Advances in Consumer Research
ISSN (Print): 0098-9258
ISSN(Online): 3079-1766

Vol. 2, Issue 1 (2025) https://acr-journal.com/

Evaluation of a 3-Phase PV and Artificial Neural Network Integrated UPQC for Load Unbalancing Conditions

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Cite this paper as: CH. Rajendra Kumar, M. Hari Priya, Dr. K Kiran Kumar, (2025) Evaluation of a 3-Phase PV and Artificial Neural Network Integrated UPQC for Load Unbalancing Conditions. *Advances in Consumer Research*, 2 (1), 423-433

KEYWORDS

Load imbalance, UPQC, custom power devices, DVR, DSTATCOM, Power quality (PQ), ANN

Received: 26/12/2024
Revised: 30/12/2024
Accepted: 07/01/2025
Published: 24/01/2025

ABSTRACT

Power Quality (PQ) issues are now a crucial topic of conversation and investigation for customers and suppliers are aware of the consequences of these issues. According to the responsibilities, the customized power appliances are used to reduce many of the PQ difficulties. In order to deliver doubled support to meet the challenges of clean energy generation and to improve the power grid PQ in the instance of distributed generation, the proposed study investigation concepts a UPQC along with an ANN control system which combines a solar array. It also uses a custom power device, such as a concurrently connected shunt and series converter, to shield delicate loads from penalties or disruptions on the grid and at the source. A load unbalancing condition, which can result from the abrupt switching of a huge load, is evaluated and examined for in the system. In MATLAB, the system activity can be assessed in situations containing load imbalance.

1. INTRODUCTION

Electric current and voltage harmonics, voltage drops or swells, voltage disruptions, interruptions are significant PQ difficulties in electrical engineering. Research to increase the ability of reduction in enhancement techniques for PQ shortcomings is growing significant in order in preserving the continuity of electrical supply, the regular use of solid-state conversion devices, particularly must be eliminated owing to various grant programs, energy preservation initiatives, and other manufacturing supports, is causing PQ-related problems to become more prevalent. [1] Although passive compensators, which use lossless reactive basic components like C and L using and not using swapping gadgets, are become used to improve the system PQ since the AC supply system inception, they have shortcomings such as higher energy loss, sluggish cyclic reaction, impact, and excessive noise. [2, 3] Custom power device (CPDs), such as DVRs (dynamic voltage restorers) and DSTATCOMs (adoption static compensators), are used to ameliorate some of the PQ problems based on the specifications.

The focused and feasible efforts were incorporated of CPD used related resilient energy resource generation mechanisms to prior it benefits on beneficial scenarios as each an endless source on energy and a surge adjuster in order to provide the end users with contamination-free and great capacity [4]. The architecture under consideration is UPQC, which allows it to integrate with the PV construction into three issues: the DC voltage systems management Link (VDC), control strategies, and maximum power point tracking (MPPT) in the PV context. When solar photovoltaic (SPV) cells and UPQC are combined, the result is improved PQ along with green energy output. The sun-oriented PV-UPQC combo features a number of advantages over the unanticipated UPQC, such as transferring the excellent PQ circuit, shielding the network from demand-side discontinuous and enhancing circuit intermission ride through the

conversion capability. [5] This work provides a voltage-said mitigation converter of inductive loads in industrial and other unbalanced loads used DVR design with 6-pulse voltage conversions. A useful custom power component which reduces the enormous demand flow is the Active Power Filter (APF), a variable energy sources which can be shut down by connecting SPV.

Nevertheless, it needs to be noted that bidirectional activities can be completed if a current source inverter powered by a VSC inverter is provided. In order to select appropriate photovoltaic cells for a given use, maximum power point tracking (MPPT) technique is examined it tracked over time [9]. Various devices, such as flywheels, isolation transformers and stable voltage transformers, are used to mitigate power-related problems. When these pieces of equipment are used, the overall cost of the coordination plan increases by 20%, making it unappealing for proper recognition [10,11]. When connecting an appropriate channel in the power construction, acoustic reductions can be attained.

The formation of reference signals is an essential part of PV UPQC control. Techniques for generating reference signals can be roughly classified as either frequency-domain or time-domain [18]. Since real-time implementation requires less computing power, time domain approaches are frequently employed. Instantaneously symmetrical component theory, synchronous reference frame theory and instantaneously reactive power theory (p-q theory) are among the most frequently used methods [20]. A harmonic variable is present in the d-axis current when demand is an imbalanced, which is the primary problem with using the synchronously reference frame theory-based approach. Therefore, to remove twice resonance component, low pass filters with a very low cutoff frequencies are utilized. Poor dynamic performance is the outcome of instability. In this study, the fundamental load active current is obtained by filtering the d-axis current using an Artificial Neural Network (ANN). This provides ideal absorption without lowering the controller capacity. Newly, phase locked loop (PLL) grid synchronization and DC-link controller performance both gained advantages from the use of ANN controllers. In a power structure, two types of networks are typically used, such as passive and active networks. These are no longer in use due to their existence in LC circuits. [12,13]. MATLAB/Simulink model is used to design and validate structure of DSTATCOM and its outcomes for both under operating conditions and under demand condition perturbations [21].

2. UNIFIED POWER QUALITY CONDITIONER

In order to regulate voltage and current PQ issues, a UPQC which combines DVR, DSTATCOM utilized [7]. The standard DC circuit is used for integrating it. DVR handles current PQ-related difficulties via DSTATCOM, which helps to reduce PQ-related voltage concerns. UPQC can be an improved approach to address power quality issues of to both voltage and current in balanced and typical demands. UPQC is an innovative method to address different PQ issues on the load side by combining shunt and series converters.

DC connector or DC circuit in the DC point of coupling connects two Voltage Source Converters (VSCs) or CSCs which constitute the foundation of the UPQC power circuit. The UPQC shunt connected unit, also known as DSTATCOM, provides much-required VAR regulation, demand current balance and neutral power balance or regulation. Typically, which is connected in across with customer demand or AC load in accordance with arrangement, either as a concurrently shunt of the UPQC. Customers can continue unchanged steady during delivery side voltage issues, also known as sags or swells, due to the system, which includes serial-connected UPQC and is known as DVR.

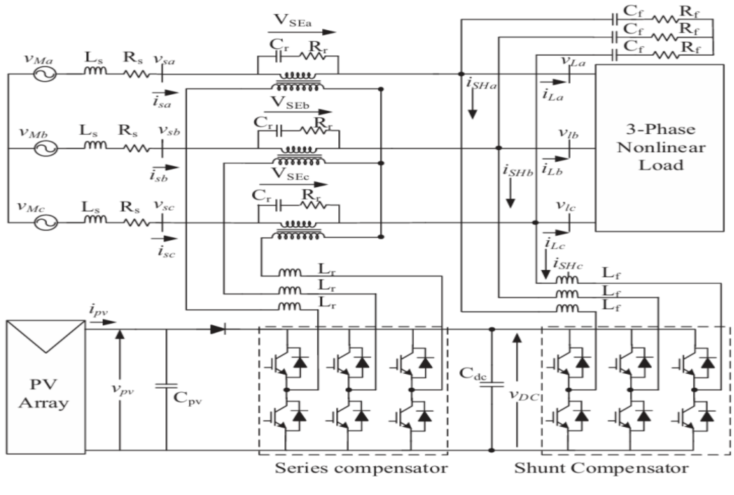


Fig.1. PV-UPQC System Design.

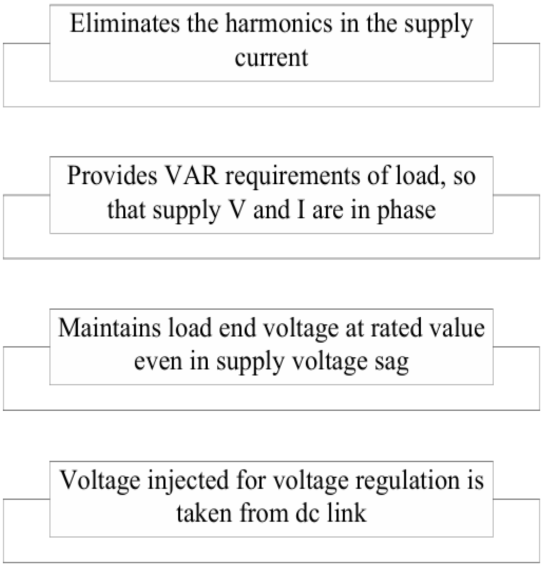


Fig. 2. UPQC Capabilities

Description of the System

Three challenges can be identified in modelling of a UPQC which is linked with PV arrangement: maximum Power Point Tracking (MPPT) absorbed DC voltage regulation systems (Vdc), active power filter control techniques. The control strategy-based unified controlling devices can be utilized to incorporate an operational shunt or a series configuration circuit when UPQC is present. For providing an integrated controller i.e. ANN, similar the PV system, this article attempts to address power quality issues.

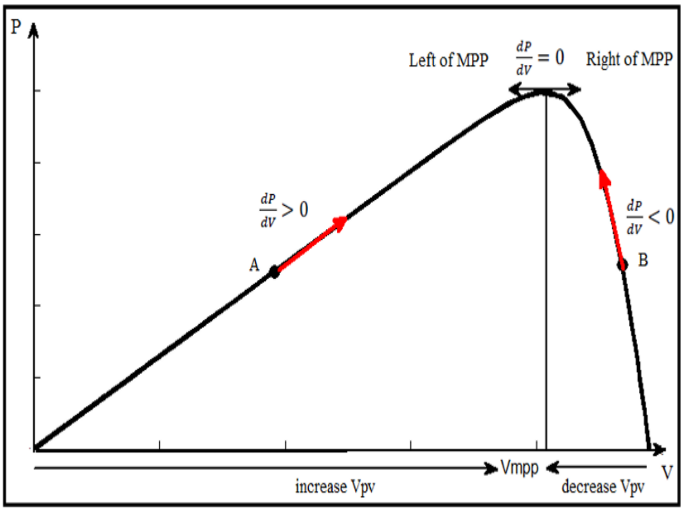
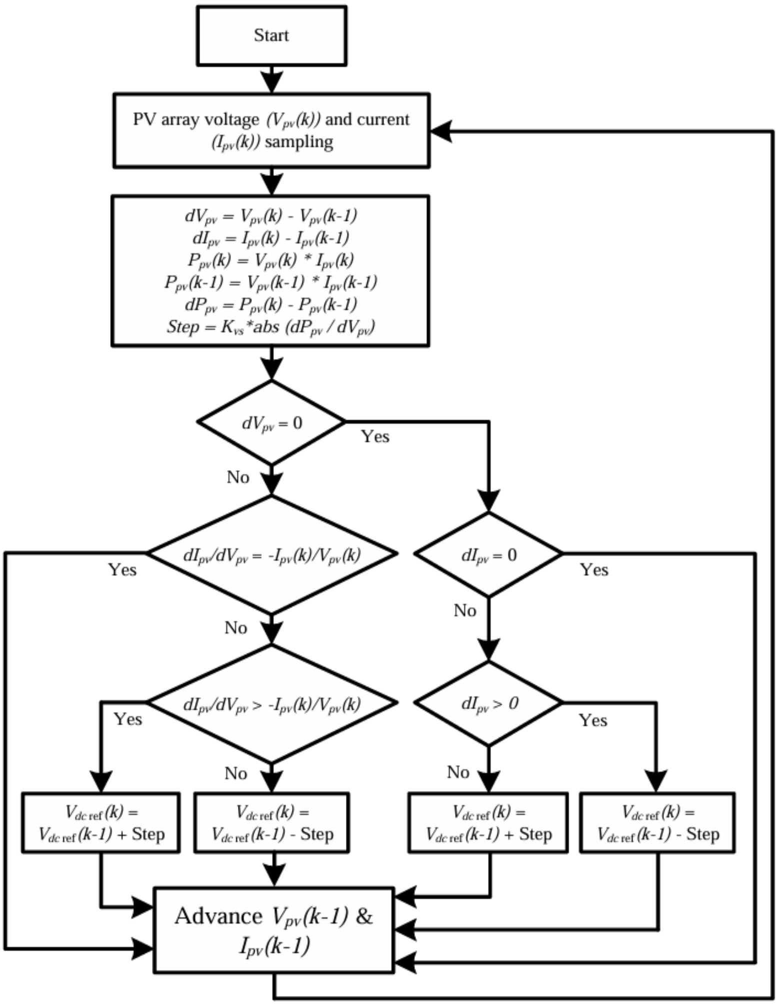


Fig. 3. P-V curve of Photo Voltaic.

The level of coincidental voltage and current enhancements of CPDs are planned and PV-UPQC appearance is investigated in static and dynamic circumstances, including swirling, load imbalances, and variations in solar radiation. Time area techniques like the d-q axis are employed for tiny computational demands. A crucial aspect of controlling PV-UPQC is the creation of reference signals. The two primary categories of signal delivering techniques are time domain and frequency domain techniques. In this study, d-axis current harmonic is filtered out get fundamental demand current using an ANN in conjunction with a moving active filter (MAF). This reduces the transfer speed without causing the regulator to malfunction. Fig. 4. Enhanced P&O MPPT Algorithm Flowchart.

In Fig. 4, an enhanced P&O MPPT flowchart is displayed. The regulation algorithm which compares with values ahead and afterward each disturbance in the PV output power value. P (K)>P (K-1), its shows that point is MPP, indicates that PV power outputs are higher than the one before it. Even with the cutoff power point, the technique can assist solar-powered photovoltaic cells collect the greatest possible energy [9]. It is also feasible to use several control calculation procedures, such as the irritate recognition strategy and the gradual conductance methodology. The presence of a serious absence of use of steady conductance conspires as it demands some effort to follow the strongest reason. A computation is necessary to creatively develop the display of the boards which are based on sunlight. Calculate collection of values, that is dependent on cut off and adjustment, which is dependent on the precise amount of the estimation of the most extreme force following sign, comprise the two components of the calculation.



This is where an unmatched constrained P&O MPPT approach of Photo voltaic cell can be used. The techniques are really improving classic P&O consistent state demonstration and the process also reduces the probability of losing the next course and provides a brief overview of common. [14]

ANALOGIES OF CONTROL:

Control of DSTATCOM:

The control circuit design for DSTATCOM is given in Fig 5. DC link fundamental voltage is being generated using MPPT approach. Prominent algorithms for MPPT [18] (INC) include Perturbation and Observation Method (P&O). The maximum power point tracking is proposed method is carried out using the P&O approach. Applying a proportional-integral control unit, fundamental voltage is used for determine voltage magnitude at DC connection. A shunt compensator is used to remove the active component of the fundamental in order to carry out the operation of compensating the load current. The present paper used the SRF approach to remove the basic component of the active demand current in order to regulate the shunt compensator. Phase and frequency data gathered with PLL must be used to initially transport the demand currents for d-q-0 domain. Voltage at PCC is the PLL input, current d-element (ILd) is subtracted of get its DC (ILdf) variable, it serves as an element of basic ABC reference level.

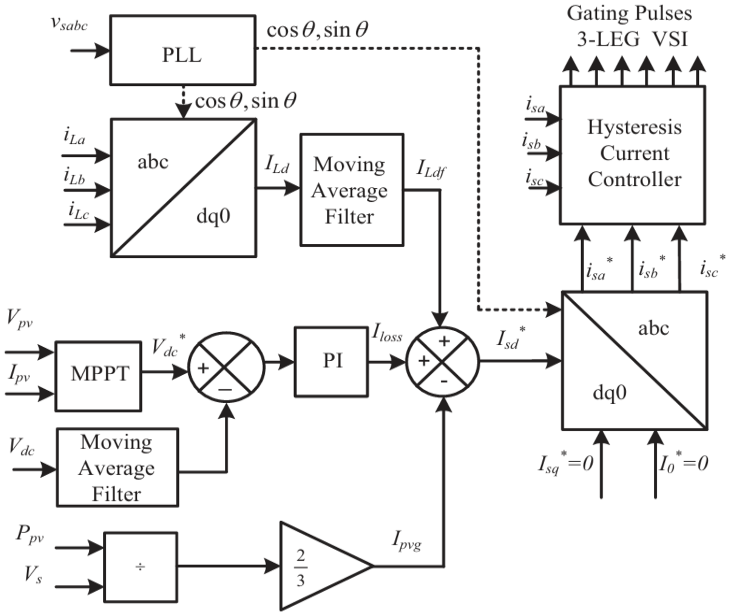


Fig. 5. DSTATCOM Control

DVR Control:

For a Dynamic Voltage Restorer (DVR) or series-connected converter, accurate regulation, phase variation and superior power control are regulating methodologies. Series converter in proposed system injects voltage signals into phases which are comparable to the system grid voltage, resulting in a tiny injection voltage signal value from series converter. Control of the series-connected converter is illustrated in Fig. 6. The PLL which produces the reference signals on the d-q-0 axis establishes the fundamental characteristics of the PCC voltage.

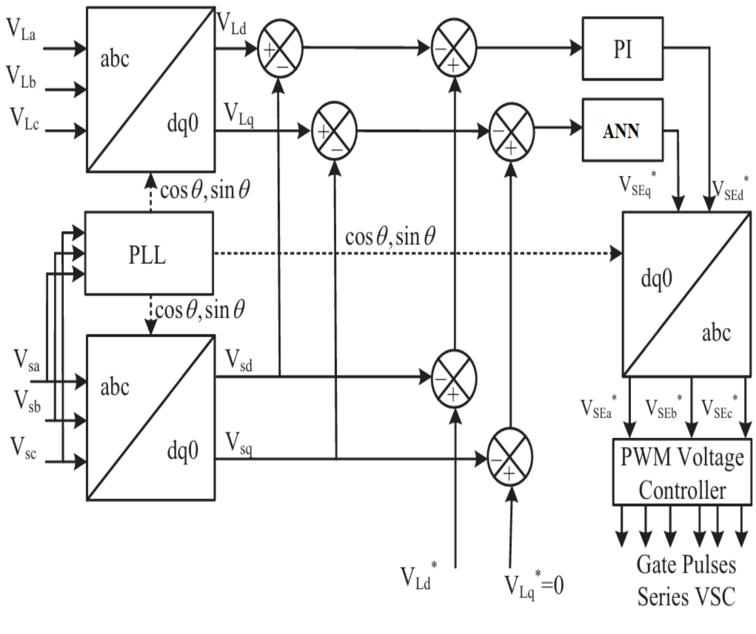


Fig.6. DVR Control

The starting signal of the load-side voltage is generated using the phase and frequency data for the PCC voltage as acquired by PLL. The stress on the PCC and the system strain at the load end are converted to create the d-q-0 frame. The PCC voltage and both standard voltage signals must be exactly at known as equal phase. The value of the parameter stays at zero at the q-axis. The PCC signal and the load side standard signal are compared to establish the desired voltage that should be applied to the series converter. The real series converter voltages are represented by the voltage difference between the PCC end and the load location. In order to create required standard signals, an ANN and PI controllers will now allow the difference signal between standard and real series converter voltages. The signals which are converted to the ABC region and delivered to the series converter as an input by means of a PWM-based voltage signal controller, which produced the necessary gate pulses.

The retrieved features constitute use of the ANN input, while the output represents the best control signals for the DC link capacitor during voltage dips. Create the ANN architecture, taking into account the number of layers, the triggering duties and the nodes in each layer. The structure should be able to understand the intricate connections between the intended control actions and the system characteristics. Select a suitable learning method for the artificial neural network. One popular supervised learning technique for ANN training is back propagation. The ANN modifies its settings during training in order to reduce the discrepancy between the expected and actual reactions. In Fig. 7, the ANN model is depicted.

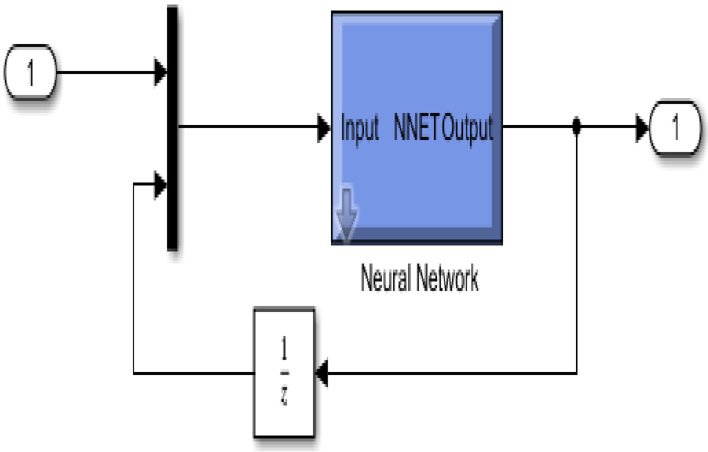
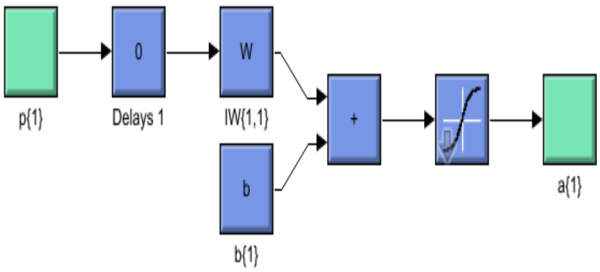
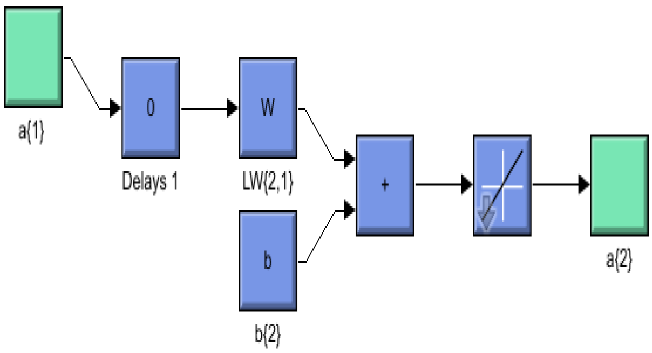


Fig.7 Control block of ANN

Considering a different set of data which did not get used for training, validate the trained artificial neural network. This renders it feasible for the ANN to generalize effectively to novel, untested situations. Apply the trained ANN to the DC link capacitor control system. The artificial neural network (ANN) generates optimum control signals as its output after receiving accurate evaluations of the system parameters. Along its operation, the ANN constantly evaluates the voltage sag/swell characteristics and system condition. The DC link capacitor control signals are dynamically modified by it according to the learnt patterns and optimal responses as depicted in Fig. 8 (a) and (b).



(a)



(b)

Fig. 8 ANN architecture

3. SIMULATION RESULTS

A UPQC integrated PV static and dynamic performance is evaluated through simulation with the MATLAB-Simulink software. The sensitive load is a three-stage diode bridged R-L load converter. The simulated study requires a solver step size of 10-6s. This configuration is studied under situations like sag and swells at solar power radiation and PCC voltage. First, MATLAB software is used to work out the PV element, mathematical study of a solar cell dual diode setups is completed. A limited computation used for producing the two identical diode replicas. The proposed P&O calculation performance is to determine the maximum power point validity. For calculation of PV-UPQC approach under the Unbalanced demand Condition, the representation is presented. The simulation model for the PV integrated UPQC system can be seen in Fig. 7. MATLAB is used to construct the model and the outcomes are tracked. After that, analysis must be done to add the necessary voltage or current to the network.

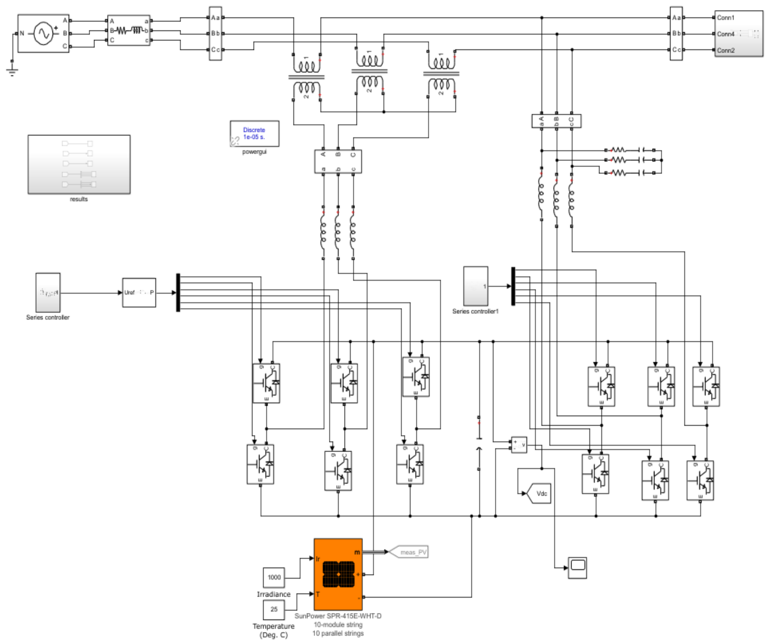


Fig. 9. Simulink Model with ANN

Solar PV-UPQC standard state and variable system behavior can be investigated through simulation studies using MATLAB software [17]. Applying a 3-Ph diode bridge rectifier with an R-L load, a non-linear load is employed. The simulation studies use a step size of 1e-6s. Various dynamic circumstances are present in the system, such as variations in photovoltaic irradiance and voltage drop and swells are at PCC end. The parameters which must be assumed for the simulation to run are the ones listed in the table which follows.

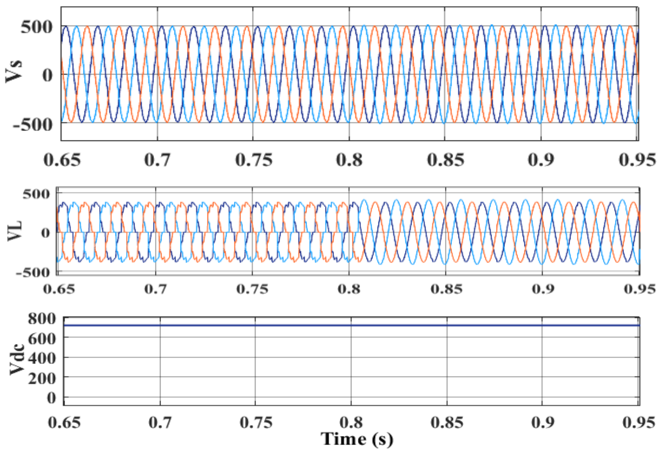
Table I: Parameters for Simulink

Parameter	Value
System Parameter	
PCC Voltage (VPLL)	415V, 50Hz
Bridge Rectifier Load	14.8 KW
DC-link Voltages (Vdc)	700V
DC-link Capacitors (Cdc)	9.3µF
Shunt inductors (Lf)	1mH
Switching frequency	10kHz
Ripple Filters	10µF, 10Ω
Series inductors (Lr)	3.6mH

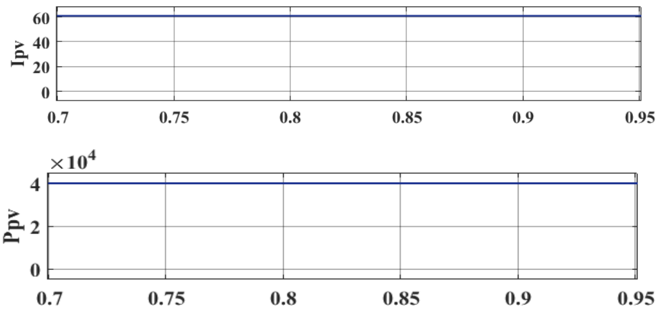
PI controller gains (Kp, Ki)	Kp=1.5, Ki=0.1
PI gains for d and q axis	Kp=8, Ki=1200
PV parameter	
Open Circuit Voltages (Voc)	864V
Short Circuit Currents (Isc)	62.65A
Voltages maximum power point (Vmpp)	701V
Currents maximum power point (Impp)	58.94A
Power (Ppv)	41.34KW

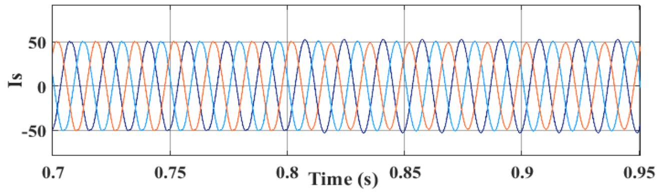
ANN tuned PV-UPQC & Outcomes investigation under demand unbalancing situations:

The grid performs more efficiently due to load balancing. There are numerous disruptions to the grid, including the abrupt disconnections of any one of the three phases. When DVR deliver proper requirement of voltage to sustain the load voltage constant and DSTATCOM regulates for the grid current to retain the load voltage and current balanced, UPQC will balance the system under such load unbalancing conditions. The diagram depicted dynamic reaction rate of PV-UPQC when demand is unbalanced. The removal of b from the load stage occurs at t=0.8s. Research often shows grid current is sinusoidal and at unity pf. When an overall load linked to the system abruptly drops, current which are drawn from the circuit rises. Additionally consistent and getting near to its expected to 700 V value is the DC Link voltage. Dynamics of the PV aided UPQC when load unbalancing is present are seen in Fig 10. The Y axis in Fig. 10 (a) displays the source voltage (Vs), load voltage (VL) and DC link voltage (Vdc), while the X axis shows the time in second. The signal connecting to the load at phase "b" became typical time t=0.8s.



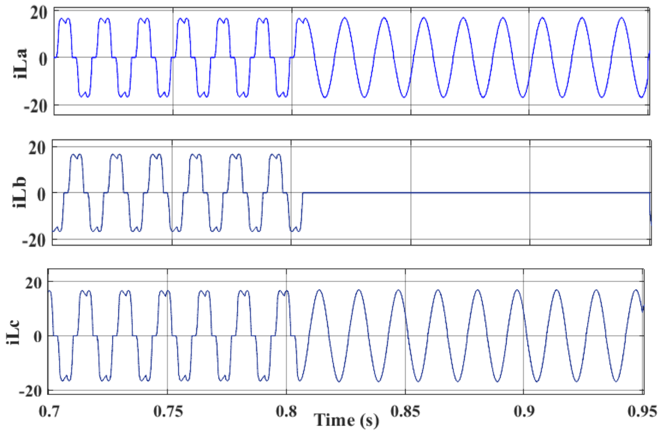
(a) Supply voltage (Vs), Load voltage (VL), DVR voltage (Vse)



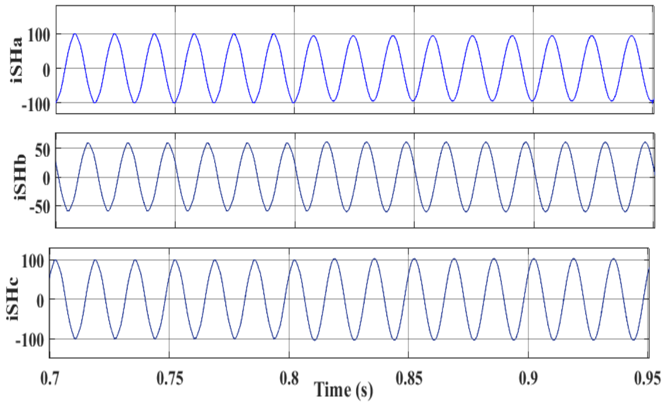


(b) SPV current (Ipv), SPV power (Ppv), Source Current (is)

Fig. 10 (b) and (d) demonstrate its current signals from grid is sinusoidal and steady of a power factor is unity. The abrupt decrease in demand is results in a significant increase in the grid current. The voltage of common DC connection stay fixed at 700V, which is compensated value.



(c) Load Current (iLa, iLb, iLc)



(d) DSTATCOM Current (iSHa, iSHb, iSHc)

Fig.10. PV-UPQC outcomes during Load Unbalancing.

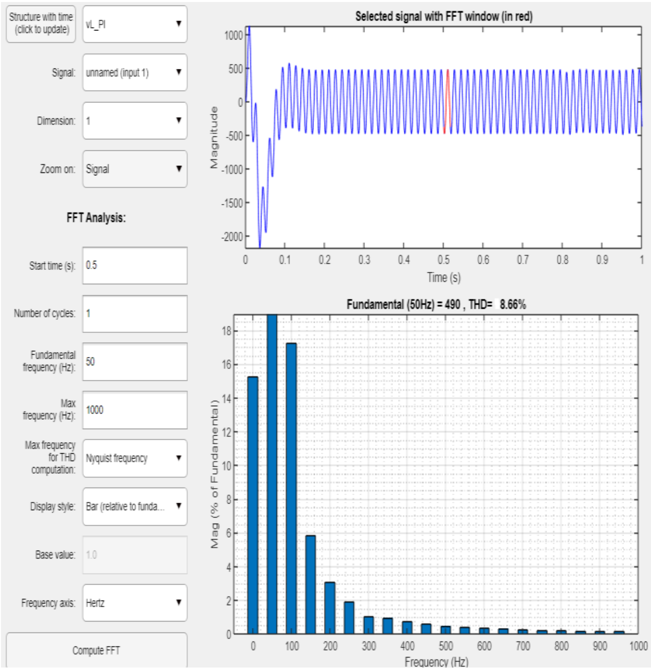


Fig. 11. Load voltage harmonics of PI controller.

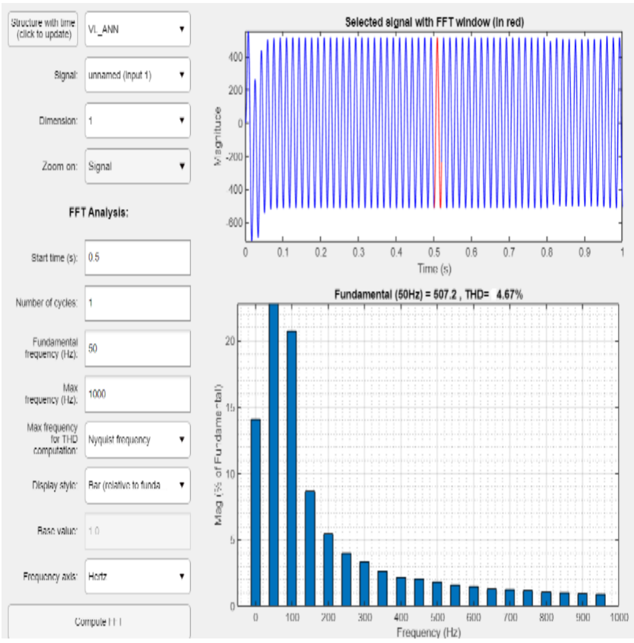


Fig. 11. Load voltage harmonics of ANN controller.

The present research minimizes harmonics in comparison to the proposed ANN controller and PI controller. In the advised ANN controller, the load voltage harmonics are 4.67%, while in the prevailing PI controller, the harmonics are 8.66%.

4. CONCLUSION

The standard of PV-UPQC is being evaluated at an outcome of power quality conditions. In order to inject the necessary voltage, the DVR needs the lowest injection voltage possible within the grid voltage. Due to load imbalance, SPV-UPQC received extensive evaluation for dynamic performance under load switching. The strategy can be shown to remain consistent after several disruptions. The SPV-UPQC system provides both active power from the solar array and reactive power adjustment. The method is mostly susceptible to variations and imbalances in the PCC voltages. Active average filters and an ANN controller is being used to carefully restore an effectiveness of d-q control under unbalanced load circumstances. For continuous power generation with improved power quality, PV-UPQC is better. Modern distribution systems like smart grids, which can generate electricity for these areas using a variety of renewable sources, can be utilized to an improve power quality in real time..

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