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A DESIGN OF ULTRA CAPACITOR FOR IMPROVING POWER QUALITY OF DISTRIBUTION GRID BY AN INTEGRATED DYNAMIC VOLTAGE RESTORER

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ABSTARCT:

Cost of various energy storage technologies is decreasing rapidly and the integration of these technologies into the power grid is becoming a reality with the advent of smart grid. Dynamic voltage restorer (DVR) is one product that can provideimproved voltage sag and swell compensation with energy storage integration. Ultra-capacitors (UCAP) have low-energy density and high-power density ideal characteristics for compensation of voltage sags and voltage swells, which are both events that require high power for short spans of time. The novel contribution of this paper lies in the integration of rechargeable UCAP-based energy storage into the DVR topology. With this integration, the UCAP-DVR system will have active power capability and will be able to independently compensate temporary voltage sags and swells without relying on the grid to compensate for faults on the grid like in the past. UCAP is integrated into dc-link of the DVR through a bidirectional dc–dc converter, which helps in providing a stiff dc-link voltage, and the integrated UCAPDVR system helps in compensating temporary voltage sags and voltage swells, which last from 3 s to 1 min. Complexities involved in the design and control of both the dc–ac inverter and the dc–dc converter are discussed. The simulation model of the overall system is developed and compared to the experimental hardware setup.

INTRODUCTIONThe technological advancements have proven a path to the modern industries to extract and develop the innovative technologies within the limits of their industries for the fulfillment of their industrial goals. And their ultimate objective is to optimize the production while minimizing the production cost and thereby achieving maximized profits while ensuring continuous production throughout the period. As such a stable supply of un-interruptible power has to be guaranteed during the production process. The reason for demanding high quality power is basically the modern manufacturing and process equipment, which operates at high efficiency, requires high quality defect free power supply for the successful operation of their machines. More precisely most of those machine components are designed to be very sensitive for the power supply variations. Adjustable speed drives, automation devices, power electronic components are examples for such equipments. Failure to provide the required quality power output may sometimes cause complete shutdown of the industries which will make a major financial loss to the industry concerned. Thus the industries always demands for high quality power from the supplier or the utility. But the blame due to degraded quality cannot be solely put on to the hands of the utility itself. It has been found out most of the conditions that can disrupt the process are generated within the industry itself. For example, most of the non-linear loads within the industries cause transients which can affect the reliability of the power supply. Following shows some abnormal electrical conditions caused both in the utility end and the customer end that can disrupt a process. 1. Voltage sags 2. Phase outages 3. Voltage interruptions 4. Transients due to Lighting loads, capacitor switching, non linear loads, etc.. 5. Harmonics As a result of above abnormalities the industries may undergo burned-out motors, lost data on volatile memories, erroneous motion of robotics, unnecessary downtime, increased maintenance costs and burning core materials especially in plastic industries, paper mills & semiconductor plants. Among those power quality abnormalities voltage sags and surges or simply the fluctuating voltage situations are considered to be one of the most frequent type of abnormality. Those are also identified as short term under/over voltage conditions that can last from a fraction of a cycle to few cycles. Motor start up, lightning strikes, fault clearing, power factor switching are considered as the reasons for fluctuating voltage conditions. As the power quality problems are originated from utility and customer side, the solutions should come from both and are named as utility based solutions and customer based solutions respectively. The best examples for those two types of solutions are FACTS devices (Flexible AC Transmission Systems) and Custom power devices. FACTS devices are those controlled by the utility, whereas the Custom power devices are operated, maintained and controlled by the customer itself and installed at the customer premises. Both the FACTS devices and Custom power devices are based on solid state power electronic components. As the new technologies emerged, the manufacturing cost and the reliability of those solid state devices are improved; hence the protection devices which incorporate such solid state devices can be purchased at a reasonable price with better performance than the other electrical or pneumatic devices available in the market. Uninterruptible Power Supplies (UPS), Dynamic Voltage Restorers (DVR) and Active Power Filters (APF) are examples for commonly used custom power devices. Among those APF is used to mitigate harmonic problems occurring due to non-linear loading conditions, whereas UPS and DVR are used to compensate for voltage sag and surge conditions. In this paper voltage compensation is done using DVR-UCAP and the control of a Dynamic voltage restorer for single phase voltage sags has been studied. Voltage sag may occur from single phase to three phases. But it has been identified single phase voltage sags are the commonest and most frequent. A control technique to detect and compensate for the single phase voltage sags was developed and simulated using the MATLAB/SIMULINK software.

POWER QUALITY Power quality is defined as the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment. There are many different reasons for the enormous increase in the interest in power quality. Some of the main reasons are:

• Electronic and power electronic equipment has especially become much more sensitive. Equipment has become less tolerant of voltage quality disturbances, production processes have become less tolerant of incorrect of incorrect operation of equipment, and companies have become less tolerant of production stoppages. The main perpetrators are interruptions and voltage dips, with the emphasis in discussions and in the literature being on voltage dips and short interruptions. High frequency transients do occasionally receive attention as causes of equipment malfunction.

• Equipment produces more current disturbances than it used to do. Both low and high power equipment is more and more powered by simple power electronic converters which produce a broad spectrum of distortion. There are indications that the harmonic distortion in the power system is rising, but no conclusive results are obtained due to the lack of large scale surveys.

• The deregulation of the electricity industry has led to an increased need for quality indicators. Customers are demanding, and getting, more information on the voltage quality they can expect.

• Also energy efficient equipment is an important source of power quality disturbance. Adjustable speed drives and energy saving lamps are both important sources of waveform distortion and are also sensitive to certain type of power quality disturbances. When these power quality problems become a barrier for the large scale introduction of environmentally friendly sources and users‟ equipment, power quality becomes an environmental issue with much wider consequences than the currently merely economic issues

III. POWER QUALITY TERMINOLOGY

DSTATCOM: Means Distribution Static Compensator. STATCOM is a static VAR generator, whose output is varied so as to maintain or control specific parameters of the electric power system

SAG is a decrease in rmsvoltage or currents to between 0.1 to 0.9 p.u at the power frequency for duration of time from 0.5 cycles to 1 minute.

Balanced Sag is an equal drop in the rms value of voltage in the three-phases of a three-phase system or at the terminals of three-phase equipment for duration up to a few minutes.

Voltage dip is sudden reduction in the supply voltage by a value of more than 10% of the reference value, followed by a voltage recovery after a short period of time.

Unbalanced Fault is a short circuit or open circuit fault in which not all three phases are equally involved.

Voltage Tolerance it is the immunity of a piece of equipment against voltage magnitude variations (Sags, Swells and Interruptions) and short duration over voltages.

Duration (of Voltage Sag) it is the time during which the voltage deviates significantly from the ideal voltage. **Critical Distance** is the distance at which a short circuit fault will lead to a voltage sag of a given magnitude for a given load position.

Current Disturbance it is a variation of event during which the current in the system or at the equipment terminals deviates from the ideal sine wave.

Voltage Disturbance it is a variation of event during which the voltage in the system or at the equipment terminals deviates from the ideal sine wave.

Power Quality it is the study or description of both voltage and current disturbances. Power quality can be seen as the combination of voltage quality and current quality.

Interruption is the voltage event in which the voltage is zero during a certain time. The time during which the voltage is zero is referred to as the "duration" of the interruption. (OR) A voltage magnitude event with a magnitude is less than 10% of the nominal voltage.

Over Voltage is an abnormal voltage higher than the normal service voltage, such as might be caused from switching and lightning surges. (OR) Abnormal voltage between two points of a system that is greater than the highest value appearing between the same two points under normal service conditions.

Under Voltage is a voltage event in which the rms voltage is outside its normal operating margin for a certain period of time. (OR) A voltage magnitude event with a magnitude less than the nominal rms voltage, and a duration exceeding 1 minute.

Swell it is a momentary increase in the rms voltage or current to between 1.1 and 1.8pu delivered by the mains, outside of the normal tolerance, with a duration of more than one cycle and less than few seconds.

Recovery Time is the time interval needed for the voltage or current to return to its normal operating value, after a voltage or current event.

Fault is an event occurs on the power system and it effects the normal operation of the power system.

Voltage Fluctuation is a special type of voltage variation in which the voltage shows changes in the magnitude and/or phase angle on a time scale of seconds or less. Severe voltage fluctuations lead to light flicker.

IV. VOLTAGE SOURCE CONVERTERS (VSC) A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is used to either completely replace the voltage or to inject the „missing voltage". The „missing voltage" is the difference between the nominal voltage and the actual.

V.PRINCIPLES FOR IMPROVING POWER QUALITY From the discussion already presented, it is evident that for improving power quality, the steps given in the following fig4 have to be taken. As also pointed out, the appropriate decomposition of power for purposes of both identification and control of the distortion elimination by filters has to be achieved. Since it is essential to use clear and consistent terminology, the term non-

IJMTARC – VOLUME – V – ISSUE - 18 – JUNE , 2017

ISSN: 2320-1363

active power filter will be used for equipment that eliminates non-active power. The actual types of these filters are to be discussed in a further chapter of this paper

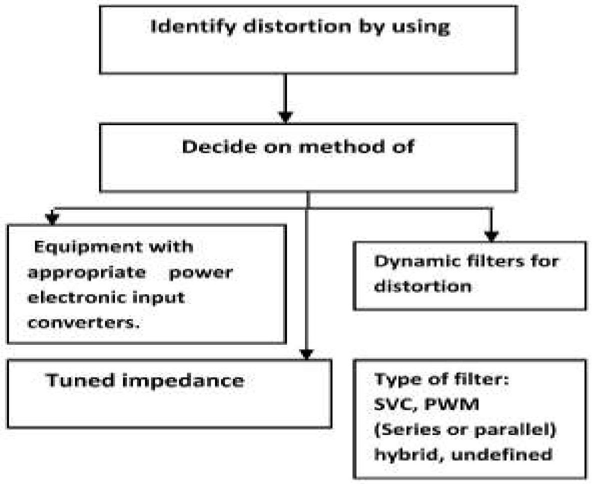

Fig : Improving power quality by distortion.

Elimination: The non-active power filters to be used can be divided into the classes of input converters, dynamic filters and tuned impedance filters.

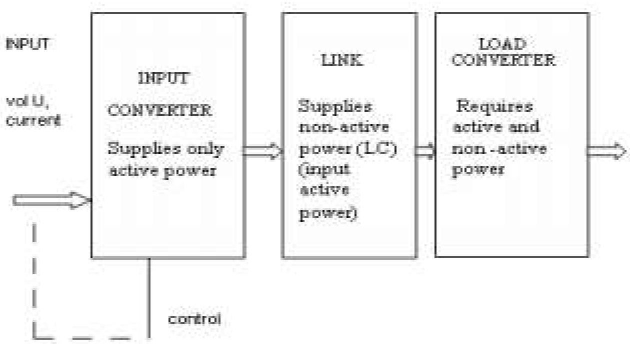

Fig : Principle of input converter to eliminate distortion loads on the power network.

V1.SIMULATION RESULTS The proposed integrated dynamic voltage restorer ultra capacitor design for improving power quality of the distribution grid and its control circuit is implemented using MATLAB/SIMULINK. Fig6 shows the simulation model of the proposed system. The system is designed such as to mitigate voltage sag and swell by using ultra capacitor based DVR. The control system of the proposed system is shown in Fig.8. The output voltage obtained is comparison with input voltage and DVR system voltages are shown in Fig8. The experimental results are depicted in Fig9(a), Fig9(b). The simulation waveforms are in good agreement with the theoretical analysis

IJMTARC – VOLUME – V – ISSUE - 18 – JUNE , 2017

ISSN: 2320-1363

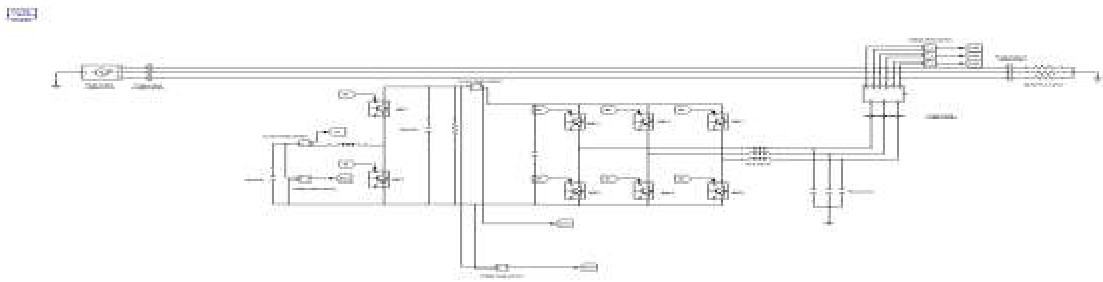

Fig 6.1Matlab/simulation conventional method of sag generation

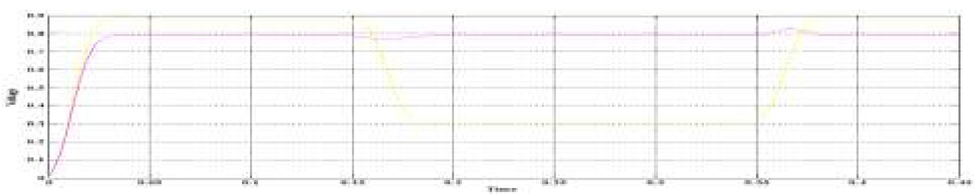

Fig 6.2Source and Load rmsvoltages V_{srms} and V_{Lrms} during sag

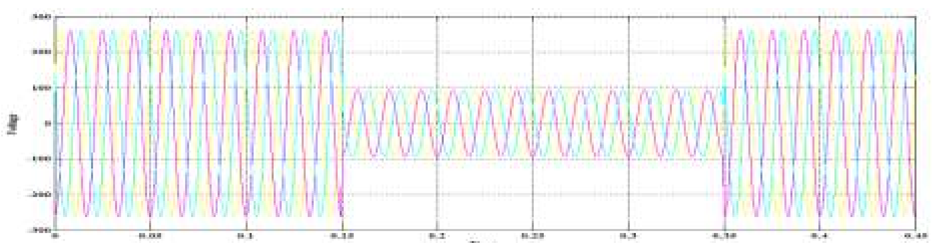

Fig 6.3Source voltagesV_{sab}(blue) ,V_{sbc} (red),V_{sca} (yellow)

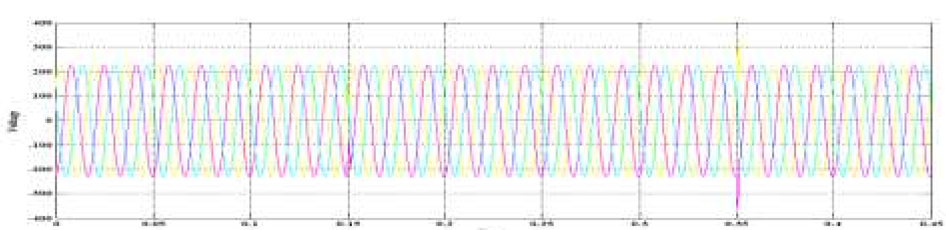

Fig 6.4load voltages V_{Lab} (blue) ,V_{Lbc} (red), V_{Lca} (yellow) during sag

IJMTARC – VOLUME – V – ISSUE - 18 – JUNE , 2017

ISSN: 2320-1363

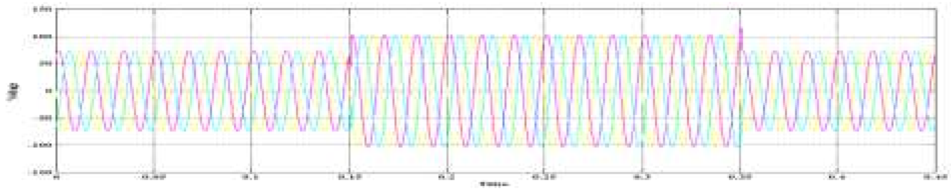

Fig 6.5 Injected voltages V_{inj2a} (blue), V_{inj2b} (red), V_{inj2c} (yellow) during sag

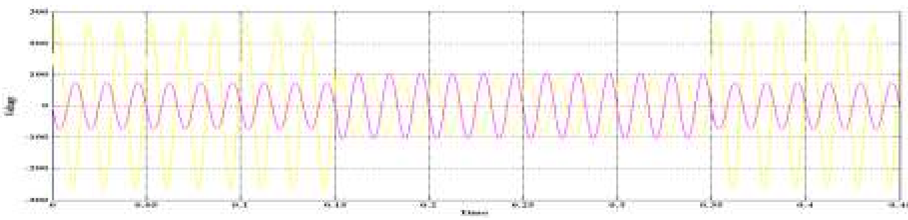

Fig 6.6V_{inj2a}(yellow), and V_{sab} (blue) waveforms during sag

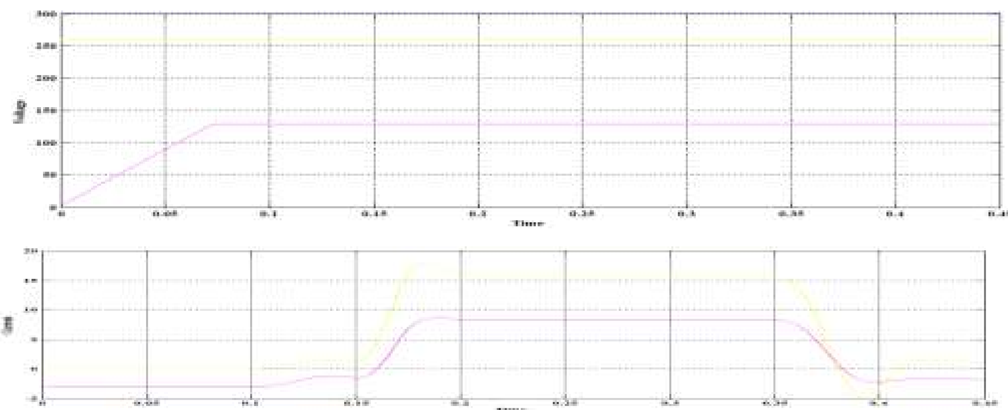

Fig 6.7 Currents and voltages of DC–DC converter

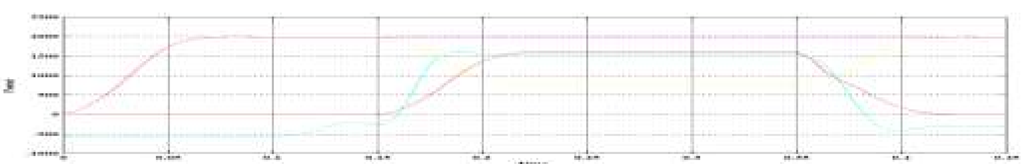

Fig 6.8 Active power of grid, load, and inverter during voltage sag

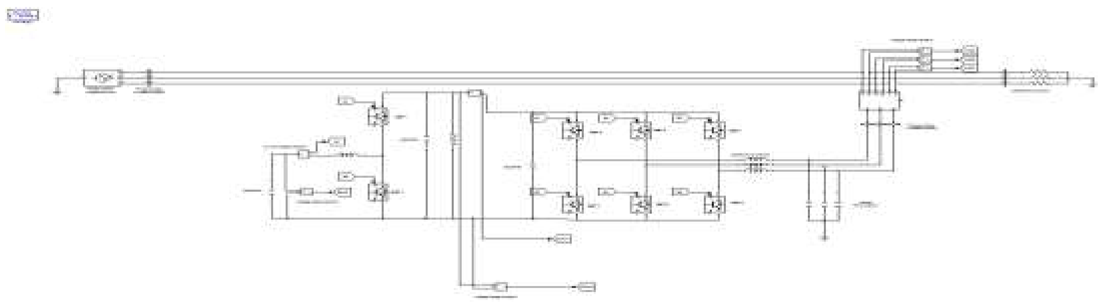

Fig 6.9 Matlab/simulation conventional method of Swell generation

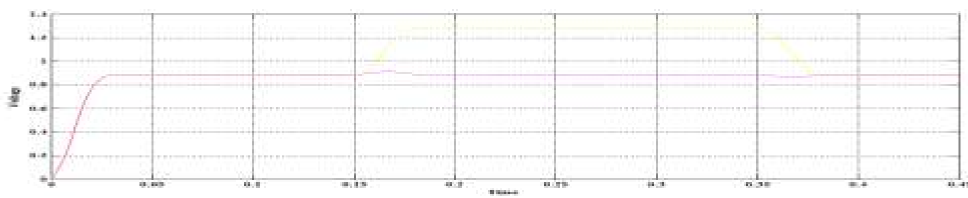

Fig 6.10 Source and Load rmsvoltages V_{srms} and V_{Lrms} during swell

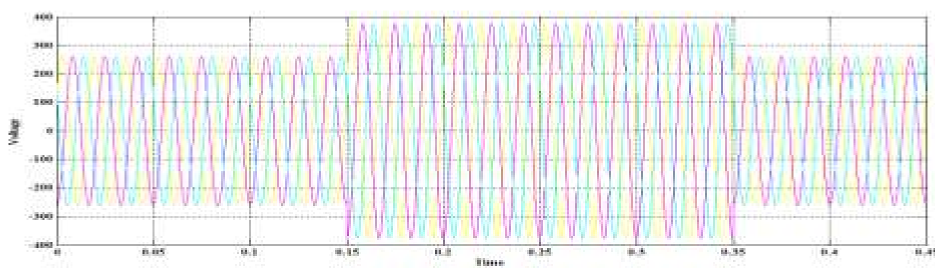

Fig 6.11 Source voltages V_{sab}(blue) ,V_{sbc} (red),V_{sca} (yellow) during swell

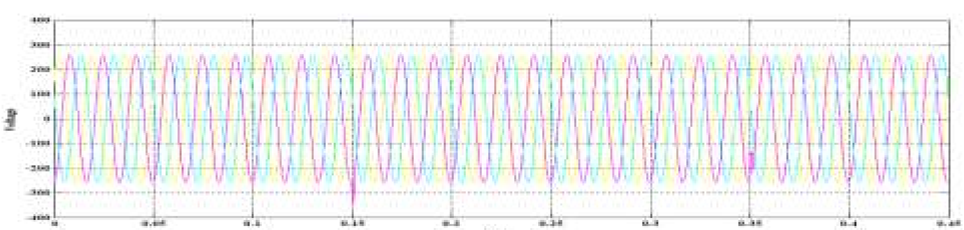

Fig 6.12 load voltages V_{Lab} (blue) ,V_{Lbc} (red), V_{Lca} (yellow) during swell

IJMTARC – VOLUME – V – ISSUE - 18 – JUNE , 2017

ISSN: 2320-1363

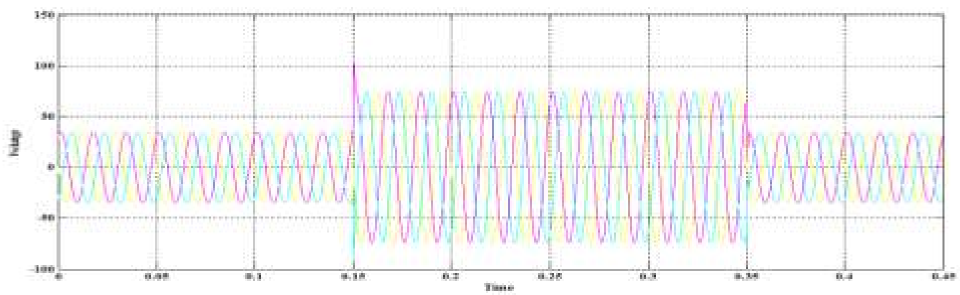

Fig 6.13 Injected voltages V_{inj2a} (blue), V_{inj2b} (red), V_{inj2c} (yellow) during swell

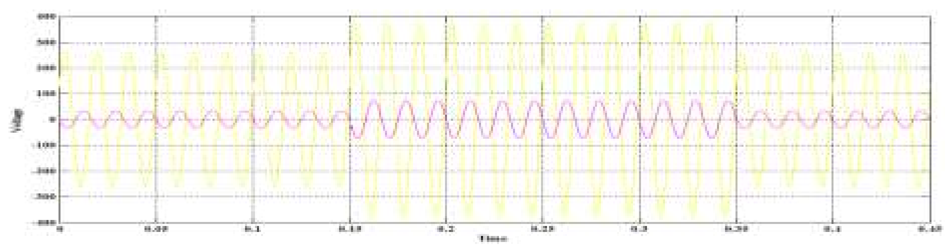

Fig 6.14 V_{inj2a}(yellow), and V_{sab} (blue) waveforms during swell

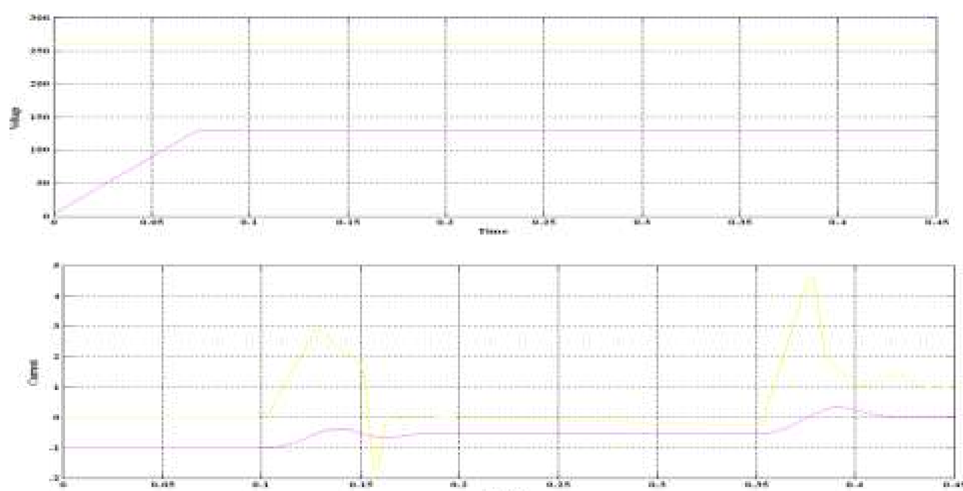

Fig 6.15 Currents and voltages of DC–DC converter during swell

IJMTARC – VOLUME – V – ISSUE - 18 – JUNE , 2017

ISSN: 2320-1363

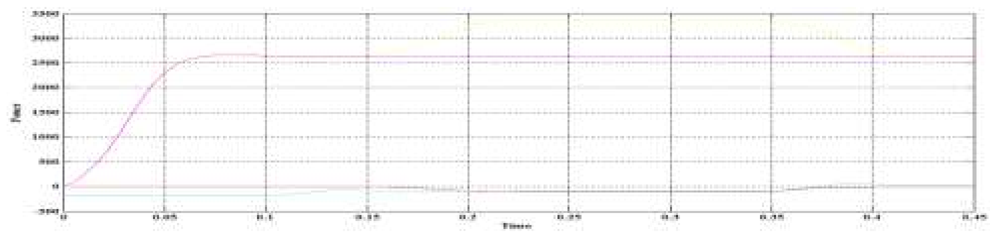

Fig 6.16 Active power of grid, load, and inverter during voltage swell

CONCLUSIONIn this paper, the concept of integrating UCAP-based rechargeable energy storage to the DVR system to improve its voltage restoration capabilities is explored. With this integration, the DVR will be able to independently compensate voltage sags and swells without relying on the grid to compensate for faults on the grid. The UCAP integration through a bidirectional dc–dc converter at the dclink of the DVR is proposed. The power stage and control strategy of the series inverter, which acts as the DVR, are discussed. The control strategy is simple and is based on injecting voltages in-phase with the system voltage and is easier to implement when the DVR system has the ability to provide active power. A higher level integrated controller, which takes decisions based on the system parameters, provides inputs to the inverter and dc–dc converter controllers to carry out their control actions. 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. The simulation of the UCAPDVR system, which consists of the UCAP, dc–dc converter, and the grid-tied inverter, is carried out using MATLAB/ SIMULINK.

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