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Power Quality Improvement using Ultra Capacitor

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ABSTRACT

Integration of Energy storage technologies into the power grid is slowly becoming a reality. So there is an increase in power quality problems on the grid. In order to improve the power quality of the distribution grid, an ultra-capacitor (UCAP) is proposed in this paper. UCAP have high power density and low energy density ideal characteristics for compensation of voltage sag and swell which are both high power and low energy event. The proposed paper integrates UCAP into dc-link of the power conditioner through a bidirectional dc–dc converter that helps in providing a stiff dc-link voltage. The simulation model of the overall system is developed and compared with the previous published work.
Keywords : Dynamic voltage restorer (DVR), Active power filter (APF), digital signal processor (DSP), ultra capacitors (UCAP), DC-DC Convertor.

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 no sinusoidal 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 the seconds 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 ultra-capacitors (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.In this project, UCAP-based energy storage integration through a power conditioner into the distribution grid is proposed. The organization of this document is as follows. In Section 2 gives Methods and Material of proposed system. In Section 3 Result and Discussion in which result are discussed.

II. METHODS AND MATERIAL

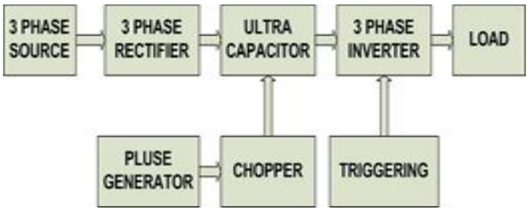

Figure1. Block Diagram of Proposed System

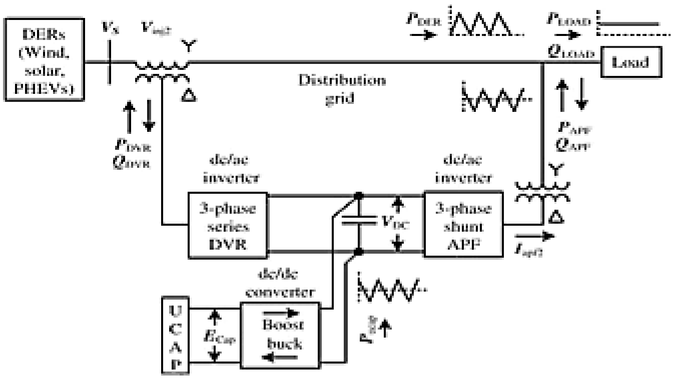

Figure 2 : One-line diagram of power conditioner with UCAP energy storage

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 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 bidirectional DC– 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.
2) To provide active/reactive support and renewable intermittency smoothing, this is in the seconds to minutes time scale.

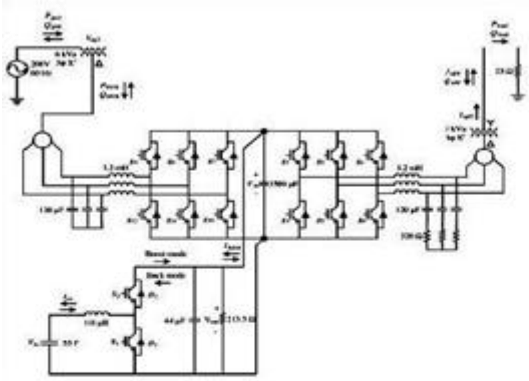

Figure 3. Model of power conditioner with UCAP energy storage

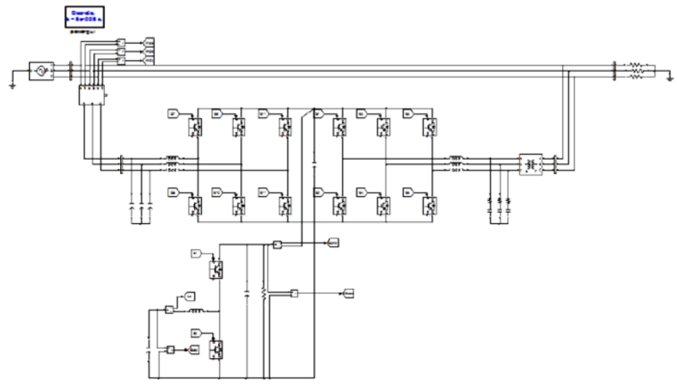

Figure 4. Simulink Model of power conditioner with UCAP energy storage

The complete circuit diagram of the series DVR, shunt APF, and the bidirectional dc–dc converter is shown in Fig. 4.1. Both the inverter systems consist of IGBT module, its gate-driver, LC filter, and an isolation transformer. The dc-link voltage V_{dc} is regulated at 260 V for optimum voltage and current compensation of the converter and the line–line voltage V_{ab} 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 31 min; and 2) to provide active/reactive support and renewable intermittency smoothing, which is in the seconds to minutes time scale. The inverter system consists of an IGBT module, its gate-driver, LC filter and an isolation transformer.

The simulation of the proposed UCAP integrated power conditioner system is carried out in MATLAB for a 208-V, 60-Hz system, where 208 V is 1 p.u. The system response for a three-phase voltage sag which lasts for 0.1s and has a depth of 0.64 p.u.

a. It can be observed from Fig. 5(a) that during voltage sag, the source voltage Vs_{rms} is reduced to 0.36 p.u., while the load voltage VL_{rms} is maintained constant at around 1.01 p.u. due to voltages injected in-phase by the series inverter. Here source voltage Vs_{rms} is indicated by green and VL_{rms} is indicated by violet.

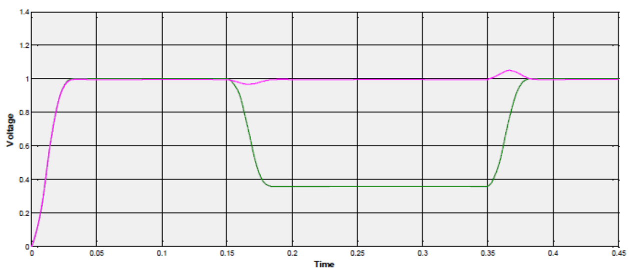

Figure 5(a). Source and load rms voltages during sag

This can be observed from the plots of the line–line source voltages (Vsab, Vsbc, and Vsca) [Fig. 5(b)] that source voltages are reduced due to voltages injected in phase by the series inverter. Here source voltages are indicated by Vsab (green), Vsbc (violet), and Vsca (blue).

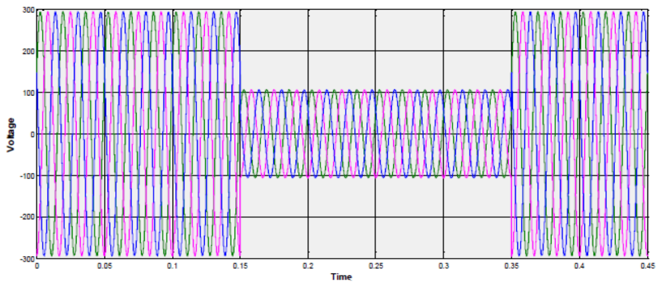

Figure 5(b). Source voltages during sag

This can also be observed from the plots of the line–line load voltages (VLab, VLbc, and VLca) [Fig. 5(c)] that load voltages are maintained constant during sag. Here load voltages are indicated by VLab (green), VLbc (violet), and VLca (blue)

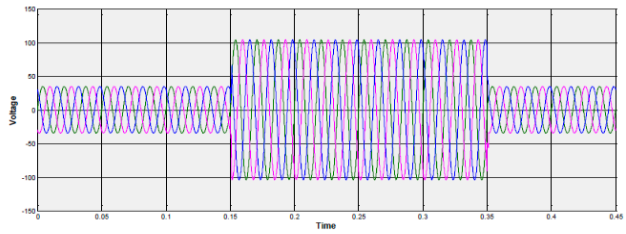

Figure 5(c) Load voltages during sag

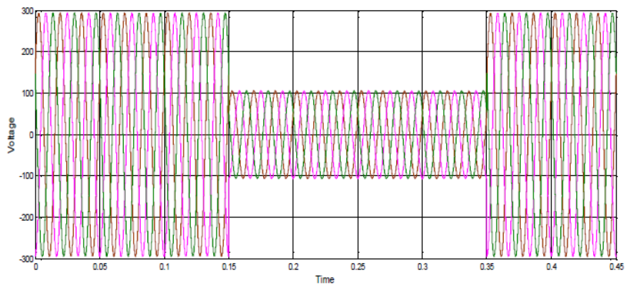

Figure 5(d) Source voltages of simple capacitor during sag

This can also be observed from the plots of the line–line load voltages (VLab, VLbc, and VLca)

III. CONCLUSION AND FUTURE SCOPE

UCAP integration through a bidirectional dc–dc converter at the dc-link of the power conditioner is proposed. The control strategy of the series inverter (DVR) is based on in phase compensation and the control strategy of the shunt inverter (APF) is based on id – iq method. 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 converter due 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 integrated UCAP-PC system which consists of the UCAP, bidirectional dc–dc converter, and the series and shunt inverters is carried out using MATLAB. The simulation of the UCAP-PC system is carried out using MATLAB. Similar UCAP based energy storages can be deployed in the future in a micro grid or a low-voltage distribution grid to respond to dynamic changes in the voltage profiles and power profiles on the distribution grid.

Table III : Results of Ultra capacitor

Parameters	**Simple Capacitor**	**Ultra capacitor**
Load Voltage	0.36V	1.01V
	Reduced	Maintained Constant
Charging Current	6A	8A
Discharging Current	2A	10A
Active Power	100W	500W
Reactive Power	25Vars	200Vars

UCAP based energy storages can be used 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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