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# Power Quality Improving in Distribution Grid Using Ultra Capacitor Based Dynamic Voltage Restorer

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**ABSTRACT**: With the advent of Smart Grid, the rapid decreasing of cost of different storage technologies and the integration of these technologies into power grid is become a reality. An improved voltage sag and swell compensation with energy storage integration can be provided by the product called Dynamic Voltage Restorer (DVR). For the compensation of Voltage sag and voltage swell, high power for short Spans of time is required. For these purpose, Ultra capacitor which have lower energy density and high power density ideal characteristics can be used. The integration of rechargeable UCAP based energy storage into the DVR topology has been proposed in this paper. With this integration the active power capability is present in UCAP-DVR and without relaying the grid, it will able to compensate temporary voltage sags and swells independently. Through a Bidirectional DC-DC converter, which helps in Providing Stiff DC-link, UCAP is integrated into DC link of DVR. The design and Control of both the DC-Ac inverter and the DC-DC converter are discussed. The Simulation model of the propose system is shown with the result

**KEYWORDS**: DC–DC converter, d–q control, DSP, dynamic voltage restorer (DVR), energy storage integration, phase locked loop (PLL), sag/swell, Ultra capacitor (UCAP.

## I.INTRODUCTION

For the first time Woodley et al. demonstrated the concept for preventing customers from momentary voltage disturbance on the utility side using inverter based dynamic voltage restorer (DVR). As a power quality product, the concept of using DVR has gained significant popularity. The rechargeable energy storage at DC terminal to meet the active power requirement of the grid during voltage disturbance was proposed in [1]. The authors also mention an alternative solution which is to compensate for the voltage sag by inserting a lagging voltage in quadrature with the line current in order avoid and reduce the active power injection into grid. Different types of control strategies have been developed in the literature [2]-[8], owing to high cost of rechargeable energy storage. As a power quality product, the penetration of DVR can be prevented by the high cost of the rechargeable energy storage. However, wing to various technological developments and higher penetration in the market in the form of auxiliary energy storage for distributed energy resources (DERs) such as wind, solar, hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicle (PHEVs) [9], [10], the cost of rechargeable energy storage has been decreasing drastically in the recent past .Therefore, there has been renewed interest to integrate rechargeable energy storage again at the dc-terminal of power quality products such as static compensator (STATCOM) and DVR in the literature [10]-[17].

Based on superconducting magnets (SMES), flywheels (FESS), batteries (BESS), and ultra-capacitors (UCAPs) different types of rechargeable energy storage technologies are prosed and compared in [10]. In [11] the author proposed a cascade H-Bridge based DVR with a Thyristor controlled inductor in order to minimize the energy storage requirement. In order to improve its steady-state series and shunt compensation, flywheel energy storage is integrated into the DVR system in [12].

By comparing all rechargeable energy, UCAPs are ideally suited for the applications in which the active support in milliseconds to second timescale is needed. Therefore, as the normal duration of momentary voltage sags and swells is

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in the milliseconds to seconds range [15], UCAP-based integration into the DVR system is ideal. low-energy density and high-power density ideal characteristics for compensating voltage sags and voltage swells are the characteristics of UCAP. Compared to batteries and for the same module size, UCAPs also have higher number of charge/discharge cycles. Compared to batteries UCAPs have higher terminal voltage. For the distribution grid Super capacitor- based energy storage integration into the DVR is proposed in [16] and [17].

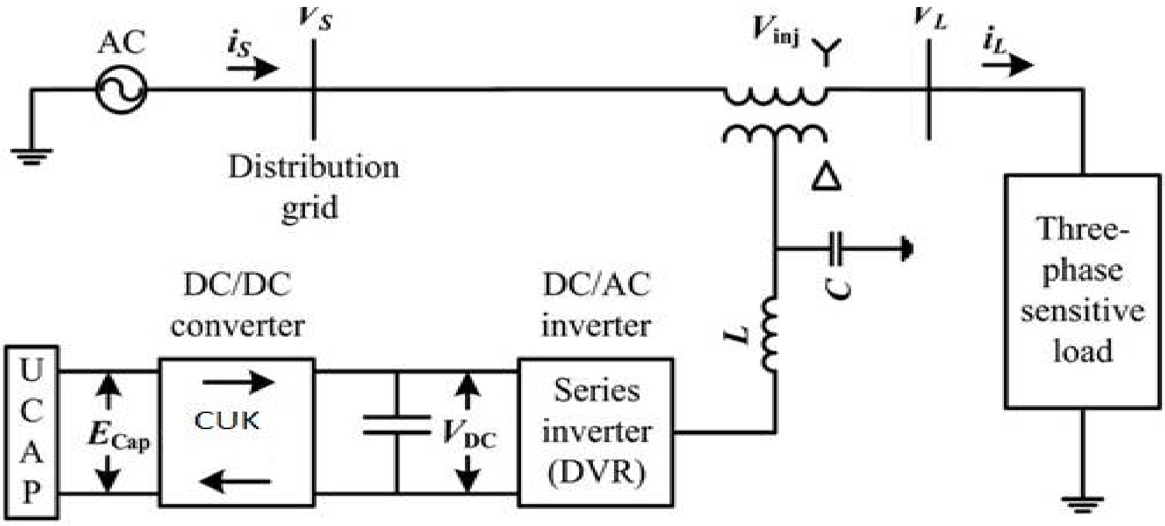


Fig. 1 Block diagram of proposed system

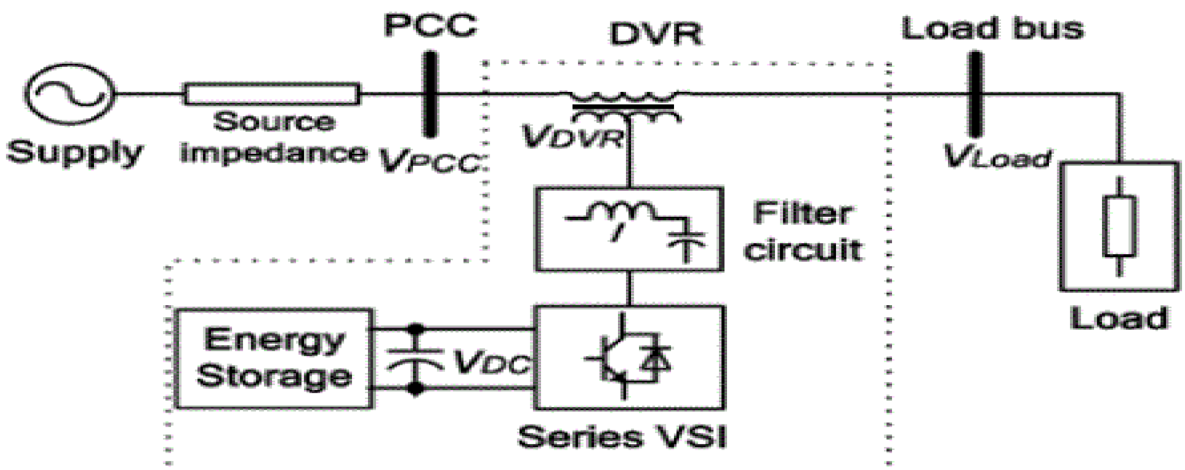


Fig.2 Basic DVR system

Based on UCAP energy storage integration to DVR into the distribution grid is proposed in this paper and the areas of application are addressed as follows.

1) With DVR system gives active power capability to the system Integration of the UCAP gives active power capability to the system for independent compensation of Voltage Sag and Swells.

2) Validation of Cuk-converter and inverter, and their interface and control.

3) To provide sag and swell compensation to the distribution grid, development of Inverter and DC-Dc converter.

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4) Integration and performance validation of the integrated DVR-UCAP system.

## II.THREE –PHASE SERIES INVERTER

**Power Stage**

The one line diagram of the proposed system is shown in the Fig. 1. Three-phase voltage source inverter, which is connected in series to the grid and is responsible for compensating the voltage sags and swells is power stage. The fig. 2 shows the model of series DVR and its controller. An insulated Gate Bipolar Transistor (IGBT) module is present in the Inverter system which also consist of gate drive. LC filter and an isolation transformer. The modulation Index m of inverter is given by

$$m = \frac{2\sqrt{2}}{\sqrt{3}V_{\mathrm{dc}*n}} V_{ab(\mathrm{rms})}$$

where n is the turns ratio of the isolation transformer

**Controller Implementation**

To provide dynamic voltage restoration there are different method to control and in quadrature with phase relay on injection is used. It leads to reactive power utilization in voltage restoration [3]. There is a complexity in implementation of phase advanced voltage restoration. But, the main reason for using these techniques is Bidirectional..

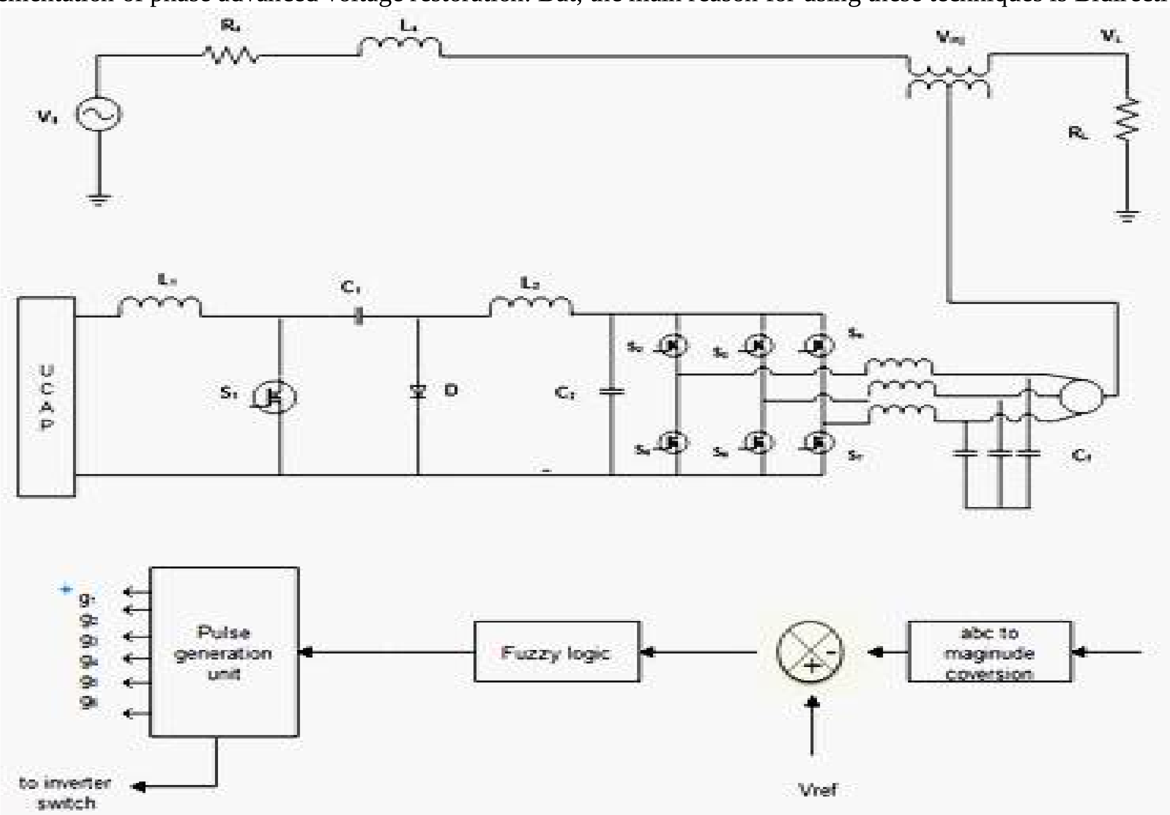


Fig. 3 Circuit Diagram of proposed system

In this paper, Cuk converter act as a boost converter during the time of Discharging power from UCAP. As an interface between the UCAP and the dc-link since the UCAP voltage varies with the amount of energy discharged a bidirectional

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DC-DC converter is required while DC-link voltage has to be stiff. Hence Cuck converter is designed to operate in boost mode.

The widely explored control is average current mode control in the literature [19]. Average current mode control is used to regulate the output voltage of converter in both buck and boost mode. During the time of charging and discharging the UCAP bank. When compared to other methods such as voltage mode control and peak current mode control, average current mode control is more stable.

The dc-link voltage $V_{out}$ tends to go below the reference $V_{ref}$ , during the time of discharging of power from inverter to the grid and the error is positive. $V_{out}$ tends to increase above the reference $V_{ref}$ during the time of absorbing of power from grid during swell event and the error is negative. Therefore, the sign of the error between $V_{out}$ and $V_{ref}$ determines the sign of $I_{ucref}$ and thereby the direction of operation of the bidirectional dc–dc converter.

## III.DC-DCCONVERTER AND UPAC

### *A. CUK CONVERTER*

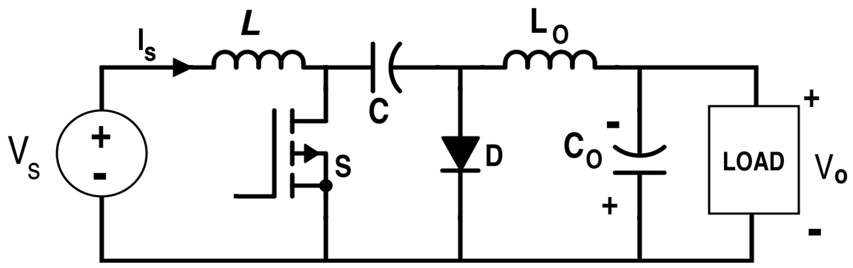


Fig. 4

The cuck converter is shown in the fig. 3. Average voltage across inductors is zero. Cs is sufficiently large and hence at steady state Vc1 can be assumed to be neglibly larger $V_d$ , $V_0$ + Vd = Vcs.

***Switch Off state:***
The inductor currents flow through the diode. Capacitor Csis charged through the diode by energy from both theinput and L1. The current IL1 decreases, because Vc1 is larger than Vd .
Energy stored in L2 feeds output and therefore IL2 decreases

***Switch ON state:***
VC1 reverse biases the diode. IL1 and IL2 flows through the switch. As VC1 > V0, C1 discharges through the switch, transferring energy to the output and L2 and therefore IL2 increases. The input feeds energy to L1 causing iL1 to increase.

**UCAP Bank Hardware Setup**
For providing grid support the choice of the number of CAPs depends on the amount of support needed, terminal voltage of the UCAP, dc-link voltage, and distribution grid voltages. There are different types o UCAP with the various capacity. For example 165F UCAPs (BMOD0165P048) has value of 48V.

**Fuzzy logic controller**
Fuzzy logic starts with and builds on a set of user-supplied human language rules. The fuzzy systems convert these rules to their mathematical equivalents. This simplifies the job of the system designer and the computer, and results in much more accurate representations of the way systems behave in the real world.
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## IV. SIMULTION AND ITS RESULT

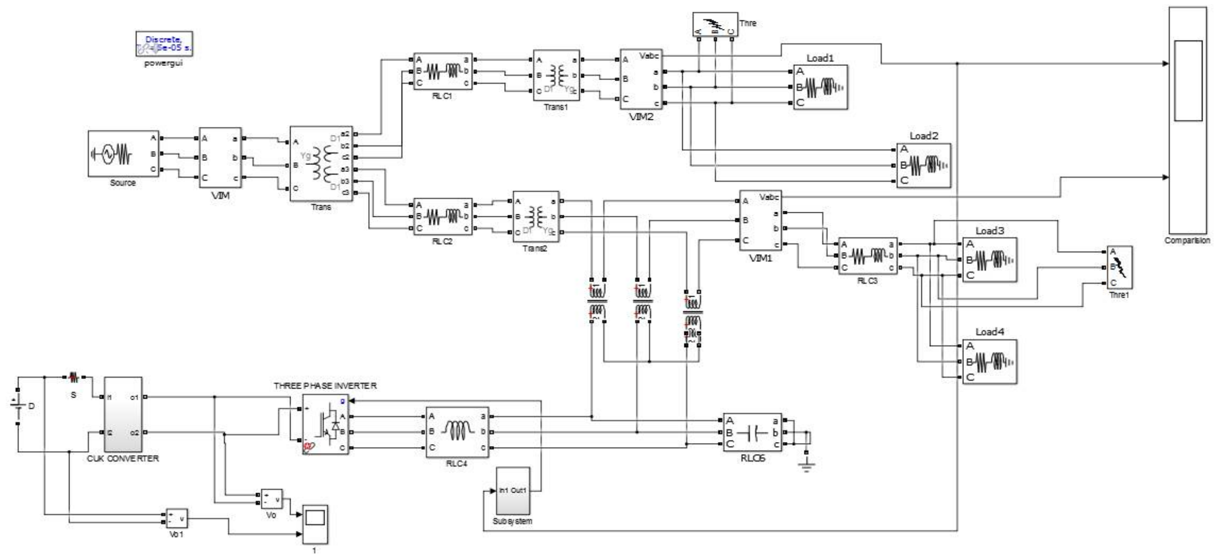


Fig. 5 Simulation of proposed system

The simulation of the prosed system is simulated in the MATLAB 2015b. Figure. 5 shows the simulated digramatic representation of the proposed system. There are two subsystems used in the simulation. One is system which represent cuck converter as shown in the figure 6. whereas second one is fuzzy logic controller as shown in the figure 7.

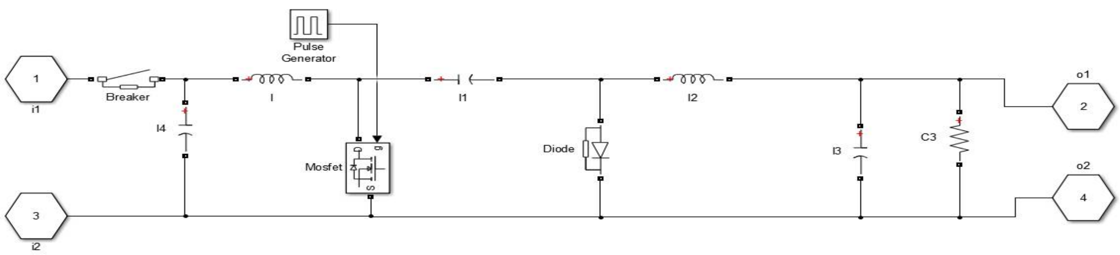


Fig. 6 simulation of cuk converter

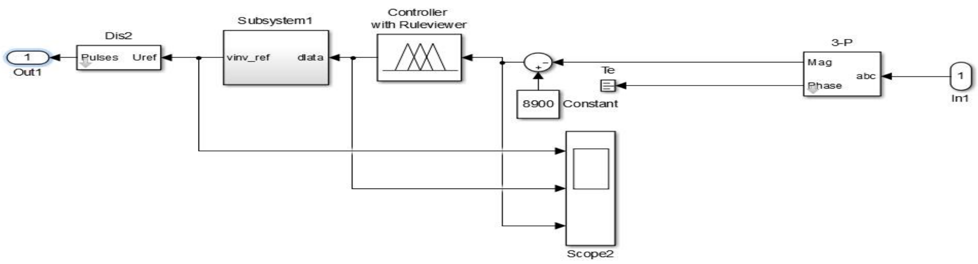


Fig. 7 simulation of Fuzxzy logic controller

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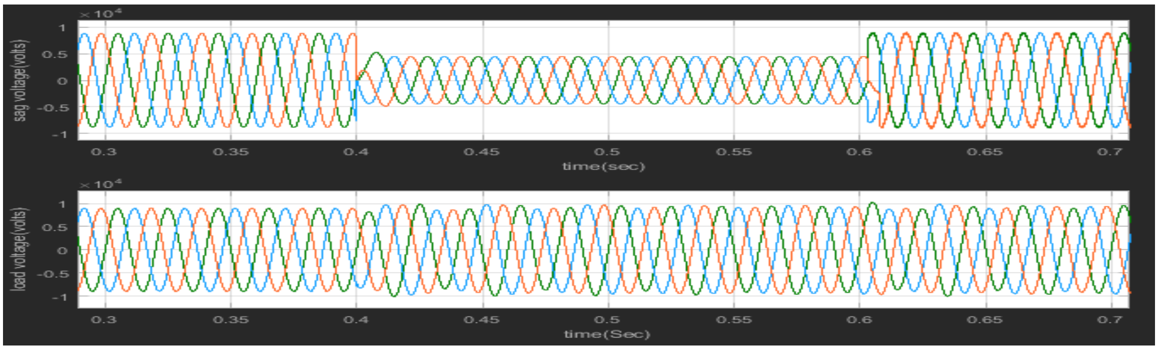


Fig. 8 (a) Sag Voltage (b) compensated voltage at load

The sag voltage occurred due to fault is shown in the figure. 8(b). The voltage sag due to fault is compensated by injection of voltage and we can measure the compensated voltage at the load as shown in the Figure. 8(b). The figure. 9 shows the output Dc voltage of Cuk convereter. The Total Harmonic Distortion of the whole system is shown in the fig 10.

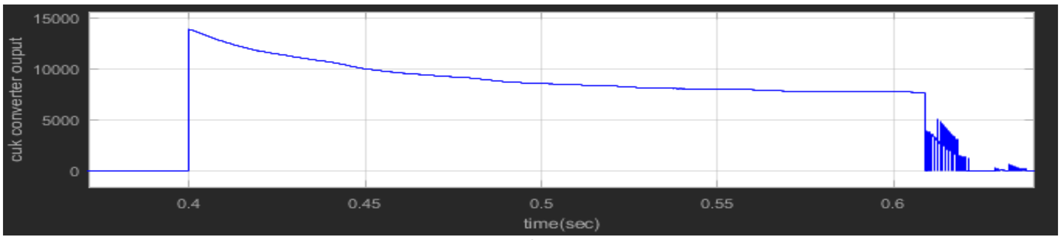


Fig.9 output of cuk converter

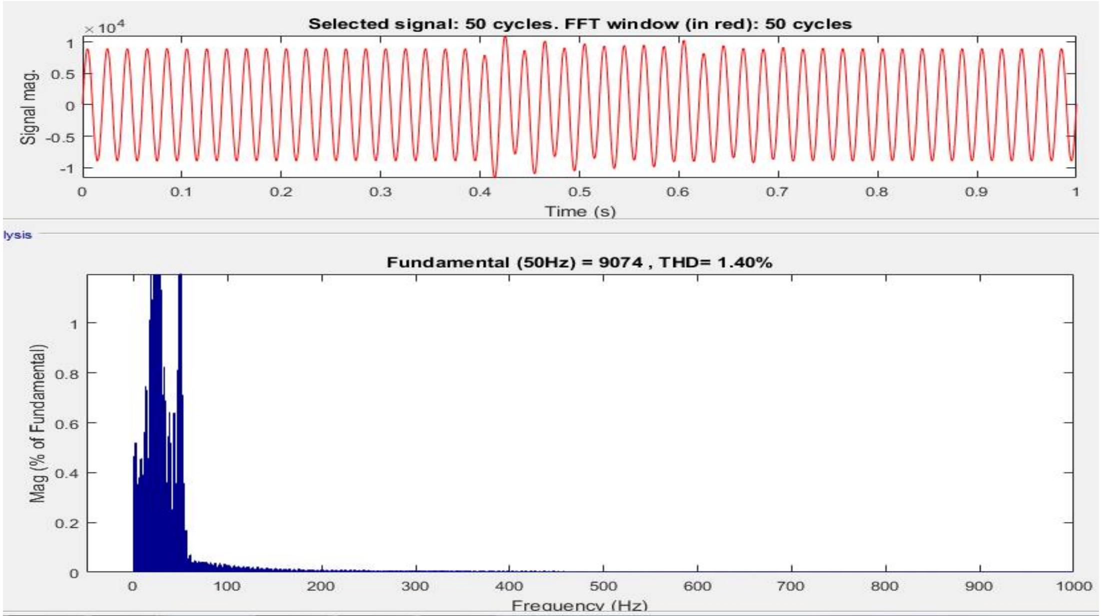


Fig. 10

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## V.CONCLUSION

The concept of integrating UCAP based rechargeable energy to the DVR system is proposed in this paper. The proposed system is used to improve the voltage restoration capability. The DVR will be able to compensate voltage sag and swell independently without relaying on the grid. The UCAP integration through a bidirectional dc–dc converter at the dc-link of the DVR is proposed. . The simulation of the UCAP-DVR system, which consists of the UCAP, dc–dc converter, and the grid-tied inverter, is carried out using MATLAB 2015b. The simulation and its result is explained in the paper to verify the proposed concept. Similar UCAP based energy storage can deployed in the future on the distribution grid to prevent sensitive load from the voltage disturbance.

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