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Ultra Capacitor And Its Effect in IPS

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ABSTRACT

Penetration of various types of distributed energy resources (DERs) like solar, wind, and plug-in hybrid electric vehicles (PHEVs) onto the distribution grid is on the rise. There is a corresponding increase in power quality problems and intermittencies on the distribution grid. In order to reduce the intermittencies and improve the power quality of the distribution grid, an ultra capacitor (UCAP) integrated power conditioner is proposed in this paper. UCAP integration gives the power conditioner active power capability, which is useful in tackling the grid intermittencies and in improving the voltage sag and swell compensation. UCAPs have low energy density, high-power density, and fast charge/discharge rates, which are all ideal characteristics for meeting high-power low-energy events like grid intermittencies, sags/swells. The simulation model of the overall system is developed and compared with the experimental hardware setup.

Keywords : Active Power filter (APF), Dc–Dc Converter, D–Q Control, Digital Signal Processor (DSP), Dynamic Voltage Restorer (DVR), Energy Storage Integration, Sag/Swell, Ultra Capacitors (UCAP).

I. INTRODUCTION

POWER QUALITY is major cause of concern in the industry, and it is important to maintain good power quality on the grid. Therefore, there is renewed interest in power quality products like the dynamic voltage restorer (DVR) and active power filter (APF). DVR prevents sensitive loads from experiencing voltage sags/swells and APF prevents the grid from supplying nonsinusoidal currents when the load is nonlinear. The concept of integrating the DVR and APF through a back–back inverter topology was first introduced in and the topology was named as unified power quality conditioner (UPQC). The design goal of the traditional UPQC was limited to improve the power quality of the distribution grid by being able to provide sag, swell, and harmonic current compensation. In this paper, energy storage integration into the power conditioner topology is being proposed, which will allow the integrated system to provide additional functionality. With the increase in penetration of the distribution energy resources (DERs) like wind, solar, and plug-in hybrid electric vehicles (PHEVs), there is a corresponding increase in the power quality problems and intermittencies on the distribution grid in theseconds to minutes time scale . Energy storage integration with DERs is a potential solution, which will increase the reliability of the DERs by reducing the intermittencies and also aid in tackling some of the power quality problems on the distribution grid. Applications where energy storage integration will improve the functionality are being identified, and efforts are being made to make energy storage integration commercially viable on a large scale. Smoothing of DERs is one application where energy storage integration and optimal control play an important role. Of all the rechargeable energy storage technologies superconducting magnet energy storage (SMES), flywheel energy storage system (FESS), battery energy storage system (BESS), and ultracapacitors (UCAPs), UCAPs are ideal for providing active power support for events on the distribution grid which require active power support in the seconds to minutes time scale like voltage sags/swells, active/reactive power support, and renewable intermittency smoothing.

II. LITERATURE REVIEW

Ultracapacitor as a conditioner in an integrated power system is the latest area of interest amongst the Power Electronics researchers. Some of the research work and literature are as given below.

Deepak Somayajula , and Mariesa L. Crow proposes the concept of integrating UCAP-based rechargeable energy storage to a power conditioner system to improve the power quality of the distribution grid[2].W. Li, G. Joos, and J. Belanger proposes methods to overcome the challenges of real-time simulation of wind systems, characterized by their complexity and high-frequency switching have been discussed.The simulation results of the detailed wind system model show that the hybrid ESS has a lower battery cost, higher battery longevity, and improved overall efficiency over its reference ESS[3].X. Li, D. Hui, and X. Lai proposes results of a wind/photovoltaic (PV)/BESS hybrid power system simulation analysis undertaken to improve the smoothing performance of wind/PV/BESS hybrid power generation and the effectiveness of battery SOC control has been presented [4]. P. Thounthong, A. Luksanasakul, P. Koseeyaporn, and B. Davat proposes mathematical model reduced-order model of the FC, PV, and SC converters is described for the control of the power plant. Using the intelligent fuzzy logic controller based on the flatness property for dc grid voltage regulation, a simple solution to the fast response and stabilization problems in the power system has been proposed[5].J. Tant, F. Geth, D. Six, P. Tant, and J. Driesen proposes the potential of using battery energy storage systems in the public low-voltage distribution grid, to defer upgrades needed to increase the penetration of photovoltaic (PV) has been investigated [6]. Y. Ru, J. Kleissl, and S. Martinez proposes the problem of determining the size of battery storage used in grid-connected photovoltaic (PV) systems . Here the electricity is generated from PV and is used to supply the demand from loads [7]. S. Teleke, M. E. Baran, S. Bhattacharya, and A. Q. Huang proposes a rule-based control scheme, which is the solution of the optimal control problem defined, to incorporate the operating constraints of the BESS, such as state of charge limits, charge/discharge current limits, and lifetime has been discussed.[8] .T. K. A. Brekkenetal. presented sizing and control methodologies for a zinc–bromine flow batterybased energy storage system. The results show that the power flow control strategy does have a significant impact on proper sizing of the rated power and energy of the system[9].

III. THREE-PHASE INVERTERS

The one-line diagram of the system is shown in Fig. 1. The power stage consists of two back-to-back three-phase voltage source inverters connected through a dc-link capacitor. UCAP energy storage is connected to the dc-link capacitor through a bidirectional dc–dc converter. The series inverter is responsible for compensating the voltage sags and swells; and the shunt inverter is responsible for active/reactive power support and renewable intermittency smoothing. The complete circuit diagram of the series DVR, shunt APF, and the bidirectionaldc– dc converter is shown in Fig. 2. Both the inverter systems consist of IGBT module, its gate-driver, LC filter, and an isolation transformer. The dc-link voltage Vdc is regulated at 260 V for optimum voltage and current compensation of the converter and the line–line voltage Vab is 208 V. The goal of this project is to provide the integrated power conditioner and UCAP system with active power capability 1) to compensate temporary voltage sag (0.1–0.9 p.u.) and swell (1.1–1.2 p.u.), which last from 3 s to 1 min [18]; and 2) to provide active/reactive support and renewable intermittency smoothing, which is in the seconds to minutes time scale.

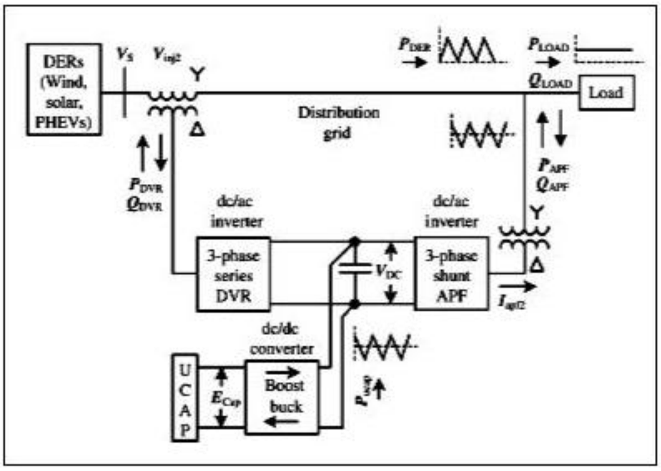

Figure.1 One-line diagram of power conditioner with UCAP energy storage.

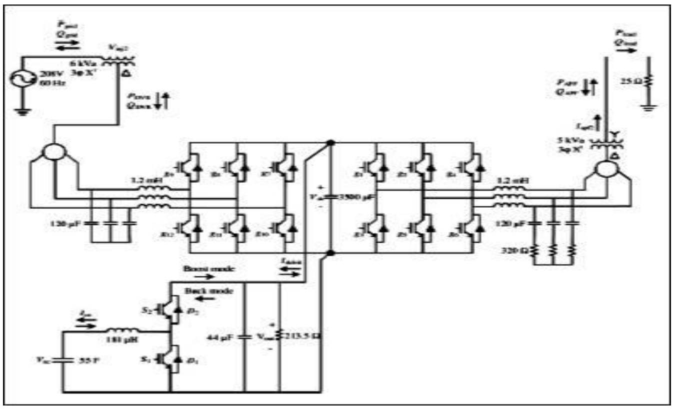

Figure 2.Model of power conditioner with UCAP energy storage

IV. Controller Implementation

Average current mode control is used to regulate the output voltage of the bidirectional dc–dc converter in both Buck and Boost modes, while charging and discharging the UCAP bank. While the UCAP-APF system is discharging power, the dc-link voltage Vout tends to be less than Vref, which causes the reference current Iucref to be positive, thereby operating the dc–dc converter in Boost mode. Along similar lines, when the UCAP-APF system is absorbing power from the grid, the dc-link voltage Vout tends to be greater than Vref, which causes the reference current Iucref to be negative and thereby operating the dc–dc converter in Buck mode. Average current mode control technique was found as the ideal method for UCAP-APF integration as it tends to be more stable when compared with other methods like voltage mode control and peak current mode control. Average current mode controller and the higher level integrated controller are shown in Fig. 3, where the actual output voltage Vout is compared with the reference voltage Vref and the error is passed through the voltage compensator C1 (s), which generates the average reference current Iucref. This is then compared with the actual UCAP current Iuc, and the error is then passed through the current compensator C2 (s). The converter model for average current mode control is based on the following transfer functions developed in :

$$G_{\mathrm{id}}(s) = \frac{V_{\mathrm{out}}\left(sC + \frac{2}{R}\right)}{s^2\mathrm{LC} + s\frac{L}{R} + (1-D)^2}$$

$$G_{\mathrm{vi}}(s) = \frac{(1-D)\left[1 - \frac{sL}{R(1-D)^2}\right]}{\left(sC + \frac{2}{R}\right)}.$$

The model of the dc–dc converter in average current mode control is shown in Fig. 4 that has two loops. The inner current loop Ti (s) has the current compensator C2 (s), voltage modulator gain VM, and the transfer function Gid (s). The outer voltage loop Tv (s) constitutes the voltage compensator C1 (s), current loop Ti (s), and the transfer function Gvi (s). The current compensator design C2 (s) must be carried out initially and the voltage compensator C1 (s) design is based on the design of the current compensator due to the dependency of C1 (s) on C2 (s). The current compensator C2 (s) must be designed in such a way that at the crossover frequency of the current loop there is enough phase-margin to make the current loop Ti (s) stable and it should have a higher bandwidth when compared to the voltage loop Tv (s). Based on these criteria, the transfer functions of the current loop Ti (s) and the current compensator C2 (s) are given by

$$T_i(s) = G_{\mathrm{id}}(s) \cdot \frac{C_2(s)}{V_M}$$

$$C_2(s) = 1.67 + \frac{231.81}{s}.$$

The closed-loop transfer function of the current loop is then given by

$$T_1(s) = \frac{T_i(s)}{1 + T_i(s)}.$$

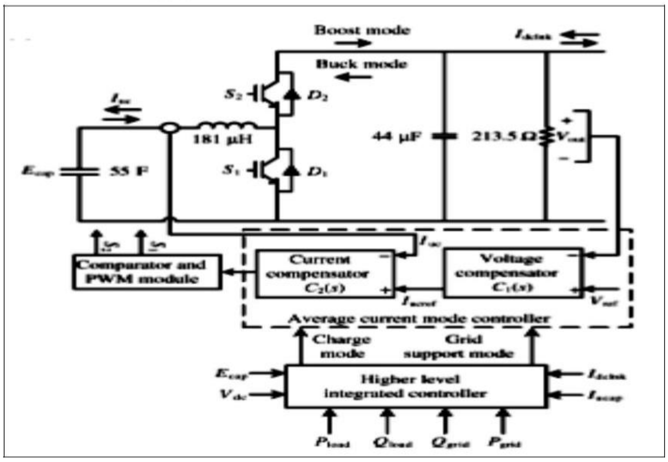

Figure 3 : Average current mode controller and the higher level integrated controller

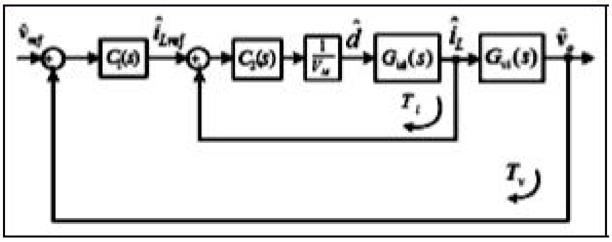

Figure 4 :The model of the dc–dc converter in average current mode control

V. CONCLUSION

In this paper, the concept of integrating UCAP-based rechargeable energy storage to a power conditioner system to improve the power quality of the distribution grid is presented. With this integration, the DVR portion of the power conditioner will be able to independently compensate voltage sags and swells and the APF portion of the power conditioner will be able to provide active/reactive power support and renewable intermittency smoothing to the distribution grid. UCAP integration through a bidirectional dc–dc converter at the dc-link of the power conditioner is proposed. Designs of major components in the power stage of the bidirectional dc–dc converter are discussed. Average current mode control is used to regulate the output voltage of the dc–dc converterdue to its inherently stable characteristic. A higher level integrated controller that takes decisions based on the system parameters provides inputs to the inverters and dc–dc converter controllers to carry out their control actions. The simulation of the UCAP-PC system is carried out using MATLAB. Hardware experimental setup of the integrated system is presented and the ability to provide temporary voltage sag compensation and active/reactive power support and renewable intermittency smoothing to the distribution grid is tested Similar UCAPbased energy storages can be deployed in the future in a microgrid or a low-voltage distribution grid to respond to dynamic changes in the voltage profiles and power profiles on the distribution grid.

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