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Recent Advances in Modelling, Simulation & Implementation of Novel Control Schemes for Power Quality (PQ) Improvement Using AI-ML (ANN) Approaches

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Abstract:- **The improvement of power quality is critical for extending the life and efficiency of power electronics equipment in a utility distribution system. In this paper, we propose a photovoltaic integrated unified power quality conditioner (PV-UPQC) with cascaded multi-level inverter configuration based on an Artificial Neural Network (ANN) approach to improve power quality..Among the proposed methods, there is no need to use a transformer and filter when multilevel UPQC is applied and it is applied and is one of its advantages. The proposed UQPC offers a PV array composition with a power converter connected to a DC-link capacitor that can compensate for voltage sag, swell, voltage interruption, harmonics and reactive power. Robust Resilient Back Propagation Neural Network controllers are used to generate the UPQC's gating pulses. The controller's reference currents and voltages are calculated using the Synchronous Reference Frame (SRF) theory.The proposed cascaded multi-level inverter-based UPQC is designed using Matlab/Simulink Software. When compared to existing ANFIS and fuzzy logic methods, the simulation results show that the suggested method produces good results. A real-time hardware system is also set up to verify the proposed UPQC's simulation results.**

Keywords:- *Power Quality, ANN,DG, UPQC, Powerelectronics, RBPN, SAPF*

I. INTRODUCTION

An electric power system is a collection of electrical components that work together to supply, exchange, store, and use energy. An electric power network is a system that distributes energy to a larger area. The generators that produce the electricity, as well as the transmission network that transports the power from the generating station to the load centres, can all be divided into an electrical lattice control network .and the distribution network that nourishes the ability to close by homes and businesses. Smaller power frames can also be found in industrial, medical facilities, commercial buildings, and private residences In today's world, three-stage AC control is the industry standard for large-scale control transmission and distribution.

Flying machines, electric rail networks, cruise ships, and automobiles all have power structures that do not rely on three-stage AC control.

The outcome of two quantities, such as current and voltage, is electric power. These two values can change over time (AC control) or be maintained at constant levels (DC control). AC control is used in most refrigerators, ventilation systems, pumps, and mechanical apparatus, whereas DC control is used in most computers and modern equipment (the electronic devices connect to the mains ordinarily have an inside or outside power connector to change over from AC to DC control). Brushless equipment can produce and utilise air conditioning power, which has the advantage of being relatively straightforward to switch between voltages. DC power remains the most rational option in sophisticated networks, and it can be more feasible to transfer across long distances at high voltages.

UNIFIED POWER QUALITY CONDITIONER (UPQC)

The Unified Power Quality Control (UPQC) device is comparable to the Unified Power Flow Control device in terms of design (UPFC). UPQC employs two voltage source inverters (VSI) linked to DC energy storage, similar to UPFC. One of the two VSIs is linked to the AC line in series, while the other is connected to the AC system through a shunt.

A UPQC that combines the operations of a Distribution Static Compensator (DSTATCOM) and Dynamic Voltage Regulator (DVR) together.

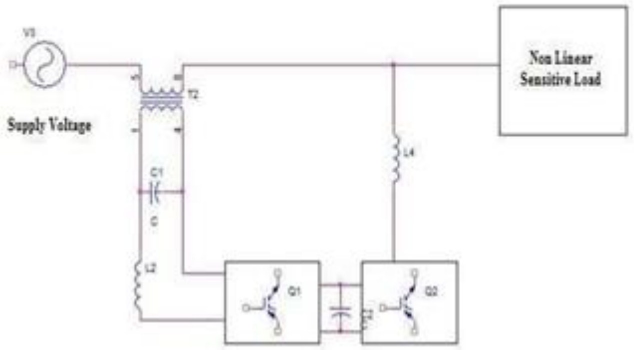

Fig 1.combination of series and shunt APF ie:UPQC

Supply voltage flicker/imbalance, reactive power, negative-sequence current, and harmonics are all compensated by a UPQC. UPQC can enhance power quality at the point of installation on power distribution or industrial power systems, to put it another way.

In the distribution system, there are several sorts of power quality issues, and each issue has a remedy. From the reference papers It has been proven that a DVR outperforms a DSTATCOM.

The Unified PQ Conditioner (UPQC) provides the best protection for sensitive loads coming from low-quality sources. It's a hybrid of DVR and DSTATCOM.

II. LITERATURE SURVEY

M. Adly, et al., 2017[1], considered sun oriented vitality transformation through photograph voltaic (PV) is a quickly developing wellspring of the green power supply. Enhancing the effectiveness of PV networks is broadly observed as essential in supporting this pattern. This worries the change of the PV cells, as well as of the power electronic circuits and controls associated with them.They showed us the use of PV array in UPQC.

AhmetTeke,et al,2011[2] suggested a novel reference signal generating approach for the unified power quality conditioner (UPQC), which is used to compensate sensitive loads' current and voltage quality concerns. A shunt and series converter with a common dc link make up the UPQC. The shunt converter minimises current harmonics generated by nonlinear loads, whereas the series converter reduces voltage sag/swell caused by nonlinear loads.

Bruno W. França, et al, 2013[3] provided an enhanced controller for the Unified Power Quality Conditioner (iUPQC) dual architecture, allowing it to be used in power quality compensation and microgrid applications. The iUPQC will give reactivepower assistance to manage not only the load-bus voltage, but also the voltage at the grid-side bus, in addition to the traditional UPQC power quality features such as voltage sag/swell compensation. To put it another way, the iUPQC will act as a STATCOM on the grid while simultaneously delivering traditional UPQC compensations at the load or microg level.

Salimchennai, 2016[4] proposed an unique control method for a unified power quality conditioner (UPQC) based on a three-level neutral point clamped (NPC) inverter, which uses fuzzy logic and Ann's to regulate series and shunt APFs, respectively. The suggested UPQC was able to adjust for all voltage disturbances while mitigating source current harmonics. It's made up of series and shunt active filters (AFs) connected by a common DC bus capacitor. A proportional integral voltage controller is used to keep the DC voltage constant. The reference signals for the shunt APF are obtained using the synchronous reference frame (SRF) theory, whereas the reference signals for the series APF are obtained using the power reactive theory (P-Q theory). To create switching signals, the control algorithm's shunt and series active power filter (APF) reference signals, as well as detected signals, were fed into two intelligent controllers.

V. VeeraNagireddy, et al, 2018[5] Enhancement of power quality was used to try to extend the life and performance of equipment in utility distribution networks. The author presents the design of a hybrid fuzzy back-propagation control system for a unified power quality conditioner in this study to improve power quality. Hybrid fuzzy-back propagation controllers are used to create the UPQC's gating pulses Back-propagation algorithms with source and load currents as input control parameters are used to calculate the controller's reference currents. For the dc voltage regulator with a terminal voltage and a dc voltage for the input control parameters, the reference voltages for the controllers are determined using fuzzy logic controllers.. In a multilevel UPQC-connected distribution system, we undertake this analysis in zero-voltage regulation mode with a power factor correction model. Using MATLAB/Simulink, we examine the outcomes of total harmonic distortion, dynamic performance, load balancing, and voltage sag mitigation.

III. METHODOLOGY

According to the literature review, power quality is currently a major source of concern for power engineers. In order for utilities to gain worldwide benefits, supply reliability is critical. To increase power quality, various types of custom power devices are proposed and examined. Custom Power refers to a group of power electronic equipment that can be used in distribution networks to improve power quality. Because distribution system failures generate the majority of customer disruptions, additional emphasis is placed on removing voltage sags, swells, and harmonics at the distribution end. Custom power devices termed DVR, DSTATCOM, and UPQC are utilised to enhance power quality, and the results are acquired using MATLAB/ SIMULINK. For distribution networks with non-linear loads and active loads, the efficacy of bespoke power devices may be determined.

Problem Statement

- Due to nonlinear/sensitive loads in the power system, a variety of issues might arise. Dealing with these issues and ensuring that the system remains stable is a difficult task for any researcher.
- The inadequacy of traditional power quality enhancing methods has necessitated vital and adaptable resolution to power quality concerns.
- Passive L-C filters, which were traditionally employed to reduce line harmonics, are larger and have fixed compensation.
- Need proper compensating method will require which response quickly to mitigate the PQ problem and conserve the system to steady-state

Objectives of the project

- To identify the source and effect of PQ problems in the power distribution system
- To develop a multilevel inverter-based Unified Power Quality Conditioner (UPQC) that can mitigate a variety of power quality issues.
- To develop the UPQC with simulation model using Predictive Phase Dispersion Modulation, Hybrid Multicarrier Pulse Width Modulation and Resilient Back Propagation Neural Network Approach for reducing the power quality issues.
- To perform feasibility investigation on PQ enhancement at PCC using proposed UPQC in the distribution system and regulate dc-link voltage and the significances to be comprehended.

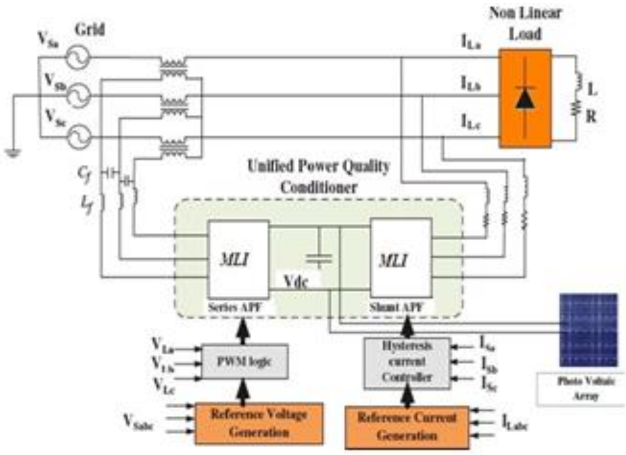

Fig2.Block diagram

The suggested PV-structure UPQC's is depicted in the diagram. The shuntcompensator is connected to the load side, while the series compensator is attached to the grid side in a right shunt configuration. This is the most popular arrangement because it allows sinusoidal currents to flow through the series converter, resulting in a lower series compensator rating. The shunt compensator compensates for load power quality issues in the current control mode. In addition to maintaining DC-link voltage, the shunt converter injects active power from the PV array.In voltage control mode, the series compensator compensates for grid voltage power quality issues such as harmonics and sags/swells. Through a boost DC-DC converter, the PV array is connected to UPQC's DC-link. The MPPT algorithm controls the boost converter, extracting the most available power from the PV array.

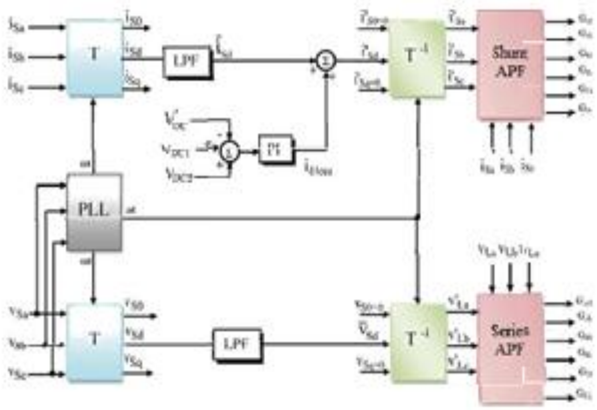

Fig 3.configuration of shunt and series

Control of Series active filter

For series APFs, the suggested Synchronous Reference Theory (SRF)-based UPQC control method can be utilised to handle PQ problems such as source-voltage harmonics, imbalanced voltages, and voltage sag and swell at the same time. The reference value to be injected is calculated by comparing the positive-sequence component of the source voltages with load-side line voltages in the proposed approach. Using the transformation matrix T provided in equation below, the supply voltages vSabc are changed d-q-0. In addition, the modified PLL conversion is employed to calculate the reference voltage.

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$$T = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 1/\sqrt{2} \\ \sin(\omega t) & \sin\left(\omega t - \frac{2\pi}{3}\right) & \sin\left(\omega t + \frac{2\pi}{3}\right) \\ \cos(\omega t) & \cos\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) \end{bmatrix} \dots (1)$$

$$T^{-1} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \sin(\omega t) & \cos(\omega t) \\ \frac{1}{\sqrt{2}} & \sin\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t - \frac{2\pi}{3}\right) \\ \frac{1}{\sqrt{2}} & \sin\left(\omega t + \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) \end{bmatrix} \dots (2)$$

$$\begin{bmatrix} V_{So} \\ V_{Sd} \\ V_{Sq} \end{bmatrix} = T \begin{bmatrix} V_{Sa} \\ V_{Sb} \\ V_{Sc} \end{bmatrix} \dots (3)$$

Control of Shunt Active Filter

A shunt active power filter eliminates the reactive and harmonic currents from a set of nonlinear loads when linked in series, resulting in a sinusoidal total current taken from the ac main. The shunt active filter's main purpose is to compensate for current harmonics created by distribution lines.shunt active filter is mainly to compensate the current harmonics generated from the distribution lines. The input current is practically sinusoidal when the shunt active filter is connected to the line, and distortions are reduced. A diode rectifier is an example of a nonlinear load.

The inverter circuit is followed by a PI controller, a PLL and hysteresis band pass controller, and finally a PLL and hysteresis band pass controller. A capacitor is used on the DC side, and the voltage of the capacitor is sensed and compared to the reference voltage. The error voltage is fed into the PI controller's input.The PWM is used to control the voltage across the DC capacitor. The PI controller is used to minimize the error. The transfer function can be represented as follows

$(S) = Kp + KiS \dots (1)$

Where Ki is the integration constant that determines the settling time and Kp is the proportional constant that determines the dynamic response of the DC bus voltage control. To eliminate the steady state error, a PI controller is utilised. The proportional and integral gain settings are chosen to maintain a constant voltage across the DC capacitor. The system voltages are sent into the Phase Locked Loop (Vsa, Vsb, Vsc).

The PLL design should allow for proper operation even when the voltage waveform is distorted and uneven.The output of PLL block is ia1, ib1,ic1 three phase currents. The PLL output currents are defined as follows.

$ia1 = (\omega t - \pi 2\ ) \dots (2)$
$ib1 = (\omega t - \pi\ 2 - 2\pi 3\ ) \dots (3)$
$ic1 = (\omega t - \pi\ 2 + 2\pi 3\ ) \dots (4)$

The distorted source voltages Vsa,Vsb,Vsc and the PLL output current signals ia1, ib1,ic1 are monitored in phase with the fundamental component. The desired reference current is obtained by multiplying the PLL output by the PI controller.

The hysteresis band pass controller comes next. The Hysteresis band pass controller is one of the most straightforward methods for signalling the inverter. In a PWM-MLI, the switches are controlled by an error signal. The disparity between the required current reference signal and the current injected by the inverter is the source of this problem.

The upper switch of the inverter is turned on and the lower switch is switched on if the error exceeds the upper limit of the hysteresis band. As a result, the current begins to slow down. If the error current exceeds the hysteresis band pass controller's lower limit, the inverter's lower switch is turned off and the higher switch is turned on. As a result, the current enters the hysteresis band once more. The error signals' minimum and maximum values are emin and emax, respectivelyThe amount of ripple in the output current from the PWM-MLI is directly controlled by the range of the error signal. The original distortion is cancelled by infusing equal but opposing current harmonic components at the point of common coupling. At the point of common coupling, the voltage source inverter is connected. The active filter is coupled in parallel with the compensating nonlinear load.

Modelling and Designing Of Cascaded Twenty Seven Level Inverter

For each balance voltage list, DC voltage coefficients are calculated. The main commitments of the suggested switching technique are described below, in contrast to the standard Robust Back Propagation Neural Network system.

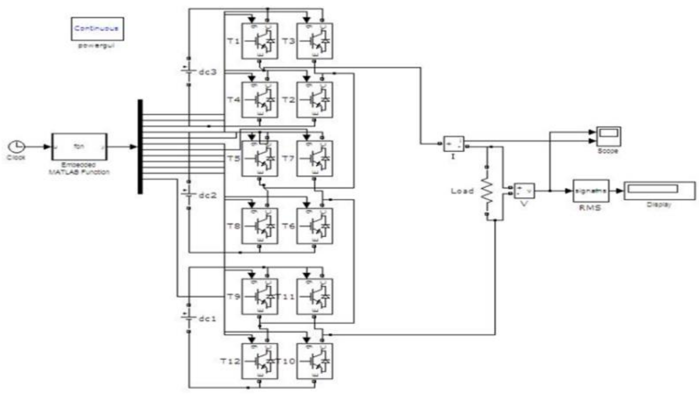

Fig 4. 27 level multi level inverter

OPERATION: DIFFERENT MODES OF OPERATION OF TWENTY-SEVEN LEVEL INVERTER

The following is a description of how the twenty-seven levels multilevel cascaded H bridge works:

Mode1:- 27 layers cascaded in a single phase In this mode of operation, the H-Bridge multilevel inverters switch1-switch6 and s are turned on without the source being connected to the load.The obtained output voltage across the load is zero.
Mode2:- Switch1, switch3, switch5, and switch8 of the single phase27 level cascaded H-Bridge multilevel inverter

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are turned on in this mode of operation. The output voltage across the load is acquired between +Vdc and +5Vdc.

Mode3:- The 27-level cascaded H-Bridge inverter switches s9 & s10 are turned on in this mode of operation. The output voltage across the load ranges from +6Vdc to +13Vdc.

Mode4:- Switch2, switch4, switch6, and switch7 of the single-phase five-level H-bridge cascaded multilevel inverter are turned on in this mode of operation. The obtained output voltage across the load is -Vdc2.

Mode5:- The single phase 27 level H-bridge cascaded multilevel inverters s11-s12 are turned on in this mode of operation. The obtained output voltage across the load is zero.

Mode6:- All the switches on the single phase 27 level H-bridge cascaded multilevel inverter are turned on in reveres condition in this mode of operation. The obtained output voltage across the load is –Vdc-Vdc13.

The resilient back propagation neural network can be used to solve a variety of limited and unconstrained optimization problems that are beyond the scope of traditional enhancement calculations. Issues involving non-differentiable, intermittent, stochastic, or highly nonlinear target work fall into this category.The n -level inverter topology requires (n -1)/2 (= N) independent DC power supplies, where N is the number of H-bridges.

A network with an input layer, a hidden layer, and an output layer must be used in the suggested application. Changes are used as pulse learning sources, and their true voltage outputs are recorded. In the neurotransmission slot, RBPN is employed to govern the converter control of switched pulsesAn RBPN approach is a well-tuned application that doesn't require any specific functional control. The neurological system based on RBPN has developed the most regulated features.

V. RESULTS AND DISCUSSION

- **THD-BY FFT ANALYSIS before implementing upqc**

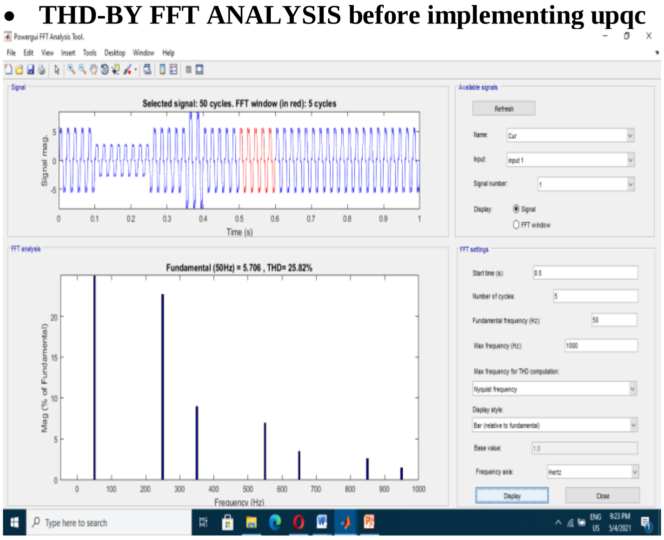

Figure 5. Current THD

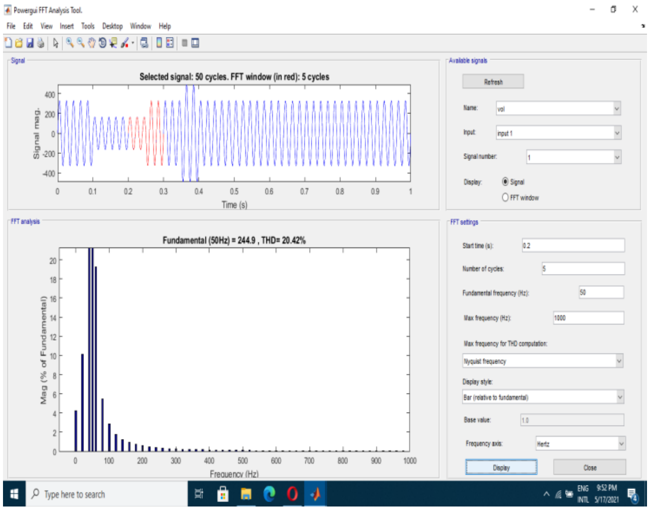

Figure 6. Voltage THD

- **THD-BY FFT ANALYSIS after implementing upqc**

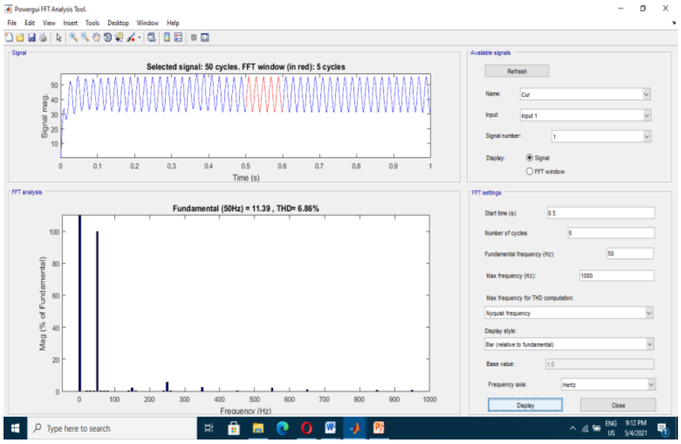

Figure 7. Simulation Result of current THD with UPQC

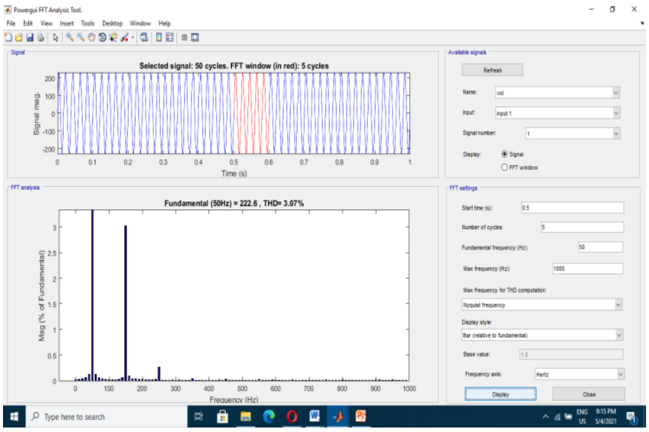

Figure 8. Simulation Result of Load Voltage THD with UPQC

The simulation result of Total harmonics Distortion in Load voltage for the proposed solar UPQC system is shown in Figure. This simulation result clearly shows the proposed system the THD into the below level of the IEEE standard, the value of load voltage THD is 3.07% with respect to 50 Hz frequency.

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The simulation result of Total harmonics Distortion in Load current for the proposed solar UPQC system is shown in Figure 14. This THD simulation result clearly shows the proposed system obtains the THD into the below level of the IEEE standard, the value of load voltage THD is 1.25% with respect to 50 Hz frequency.

IV.SCOPE AND CONCLUSION

- This project work shows a novel unified power quality conditioning system that is connected to the solar cell and has a cascaded multi-level inverter configuration system that can compensate for voltage and current disruptions in grid systems at the same time.
- A 27-level inverter UPQC prototype is used in this study. The suggested ML-performance UPQC's is examined under various disturbance circumstances, and it is demonstrated that it can correct for sag/swell and interruption compensation.
- The load current and load voltage THD response of the proposed system 6.86% and 3.07% respectively for an inductive load which can reduced even more if an higher level inverter setup is used but then the cost also increases.So further research have to be done to get a THD less than 5% by also keeping the cost in mind.

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