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Compensation of DVR with Supercapacitor based Energy Storage

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***Abstract*— The primary aim of the this presented paper is for explaining quality of power, the issues with the voltage of the medium level network as well as the negative impact on the loads with critical system as well as demonstrate the devices of the custom power used for justification in its details. In the above study, we have discussed about DVR for the improvement of quality of power known to be one of the devices with custom power as well as the having great efficiency and also have the efficiency in the solution for the improvement in the quality of the power. The basic concept of the operation, the components of the power circuit, the structure, the techniques of compensation, modes of operation along with the several methods for the control of DVR explained in the detail. The effectiveness as well as the performance of provided DVR which has been connected with the testing system. For showing purpose of the DVR for the justification of quality of power; issues with DVR, connected to the system having the load which is non-linear and the faults which are applied. The graph of the power has been calculated. Also, the current of the load graph of the outcome attained presents few ripples as well as the continuous flow.**

Keywords*— Dynamic Voltage Restorer - DVR, Supercapacitor SC, Thyristor Control Reactor TCR

I. INTRODUCTION

The Now-a-days, in spite of the extensive conventional usage of sensitive gear such as computers as well as of the PLCs, rapidity of the procedures of industries is helpless against the disabilities related to the voltages [1-3]. Swell as well as the saggy voltages are some practical instances of the susceptibilities causing improper functioning in system.

Dynamic Voltage Restorer is known to be a source of transformer for the voltage under the control as well as it has been installed among primary source of energy as well as the load so that the voltage levels can be stabilized [4-5]. It is able to sense the rapid disturbance and noise in the voltage of the system. Fig.1 presents the structure that is generally network with simulations in the article.

In this thesis, we are using Thyristor Control Reactor for providing the reactive power. It has been attached to load side of system for removing harmonics by the current that is injected as well as for selecting the firing angles for the Thyristor Control Reactor (TCR).

A duo of thyristors in Thyristor Control Reactor is attached anti-parallelly. Every thyristor is compulsorily enforced into transmission with the help of using of a pulse to the input of the gate of TCR in one of the two positives as well as of half cycles which is negative of supplied volt. Then current flow will be blocked right next the AC current crosses 0 (zero). The maximum current will flow if thyristors of TCR are fired at the crest voltages.

Supercapacitors SC are proficient of super quick charging as well as discharging, and in fact are also being able to go over a huge no. of cycles for discharging and well as that of charging, without deprivation, in contrary to batteries. Hence, it is proposed to operate the storage system of supercapacitor to store suitable quantity of energy to the system to be released improve its fluctuations. Quantity of energy store unit weight in first generation supercapacitor is well-thought-out lesser than that of batteries made of electro chemicals. The voltage differs with the stored energy. In order to capably recover as well as storing energy, classical electronic control as well as switching equipment is mandatory.

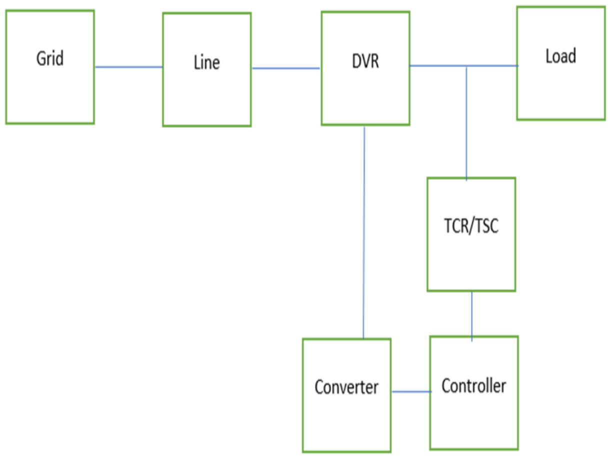

Fig 1 Block Diagram of The Complete System

II. MODELING OF THE SYSTEM

A. *DYNAMIC VOLTAGE RESTORER*

The DVR has been a means for recompensing short-term insufficiencies of the power in the insensitive loads. The ability of DVR to compensate varies with extreme injection voltage as well as the capabilities of power during saggy voltages. When the continuous voltage drops occur, Dynamic Voltage Restorer (DVR) can pay it off with a very operative approach such as DVR algorithm. The algorithm reduces the real power distributing necessity. Though, the limitations of the same on restoring the load current as well as the load voltage causes fluctuations in the angle of the phase.

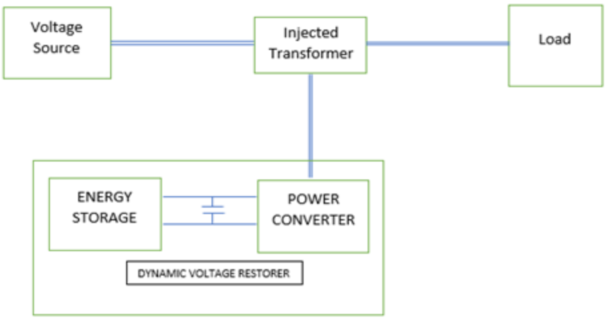

Fig 2: Block Diagram for Understanding the DVR

In the thesis, the usage of the TCR has provided the reactive power. It has been fixed on side of the load of network for the elimination of injecting current harmonics and by selecting the firing angles which are best for power of the electronic device [3]-[4].

B. Operations of Dynamic Voltage Restorer

The dynamic voltage restorer usually in standard conditions used to operate in the mode of standby. During noise as well as disturbances or faulty conditions, nominal voltage of the system can be will be contrasted to the variations in the voltage. Through this we got the value of the differential voltage which the restorer has to inject in the resultant output to sustain voltage of the supply to the load within limits.

The amplitude as well as the phase angle of the injected voltages are adjustable which consents control of real as well as reactive power exchange b/w DVR as well as system of the distribution. The input of the DVR's terminal (DC Voltage) has been connected to a proper device for storing energy. As cited, the transfer of reactive power among the distribution system as well as the Dynamic Voltage Restorer is generated using Dynamic Voltage Restorer without the reactive components of AC passive internally. The real power using Dynamic Voltage Restorer input DC terminal has been provided which is interchanged at outcome of DVR AC terminals by an exterior source of energy or we can say the storage system for energy.

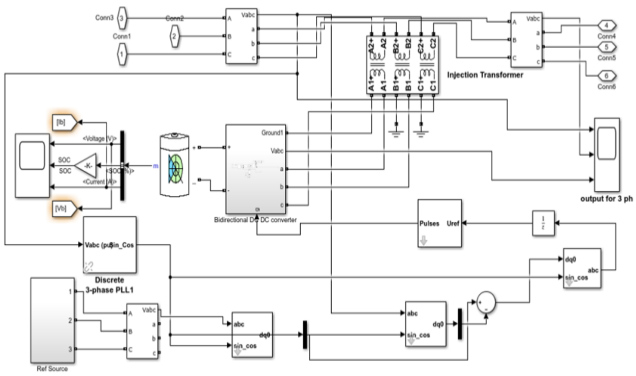

Fig 3. Simulink Model of DVR

C. SUPERCAPACITOR MODELING

The Though there are several advantages, it has disadvantages which are related to the UCs. One will be able take its care during control designing.

The energy stored with respect to its weight in the UC of first generation is lower when compared to the electrochemical batteries. The amount of energy stored brings variations in the voltage. To make sure that the energy is stored and recovered efficiently, switching equipment and the electronic control is essential.

There are various models developed for description of the Double-Layer SC. The most widespread model known as the two branches model is used in our study, that is well-known. (As represented in figure 5).

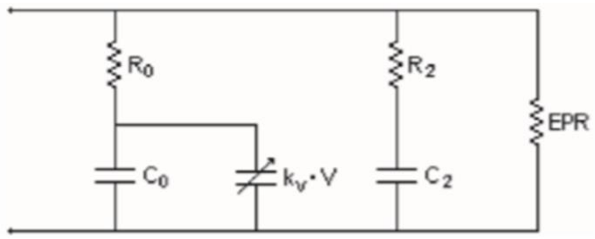

Fig 4. Equivalent Model for Two Branches Supercapacitor Model

D. Bidirectional DC to DC Converter for Super Capacitor

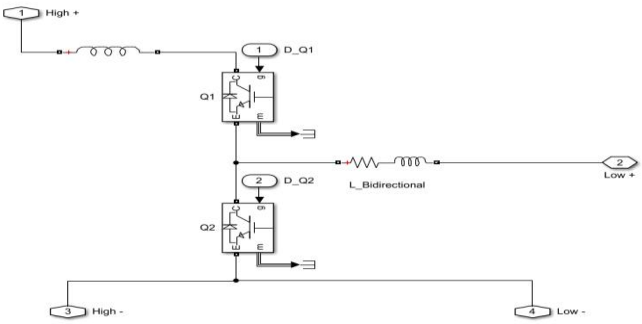

Fig 5. Bidirectional DC- DC Converter for Supercapacitors

III. CONTROLLING THE SYSTEM

A. CONTROL OF A DYNAMIC VOLTAGE RESTORER

A Using the equation written below, the instantaneous values of the 3-phase voltages V_a, V_B and V_C are being transformed into the system of αβ coordinates. The resultant vector consists of Vsα as well as Vsβ.

$$\begin{bmatrix} V_{s\alpha} \\ V_{s\beta} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{sa} \\ V_{sb} \\ V_{sc} \end{bmatrix} \qquad (1)$$

Also, the reference voltages V_{qRef} as well as V_{dRef} are achieved with the help of quantified controlling strategy. The error voltages V_{dError} and also the V_{qError} are attained by comparison of the 'd' as well as the 'q' voltage components with their corresponding reference voltages V_{qRef} as well as V_{dRef} .The resulting difference voltages $V_{dInjected}$ as well as $V_{qinjected}$ are formerly injected to the system using the help of Dynamic Voltage Restorer. In order to create the injected voltages, $V_{dInjected}$ as well as $V_{qinjected}$ are shifted back to the designed system of $\alpha\beta$ coordinates using a suitable opposite transfer-matrix.

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So, the vector of the resultant in coordinate system of αβ is further transformed again into coordinate system which was original with the use of following equation:

$$\begin{bmatrix} V_{sd} \\ V_{sq} \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} V_{s\alpha} \\ V_{s\beta} \end{bmatrix} \quad (2)$$

Finally, the resulting instantaneous voltages which are V_{a0}, V_{b0} as well as V_{C0} are being fed into the block of the voltage source convertor (VSC). The voltages created with the help of the VSC are being fed into the 3-Phase-series-connected converter. So, the appropriate voltages of serial in the unity to presently available errors of the voltage are now fed into system to re-establish swell as well as sag voltages returned back to their pre-fault conditions.

B. ANALYSIS OF TCR

Use The Reactor which is controlled by the Thyristor is known to be self-controller which is handled with the help of many thyristors. The reactance that is operative is attainable with taking the control of firing angles of thyristors in a firm limit. One pair of the thyristors which are present in the TCR has been applied anti-parallelly.

Both of the thyristors have to undergo the conduction due to the pulse application to the input of the gate in any one of the positive as well as the negative half cycles of voltage which is supplied to it. Thus, flowing of the current will be blocked once the current of ac exceeds the zero limit.

In the case when the thyristors are fired at the voltages of the crest, then flow of the current in the thyristors is the most. The current which flowing in reactor could be transformed from the extreme to zero by having variations in the angle of the firing delay with respect of peak for voltage which is applied in each of the half-cycle. Principally, the flow of current has been reactive and it lags approx. 90^o of voltage.

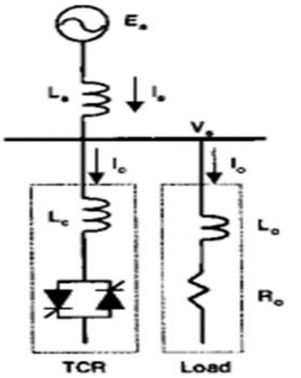

FIG 4. Thyristor Control Reactor

The Reactor of the controlled for the thyristor (Fig.1) presents the composed TCR that is conventional of a constant reactor of the inductance, and the thyristor which is bi-directional. The current which is passing through reactor could be measured from the extreme to the zero level with the help of the angle control of the delay in the firing. Basically, the turning-ON of thyristor is overdue because of peak of the voltage which is applied in each of-half-cycle. So, period of conduction of the current has been controlled in the form as it has been presented in the Fig.2.

In case of any delay in the thyristor of an angle a (0 5 a 5 n12) with concern to voltage crest, the reactor current is presented with v(t) = $V \cos \omega$ as follows:

$$i_c(t) = \frac{1}{L_c}\int_0^{\omega t} v(t)dt = \frac{V_s}{\omega L_c}(\sin \omega t - \sin \alpha) \quad (3)$$

It's obvious that the current magnitude in reactor can be variable incessantly by the delay angle in the controlling from the extreme (d) to the zero level (a = n/2), as presented.

Principle as well as the substance of harmonic flowing of the current in the reactor I(t) can be expressed in the form of a function of the angle a, respectively:

$$i_{cf}(\alpha) = \frac{V_s}{\omega L_c}\left(1 - \frac{2}{\pi}\alpha - \frac{1}{\pi}\alpha - \frac{1}{\pi}\sin 2\alpha\right) \quad (4)$$

$$i_{cn}(\alpha) = \frac{V_s}{\omega L_c}\frac{4}{\pi}\left\{\frac{\sin\alpha\cos(n\alpha) - n\cos\alpha\sin(n\alpha)}{n(n^2-1)}\right\} \quad (5)$$

In which the value of $n = 2k + l, k = 1,2,3 \ldots$

It is obvious from the (4) and (5) that TCR is able to control the principles of the current from the zero level to the extreme level because it is variable reactor that is controlled with the help of the delay angle a. If there is any unbalanced 3-phase system, then triple-n harmonic currents (3'd, 9Ih, 15", etc.) start circulating in the delta which is applied to the TCRs and is restricted from entering the system of power.

The value of the else harmonics can be produced with the help of the TCR. From Fig. 4, bus voltage V can be expressed:

$$V_s = \frac{Y_s E_s}{Y_s + Y_c + Y_o} \quad (6)$$

Y can be varied if delay angle a is controlled. What it implies is that, V can be varied and the generation of the sag of voltage by thyristor switch firing of TCR, as well as the extreme drop of voltage has been decided with the help of the purpose of the ratio among the L and the L, under the provided conditions of load.

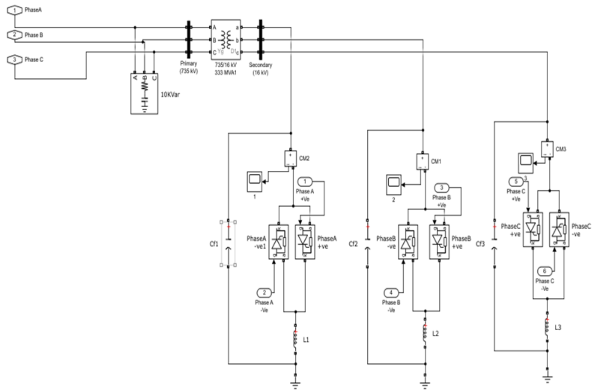

Fig 5: Simulink Model of TCR

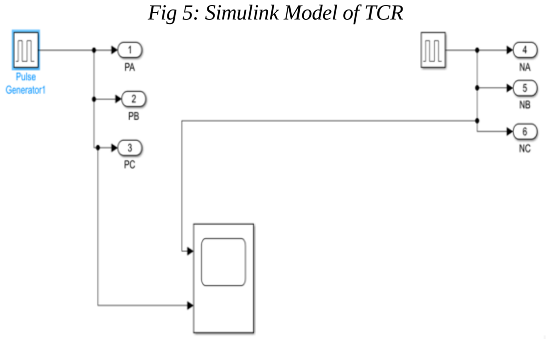

Fig 6: Simulink Model for Firing Control Of TCR

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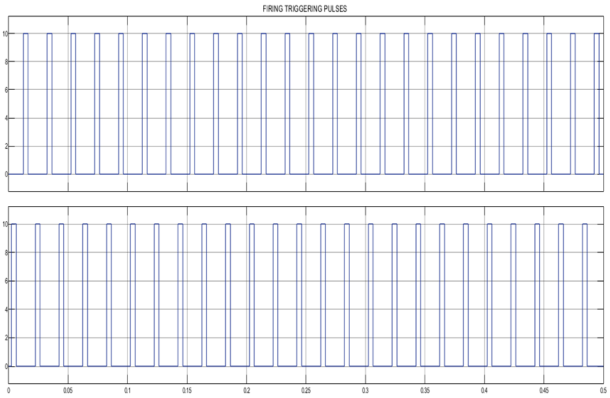

Fig 7: Firing Pulses for FC-TCR

IV. SIMULATION AND RESULTS

A. SIMULINK DIAGRAM OF COMPLETE SYSTEM

Simulink diagram of the complete system which consists of the following systems:

i. An Injection/ Booster transformer.
ii. DC charging circuit.
iii. Storage Devices (Super Capacitor).
iv. Bi-directional DC-DC Voltage Converter.

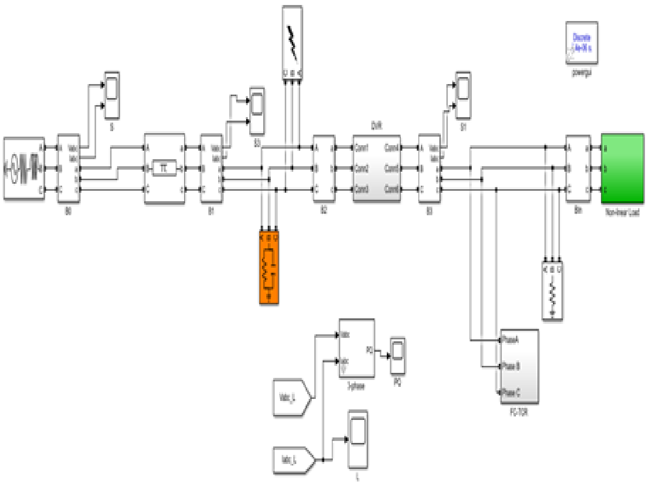

Fig 8. Simulink Model of the Complete System

A. SIMULATION RESULTS

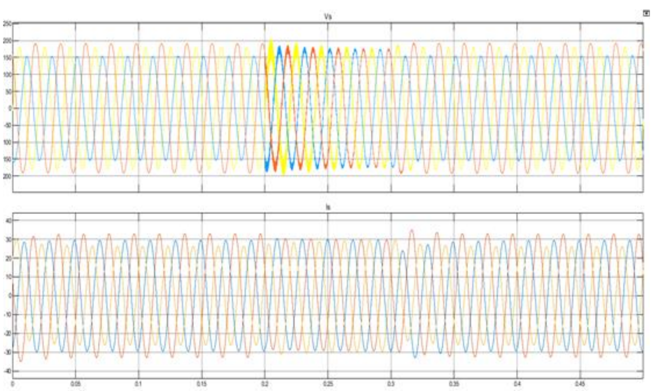

Fig 9. Output showing the Source Voltage (Vs) and Source Current (Is)

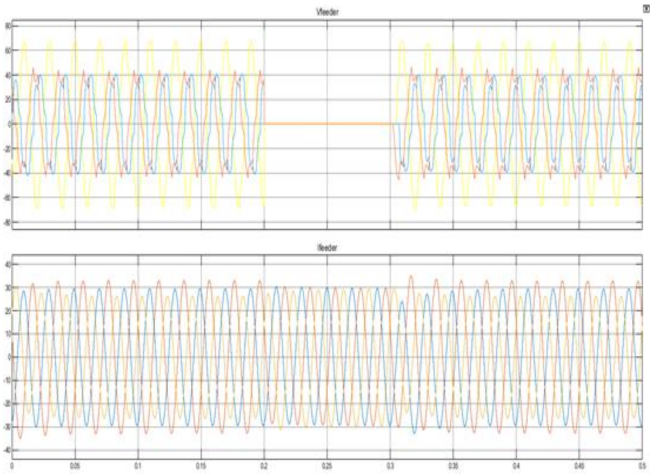

Fig 10. Output of feeder Voltage (V_{feeder}) and Feeder Current (I_{feeder})

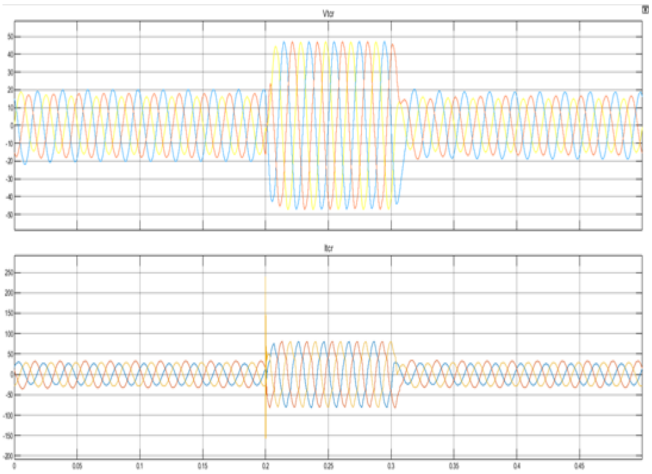

Fig 11. Output showing the DVR Voltage (V_{DVR}) and DVR Current (I_{DVR})

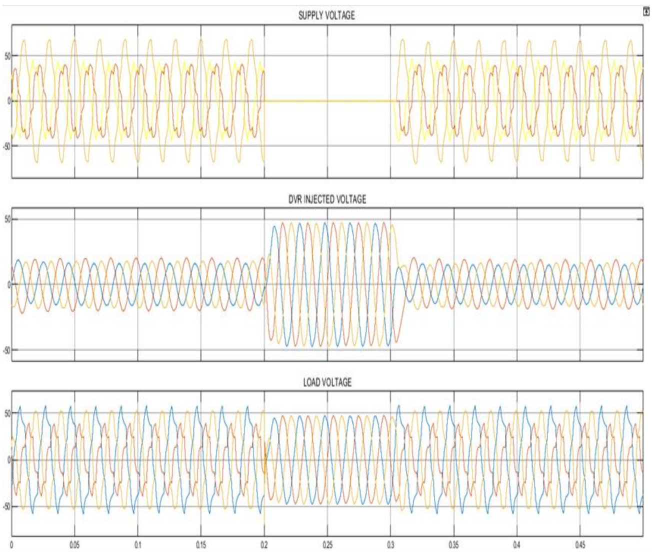

Fig 12: Output showing the overall Source Voltage, after feeder, DVR Injected Voltage and Load Voltage

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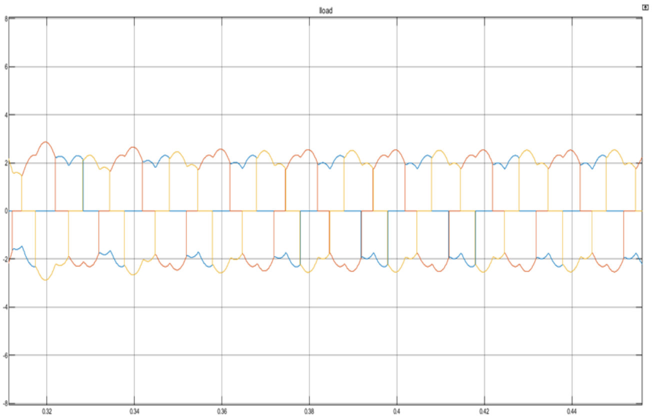

Fig 13: Output showing Continuous Current Passing to the Load after TCR (I_{LOAD})

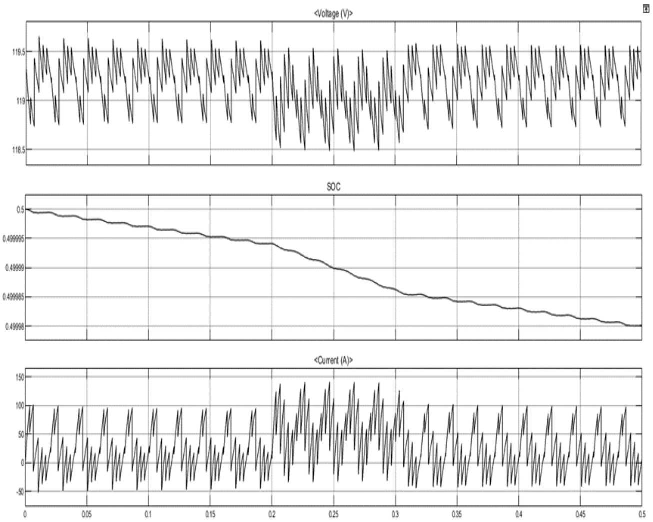

Fig 14: Output showing the Supercapacitor Voltage and Supercapacitor Current

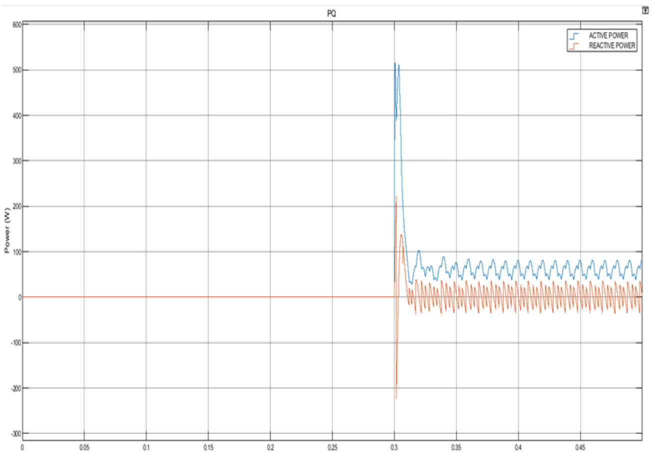

Fig 15: Outputs of the Active Power (Blue) and Reactive Power (RED)

V. CONCLUSION

The primary aim of the work is for explaining quality of power, the issues with the voltage of the medium level network as well as the negative impact on the loads with critical system as well as demonstrate the devices of the custom power used for justification in its details. In the above study, we have discussed about DVR for the improvement of quality of power known to be one of the devices with custom power as well as the having great efficiency and also have the efficiency in the solution for the improvement in the quality of the power. The basic concept of the operation, the components of the power circuit, the structure, the techniques of compensation, modes of operation along with the several methods for the control of DVR explained in the detail. The effectiveness as well as the performance of provided DVR which has been connected with the testing system. For showing purpose of the DVR for the justification of quality of power; issues with DVR, connected to the system having the load which is non-linear and the faults which are applied. The graph of the power has been calculated. Also, the current of the load graph of the outcome attained presents few ripples as well as the continuous flow.

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