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A Standard Module Of Dc Dps – Aacc To Enhance The Stability Of Cascaded System

[1]K.Sita Rama Rao,[2]T Amar Kiran
[1]M.Tech(Research scholar),[2]Associate Proffesor in Dept. of EEE
Godavari Institute of Engg. & Technology
Rajahmundry,A.P,INDIA
Email Id: [1]srisitaramkumpatla@gmail.com,[2]amar397301@gmail.com

Abstract:
In a dc DPS there are a range of ways to attach the subsystems among which a typical connection style is cascaded converters. The cascaded system may have stability problem due to the interaction between the subsystems even while each subsystem is independently well calculated to be stable on its own. Solutions for explaining the instability problem have been proposed and can be broadly classified into two type's passive and active methods. Passive methods occupy passive components such as resistors, capacitors and inductors to improve system stability. A resistive load was added to amend load dynamic characteristics by this means improving system stability. This paper introduces an adaptive active capacitor converter (AACC) connected in parallel with the intermediate bus of the cascaded system. The AACC is equal to an adaptive bus capacitor varied with the cascaded system's output power which decreases the output impedance of the source converter to avoid interacting with load converter's input impedance. As a result the cascaded system becomes stable. The AACC only needs to detect the intermediate bus voltage without changing anything of the existing subsystems. therefore it serves as a standard stabilizer for dc DPS.

Keywords: Active capacitor converter, adaptive control, cascaded system, modularization, stability.

Introduction:

An adaptive active capacitor converter (AACC) is bringing in to stabilize the cascaded system. The AACC is connected in parallel with the cascaded system's intermediate bus and only needs to detect the bus voltage without any change of the existing subsystems. Hence it can be intended as a standard module for dc DPS. The equivalent bus capacitor emulated by the AACC is adaptive according to the output power of the cascaded system and thus the power loss of AACC is minimized and the dynamic response of the system is better than that of the system using a passive capacitor. Connecting converters in cascade is a basic configuration of dc distributed power systems (DPS). The impedance interaction between alone designed converters may make the cascaded system unstable. The AACC serves as an equivalent bus capacitor to lessen the output impedance of the source converter thus avoiding the connection with the load converter's input impedance and as a result the cascaded system becomes stable. dc distributed power system (DPS) has been used widely in such applications as space stations, aircraft, communication systems, industrial autonomous production lines and defence electronic power systems for the last 20 years due to its flexile system configuration, high-efficiency energy conversion and high-density power delivery capaility.

Related Work:

One of the dc DPS's attractive characteristics is modularity design in which each subsystem is first designed separately as a module and then all subsystems are integrated to form a dc DPS. The modularization characteristic of dc DPS cuts down the system's development cycles and costs effectively. It was also pointed out that if both the source converter and the load converter are stable individually and *Zo* is less than *Z*in in the entire frequency ranges the stability of the cascaded system will be guaranteed. This is the so-called Middlebrook criterion. Consequently a variety of impedance criteria aiming at a more accurate and practical prediction of the subsystem interaction had been developed in the last two decades. The former approach however is usually multifaceted in implementation and sometimes conflicting with other control objectives. For the latter approach the power buffer is connected in series in-between the subsystems and would affect the impedance interaction during the fleeting that may not be acceptable in some applications.

Existing Method:

preceding advances of stabilizing the cascaded systems need to amend the source and/or load converter's internal structure such as the topology and control circuit that are contradictory to the modularization characteristic of dc DPS. The passive methods bring upon significant power dissipation. Active methods for stabilizing the system are based on modifying the control of the source converter and/or load converter or adding a power buffer between the source and load subsystems.

Disadvantages:

Clarifications need to transform the internal structure, including the main circuit and/or control circuit of the dc DPS's subsystems leading to redesign of the subsystems that have already been modularly designed. This contradicts with the objective of the modularity design of dc DPS and increases the system's development cycles.

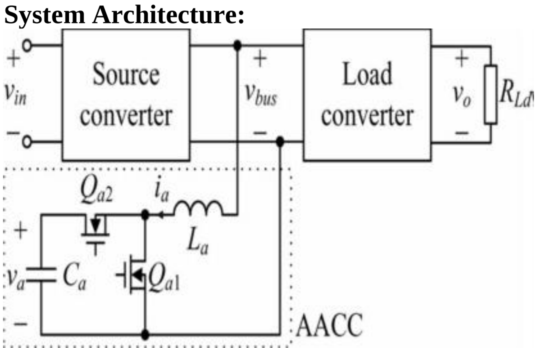
Proposed Method:

The AACC is correspondent to an adaptive bus capacitor varied with the cascaded system's output power which reduces the output impedance of the source converter to avoid interacting with load converter's input impedance. As a result the cascaded system becomes stable. The AACC only needs to detect the intermediate bus voltage without changing anything of the existing subsystems.

Advantages:

The equivalent capacitor of the AACC is adaptive make sure a minimal additional power loss and a better dynamic response of the system than that using a passive capacitor. It analyzes the impedance characteristics and instability problem of the cascaded system.

System Architecture:



The AACC is composed of switches *Qa*1 and *Qa*2, inductor *La*, and capacitor *Ca*. It is connected to the intermediate bus of the cascaded system. By controlling *La* 's current appropriately the terminal characteristic at the bus side of AACC will present an adaptively varying *C*bus that ensures the stability of the cascaded system in the entire load range and improves the dynamic response. The AACC is also appropriate for the cascaded system with multiple load converters. In this case the AACC has the same operation principle with the system which just makes the source converter's output impedance lower than the total input impedance of the multiple load converters.

Control Of Aacc:

For proper operation of the AACC *va* must be regulated at a value higher than *v*bus. A voltage closed loop must be included in the controller to enforce. Specifically *va* is sensed and compared with the voltage reference *Va* ref and the amplified error signal *v*4 is obtained. The sum of *ia* ref and *v*4 with the weighted resistors *R*17 and *R*18, respectively, is used as the current reference of *ia*.

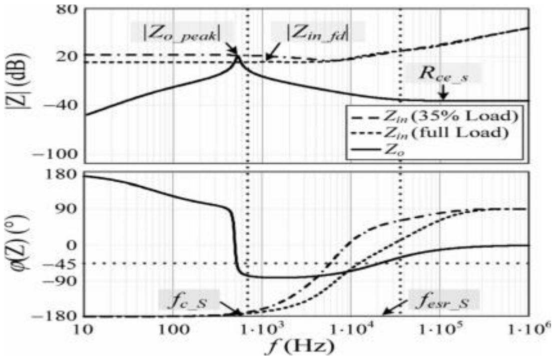
Output Filter Capacitor *Ca*:

To ensure the proper operation of AACC, the instantaneous voltage of *Ca* must always be higher than the input voltage of AACC, i.e.,*va* (*t*) ≥ *V*bus.

Inductor Of Aacc:

Two factors must be taken into consideration when choosing the value of *La*. One is to ensure that the inductor current is capable of tracking the current reference, and the other is that the inductor current ripple should be kept small. Here, the AACC's inductor current, *ia* , needs to track the oscillation ripple, whose oscillation frequency is the cut off frequency of the source converter's voltage loop gain.

Impedances Of The Source And Load Converters At Different Loads:

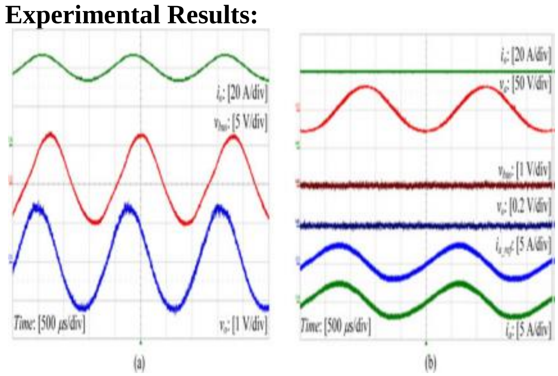


It can be seen that, *Zo* peak = 13.5 Ω, the input impedance of load converter at full load *Z*in *f d* is equal to 4.8 Ω, *Rce S* = 0.017 Ω, *fc S* = 550 Hz, and *f*esr *S* = 22.5 kHz. we can calculate the oscillation angular frequency and *C*bus max, i.e.,

$\omega = 2\pi fc\ S = 3455$ rad/s and

*C*bus max = 1950 μF.

Experimental Results:



The experimental results of the cascaded system with and without AACC at different loads are given where the waveforms of *v*bus, *vo* and *va* , are their alternative current components to clearly show the oscillation. It can be seen that the cascaded system is unstable at full load and half load when the

AACC is absent, and the oscillating frequencies of the bus voltage and output voltage are both about 550 Hz that is the intersection frequency of impedances, when the AACC is introduced, the cascaded system becomes stable at full load and half load, and no oscillation occurs in *v*bus and *vo* .

Conclusion:

The proposed converter only needs to detect the bus voltage of the cascaded system without changing anything for the existing subsystems, so it can be designed as a standard module for dc DPS. The experimental results verify the validity of the theoretical analysis. This study presents the AACC as an equivalent adaptive bus capacitor varied according to the output power of the cascaded system, avoiding the impedance interaction in cascaded system by reducing the output impedance of the source converter. The AACC is an effective means to solve the instability problem in dc DPS. When the oscillation of the cascaded system is minor, the AACC provides less energy to provide a smaller equivalent capacitor. When there is no oscillation of the cascaded system or the oscillating voltage is within the allowable scope, AACC will be shut down. Hence, the use of AACC does not only ensure the stability of the cascaded system, but also incurs insignificant loss.

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