean}_{dc}\approx\underbrace{\frac{3}{2}\frac{V_{gm}}{V^{*}_{dc}}}_{G}i^{*}_{gd}=Gi^{*}_{gd}$$

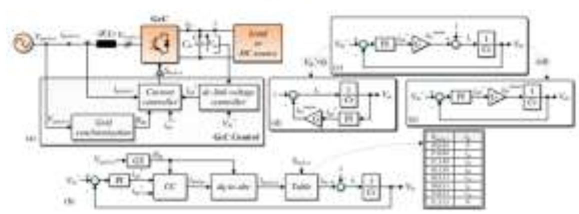

Fig. 4. (a) Commonly used control structure for Grid-connected Converters (b) Model of the dc-link voltage control system (c) Simplified model of the dc-link voltage control system (d) Equivalent simplified model when Vdc * =0 (e) Equivalent simplified model when i=0

For a simplest, but reasonably accurate modeling of the dclink voltage control, the simplified model given by Fig.1.c is considered. This simplified model is based the following assumptions: 1) the dynamic of CC loop is very fast with regard to that of

Journal of Engineering Sciences
Vol 10, Issue 11, Nov /2019
ISSN NO:0377-9254

the dc-link voltage control loop and 2) the nonlinearities are neglected. According to Fig.1.c, the dc-link voltage controller has two inputs: 1) the dc-link voltage reference Vdc * and 2) the input current i. To study the dc-link voltage control loop, the superposition method is considered. Using this method and supposing that the PI controller transfer function is equal to (Kpdc+Kidc/s), two systems are derived from Fig.1.c. For the first system (Fig.1.d and equation (2)), i is neglected, while Vdc * is considered as an input. For the second system (Fig.1.e and equation (3)), i is considered as an input, while Vdc * is neglected.

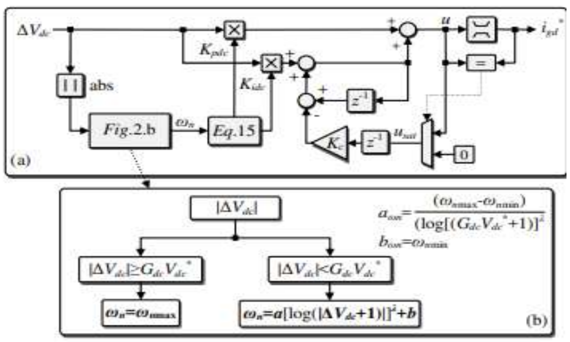

Fig. 5. (a) Adaptive anti-windup PI controller scheme (b) Computation

Simulations are done in order to compare the performances of the adaptive PI controller (including the anti-wind-up action) with those of the standard PI controller. The used simulation parameters are depicted on Tab.1 and the obtained simulation results are shown on Fig.. Fig.a compares between simulations results obtained with the standard PI control (for constant PI gains tuned for ωn=ωnmin and ωn=ωnopt) and those obtained with the proposed adaptive PI control. The natural frequency ωnopt is determined so that, when a step jump equal to Imax is applied to the input current i, the resulting Mp value is equal to GdcVdc * =10%Vdc * . So, based on equation (9), ωnopt is computed as follows

$$\omega_{nopt} = F_5(0.7)\frac{I_{max}}{G_{dc}V_{dc}^*} = \frac{416.88\times 1.25}{0.1*150} = 34.74\text{rad/s}$$

It can be noted that the adaptive PI control ensures shorter transient time with lower drop of the dc-link voltage after a step jump (at t=0.5s) of the input current i equal to Imax.

SIMULATION RESULTS

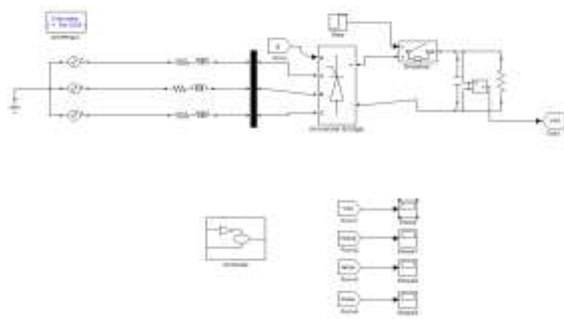

Fig6: Proposed Simulation diagram

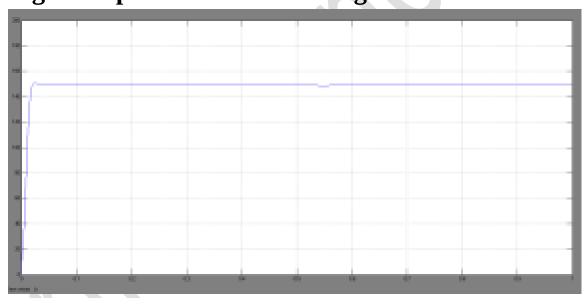

Fig7: Vdc

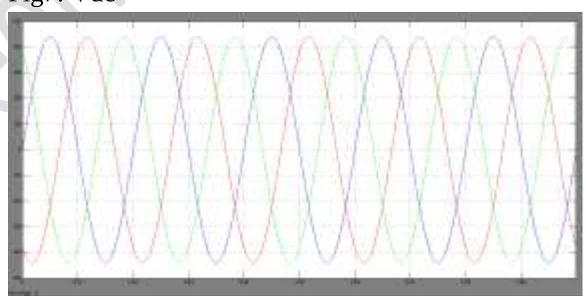

Fig8: Vabc

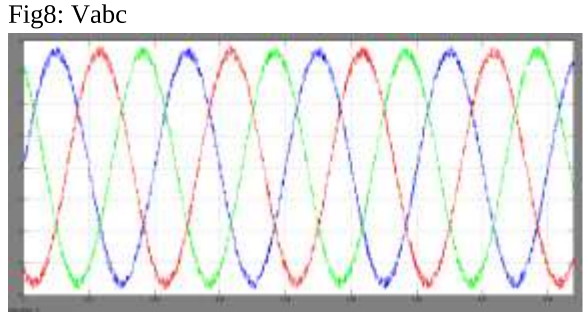

Fig9: Iabc

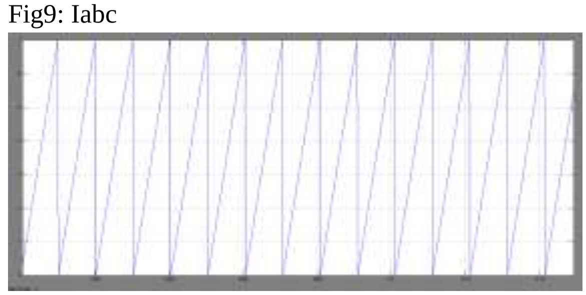

Fig10: Theta

Journal of Engineering Sciences

Vol 10, Issue 11, Nov /2019
ISSN NO:0377-9254

CONCLUSION

This paper 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] D. Casadei, M. Mengoni, G. Serra, A. Tani, and L. Zarri, "A control scheme with energy saving and dc-link overvoltage rejection for induction motor drives of electric vehicles," IEEE Trans. Ind. Appl., vol. 46, no. 4, pp. 1436–1446, Jul./Aug. 2010.

[2] Li, F., Zou, Y.P., Wang, C.Z., Chen, W., Zhang, Y.C., Zhang, J., "Research on AC Electronic Load Based on back to back Single phase PWM Rectifiers," Applied Power Electronics Conference and Exposition, 2008. APEC 2008. Twenty-Third Annual IEEE. 2008, pp.630-634. 2008.

[3] 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.

[4] X. Yuan, F. Wang, D. Boroyevich, Y. Li, and R. Burgos, "Dc-link voltage control of a full power converter for wind generator operating