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MODELING AND SIMULATION OF DVR WITH ULTRACAPACITOR FOR FAST VOLTAGE SAG MITIGATION IN DISTRIBUTION SYSTEM

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Abstract -- This paper presents the analysis of Ultra capacitor (UC) energy storage device interfaced with Dynamic Voltage Restorer (DVR) for fast mitigation of deeper and extended voltage sags using MATLAB/Simulink® software package. [1] The model is designed with a user-friendly icon and a dialog box like Simulink block libraries. Power quality issues are analysed in detail and —Voltage Sag in distribution systems is taken for a case study. A new model of Ultra capacitor is proposed and is verified experimentally. Simulation results for Ultra capacitor model are also derived and are found in exact accordance to the experimental modelling. [2] A complete study of Dynamic Voltage Restorer and its simulation using two control strategies viz. d-q-o algorithm and PI controller algorithm is done. To interface Ultra capacitor with DVR, a buck-boost converter controlled with hybrid control algorithm is proposed. Numbers of simulations are carried out on distribution —Test System and mitigation of voltage sag is observed in each case. The simulation results prove the advantages of the proposed system over the conventional system in terms of fastness sag depth and sag extension. The final results are going in the favour of DVR + UC system. The proposed method, if implemented practically will help the distribution system to improve power quality and can serve the customers in a better way.

Index Terms – Ultracapacitor, Dynamic Voltage Restorer (DVR), Modelling, Voltage sag, Voltage swell

I. INTRODUCTION

Ultra capacitor (UC) or Electric Double Layer Capacitor (EDLC) is a device with a high power density but relatively low energy density as compared to batteries. Figure 1 shows the Ragone chart showing energy density vs. power density for various energy-storage devices.

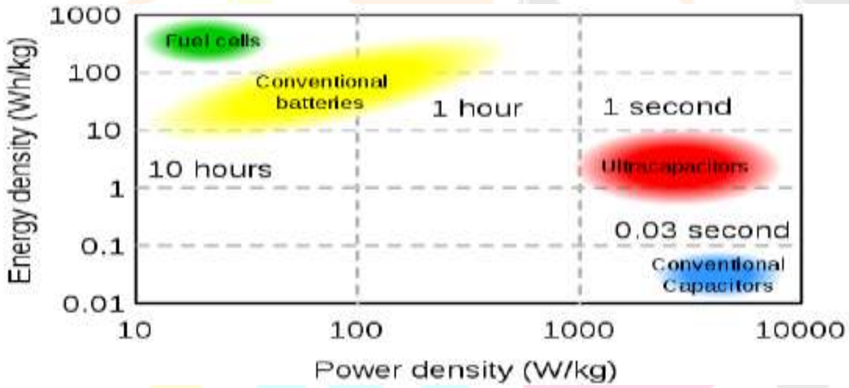

Figure 1: Ragone chart showing energy density vs. power density for various energy-storage devices

The physical principle of these capacitors is based on the double layer effect [1]. EDLCs do not have a conventional dielectric. Rather than two separate plates separated by an intervening substance, these capacitors use "plates" that are in fact two layers of the same substrate, and their electrical properties, the so-called "electrical double layer", result in the effective separation of charge despite the vanishingly thin (on the order of nanometers) physical separation of the layers. The lack of need for a bulky layer of dielectric permits the packing of "plates" with much larger surface area into a given size, resulting in extraordinarily high capacitances in practical-sized packages. They have energy density about 1-10 Wh/kg with wide operating temperature range about -40 to 65 oC [2, 3].

Double layer capacitor uses activated charcoal as insulating medium. Activated charcoal is a powder made up of extremely small and very "rough" particles. The overall surface area of even a thin layer of such a material is many times greater than a traditional material like aluminum, allowing many more charge carriers to be stored in any given volume. Ultra capacitors have capacitance in terms of thousands of farads. EDLCs can only be used at low potentials of the order of 2 to 3 V because charcoal is not a very good insulator like conventional insulators used in capacitors. Higher voltage can be achieved by connecting in series. Figure 1.2 shows the cross section of Ultra capacitor.

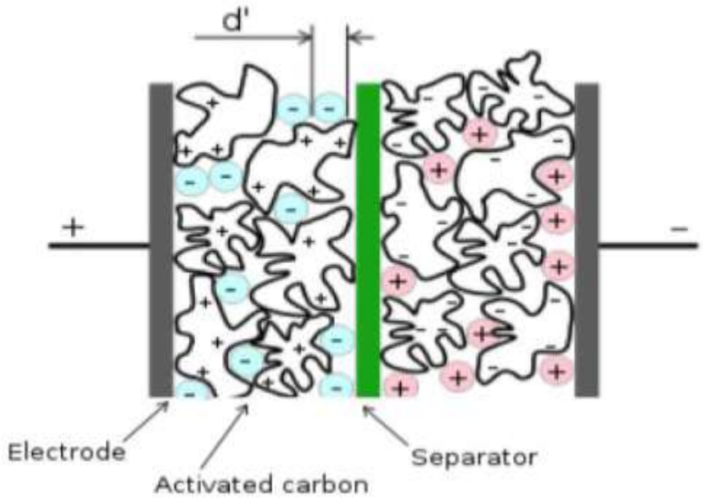

Figure 2: Cross-section of ultracapacitor

II. DYNAMIC VOLTAGE RESTORER

. Among the power quality problems (sags, swells, harmonics…) voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of these devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. DVR is a recently proposed series connected solid state device that injects reactive power (can be interpreted as injection of voltage, as it in series) into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also added other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations [13, 14]. The basic configuration and location of DVR is shown in Figure 5.1

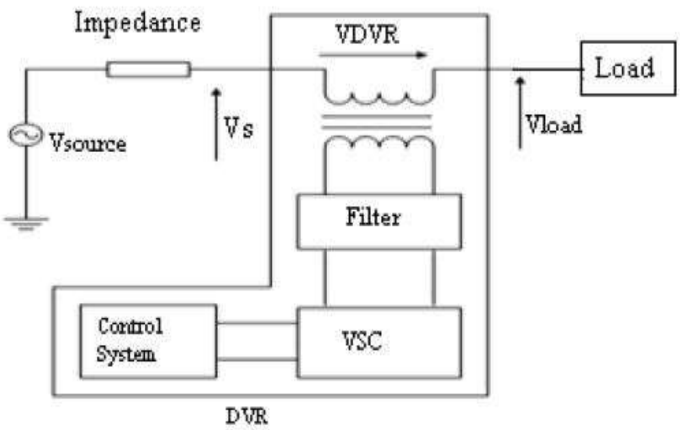

Figure 3: Location and schematic of DVR

III. TIME DOMAIN MODEL

In order to model the behaviour of UC, certain requirements are set before formulation of equivalent circuit model of UC. For that the model should be as simple as possible, model should describe the behavior of UC accurately & parameters should be determined by using UC terminal measurements. As UC has complex physical nature, it is very much preferable to do analysis of UC based of distributed parameter system. UCs are modeled based on three physical aspects: (1) electrochemistry of two different materials interfaced in different phases, which is modeled as an RC circuit. The resistive element depends on the resistance of electrode materials, resistance of electrolytic solvent, pores width membrane porosity, quality of the connection electrode-collector. (2) Based on the theory of the interfaced tension in the double layer, the capacitance of the UC varies linearly with the capacitor terminal voltage (3) Double layer charge distribution shows certain self-discharge.

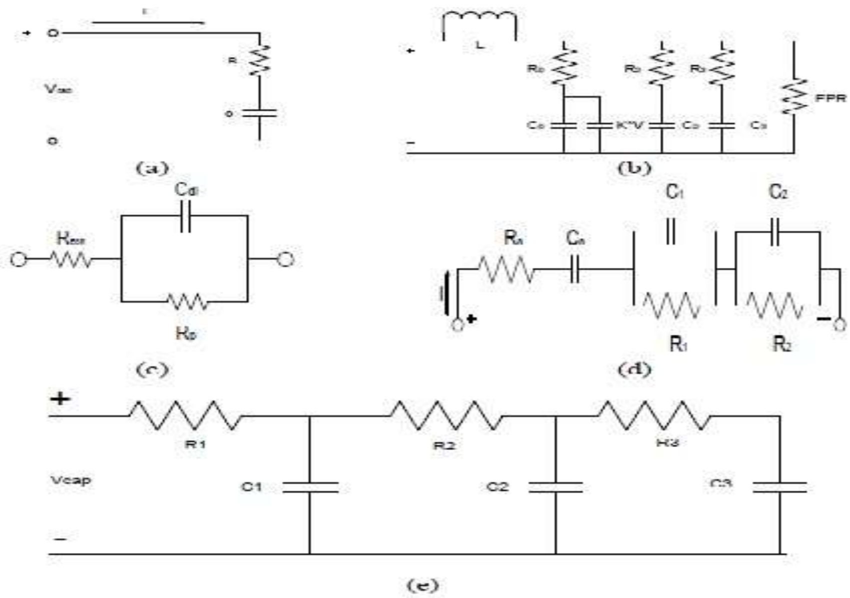

Fig. 4: (a) Simple UC Model (b) RC parallel branch model (c)UC Model with ESR and Rp (d) RC Branch Series – Parallel Model (e)Transmission line Model

Various time domain model of UC have been proposed by different authors to study its electrical behaviour under various operating condition [3], [4]. Model in Fig. 4(a), (c) and (d) are incomplete to describe the behaviour of UC under various operating conditions. Therefore, more efficient ultra capacitor models have been proposed recently by many authors are shown in Fig.4(b) and (e), but many of them have ignored the temperature dependency of UC dynamics. The model used in this paper as shown in fig4(b) takes in to account temperature effect and it fits in various operating conditions more accurately. Here, the identification process is much simpler and it does not require very sophisticated instrumentation.

IV. ULTRACAPACITOR AND DVR MODELLING

Ultracapacitor Modaling

In order to model the behavior of UC, certain requirements are set before formulation of equivalent circuit model of UC. For that the model should be as simple as possible, model should describe the behavior of UC accurately and parameters should be determined by using UC terminal measurements. UC is modeled based on three physical aspects: (1) electro-chemistry of two different materials interfaced in different phases, which is modeled as an RC circuit. The resistive element depends on the resistance of electrode materials, resistance of electrolytic solvent, pores width membrane porosity, quality of the connection electrode-collector.

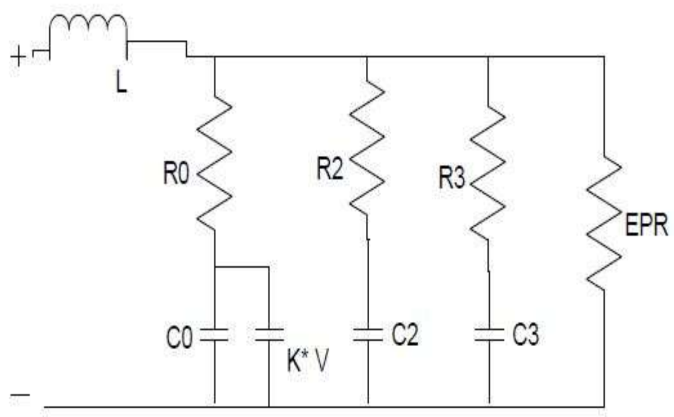

Figure 5: Proposed UC equivalent circuit

DVR modeling

In this work a system is proposed which will interface Ultracapacitor with DVR with the help of buck boost converter. The system block diagram is shown in Figure 1.5. The work is focused on *"Voltage Sag"* problem in the distribution system. The end result shows successful demonstration of the proposed system by MATLAB/Simulink® simulations. Figure 1.5 it is inject voltage in line with inject transformer. Therefore mitigate voltage sag and voltage swell. By using Ultracapacitor with DVR the mitigation is very fast for sensitive load.

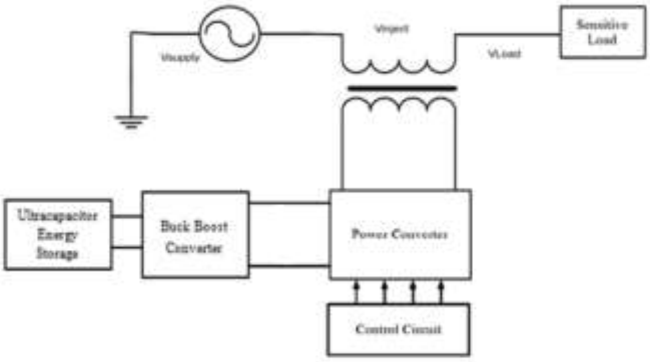

Figure 6: Proposed system block diagram

V. Simulation

UC Simulation

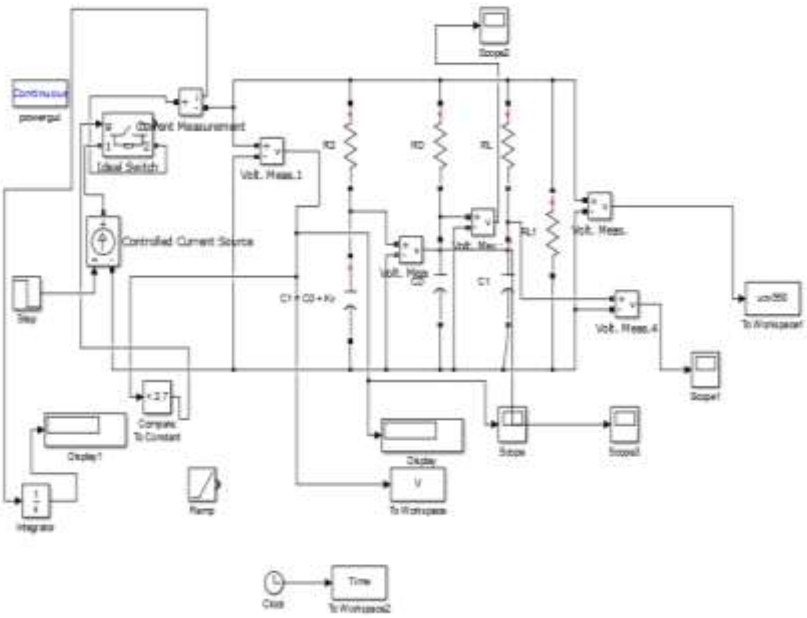

Figure 7: MATLAB simulation of Ultracapacitor

UC Result

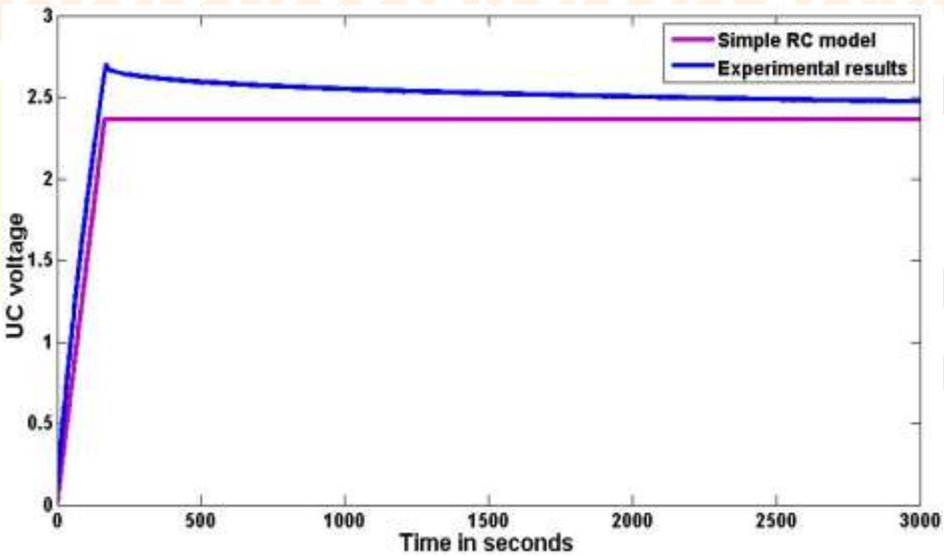

Figure 8: Experimental and simulated results with simple R-C branch model for BCAP 0350 with constant current 5 A

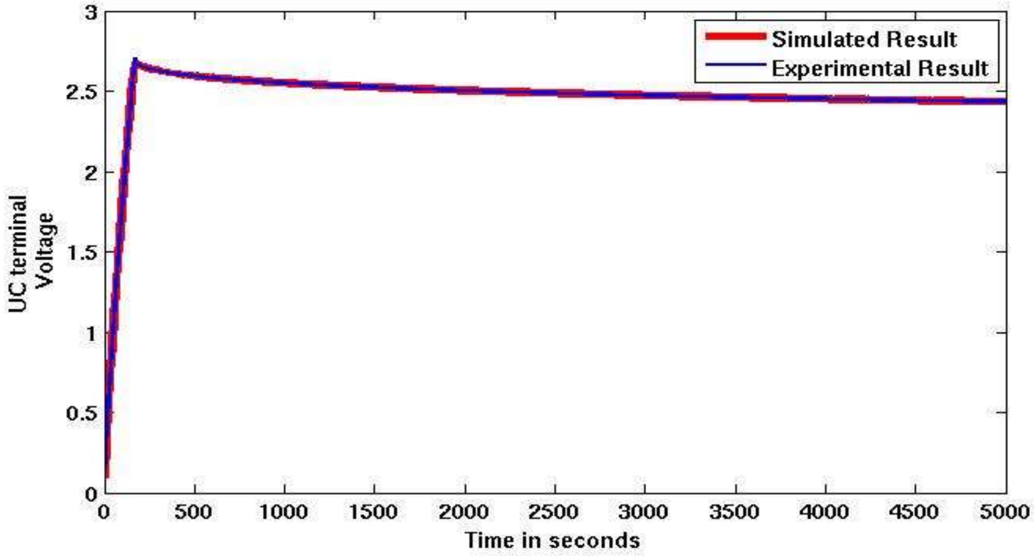

Figure 9: Experimental and simulated results with proposed model BCAP

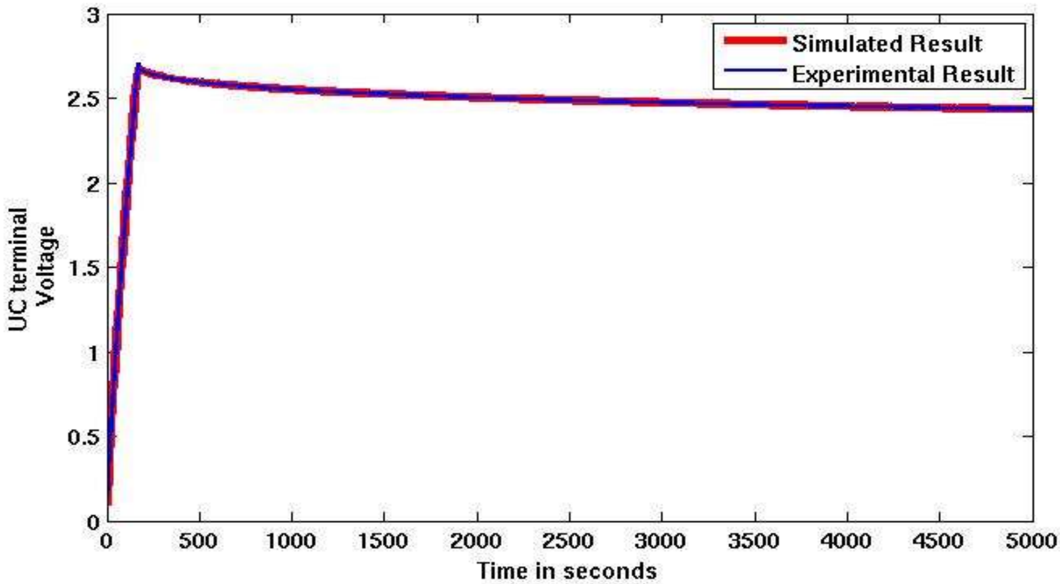

Figure 10: BCAP 0350 with constant current 5 A (Including self-discharge)

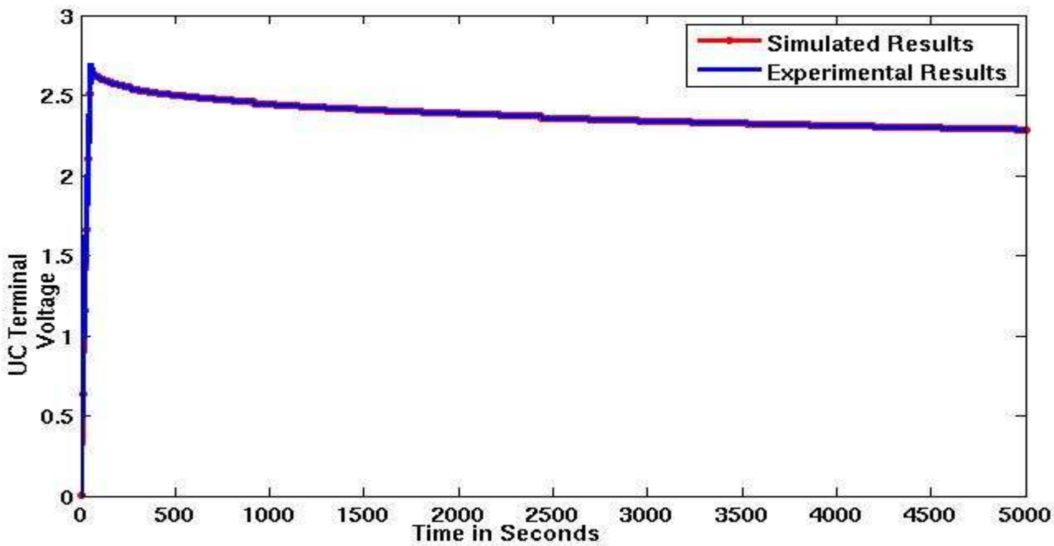

Figure 11: Experimental and simulated results with proposed model for BCAP 0150 with constant current 4A

Matlab/Simulink® model of DVR using d-q-0 transformation

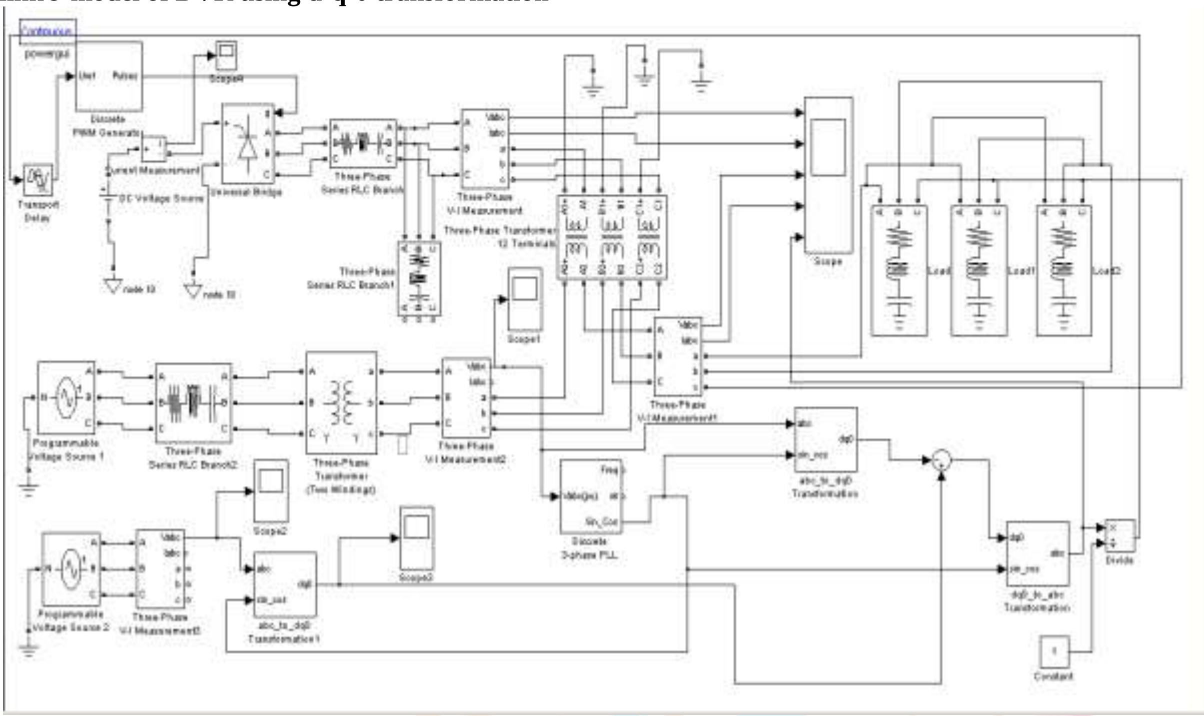

Figure 12: MATLAB/Simulink® Model of DVR using d-q-0 transformatio

Simulation results of DVR using d-q-0 transformation

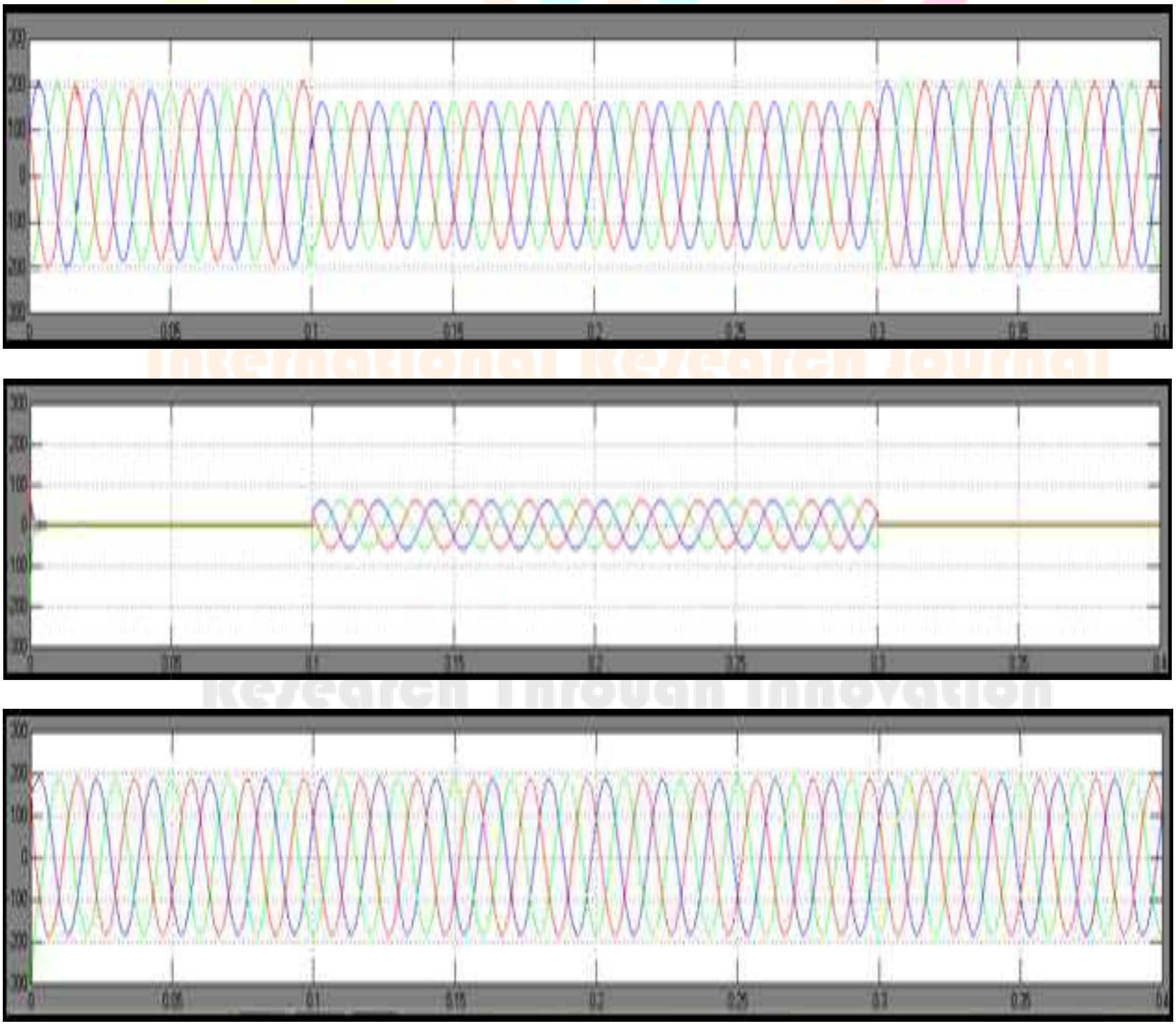

Figure 13: Simulation results of DVR using d-q-0 transformation

VI. CONCLUSION

From all these analysis it can be concluded that, the integration of ultracapacitor energy storage device with dynamic voltage restorer (DVR) is a better solution to mitigate voltage sag than DVR with DC bus capacitor only or DVR interfaced with battery energy storage device. Investigations were carried out on a 400 V test system with MATLAB/Simulink modeling and the superiority of UC with DVR is shown in the analysis done and this integration is faster in comparison to battery backup DVR by nearly 16 ms, a sufficient margin to decide the device will trip or not. The ultracapacitor experimental modeling is also shown in the dissertation work. Proposed model represents the UC characteristics precisely and accurately. As compared to methods which require pulsed charging with precise current, voltage and impedance measurements and analysis of frequency spectrum of UC, aforementioned method is simpler for calculation equivalent circuit parameters. The proposed method requires simple constant current charging and measurement of voltages taken over a period of time. The Simulated results matches with actual results which validate the proposed model can be used for modeling of UC for analysis during its application development. The buck boost converter is also designed by hybrid control algorithm and it works in accordance with the system requirement. It was seen that DVR with DC bus capacitor only cannot mitigate deeper voltage sags which DVR + UC is able to do. So, in end it can be said that DVR interfaced with Ultracapacitor can mitigate deeper and extended voltage sags very fast in comparison to all other methods discussed.

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VII. REFERENCES

[1] G.L. Bullard, H.B. Sierra-Alcazar, H.L. Lee, J.L. Morris, ―Operating principles of the ultracapacitor‖ IEEE transactions on Magnetics, vol. 25, no. 1, January 1989, pp. 102-106

[2] Lisheng Shi, Student Member, IEEE, and M. L. Crow, Senior Member, IEEE, ―Comparison of Ultracapacitor Electric Circuit Models‖ IEEE transactions on Magnetics, vol. 44, no. 3, July 2008, pp. 1-6

[3] Sheldon S. Williamson, Alireza Khaligh, Sung Chul and Ali Emadi ―A physical based model of power electric double-layer supercapacitors‖, IEEE transactions on Magnetics, vol. 36, no. 1, January 2000, pp. 3069-3076.

[4] Zhang Li, Song Jin-yan, Zou Ji-yan, and Wang Ning ―Electrochemical capacitor technology for actuator applications‖, IEEE transactions on Magnetics, vol. 32, no. 2, April 1989, pp. 245-250.

[5] Alon Farkas and Richard Bonert ―A comparison of two equivalent circuits for double layer capacitors‖, IEEE Trans. Comp., Hybrid, Manufac. Tech. 22, pp. 692-698.

[6] Juanhua Wang, Jiancheng Zhang, Yun Zhong, A. F. ―Carbon properties and their role in supercapacitors‖ J. Power Sources 2006, 157, pp. 11–27.

[7] A. Yoshida, K. Imoto, H. Yodeda, A. Nishino, ―An electric double layer capacitor with high capacitance and low resistance‖, IEEE Trans. Comp., Hybrid, Manufac. Tech. 15 (1) (1992) pp. 133–138.

[8] Yang Wang, Joan E. Carletta, Tom T. Hartley and Robert J. Veillette, ―Mathematical modeling of sol–gel derived carbon xerogels as double layer capacitors‖, Electrochem. Soc. Proc. 25–96 (1996) pp. 153–166.

[9] R. Faranda, M. Gallina and D.T. Son ―A Mathematical model of an electrochemical capacitor with porous electrodes‖, Electrochem. Soc. Proc. 25–96 (1996) pp. 167–179.

[10] B. Vural, M. Uzunoglu, O. Erdinc and O. C. Onar, ―Ultracapacitor electrical modeling using temperature dependent parameters―, ESSCAP'2004, Belfort (2004) pp. 224-228

[11] L. Zubieta, R. Bonert, ―Characterization of double layer capacitors for power electronic applications‖, IEEE Transaction on industry application, vol. 36, no. 1, January/February 2000, pp. 199-204.

[12] Mahinda Vilathgamuwa, A.A.D. Ranjith Perera and S.S. Choi, ―Mitigation of Voltage Disturbances Using Adaptive Perceptron- Based Control Algorithm‖ IEEE Transactions on Power Delivery, Vol. 20, No. 1, pp. 309-318, January 2005

[13] Rosli Omar and N.A Rahim, ― Voltage Sag Detection Technique for a Dynamic Voltage Restorer‖ IEEE Transactions on Power Delivery, Vol. 40, No. 1, pp. 203-212, January/February 2004

[14] Mehmet Tümay ―The DC link energy control method in dynamic voltage restorer system‖ Electrical Power and Energy Systems 25 2003, pp.525–531

[15] Rosli Omar and N.A Rahim ―Dynamic Voltage Restorer Against Balanced and Unbalanced Voltage Sags: Modeling and Simulation‖ IEEE Transactions on Power Delivery Vol. 42, No. 1, 2006, pp.1-6

[16] H.P. Tiwari and Sunil Kumar Gupta ―Supervisory control of dynamic voltage restorers‖ IEE Proc.- Gener. Transm. Distrib. Vol. 151, No. 4, pp. 509-516, July 2004