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Performance of DVR Under Fauly Condition And Control using ANN based Controller

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***Abstract*—The chief objective this research paper holds are improvement of the quality of power. One of the important characteristics for improving the quality of power is the THD i.e., Total Harmonic Distortion. A THD analysis with various injection transformer ratings of DVR is shown in Fig 16. With the help of the Fast Fourier Transform (FFT) analysis for the voltage signal to analyze the Total harmonic distortion (THD). Before moderation we have 24.12% THD, while after moderation, for PI controller it is 2.77 % THD and 2.15% for ANN controller. We have also learnt about various devices which are used for this purpose and further we investigated about the dynamic voltage restorer it's constructional features. It's working principle and various operating mode by which it improves the power quality in the supply and distribution network. All this work is shown by using MATLAB/ SIMULATION to observe real time operation of the DVR.**

***Keywords*— *Dynamic Voltage Restorer- DVR, Proportional Integral- PI, Total Harmonic Distortion- THD,* Artificial Neural Network- ANN**

I. INTRODUCTION

As a growing and extremely ambitious environment, one of the utmost crucial components to industrial as well as business sectors is Power quality. In the low power distribution system, Voltage sag is a crucial kind of power quality disturbance. Voltage sag is characterized by two crucial features: the duration as well as the magnitude of voltage sag. At power frequency having 0.5 cycles with around to 1-minute durations, a decline of utility supply between 0.1 - 0.9 per unit voltage magnitude in RMS value is defined as voltage sag. The classification of the voltage sag is done on the basis of IEEE standard 1159-1995[1]. DVR is a solid-state device which is put in series connection through the injection transformer between the sensitive load and the supply side. Device injects voltage deviation for regulation of the load voltage into the system at any phase angle as well as magnitude. Different methods are being used for mitigating the voltage sags but currently main method of using the DVR is observed as the custom power device which is most effective as well as cost friendly, helping in the sensitive load's protection as well as safety in distribution systems. [2]. In [3], there are four variations of DVR topologies that are covered along with the scenarios of with as well as without energy storage. The variety of devices for storage of energy executed in the DVR like ultra-capacitor, battery, super magnetic coil and flywheels. The different storage of energy is needed for sourcing power such as reactive as well as active to the DVR. There are various issues as well as solutions found in theory related to using DVR concerning controllers which are non-linear [4-7].

II. MODELING AND SIMULATION

A. *DYNAMIC VOLTAGE RESTORER*

The fig. 1 highlights the power circuit block diagram of the Dynamic Voltage Restorer system. **DVR** which stands for Dynamic Voltage Restorer is a device which is static var device and whose uses can be seen in a couple of distribution as well as transmission systems [1].

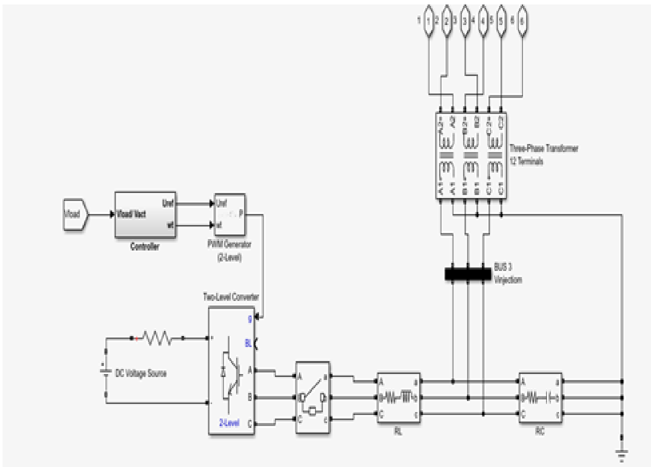

Fig 1: Simulink Model of the Complete System

It is compensation device which is connected in series format and which helps in protecting the sensitive load from problems related to quality of power like swells, voltage sags, distortion and unbalance that use VSC which stands for voltage source converters through power electronic controllers.

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B. *Conventional Configuration and Operations of DVR:*

a. The DVR general configuration comprises of:
   - i. An Injection/ Booster transformer
   - ii. DC charging circuit
   - iii. Storage Devices
   - iv. A Voltage Source Converter (VSC)
   - v. A Harmonic filter
   - vi. A Control and Protection system

b. Operations of DVR

The dynamic voltage restorer usually in standard conditions used to operate in the mode of standby. During noise as well

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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 loadowithin limits.

The amplitude as well as the phase angle of the injectedovoltages 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.

C. TOTAL HARMONIC DISTORTION

The Total Harmonic Distortion is a harmonic distortion's measurement which is there in a signal. THD can be said to be the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency.

The THD of the main system (uncontrolled) has been shown in the figure 2. The THD of 50 Hz frequency is 24.12% which is much higher as is enough to degrade the quality of the system by heating up or by giving higher electromagnetic emissions. Also, higher core loss.

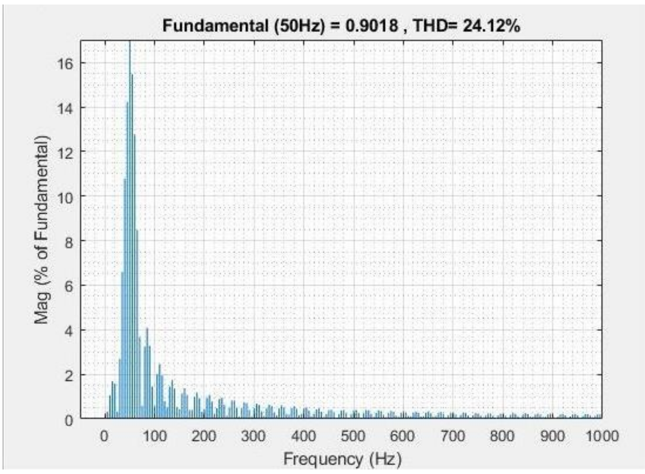

Fig 2. The Total Harmonic Distortion (THD) of the Main System (uncontrolled)

To overcome this issue, we need to keep check of the injected voltage magnitude to reduce the THD. The main problem is to overcome from unwanted voltage and to maintain the voltage magnitude of the constant voltage at load during supply disturbances i.e., to get a controlled voltage from DVR, a controller is need to be designed.

III. CONTROLLERS

A. Proportional-Integral (PI) controller

In the above sections, as we have discussed that the controller's main goal is to maintain the voltage magnitude of the constant voltage during the scenario of supply disturbances at the sensitive load. The mentioned control method is made on the basis of comparison of the load voltage as well as source. Using park transformation, the transformation for three-phase voltage is done into the dq0. The voltage is constant after the conversion with d-voltage is 1 in p.u. as well as q-voltage is 0 in p.u. under considering the scenarios of the normal as well as balanced conditions but it majorly varies which put under the abnormal conditions.

Afterwards, the voltage difference is improved by PI controller by doing comparison of d-voltage as well as q-voltage with the voltage which is desired. After this, it goes through dq0 to abc transformation and is converted into abc component which considered to be a main signal for the generation of the PWM inverter's source of voltage switching pulses. One of the key parts is removed from the controller when voltage drop happens in the system is to inject voltage deviation, detect voltage sag as well as turn off the inverter. Fig..2, highlights the PI controller which is put on the feedback path [8].

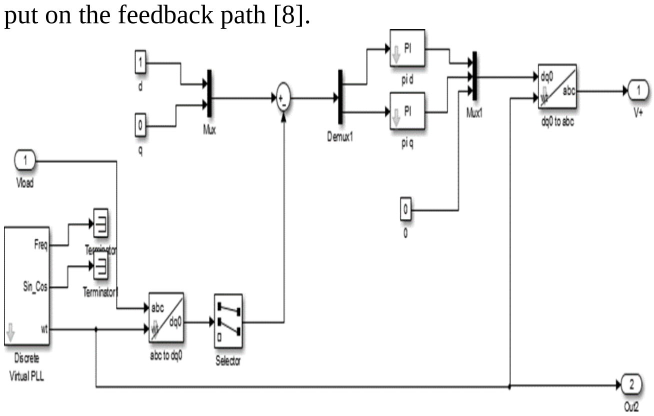

Fig 3: Simulink Model of PI controller with d-q transformation

From the Sensitive load voltage, the input of the controller comes and the VSL is measured at Sensitive Load with the help of measurement of V-I which is three-phase in $p.u.$ Then transformation of VSL is done into the dq term. Detection of the voltage drop is done with the help of measurement of error amid the dq-voltage as well as the reference value. PI controller processes such errors. The d-reference is set to rated voltage as unity in p.u. while q-reference is set to zero.

B. TOTAL HARMONIC DISTORTION

The THD present in system (input 1) is much higher that is 24.12% and needed to be reduced as much as possible because lower THD in the power system implies lower peak currents, lower electromagnetic emissions, less heating and less core loss in the systems.

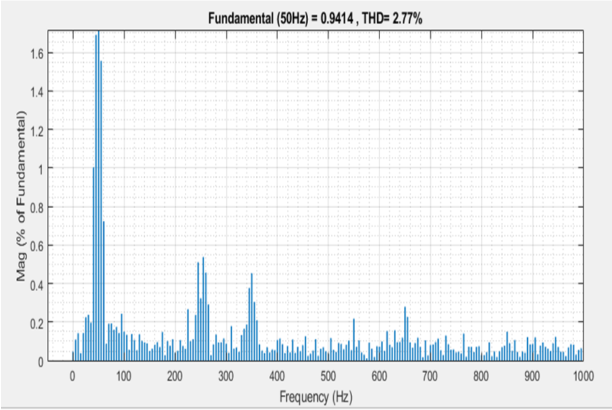

Fig 4. The Total Harmonic Distortion (THD) of the Main System (PI controller based)

As we can see in the figure, the THD has reduced to 2.77%. The use of PI Controller has improved the THD to the great extent but will try to make it more improved by using the Neural Network.

C. NEURAL NETWORK BASED CONTROL

An ANN is found to be based on the grouping of connected nodes or units called artificial neurons, which similar to biological brain, it loosely models neurons. Similar to the synapses which occurs in a biological brain, each connection sends a signal to many other neurons. On receiving the signal by the artificial neuron, it processes as well as signals neurons connected to it. At any connection, the "signal" is a real number, and each neuron's output is determined the sum of its inputs by using by a non-linear function. These connections are named as *edges*. Edges as well as neurons have a *weight* which modify accordingly as the proceeding of the learnings. The signal's strength at the connection increases or decreases according to the weight. Neurons have a threshold like in cases the signal is sent only when the aggregate signal crosses the threshold. Neurons are collected into layers and the function of various layers is to perform various transformations on the inputs. Starting from the input layer (first layer), the signal travels to the output layer (last layer), after multiple times traversing layers.

By processing examples, neural networks are trained or they learn and every one of these contains a known "input" as well as "result" which helps in developing probability-weighted associations among two and these are saved within the net's data structure itself. Neural network training from a mentioned example is done by computing the difference in a target output as well as the processed output of the network (often a prediction). This is the error. According to a learning rule, the network adjusts its weighted associations and uses this error value. Successive adjustments results in producing output of the neural network which is very likewise when compared to target output. After conducting many number of adjustments, based upon certain criteria the termination of the training is declared.

Two input nodes composed the Input layer: DC capacitor voltage as well as the foundation voltage while talking about the twenty nodes comprises the hidden layer - which have the sigmoid function and is activated. One node composed the output layer and it is the finest thinkable gate control signal. The weighted sum of the inputs function along with the bias generates the neuron's output as shown below:

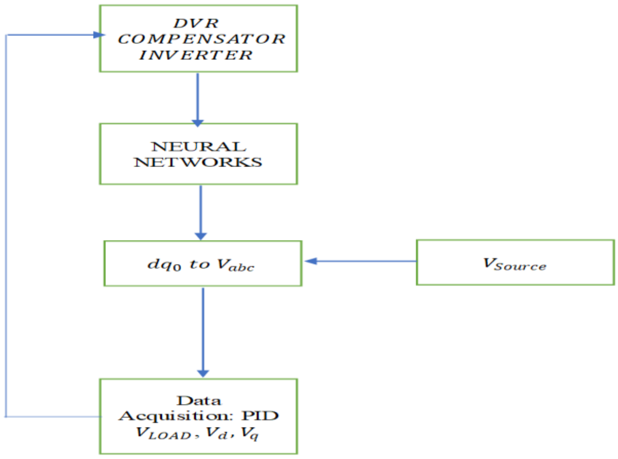

Fig 5: Block Diagram of Artificial Neural Network (ANN) System

$$y = f(w_{ij}x_{ij}) + b_j \quad (1)$$

$$e = \frac{1}{p}\sum_{i=1}^{p} \| y^{(i)} - v^{(i)} \|^2 \quad (2)$$

$$a_j = \tan sig \left(\sum_{k=1}^{n} w_k v_k + bias\right) \quad (3)$$

By using the mean- square error¸ the performance is calculated as given in Fig. 7 and Equation (3) where, p= number of training information; v = required output; y = ANN output vector Well-trained ANN provide as set of contribution parameter's output, the orientation voltage and the desired value is very close and showing the error which is close to zero. A weighted sum is computed for n inputs, V_k, k = 1, 2. . . n, of each neuron, a_j and provides the outcome like the Equation (4) highlighted.

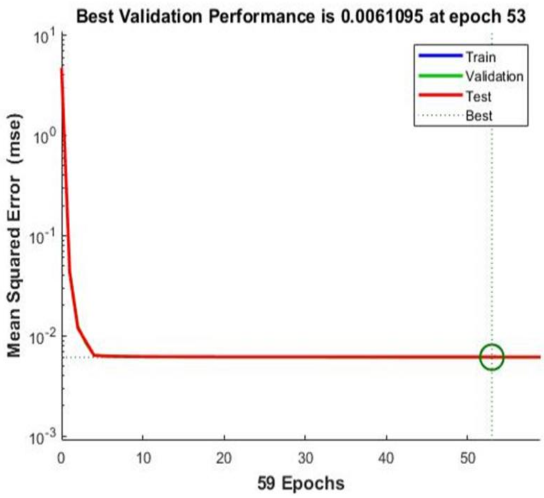

Fig 6: Convergence Curve of Iterations

Fig.5 ANN DVR grouping of inverter control system. For the mentioned case, there are system inputs as well as out voltage having 1200 patterns in the information set, which can be separated into two sub-databases. 70%, of the samples are utilized in training the ANN, while talking about the rest 30%, they are utilized to authenticate as well as test the network.

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The vital weighted sum of tan sigmoid function of which continuously have the connection of bias to it which could be viewed as an added input that provides a result. W_k= synapse weight connected with the n inputs. The goal of manage system is maintaining the scale of voltage at the situation wherever the condition under system disturbances is that the sensitive load is related.

- The load terminals produce harmonics which are in relation to main drive and are similar to sensitive load. At the load terminals, voltage sag is warped via a mistake of 3-phase. The mentioned trouble of voltage is sensed independently as well as passed through succession analyzer.
- The format of general arrangement's control consists of a method for voltage modification that computes the mentioned voltage which can be given in by the DVR.
- The regulator input is an error signal which is received from the injected voltage rate as well as from the reference voltage. The proposed DVR control is focused on ANN regulator highlighted in Fig.8. To produce the necessary injected voltage, the PWM signal generator which maintains the DVR inverter.
- For improvements in performances of the momentary as well as steady state, there is careful documentation done for ANN controller.

D. TOTAL HARMONIC DISTORTION (THD)

The THD present in the system (input 1) is much higher that is 24.12% and needed to be reduced because of which we implemented the PI controller as well as the THD of PI was reduced to 2.77%. To further reduce the THD, we used Neural Network and the results obtained were better than the PI controller. The THD for the system has now been reduced to 2.15% for the same 50 Hz frequency. The figure below showing the same.

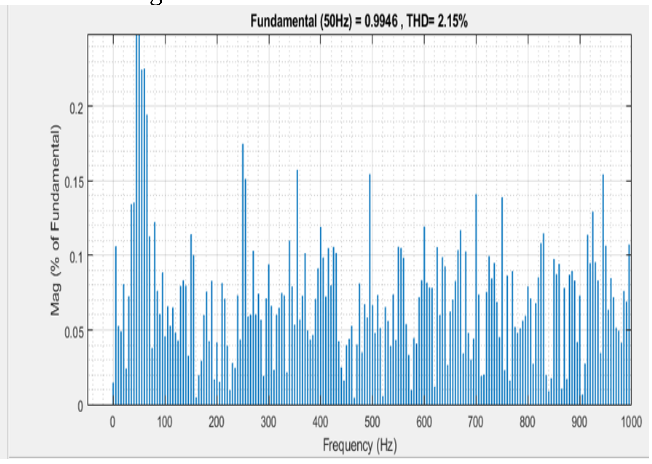

Fig 7: The Total Harmonic Distortion (THD) of the Main System (ANN controller based)

IV. RESULTS AND CONCLUSION

A. In case of first simulation, it was conducted with no DVR as well as a three-phase fault is given to the system.

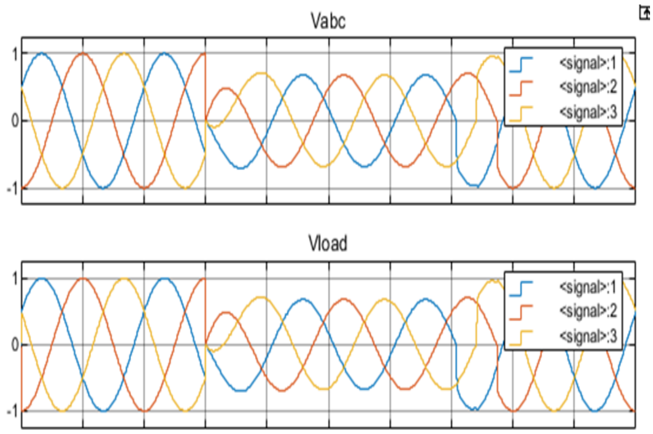

Fig 8. shows the output of the saggy voltage. (a) Source Voltage with fault (b) Output voltage of load side

B. Voltage and current after designing a DVR and adding it to inject the voltage. No controller has been designed till now, output is without controlling the DVR

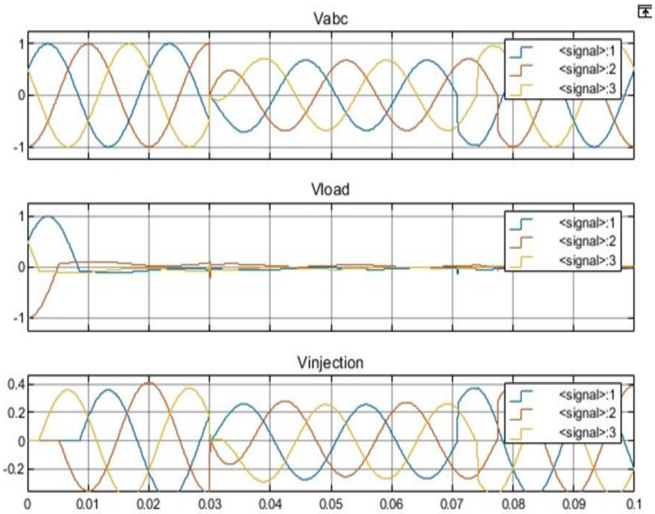

Fig 9. shows the output of the saggy voltage after DVR inject voltage (a) Source Voltage with fault (b) Output voltage of load side (c) Uncontrolled DCR injected Voltage

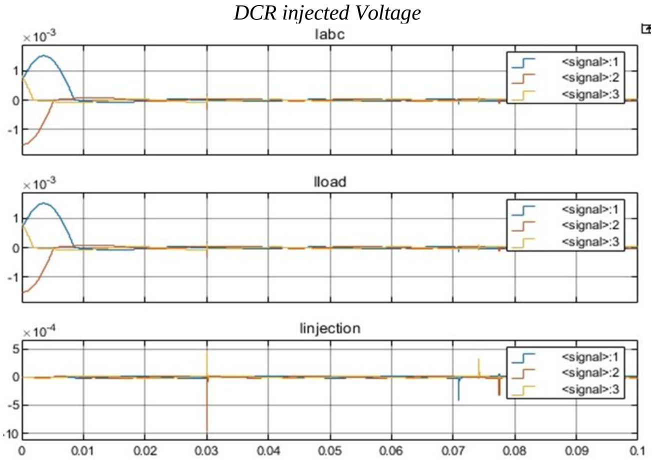

Fig 10. shows the output of the saggy current after DVR inject voltage (a) Source Current with fault (b) Output Current of load side (c) Uncontrolled DCR injected Voltage

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C. Voltage and current after designing a PI Controller based DVR and adding it to inject the voltage

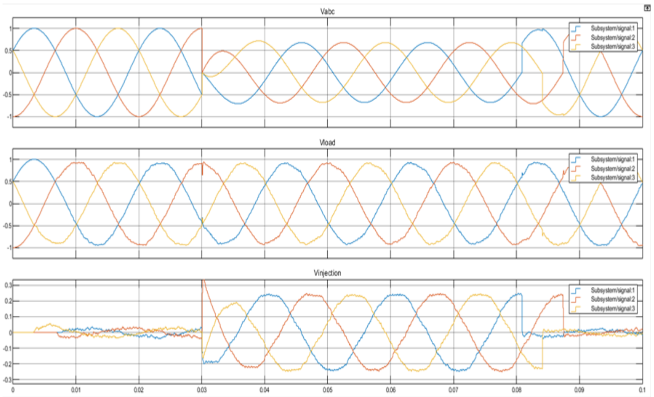

Fig 11. shows the output of the saggy voltage after DVR inject voltage (controlled using PI Controller) (a) Source Voltage with fault (b) Output voltage of load side (c) PI controller based controlled DVR injected Voltage

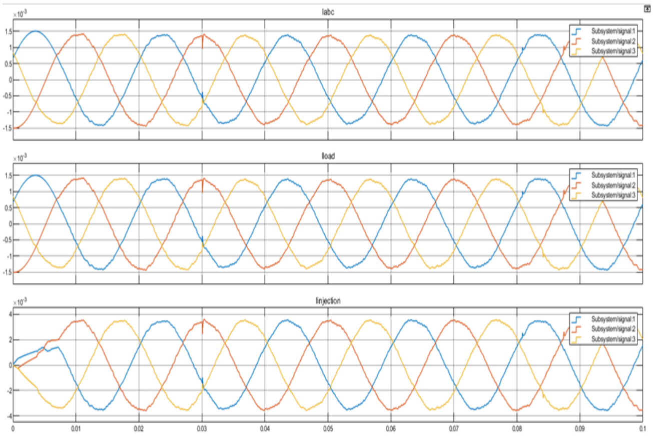

Fig 12 shows the output of the current after DVR inject voltage (controlled using PI Controller) (a) Source Current with fault (b) Output Current of load side (c) PI controller based controlled DVR injected Current

D. Voltage and current after designing a ANN based Controller for controlling the DVR and adding it to inject the voltage

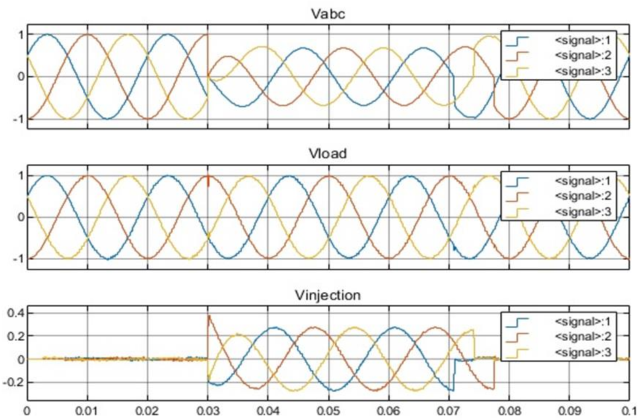

Fig 13. shows the output of the Voltage after DVR inject voltage (controlled using Neural Network Controller) (a) Source Voltage with fault (b) Output Voltage of load side (c) Neural Network controller based controlled DVR injected Voltage

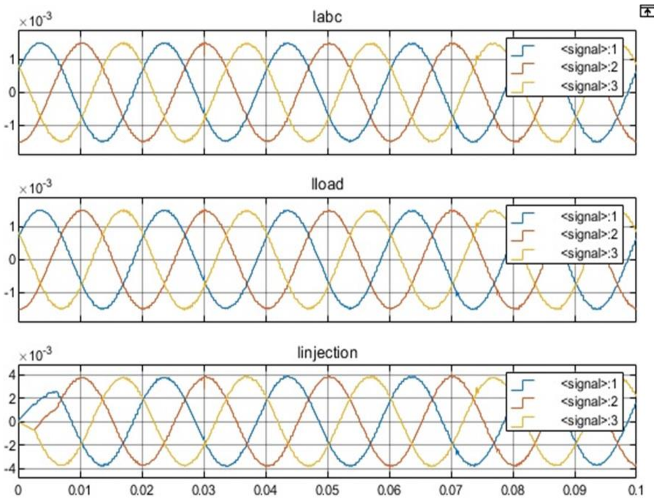

Fig 14. shows the output of the Current after DVR inject voltage (controlled using Neural Network Controller) (a) Source Current with fault (b) Output Current of load side (c) Neural Network controller controlled DCR injected Current

E. CONCLUSION

The chief objective this research paper holds is improvement of the quality of power. One of the important characteristics for improving the quality of power is the THD i.e., Total Harmonic Distortion. A THD analysis with various injection transformer ratings of DVR is shown in Fig 15. With the help of the Fast Fourier Transform (FFT) analysis for the voltage signal to analyze the Total harmonic distortion (THD). Before moderation we have 24.12% THD, while after moderation, for PI controller it is 2.77 % THD and 2.15% for ANN controller.

We have also learnt about various devices which are used for this purpose and further we investigated about the dynamic voltage restorer it's constructional features. It's working principle and various operating mode by which it improves the power quality in the supply and distribution network. All this work is shown by using MATLAB SIMULATION to observe real time operation of the DVR.

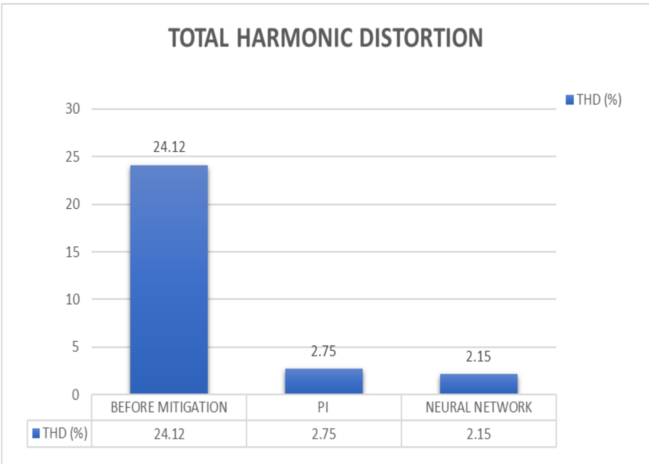

Fig 15. Graphical Presentation of THD values of the system for various controllers

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