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POWER QUALITY IMPROVEMENT BY DYNAMIC VOLTAGE RESTORER USING ANN CONTROLLER AND ISM CONTROLLER

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Abstract— An industrial load is mostly depending on semiconductor devices; control of that loads is important cause industrial loads sensitive against power system disturbance. Hence, in the distribution system, power quality has most important. Voltage and power quality have more problems due to an increase in the use of nonlinear loads such as microcontrollers, power electronic devices, etc. Thus, it needs to identify that problem and the requirement of compensation. Thus, the solution is a dynamic voltage restorer which identifies voltage sag & compensate that sag fast & accurate. In this paper, the simulation of dynamic voltage restorer (DVR) was made by using an artificial neural network. DVR injects the voltage in the system when voltage sag or swell occurred due to fault. The ANN is trained online by data generated by the uncompensated model. These data should be used as a target for ANN. There are many types of training, here we feed-forward backpropagation, Levenberg-Marquardt training algorithm used. ANN is used as a controller for controlling the DVR (Dynamic Voltage Restorer) through an IGBT gate inverter. For mitigating voltage sag & swell inject voltage by DVR with ANN exactly. Also, another method is Integrated Sliding Mode Control using DVR for compensating voltage sag caused due to three-phase faults. The sag or swell detection method is eliminated by using the DVR-SMC model. Hence, this method increases the dynamic response of the DVR & inject the voltage sag with proper amplitude and phase. The comparison between the ANN-based DVR model and ISMC based DVR model has studied about compensation of voltage sag after a fault occurred. From this, obtain best compensation method.

Keywords--- Dynamic Voltage Restorer, Artificial Neural Network, Power quality, ISMC- Integrate sliding mode control.

I. INTRODUCTION

The digitalization increases in the world for the fast operation and saving time for any type of work, use of electricity, and nonlinear loads (e.g. computers, PLCs, X-ray machines, power electronic devices, variable speed drives) require a high-quality power supply for proper operation. Every customer required high quality, uninterruptable, smooth sinusoidal & high frequency of power supply. Practically, a large number of nonlinear loads are connected in this distribution system, which conspicuously effects on the quality of the power supply. Resulting, the high quality of power is decreased for many customers. However, need to compensate for the voltage and improve power quality. Power quality has classified as following based on voltage distortion:

i) short duration variations: voltage sags, swells & interruptions

ii) Long duration variations: sustained interruption, Undervoltage & overvoltage,

iii)Transients,

iv) Harmonics, inter-harmonics, etc.

The voltage sag is the most serious problem of quality of the power. Due to the fault or start of the large induction, motor Voltage sag occurred. A voltage sag is defined as the short drop in the RMS voltage value 10% to 90% of the nominal RMS value and lasting for 0.5 cycles (10msec) up to 1 min. Voltage swell is raised in RMS voltage from110% to 180% of the nominal RMS voltage for a duration of 10msec to 1min. The voltage swells rarely occur as compared to voltage sags. Cause of switching of large capacitors, connecting, or disconnecting heavy loads. The harmonics are caused by current as well as voltage distortion. Mostly due to current distortion. The main reason for harmonic distortion is nonlinear loads connected to the distribution system. For compensate the voltage sags & swells have many methods. Different custom power devices used to mitigate the voltage sags & swells such as Static Var Compensator (SVC), Integrated sliding mode controller (ISMC),

Dynamic Voltage Restorer (DVR), Fuzzy logic, etc. In this paper, we preferred dynamic voltage restorer (DVR) due to its compactness & less maintenance cost with ANN controller as well as sliding mode controller.

Farzamnia et.al. [1], DVR modelling has been carried out using the MATLAB, a Proportional-Integrator (PI) controller with application of Pulse Width Modulation (PWM). In proposed system, ANN controller with DVR and second (SMC) sliding mode control with DVR both simulation carried out. By comparing, both compensations result get best method of compensation. Haque Sunny[2] , Artificial Neural Network (ANN) based controller for enhancing restoration and harmonics suppression capabilities of DVR. Comparison ofthe ANN with the popular PID controller, andnonlinear Fuzzy controller has been carried out, where the ANN controller appeared as the best option to restore system voltage. The % THD of ANN controller is 13.5%. In proposed implementation, developed THD less than 13.5%. Comparison of ANN-DVR compensation with Sliding mode control-DVR compensation, and resulting get best compensation method. Ibrahim [3], the modeling and simulation of DVR controlled by Artificial Neural Network (ANN) controller has been achieved using MATLAB/Simulink. The ANN based DVR effectively mitigates voltage sags, swells associated with the grid side and also reduced the load harmonics to 3.5%. Here, in proposed implementation, ANN-DVR we develop the Total harmonic distortion at load side after fault restoration less than 3.5%. Vanitha et.al. [4] , application of ANN to operate DVR for providing better performance to mitigate the voltage sag, swell THD value of ANN 21.70%. In present paper, development in THD is much less than 21.70%. Also The proposed implementation handles various fault condition like, single line to ground fault and L-L fault without any difficulties and injects the appropriate voltage component to correct any fault situation to maintain the load voltage balanced.
Kumar and Chowdary [5] A DVR with sliding mode control strategy is used to alleviate the voltage sags caused due to faults occurring on the parallel feeders in a Three-phase distribution system. In proposed method, implementation of SMC -DVR is done. Telu et.al[6] A Sliding Mode Controller is designed and developed for a single phase DVR. Usage of Sliding Mode Control to DVR, Pre-sag compensation method referred. In proposed implementation, approximate compensation of voltage sag and swell using in-phase method. Also, THD of load voltage is less. Samani et.al. [7] The sliding mode control of DVR is used. Also, pre-sag voltage compensating, method is used, which is an effective and useful method of voltage improvement. In proposed implementation, in-phase compensation method is used.

This paper includes, an Implementation of ANN-DVR control strategy for compensation of voltage sag and swell. We have designed and train the ANN with help of MATLAB. The potential difference restoration and THD mitigation capability of the ANN controller are developed. Also implementation of ISMC-DVR control strategy is done. Compare the compensation of Voltage and THD of restored load voltage. From comparison, get best method of compensation after disturbance in the system. The DVR and other parts of the distribution system of both models have been designed and simulated by using MATLAB/SIMULINK.

❖ Power Quality Problems

Power quality is obtaining increasing attention by the utilities, as well as by both industrial and commercial electrical consumers. Power quality can be defined as having a bus voltage that closely resembles a sinusoidal waveform of the required magnitude. The users demand higher power quality to use more sensitive loads, to automate processes and improve quality. Some basic criterion's for power quality are constant (rms) value, constant frequency, symmetrical three-phases, pure sinusoidal wave shape and limited THD. These parameter values should be kept between certain limits determined by standards, if the power quality level is considered to be high. The costly effects of power quality problems are most clearly seen in large industrial and commercial facilities when equipment or products suffer damage. For better power quality, minimize the harmonic distortion in system voltage. In proposed work, we try to achieve minimum total harmonic distortion by using different controller such as (ANN) artificial neural network,(SMC) sliding mode control with DVR. So that we get proper magnitude and amplitude of voltage compensation.

II. DVR and Control technique:

2.1 DVR

The DVR is a custom power electronic device that injects the voltage into the system to regulate the load voltage. It is arranged with any controlled switching element such as IGBT, Capacitor bank as a storage device, Filter circuit & injection transformer. This DVR is located in the system between the distribution system & load so that it can reliably compensate as the voltage sag detected. However, the DVR manages the role in harmonic compensation & power factor correction.

Fig.1 shows the DVR series connected topology through Injection transformer. An injection transformer is connected in series with the system through the high voltage side of the injection transformer. The low voltage side of the injection transformer is connected to DVR. The DVR is controlled by the Artificial neural network.

Basic Components:

1. **Energy storage:** The capacitor bank or dc voltage source can be used as energy storage to compensate for the potential difference when the disturbance occurred.
2. **Voltage Source Inverter(VSI):** It converts DC to AC voltage.
3. **Filters:** The low pass filter is used to eliminate the switching harmonics in the injected voltage. Here, an LC filter is used which connects next to the inverter side. A filter prevents the injection transformer from passing switching harmonics through it & compensates the harmonic free voltage.
4. **Injection Transformer:** The voltage supplied by the VSI is step up to the required level so that it can inject properly in the system.

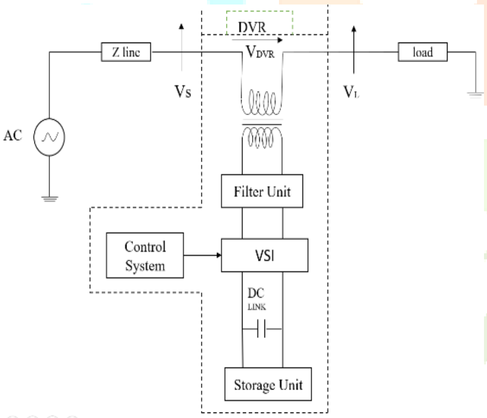

Fig.1: DVR series connected topology[1]

2.2 DVR Control Technique

The DVR is controlled by the controller. ANN is used as a controller. To detect the voltage sag or swell in the power system is the main function of the dynamic voltage restorer and compensate the required voltage to generate the gate pulses by pulse width modulation generator. Then IGBT inverter converts the DC input voltage to sinusoidal AC using an injection transformer & LC filter. In this paper, the in-phase compensation method is used for compensating voltage disturbance which helps to restore the load voltage definite amplitude and phase. The main function of the ANN controller-based DVR is detecting the disturbance in the system & inject the voltage & disconnect the DVR when voltage sag is removed.

2.3 The DVR Operation Modes

Generally, the operation of the DVR can be categorized into three operation mode: protection mode, standby mode (during steady state) and injection mode (during sag).

i) Protection mode

The DVR will be isolated from the system if the system parameters exceed the predetermined limits primarily current on load side. The main reason for isolation is protecting the DVR from the over current in the load side due to short circuit on the load or large inrush currents. The control system detects faults or abnormal conditions and manages bypass (transfer) switches to remove the DVR from system thus, preventing it from damages. If the distribution circuit is weak there is a need to inject small compensation voltage to operate correctly. During short circuit operation, the injected voltages and magnetic fluxes are virtually zero, thereby full load current pass through the primary. So, the short circuit impedance of the injection transformer determines the voltage drop across the DVR.

ii) Injection mode

The primary function of the dynamic voltage restorer is compensating voltage disturbances on distribution system. To achieve compensation, three single phase ac voltages are injected in series with the required magnitude, phase and wave shape. The types of voltage sags, load conditions and power rating of the DVR will determine the possibility of compensating voltage sag.

There are three different methods of DVR voltage injection which are

- Pre-sag compensation method
- In-phase compensation method
- In-phase advanced compensation method

III DVR with different controller

3.1 Artificial Neural Network

The term Artificial neural network is the mathematical model or computational model which are inspired by the human nervous system. It is a network of interconnected neurons that compute values from inputs. In this, neurons have different layers. E.g. Three-layer network: first layers: It has input neurons. That input neuron sends data via synapses to the second layer of neurons, after that data sends towards the 3rd layer through next synapse i.e. output. As more layers in the network, the system becomes more complex but the accuracy is more. The biological structure functionality if we achieve artificially then it is an artificial neural network. Summation collects the input signal & calculate the weighted sum. Activation function defines particular output for a given node-based input provided. There are the different architecture of neural networks. The most popular network is the feedforward network, data flows through the connecting path, from the input layer via hidden layers towards the output layer as shown in fig.2 We can design and train the ANN in MATLAB/ SIMULINK.

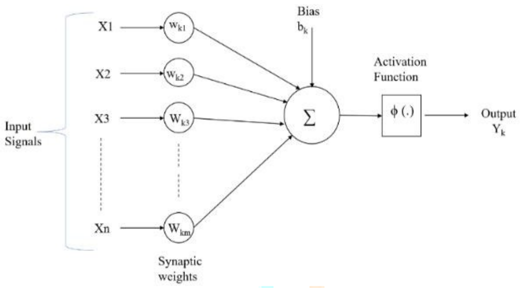

Fig.2 Nonlinear Model of Neuron

3.1.1 DVR with ANN control technique

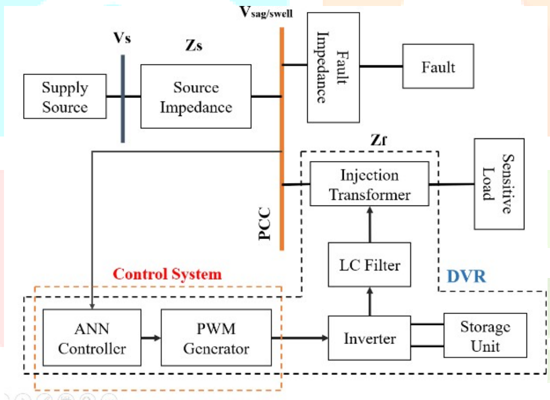

Fig.3 ANN controller with DVR scheme.[2]

Above figure 3 shows the position of the DVR in the distribution system. The control system consists of an ANN controller and PWM generator. Pulse width modulation is a modulation technique that compares the carrier signal to the reference signal, for controlling the amplitude of the to control the devices. Output of the control system is given to the inverter. Inverter convert the DC voltage supplied by the energy storage device to an AC voltage and output gives to LC filter. The LC filter removes higher order harmonics. It gives output to Injection transformer, that injects voltage in phase with line and compensate the voltage sag or swell.

3.1.2 ANN Training

The fault should be generated by using three-phase faults. By using uncompensated model data generates. Training of ANN is done by using an uncompensated model. To generate voltage sag or swell, and the uncompensated model with fault has simulated & data collected which is taken as an input to the ANN. The faultless or normal uncompensated model has simulated & that data utilized as a target to ANN. Many types of ANN training algorithm: Quasi-newton method, Levenberg-Marquardt algorithm. Since, along with these methods, the Levenberg-Marquardt training algorithm is much reliable. The operating process of the LM algorithm has the fastest with high accuracy as compared to another algorithm. For training purpose feed-forward backpropagation network is used, LM training algorithm & MSE performance were observed. The regression plot is shown in fig.5. The mean square error best performance results of training obtained is 1.2134× 10^-13 in Epochs 42. The Layer arrangement inside the mask of the ANN training block shown in fig.4

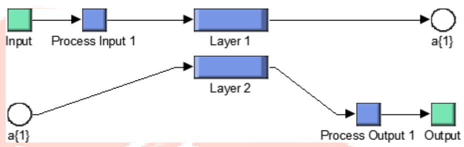

Fig.4 Layer arrangement inside the mask

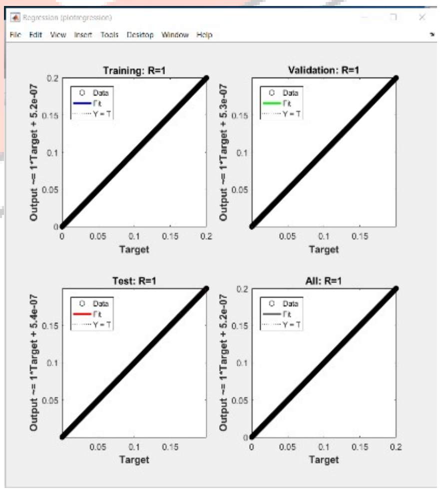

Fig.5 Regression plot of ANN trained model

The ANN controller output gives to PWM generator which function is to modulate the signal. Theoutput of PWM was provided to the IGBT gate of (VSI) inverter. THE trained ANN model has two layers one input and one output. Also include 10 hidden layers in ANN trained model. The hidden layer neurons have symmetric tangent sigmoid transfer function & the second layer has linear Purlin transfer function as the activation function.

The Mean Square Error is displayed as a performance quantifying parameter for the training of the Neural network model. The flow chart for ANN training is shown in fig.6.

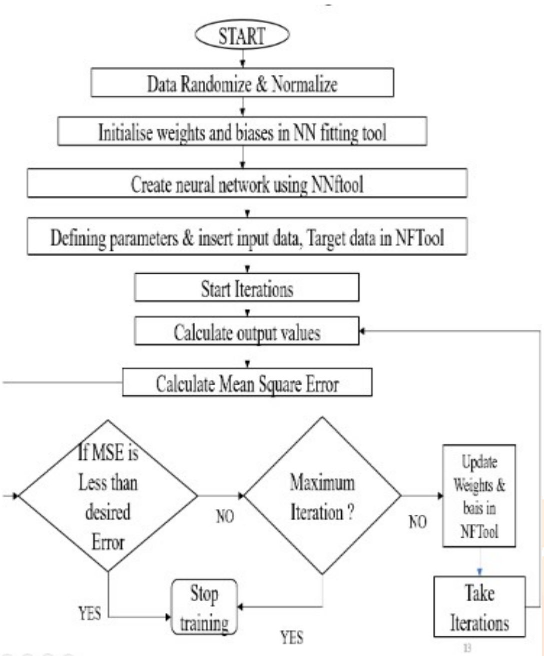

Fig.6 Flow chart of ANN Training

3.2 DVR with Sliding Mode controller

3.2.1 Sliding Mode Controller

The sliding mode control is the second and higher Order system. Sliding mode control is a vigorous control system that has to change the state of the system to get expected results. In this system, the sliding line should be defined so that states of the system easily slide on these lines to stable at one point. In the case of the ideal system i.e.

$$S = CX_1 + CX_2 = 0$$

$$S = CX_1 + C\dot{X}_2 = 0$$

Here, $X_2 \doteq X_1$

the sliding line and its phase velocities are nearly equal to zero. X1(t) and x2(t) satisfies the condition S = 0 at t ≥ t h, but practically it is tough to achieve this cause of the fast switching and inertia of physical systems.

Consider the system,

$$X = -\alpha x + u \qquad (1)$$

Suppose, the time-varying system

$$S = x + \beta x \qquad (2)$$

Since S = 0 is referred to as a sliding surface.

It is a linear differential equation which has solution x = 0.

The motion of the system on the sliding surface should be given as average system dynamics on both sides of the surface.

Let, the function $V = S^2$

By taking the derivative of this we get

$$V = 2SS = 2x + \beta x\ \{x + \beta(-\alpha x + u)\} \qquad (3)$$

u is sufficiently large compare to system states and α is positive, so the control is

$$u = -Ks\, g_n(x + \beta x) \qquad (4)$$

From this, the derivative of V is always negative for positive hysteresis control.

Hence S = 0

$$x = -1\beta x \qquad (5)$$

This equation defines a sliding line. This is the two-stage process. In the first stage, converging the sliding line. The difficult stage is to stay on a sliding line. This gives exponential convergence with time constant β. It requires

$$u = x - \alpha\beta . x\beta \qquad (6)$$

The choice of the smallest α is more difficult for convergence of the first stage.

3.2.2 Sliding Mode Control with DVR

The Block diagram of the Sliding mode controller with DVR is shown in figure 7. It includes a reference voltage calculator, sliding mode controller, inverter, filters, and injecting transformer. The output of the filter is connected to the system through an injection transformer.

The control block diagram of the Sliding mode controller is shown in fig.8. It includes a reference voltage calculator, sliding mode controller, inverter, filters, and injecting transformer. The output of the filter is connected to the system through an injection transformer. The reference voltage injected by the DVR is calculated by the subtracting reference source voltage and actual source voltage. Then, that generated reference voltage is subtracted from the actual injected DVR voltage, an error is processed by the sliding mode controller. The output of the Sliding mode controller is given to the inverter for switching purposes. The advantage of the Sliding mode controller is robust, stable condition for large supply and load variations, good dynamic response, and simple implementation. The control system of sliding mode control using dynamic voltage restorer is shown in fig.9.

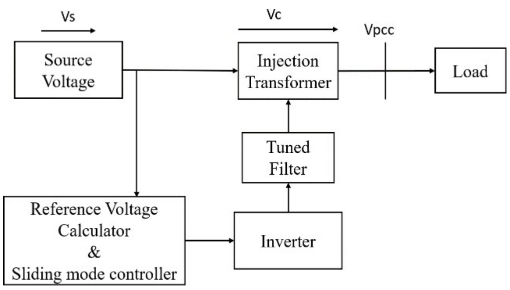

Figure 7: Block diagram of DVR with SMC

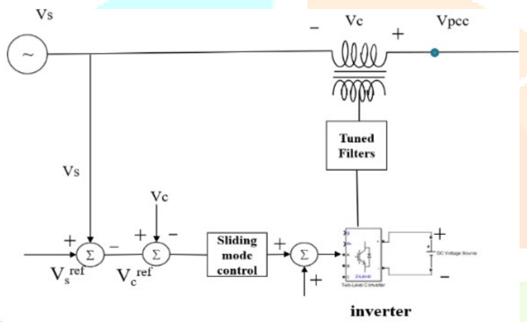

Fig.8 block diagram of SMC with DVR[5]

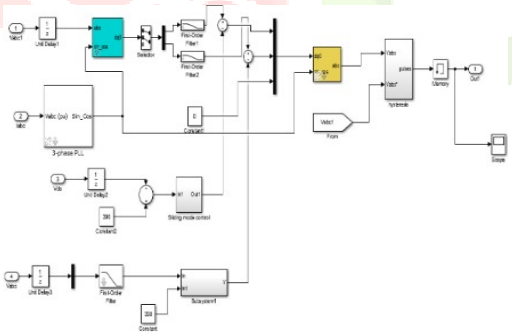

Fig.9 Simulation of a control system of SMC with DVR

IV. MATLAB SIMULATION

4.1 Simulation of DVR with ANN controller

The simulation of ANN using DVR shown in fig.10. The simulation consists of three-phase voltage sources with a nonlinear load connected in the system. Injection transformer, DVR, and ANN controller. The total harmonic distortion developed is 1.26% Shown in fig.11. The simulation result is shown in fig.14. The simulation is conducted with the three-phase programmable voltage source with three-phases to ground fault to introduce sag. Voltage sag is generated between 0.10 to 0.20 sec. shown in fig.14.

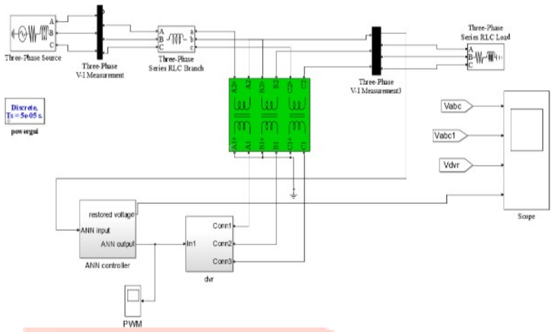

Fig.10 simulation of ANN-based dynamic voltage restorer to enhance power quality.

Here, total harmonic distortion was observed in the above simulation. THD of simulation of ANN-based DVR model is shown in fig.8. When three-phase faults occurred in the system, voltage sag created near about 50% shown in output results. THD after the fault of ANN-based DVR is 47.88%. The THD of the restored load voltage is 1.26% & the fundamental magnitude is 0.9499.

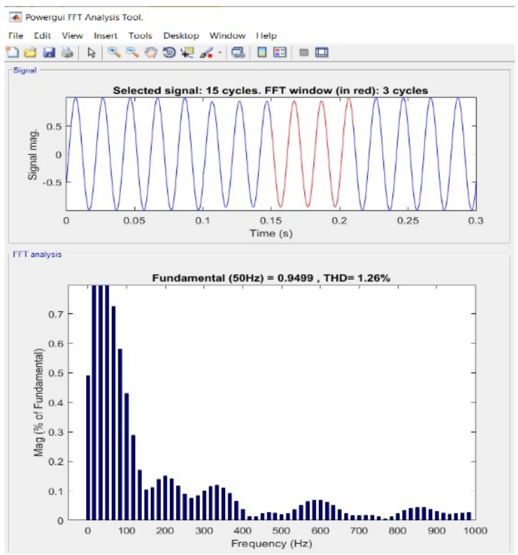

Fig.11 THD developed on the load side.

4.2 Simulation of DVR with ISMC

The simulation of the Integrated Sliding Mode Controller using DVR is shown in fig.12. A three-phase programmable voltage source, RLC series branch, and three-phase RLC load are used. DVR is controlled by an Integral sliding mode controller and inject voltage in line through the injection transformer. The output waveform is shown in the figure 15.

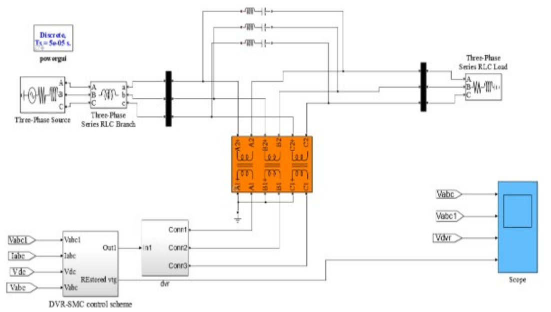

Fig.12 simulation of power quality enhancement using sliding mode control based dynamic voltage restore

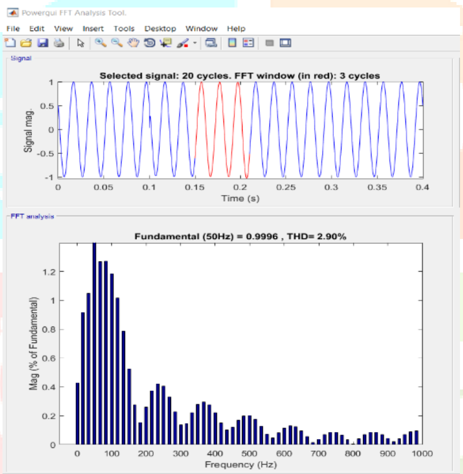

Fig.13 THD of a restored voltage of ISMC based DVR

V. Results & Discussion:

5.1 Results of ANN based DVR

The output results of the artificial neural network-based DVR are as follows: The result of the simulation is shown in fig.14. i) Source voltage at normal condition. ii) waveform is voltage sag after fault, iii) Injected voltage by DVR with ANN & iv) Restoration voltage. From these simulation results, it understands that voltage sag alleviation in line with the system through injection transformer is completed with proper amplitude and phase voltage by using ANN-based DVR.

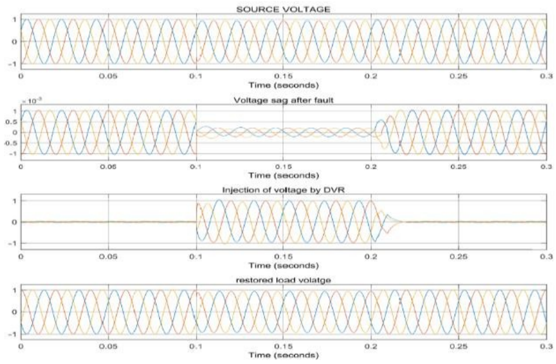

Fig.14 Results of simulation of ANN-based DVR: 1) Source voltage 2) voltage Sag waveform after fault 3) Injected voltage by DVR 4) Restored waveform.

There are many advantages of Artificial based dynamic voltage restorer. Such as, the ANN system is developed by learning or programming. Neural networks teach themselves the patterns in the data freeing the analyst for more interesting work, flexible in a changing environment, Performance of Neural Network is very good & accurate.

5.2 Result of ISMC based DVR

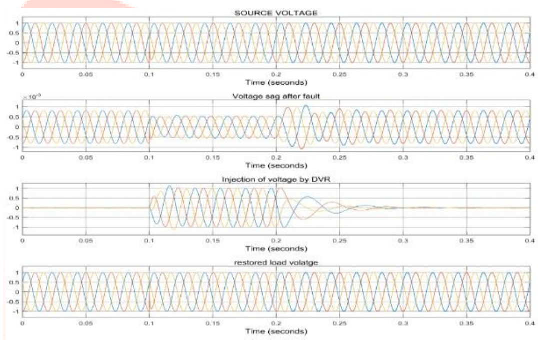

Fig.15 Results of simulation of ISMC based DVR 1) Source voltage 2) Voltage Sag after a fault at source 3) Injected voltage by DVR 4) Restored waveform.

The output results of the artificial neural network-based DVR are as follows: The result of the simulation is shown in fig.15. . i) Source voltage at normal condition. ii) waveform is voltage sag after fault, iii) Injected voltage by DVR with SMC & iv) Restoration voltage. From these simulation results, it understands that voltage sag alleviation in line with the system through injection transformer is completed with proper amplitude and phase voltage by using ANN-based DVR.

5.3 THD comparison:

THD of ANN-based DVR, the THD of the restored load voltage is 1.26 % & fundamental magnitude is 0.9499. THD of fault voltage 47.88%, from this we understand that restoration or injection of voltage by using Artificial Neural Network-based Dynamic Voltage Restorer is near about 99%. In the case of ISMC based DVR, the Total Harmonic Distortion of restored voltage is 2.90% shown in fig.13. Since, by comparing THD of both models i.e. ANN-based DVR and ISMC based DVR, best results getting from ANN-based DVR.

Controller	% THD	Voltage restoration and THD mitigation capability
ANN	1.26 %	Excellent
ISMC	2.90%	Moderate
Fuzzy[1]	24.4%	Acceptable

Table no.1: THD comparison

VI. CONCLUSION

In this paper, Implementation of ANN controller-based DVR have been achieved using MATLAB/ SIMULINK. From obtained results, the ANN-based DVR successfully compensate the voltage sags greater than 50% and reduced the harmonics in the load. The total harmonic distortion of restored voltage is 1.26% which is an acceptable THD limit by IEEE standards. From this, we understand that restoration or injection of voltage by using Artificial Neural Network-based Dynamic Voltage Restorer is excellent. This ANN controller-based DVR can handle the various fault conditions like L-G, L-L Fault, L-L-L-G Fault without any interruption and injects the accurate voltage with proper amplitude and phase to continue supply voltage. By observing simulation results of SMC-based DVR get THD of restored voltage is 2.90%. Both models can alleviate the voltage sag with the exact phase & proper amplitude. Sliding mode control is a robust control method that changes the structure of the controller by changing the state of the system to get the desired results. From table no.1, comparison between THD of the ANN-based DVR AND ISMC based DVR, the alleviation of voltage sag is successful, fast & accurate by using ANN-based DVR.

REFERENCES

1. A. H. Abed, J. Rahebi and A. Farzamnia, ”Improvement for power quality by using dynamic voltage restorer in electrical distribution networks,” 2017 IEEE 2nd International Conference on Automatic Control and Intelligent Systems (I2CACIS), Kota Kinabalu, 2017, pp. 122-127.
2. Md. Samiul Haque Sunny; Eklas Hossain; Mikal Ahmed; Fuad Un-Noor "Artificial Neural Network-Based Dynamic Voltage Restorer for Improvement of Power Quality" 2018 IEEE Energy Conversion Congress and Exposition (ECCE)
3. S. B. Ibrahim* "Voltage quality enhancement in distribution system using artificial neural network (ANN) based dynamic voltage restorer" Nigerian Journal of Technology (NIJOTECH) Vol. 37, No. 1, January 2018, pp. 184 – 190.
4. Mr. O. Karthikeyan, A. Mohamed Ansari, K. Sathish Babu, M. Tamilselvi, R. Vanitha, "Artificial Neural Network based Compensation of Voltage Sag and Swell by using Dynamic Voltage Restorer" 2019, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181.
5. G.V. Nagesh Kumar, D. Deepak Chowdary, "DVR with Sliding Mode Control to alleviate Voltage Sags on a Distribution System for Three-Phase Short Circuit Fault" 2008 IEEE Region 10 Colloquium and the Third International Conference on Industrial and Information Systems, Kharagpur, INDIA December 8 -10, 2008.
6. Rohini Telu, Balamurali Surakasi, Prasad Chongala, Nalini Telu/ "Sliding Mode Controller and Its Application to Dynamic Voltage Restorer (DVR) International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 2, Issue 3, May-Jun 2012, pp.562-567.
7. Hadi Ezoji; Alireza Taheri; Mehdi Saki; A. Sheikholeslami; Arash Ghatreh Samani "Dynamic Voltage Restorer Using Sliding Mode Control to Improve Power Quality in Distribution System" 2012 11th International Conference on Environment and Electrical Engineering10.1109/EEEIC.2012.6221513.