Transient Voltage Stabilization Using Dynamic Voltage Restorer with ANN Controller-Based Reactive Power Compensation

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Abstract—

A customized power device called a Dynamic Voltage Restorer (DVR) is an efficient way to safeguard delicate loads in power distribution networks against voltage fluctuations. The effectiveness of the control method used to switch the inverters is what defines the DVR's effectiveness. The general method for doing such is called Proportional-Integral-Derivative (PID) control. Because this linear approach is used to regulate a non-linear DVR, its ability to restore the power quality is constrained, and it generates a substantial quantity of harmonics. This study suggests an Artificial Neural Network (ANN) based controller as a remedy for improving the restoration and harmonics suppression capacities of DVR. The suggested controller showed improved performance with a mere 13.4% Total Harmonic Distortion (THD) in a comprehensive comparison of neural network controllers with PID-driven controllers and fuzzy logic-driven controllers.

Keywords: Power quality, Dynamic Voltage Restorer, Artificial Neural Network, Total Harmonic Distortion.

I.INTRODUCTION

Each and every breakdown or improper functioning of electrical components is referred to as a power quality problem. The ideal situation for electric utility consumers is to have a constant supply of electricity with a smooth sinusoidal voltage at the agreed-upon intensity level and frequency. In reality, nonlinear loads are common in power systems, particularly distribution systems, which negatively impact the quality of the power supply. These nonlinear loads cause a great deal of the source waveform's quality to be lost. As a result, there are several power quality issues [1]. In order to be considered a voltage swell, the rms voltage must climb from 110% to 180% of the normal rms voltage over a time of between 10 msec (0.5 cycles) and one minute. Due to their rarity in networks, the switching of large capacitors or the beginning and halting of high loads are the major factors of voltage swell [1, 2].

Much research has been done on the use of DVR to enhance the operational stability of a given system. It was suggested [3] to use DVR in a feedback and feed-forward control strategy to reduce voltage sags. The suggested linear controller for the DVR has shown to be reliable and effective despite changes in supply and load. The fluctuation of the DVR, which linear controllers are unable to efficiently and effectively regulate, was not addressed by the investigation, though. Voltage sags and swells may be reduced using a variety of techniques, but the usage of a specialized power unit is seen to be the most effective one to reduce voltage quality problems, a variety of Bespoke Power devices might be employed.

Simulink in MATLAB was suggested for the modelling and simulation of DVR [4]. The DVR quickly mitigates voltage sags and swells, according to simulated data using an abc to dq0 oriented control approach. The researchers did not, though, solve the phase balance problem. [5] Suggested utilizing PI and a fuzzy logic controller in a DVR to reduce voltage sags. The findings demonstrated that the DVR was able to achieve good voltage control under various fault scenarios. The investigation, though, did not take into account the harmonics that the device's nonlinear load produces. A closed-loop regulator was added to the DVR system as part of a Phase Advance Compensation (PAC) technique. The effort, though, neglected to take into account what would happen to the DC connection once the capacitor within had been depleted [6]. In order to compensate for voltage sags and swells, a control system based on the dq0 approach was created. The simulation revealed that the DVR performs satisfactorily in promptly reducing voltage sags and swells and offering great voltage stability [7].

Modern power systems use complex and modern technology, which causes a number of issues with voltage imbalance, and flickering [8-10]. The most significant power quality problems are regarded to be voltage sags brought on by transmission and distribution system defects, transformer energizing and starting of big induction motors [11–14]. In the old days, DVR have been used to address these problems using a variety of strategies, as well as the Static VAR Compensator (SVC) [11], and various optimal inverter designs were discussed in [15-17]. By letting the DVR operate as a virtual impedance, the P+Resonant control technique restricted fault current [12]. To combat voltage peaks and valleys, authors employed a Proportional-Integral (PI) technique in [18], whereas in [19] used the dq0 idea has been used. For standalone systems, a DC-DC converter is used [20]. In order to boost the capacity for correction during sags, the converter was employed [21]. In [14], sliding mode control was used to reduce sags in parallel feeders for three-phase transmission. In contrast to the previously stated studies, the high-performance DVR designed and implemented in this research uses an ANN control in a power system network.

A network of distinct nodes that function as neurons and are arranged in multiple layers, or ANN, roughly mimics the structure of animal brains. Upon receiving information, each node passes it on to the following node after performing the relevant steps. All the layers work together to process any input and provide an output. All of the nodes must be educated with pertinent data before any given job can be carried out by an ANN. In this instance, the defect data and accompanying mitigation measures are used to train the ANN. A feed-forward ANN is trained for this purpose using backpropagation and Levenberg Marquardt optimization. This ANN approach's dynamic character, which results from its capacity to be educated for all potential failure instances, ensures its robustness. The findings demonstrate that, in contrast to fuzzy logic and PID control methods, which produced Total Harmonic Distortions of 24.4% and 19.7%, accordingly, the suggested DVR operates flawlessly against voltage sags and swells with just 13.4% THD. Figure 1 shows the block diagram of the proposed system.

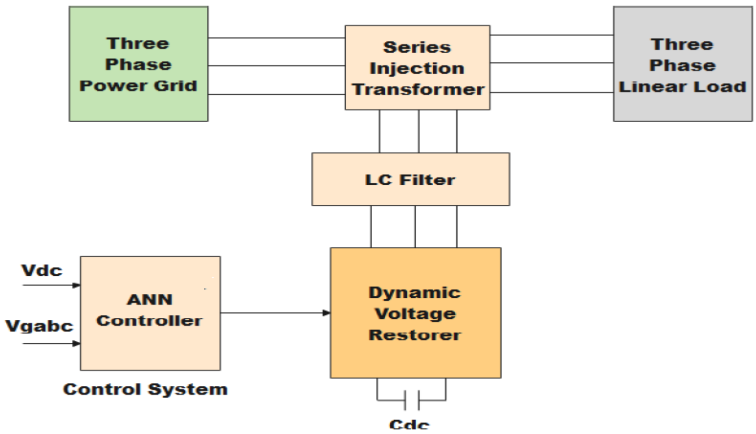

Fig. 1: Block diagram of the proposed system

2. DVR operation principle

The potential divider technique is frequently used to determine the voltage unbalance amplitude at the Point of Common Coupling (PCC) in transmission networks which is the design that is more prevalent in the commercial utility grid. This model's representation of the power quality concerns is seen in Figure 2, in which the voltage rating at the PCC is supplied by:

$$V_{sag/swell} = Z_f/(Z_s + Z_f)$$

DVRs are complex fixed mechanisms that recover the magnitude of behaviour throughout voltage instability by supplying the necessary voltage. In essence, this implies that the system is powered up by the component in order to restore the energy to the needed level for the load. A transformer linked in conjunction with the load and a controlling mechanism works together to pump electricity into the mechanism. One sort of DVR has energy storage, whereas the other does not. Without energy storage, devices revert to their original voltage waveform by using the reported that in order from the source.

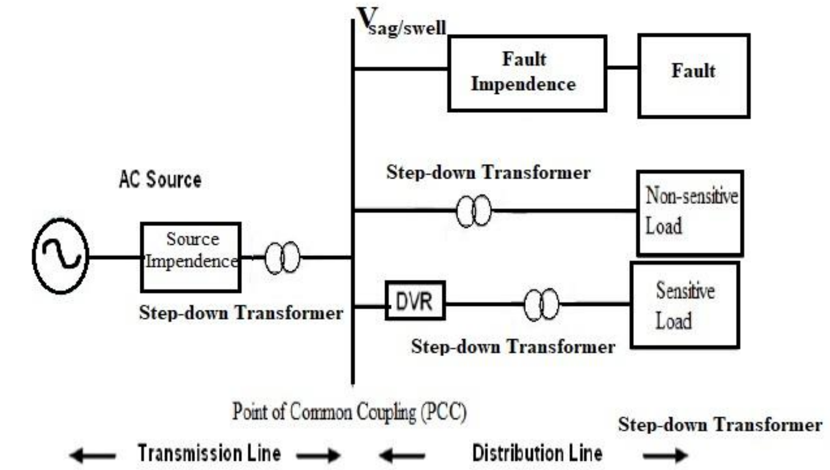

Fig. 2: Block diagram of power system representing the allocation DVR during Fault

The alternative form compensates for voltage sag via energy storage. A DVR with collection differs from an Uninterruptible Power Supply (UPS) in that it only delivers the portion of the pattern whose magnitude has indeed been lowered owing to the voltage dips. DVR technologies are incredibly effective and quick to react. Neither of the storage-related problems at hand applies to platforms lacking storage.

3. ANN Training

ANN model or computer model borrows features from biological neural network's structure and functionality [22]. These systems, which rely on a vast number of often unknowable inputs, can be applied to evaluate or approximate functions [23]. The gradient output will be calculated using a hypothesis. The overall summary applies to the calculated output of the system [24]. The controller's main concerns are given the great reaction to the intended DVR correction and a rapid, extremely accurate detection of the disruptive signal. The conventional controller cannot function properly when there are parameter changes, load disturbances, non-linearity, etc. According to a recent study, an ANN-based system keeps the DVR stable across a variety of operating settings while offering quick dynamic reactions. The LM training algorithm, however, was shown to be considered the most effective of all the training methods. Comparing the LM method to the other training algorithms, it was clear that it had the highest accuracy and was the fastest to converge. As a result, the training time for ANNs is dependent on the method employed. The training employed the Lavenberg-Marquardt training method, feed forward back propagation, net fitting, and mean square error performance. The training session lasted 22 minutes and included 310 iterations.

The training had its highest outcomes between Epochs 75 and 310. The network's outputs and the targets are correlated in a regression plot, which has a regression coefficient of 0.99. Neurons, which are nonlinear components of the ANN and are coupled, are present. It often depicts a collection of linked, extremely basic nonlinear units with learning and adaptive capabilities. The primary attributes of neural networks are their architecture, how they interact with their surroundings, how they are trained, and how well they can handle information. The output neurons have a linear activation function, whereas the buried layer neurons have a tangent sigmoid function. The traditional PI-based DVR's input and output data are gathered and saved in a MATLAB workspace. The ANN is trained using these data. Offline neural network training is carried out using a training data set that has already been created. This was done to introduce a disturbance into the source side and show how the DVR performed in this non-linear environment.

To optimize the DVR's functional properties, a multi-layer neural network-based management system is created. The data acquired from the PI controller is kept in the MATLAB workspace and utilized for offline neural network controller training. In this case, the output layer's activation function is simply linear, whereas TrainLM is employed for the source layer and hidden layers. In this work, the Levenberg Marquardt Back Propagation (LMBP) training method is employed. Effectiveness in terms of pay is determined by input and progress. A reference signal for the PI controller and two components for measuring were chosen. To receive a reference signal, neural networks are trained (PI controller output). The signal is transmitted to a hysteresis control where it is used to generate the required gating pattern. The traditional PI-based DVR's input and output data are gathered and saved in a MATLAB workspace. The ANN is trained using these data. Offline neural network training is carried out using a training data set that has already been created. The neural network model's back-propagation training uses the mean squared error as an effective measuring variable. To exhibit the performance of the DVR under Sensitive linear conditions as shown in Figure 3 which is a simulation schematic of the DVR employing an ANN controller.

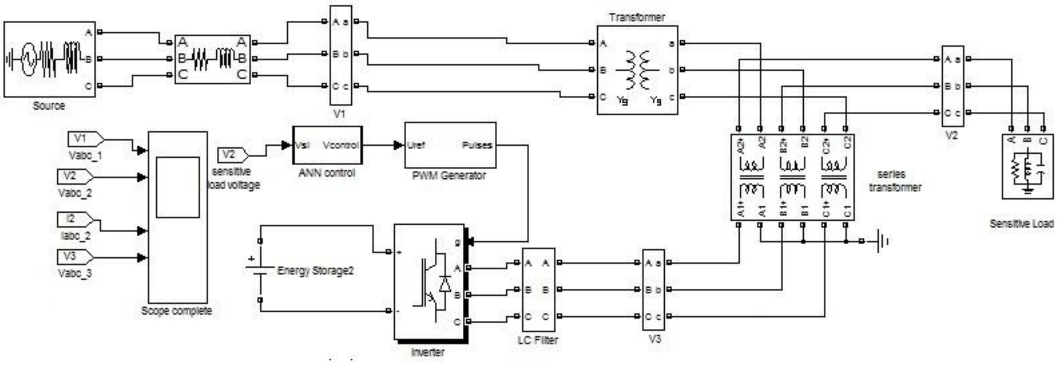

Fig. 3: ANN controller-based simulation model for sag alleviation.

4. RESULTS AND DISCUSSIONS

The MATLAB/Simulink simulation results are used to validate the work. To safeguard a sensitive load under voltage disturbance circumstances, DVR with ANN control is used. As shown in Figures. 4 and 5, two separate instances are taken into consideration for the validation in this study. The power origin is integrated with such a phase-to-phase fault to produce sag (50% of the normal voltage level) and a phase-to-ground fault to add a rise (25% over the rated voltage) in the scenario. Around 0.2 and 0.4 seconds and 0.5 and 0.7 seconds, accordingly, voltage swell and sag are produced.

4.1 Case I: Simulation not including a DVR attached to the distribution network

Whereas Figure 5 represents the voltage created across the sensitive load without the addition of DVR, figure 4 illustrates the rise and fall of the voltage formed on the power supply. From Figure 5, it is obvious that the instability seen on the source side (figure 4) of the system is passed to the load, and this might result in failure or malfunction of the load, particularly if it is of the sensitive kind. According to Fast Fourier Transform (FFT) research, the nonlinear load caused a total voltage harmonic distortion (THDv) of 11.09% if a Model DVR was not attached.

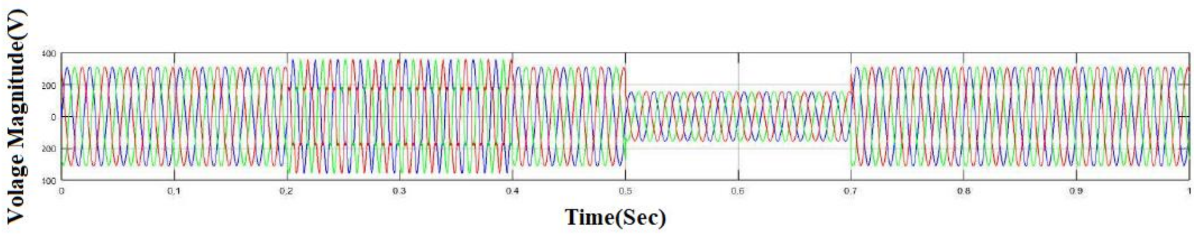

Fig. 4: Voltage Waveform Displaying Supply Side Produced Sag and Swell

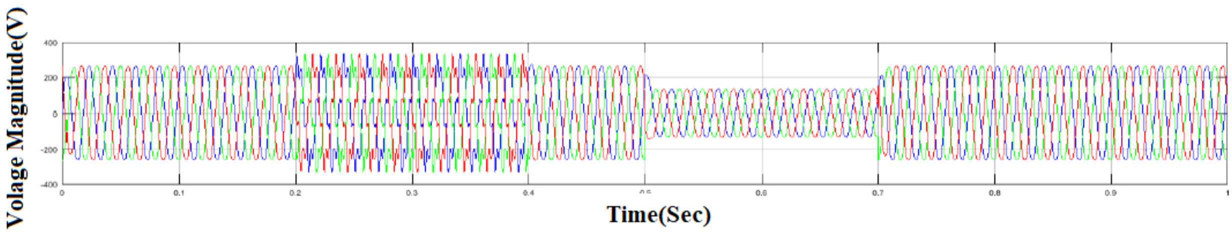

Fig. 5: without Including DVR, the Voltage Waveform over the Load

4.2 Case II: Simulation with Sensitive Load connected through ANN-Based DVR

Both dip and surge produced on the generator side are shown in Figure 6, and the new range from across delicate load with the addition of DVR is shown in Figure 7. According to Figure 7, when a load is added through a DVR, the load voltage is stabilized to its present value by the DVR's operation in both amplitude and phase. The outcome shows the DVR's capacity to take in reactive power during swell and inject active power to lessen the sag. The THDv linked with the demand linked through the DVR is detected to have decreased to 3.92% when ANN is employed to manage the DVR, which falls within the permitted limit as illustrated in Figure 8.

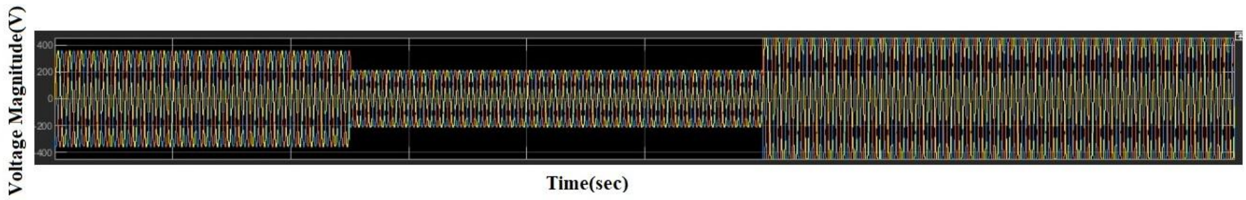

Fig. 6: Voltage Waveform Displaying Supply Side Produced Sag and Swell

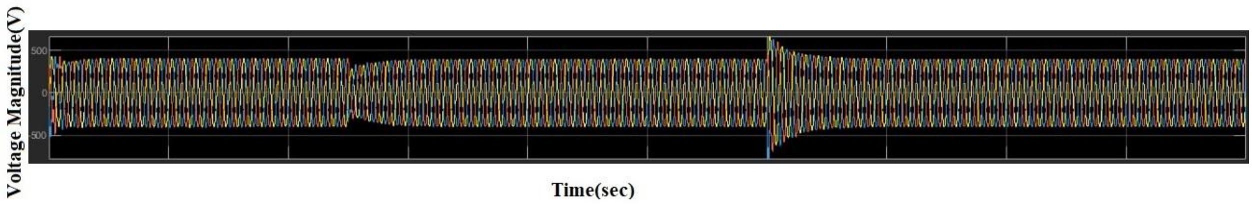

Fig. 7: With the integration of DVR the voltage generated across the sensitive load

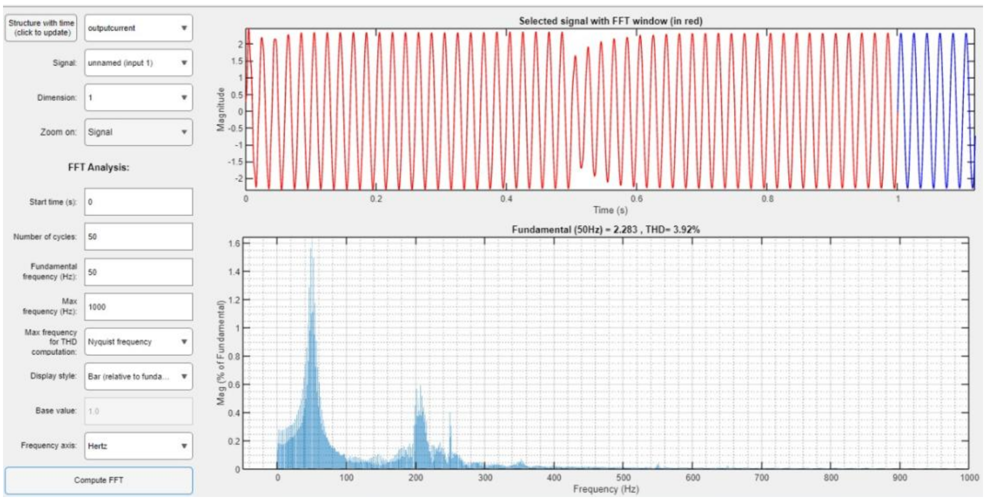

Fig. 8: THDv got generated using a sensitive load and a DVR Setup.

5. Conclusion

DVRs are a common option for improving the quality of electricity in power systems and a variety of control systems are available to operate these devices. The implementation of ANN to control DVR has been shown in this research to provide higher efficiency than conventional systems to minimize voltage sag, swell, and harmonics. The challenge description, conceptual context, technique design, and ANN training process have all been well explained. The effectiveness of the DVR under voltage sag is shown by simulation results that have been given. An evaluation of the suggested approach with the well-known PID controller and the nonlinear fuzzy controller has been made, and the suggested ANN controller emerged as the right option for restoring system voltage while substantially reducing THD.

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