Power Quality Enhancement Using Artificial Neural Networking (ANN) Based Dynamic Voltage Restorer (DVR)

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Abstract*—The power quality, which can affect consumers and their utility, is a key concern of modern power system. The sensitive equipment is damaged by voltage harmonics, sag and swell. Therefore, as usage of sensitive equipment has been increasing, power quality is essential for reliable and secure operation of the power system in modern times. The potential distribution flexible AC transmission system (D-FACTS) device, a dynamic voltage restorer (DVR), is widely used to address problems with non- standard voltage in the distribution system. It induces voltages to preserve the voltage profile and ensures continuous load voltage. The voltage sag and swell is compensated by DVR with an artificial neural network (ANN) controller. For the generation of reference voltage for voltage source converter (VSC) switching, and for the voltage conversion from rotating vectors to stationary frame, synchronous reference frame (SRF) theory is applied. The DVR Control Strategy and its performance is simulated using MATLAB software. It is also shown a detailed comparison of the ANN controller with the conventional Proportional Integral controller (PI), which showed ANN controller's superior performance with less Total Harmonic Distortion (THD. Dynamic Voltage Restorer (DVR) is a custom power device used as an effective solution in protecting sensitive loads from voltage disturbances in power distribution systems. The efficiency of the control technique, that conducts the switching of the inverters, determines the DVR efficiency. Proportional-Integral-Derivative (PID) control is the general technique to do that. The power quality restoration capabilities of this controller are limited, and it produces significant amount of harmonics – all of which stems from this linear technique's application for controlling non-linear DVR. As a solution, An Artificial Neural Network (ANN) based controller for enhancing restoration and harmonics suppression capabilities of DVR. A detailed comparison of Neural Network controller with PID driven controller and Fuzzy logic driven controller is also illustrated, where the proposed controller demonstrated superior performance with a % Total Harmonic Distortion.

Index Terms*—Power Quality (PQ) Issues. Dynamic Voltage Restorer (DVR), Artificial Neural Network (ANN), Pulse Width Modulation (PWM), Total Harmonic Distortion (THD).

I. INTRODUCTION

Modern power systems face increasing challenges in maintaining high-quality electrical power due to the growing integration of nonlinear loads, renewable energy sources, and industrial automation. Power quality (PQ) issues such as voltage sags, swells, harmonics, flickers, and transients can severely impact sensitive equipment, leading to malfunctions, production losses, and financial damages. Ensuring stable and clean power is crucial for industries, hospitals, data centers, and smart grids. The Dynamic Voltage Restorer (DVR) is one of the most effective custom power devices (CPDs) used to mitigate voltage-related disturbances. It operates by injecting compensating voltage in series with the supply to restore the load voltage to its nominal value. Traditional DVRs use PI/PID controllers, but they have limitations in handling fast-changing, nonlinear disturbances. o enhance the dynamic response and accuracy of DVRs, Artificial Neural Networks (ANN) are employed. ANNs offer: Adaptive learning for varying power system conditions. Faster detection and compensation of voltage sags/swells compared to conventional methods. Robustness against noise and parameter variations. Superior harmonic suppression when integrated with advanced control techniques

II. OBJECTIVE

Develop Power quality enhancement using Artificial Neural Network (ANN) based Dynamic Voltage Restorer (DVR). The sensitive equipment has been increasing, power quality. The system will:

1. Application of ANN to operate DVR for providing better performance than existing Systems to mitigate voltage sag, swell, and harmonics.

2. Increasing power quality of the system.
3. Improve the power factor.
4. Improve the efficiency of power system.
5. Improvement of power quality by using ANN and DVR.

III. METHODOLOGY

System Modeling & Simulation

A. Power System & DVR Modeling (MATLAB/Simulink)
   a) Design a test power network with: Source impedance + Nonlinear loads (rectifiers, motors).
   b) Disturbance injection (simulated sag/swell, harmonics).

B. Develop DVR model with:
   a) Voltage Source Inverter (VSI) (H-bridge/multilevel).
   b) Energy storage battery/super capacitor
   c) Passive filter for harmonic suppression.

C. ANN Controller Design
- Data Generation: Simulate voltage disturbances to create a training dataset (input: distorted voltage, output: reference compensation signal).
- ANN Selection: Feed forward Neural Network (FFNN) for fast response.
- Back propagation (BP) training for adaptive learning.

D. Training & Validation:
- Use Levenberg-Marquardt or Bayesian Regularization algorithms.
- Validate with unseen fault scenarios.

E. Control Strategy Implementation

A. ANN-Based Control Loop

Step 1: Sense grid voltage (dq0 transformation for sag/swell detection).

Step 2: Feed voltage error to ANN controller (replaces traditional PI).

Step 3: Generate PWM signals for VSI using ANN-predicted compensation voltage.

F. Performance Evaluation Metrics:
1. Voltage restoration time (target: <1 cycle).
2. THD analysis (post-compensation).
3. Energy efficiency (DVR power loss).

IV. SIGNIFICANCE

1. Enhanced Power Quality: The project aims to significantly improve the power quality in systems prone to voltage sags, leading to better performance of sensitive electronic and industrial equipment.
2. Economic Benefits: By minimizing downtime and preventing equipment damage, the solution reduces operational costs and avoids the high cost of repairs and replacements.
3. Technological Advancement: The integration of ANN with DVR represents an advanced application of artificial intelligence in power systems, showing how machine learning and control systems can be used to address real-world problems.
4. Widespread Application: The solution can be widely applied across industries such as manufacturing, data centers, telecommunications, healthcare, and more, where power quality is critical for continuous operation.
5. Sustainability and Efficiency: By improving the reliability and efficiency of power systems, the project contributes to more sustainable energy usage, with less waste and better resource management.

V. WORKING

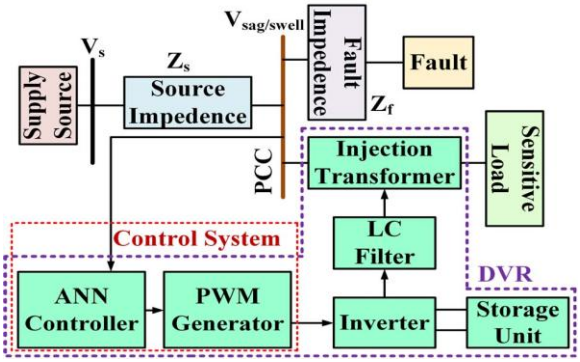


Fig.01 Block Diagram Project

Power Supply & Grid Side:
- Vs: Supply voltage with source impedance (Zs).
- Fault (Zf): Causes voltage sag/swell (Vsag/swell).

DVR System:
- Injection Transformer: Injects compensating voltage.
- Inverter (VSI): Generates corrective voltage using PWM signals.
- LC Filter: Reduces harmonics from inverter output.
- Storage Unit: Provides DC power for

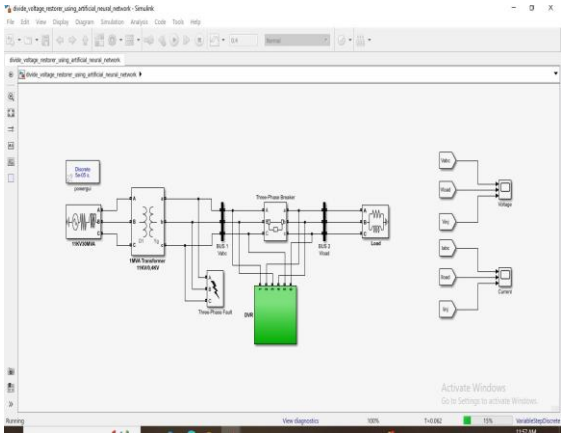
compensation.

ANN-Based Control:

- ANN Controller: Replaces traditional PI; processes voltage error and generates optimal compensation signals.
- PWM Generator: Converts ANN output to switching signals for the inverter.

Load Side:

- Sensitive Load: Protected from disturbances by DVR.



Three-Phase Source/Grid: Supplies power to the system.

Transformer: Steps down voltage (e.g., 11kV/415V).

DVR Block: Compensates for voltage disturbances.

ANN Controller: Replaces conventional control (PI/Fuzzy) for dynamic response.

Switch: Simulates faults or load changes.

Simulation Status:

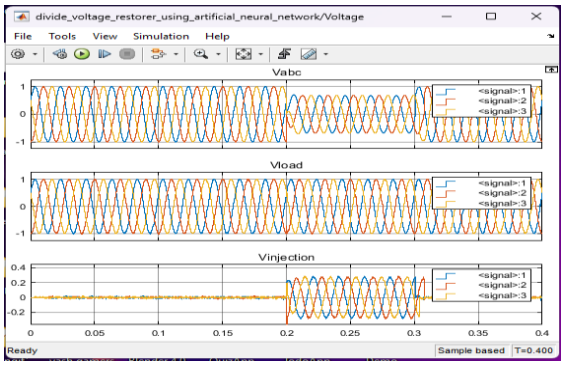
Running at T=0.062 (simulation time).

Solver: Variable Step Discrete (for power electronics simulation).

UI Elements:

Power pad: Possibly a custom library for power systems.

View/Info Tabs: Monitor voltage waveforms or system diagnostics.



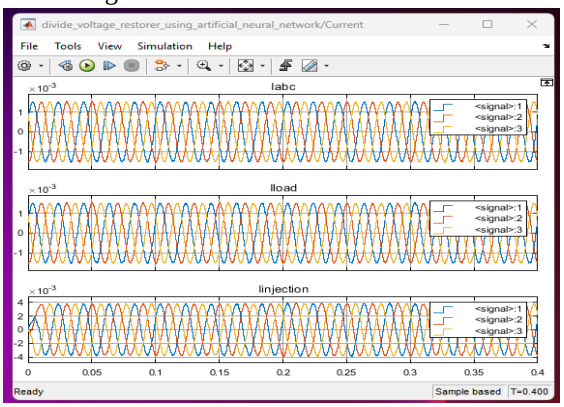
The image appears to show simulation results from a MATLAB/Simulink model of an ANN-based Dynamic Voltage Restorer (DVR) system.

Voltage Plots (Likely time-domain waveforms):

- Vabc: Probably shows the 3-phase source voltage (peaks at ±1 pu, indicating nominal voltage).
- Vload: Displays the load voltage after DVR compensation (stable at ±1 pu despite disturbances).
- Vinjection: Represents the compensating voltage injected by the DVR (peaks at ±0.4 pu to correct sags/swells).

Observation:

- The DVR successfully compensates for the voltage sag by injecting an appropriate voltage. The system stabilizes quickly after the voltage disturbance.



Current Measurements (Scale: 10^{-3} or mA range):

- Iabc: Source current (likely 3-phase grid current).
- Iload: Load current (protected by DVR).
- Iinjection: DVR's compensating current (injected to correct voltage disturbances)

VI. CONCLUSION

By integrating ANN with DVR, this project seeks to provide a more intelligent, adaptive, and efficient solution for power quality improvement, ensuring reliable and stable power in modern electrical networks.

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