FUZZY LOGIC BASED CONTROL OF UPQC FOR POWER QUALITY & POWER FLOW IN DISTRIBUTION SYSTEM USING RENEWABLE ENERGY RESOURCES

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ABSTRACT

The integration of distributed energy resources and storage into distribution networks and microgrids has heightened the importance of sustainable energy management. However, this has led to challenges in power quality (PQ) due to the proliferation of power electronic-based devices. To address this, the article introduces a novel approach: a photovoltaic (PV) integrated Unified Power Quality Conditioner (UPQC) with an adaptive compensating technique using the variable leaky least mean square (VLLMS) algorithm. This soft computing method ensures rapid convergence to desired conditions while maintaining parameter updates within specified limits. The VLLMS-based algorithm directly extracts fundamental components from polluted source voltage and load current, eliminating the need for low-pass or moving average filters. It generates reference signals for switching shunt and series voltage source converters (VSC) of the UPQC. By incorporating the feed-forward component of PV, the compensating technique effectively manages power balance between the grid, load, and PV, addressing issues like current harmonics and poor power factor at the point of common coupling (PCC), while regulating the DC-link voltage. A fuzzy logic controller enhances system performance. Meanwhile, the series converter maintains pure sinusoidal voltage at the load terminal regardless of sag/swell and harmonics in the grid voltage. Simulation validates the efficiency of the proposed system.

Keywords: Unified Power Quality Conditioner (UPQC) , Unified Power Quality Conditioner (UPQC)

1. INTRODUCTION

The surge in power electronic-based devices in distribution systems has heightened power quality (PQ) issues, necessitating solutions like distribution static compensators (DSTATCOMs), dynamic voltage restorers (DVRs), and unified power quality conditioners (UPQCs). While DSTATCOMs address current-related PQ problems and DVRs tackle voltage issues, UPQCs offer comprehensive solutions for both current and voltage PQ issues simultaneously. However, compensating voltage interruptions with UPQCs in the absence of additional energy support presents challenges. Integration with distributed energy resources (DERs) like PV and wind addresses this, making PV-UPQC an ideal solution for microgrids and distribution networks.

Effective control is pivotal for the operation of power electronic-based systems like PV-UPQC. The control strategy determines reference signals for inverter switching, crucial for achieving desired outcomes. In a PV-integrated UPQC, the PV scale depends on the UPQC's dc-link voltage and configuration. Control strategies must manage power flow between PV, grid, and load while enhancing PQ, necessitating sophisticated techniques. Synchronous reference frame and instantaneous reactive power theory are common but suffer from poor tracking and complexity. Soft computing techniques, like neural networks, offer adaptive control schemes, with varying step-size LMS and leaky LMS algorithms improving convergence and performance.

In this context, a variable leaky LMS-based adaptive control scheme is implemented in a grid-integrated PV-fed UPQC to determine reference signals for shunt and series compensators. However, the role of the shunt compensator in power balance and the capability of the series compensator under highly distorted voltage supply remain unexplored. Therefore, this work aims to analyze PV-UPQC functionalities in distribution systems under various conditions to maximize utilization while improving PQ.

2. RELATED DESCRPTION

2.1 POWER

Electrical power:The rate at which electrical energy is consumed or dissipated into other forms of energy is called an electrical power.

1. Power is denoted by P.
2. The S.I unit of power is Watt.

The mathematical representation for power is P =V X I. Here, V is the voltage and I is the current.

Types of electrical power:

There are two types of electrical power such as:

1. DC power - It is defined as the product of voltage and current and is produced by DC sources like generators, batteries, fuel cells, etc.
2. AC power - A flow of charge that exhibits a periodic change in direction is called AC power.

AC power is further bifurcated into three types as follows:

1. Apparent power - It is the product of the root-mean-square current and the root-mean-square voltage. It is the ideal power and is represented by S. The mathematical expression for apparent power is S = Vrms × Irms.
2. Active power - It is the amount of power consumed or used within an alternating current circuit. It is the real power and is represented by P. The mathematical expression for apparent power is S=Vmax x Imax cosΦ. Here, & is the impedance phase angle between the voltage and the current.
3. Reactive power R - Reactive power is the power developed in the circuit and is represented by Q. The mathematical expression for apparent power is Q=Vrms x I rms sinΦ

2.2 DEFINITIONS

HARMONICS

Defined as deviations from the fundamental frequency sine wave, expressed as adcitional sine waves o frequencies that are o multiple of the generated frequency. They are expressed as third, fith, seventh elc harmonics, denoting their frequency as a multiple of the primary wave frequency.

HARMONICS CONTENT:

A measure of the presence of harmonics in the waveform expressed as a percentage of the fundamental frequency The total harmonic content is expressed as the square root of the sum of each of the harmonics amplitudes. expressed as percentage of the fundamental.

HARMONIC DISTORTION:Nonlinear distortion of a waveform characterized by the appearance in the output of harmonics other than the fundamental component when the input wave is sinusoidal.

LINEAR LOAD:

AC electrical loads where the voltage and current woveforms ore sinusoidal. The current at any time is proportional to voltage. Linear Loads are: power factor improvement capacitors, indescent lamps, heaters etc

NON-LINEAR LOAD

Applies to those ac loads where the current is not propotional to the voltage. foremost among loads meeting their definition are gas discharge lighting having saturated ballast coils and thyritor (scr) controlled loads. the nature of non-linear loads is to generate hormonics in the current waveform. this distortion of the current woveform lands to distortion of the voltage waveform. urder these conditions, the voltage waveform is no longer proportional to the current. non linear loads are: computer, laser printers, smps, reactifier, plc, electronic ballast, refrigerator, tv etc.

3. IMPLMENTATION STUDY

Power quality is gaining increasing attention in the electric power industry. The consumer of electrical energy requires electric power with a certain quality , but loads can have a negative impact on the electrical system and are thus also subject to asssessment in terms of quality.power is linked to the interaction between electrical systems and loads and must take into account both the voltage quality and power quality.The power supply sysytem can only control the quality of the voltage , it has no control over the currents that particular loads might draw Therefore , the standards in the power quality are related to maintaining the supply voltage within certain limits.

3.1 PROPOSED MODEL

A voltage swell is opposite of voltage sag. It is a short duration phenomenon of increase in RMS line voltage of 110% to 180% of the of the normal line voltage.A swell is the reverse form of a Sag, having an increase in AC Voltage for a duration of 0.5 cycles to 1 minute's time. For swells, high-impedance neutral connections, sudden large load reductions, and a single-phase fault on a three-phase system are common sources. Swells can cause data errors, light flickering, electrical contact degradation, and semiconductor damage in electronics causing hard server failures. Our power conditioners and UPS Solutions are common solutions for swells.It is important to note that, much like sags, swells may not be apparent until results are seen.

Having your power quality devices monitoring and logging your incoming power will help measure these events. UPQC is unified power quality conditioner it is obtained from the facts (flexible alternating current Transmission system).The provision of both DSTATCOM and DVR can control the power quality of the source current and the load bus voltage. In addition, if the DVR and STATCOM are connected on the DC side, the DC bus voltage can be regulated by the shunt connected DSTATCOM while the DVR supplies the required energy to the load in case of the transient disturbances in source voltage. The configuration of such a device (termed as Unified Power Quality Conditioner (UPQC)) is shown in Fig. 5.1 This is a versatile device like a UPFC. However, the control objectives of a UPQC are quite different from that of a UPFC.

4. METHODOLOGIES

1)Voltage sag (dip)

Description:A decrease of the normal voltage level between 10% and 90% of the nominal rms voltage at the power frequency, for durations of 0,5 cycle to 1 minute.

Causes: Faults on the transmission or distribution network (most of the times on parallel feeders).

Faults in consumer's installation. Connection of heavy loads and start-up of large motors.

Consequences: Malfunction of information technology equipment, namely microprocessor-based control systems (PCs, PLCs, ASDs, etc) that may lead to a process stoppage. Tripping of contactors and electromechanical relays. Disconnection and loss of efficiency in electric rotating machines.

2)Very short interruption

Description: Total interruption of electrical supply for duration from few milliseconds to one or two seconds.

Causes: Mainly due to the opening and automatic reclosure of protection devices to decommission a faulty section of the network. The main fault causes are insulation failure, lightning and insulator flashover.

Consequences: Tripping of protection devices, loss of information and malfunction of data processing equipment. Stoppage of sensitive equipment, such as ASDs, PCs, PLCs, if they're not prepared to deal with this situation.

3)Long interruptions

Description: Total interruption of electrical supply for duration greater than 1 to 2 seconds.

Causes: Equipment failure in the power system network, storms and objects (trees, cars, etc) striking lines or poles, fire, human error, bad coordination or failure of protection devices.

Consequences: Stoppage of all equipment.

4)Voltage spike

Description: Very fast variation of the voltage value for durations from a several microseconds to few milliseconds. These variations may reach thousands of volts, even in low voltage.

Causes: Lightning, switching of lines or power factor correction capacitors, disconnection of heavy loads.

Consequences: Destruction of components (particularly electronic components) and of insulation materials, data processing errors or data loss, electromagnetic interference.

5)Voltage swell

Description: Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds.

Causes: Start/stop of heavy ,badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours).

Consequences: Data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too high.

6) Harmonic distortion

Description: Voltage or current waveforms assume non-sinusoidal shape. The waveform corresponds to the sum of different sine-waves with different magnitude and phase, having frequencies that are multiples of power-system frequency.

Causes: Classic sources: electric machines working above the knee of the magnetization curve (magnetic saturation), arc furnaces, welding machines, rectifiers, and DC brush motors.

Consequences: Increased probability in occurrence of resonance, neutral overload in 3-phase systems, overheating of all cables and equipment, loss of efficiency in electric machines, electromagnetic interference with communication systems, errors in measures when using average reading meters, nuisance tripping of thermal protections.

7)Voltage fluctuation

Description: Oscillation of voltage value, amplitude modulated by a signal with frequency of 0 to 30 Hz.
Causes: Arc furnaces, frequent start/stop of electric motors (for instance elevators), oscillating loads.
Consequences: Most consequences are common to undervoltages. The most perceptible consequence is the flickering of lighting and screens, giving the impression of unsteadiness of visual perception.
8)Noise
Description: Most consequences are common to undervoltages. The most perceptible consequence is the flickering of lighting and screens, giving the impression of unsteadiness of visual perception.
Causes: Electromagnetic interferences provoked by Hertzian waves such as microwaves, television diffusion, and radiation due to welding machines, arc furnaces, and electronic equipment. Improper grounding may also be a cause.
Consequences: Disturbances on sensitive electronic equipment, usually not destructive. May cause data loss and data processing errors.
9)Voltage unbalance
Description: A voltage variation in a three-phase system in which the three voltage magnitudes or the phase-angle difference between them are not equal.
Causes: Large single-phase loads (induction furnaces, traction loads), incorrect distribution of all single-phase loads by the three phases of the system (this may be also due to a fault).
Consequences: Unbalanced systems imply the existence of a negative sequence that is harmful to all three- phase loads. The most affected loads are three-phase induction

5 RESULTS AND DISCUSSION SCREEN SHOTS

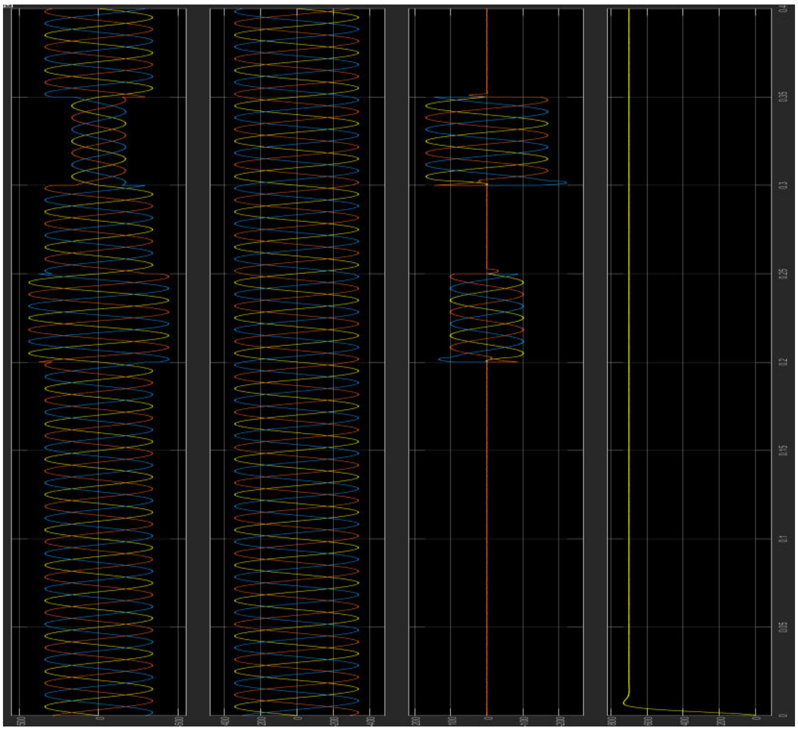

Figure 1 Behaviour of PV-UPQC sysytem under voltage sag/swell condition

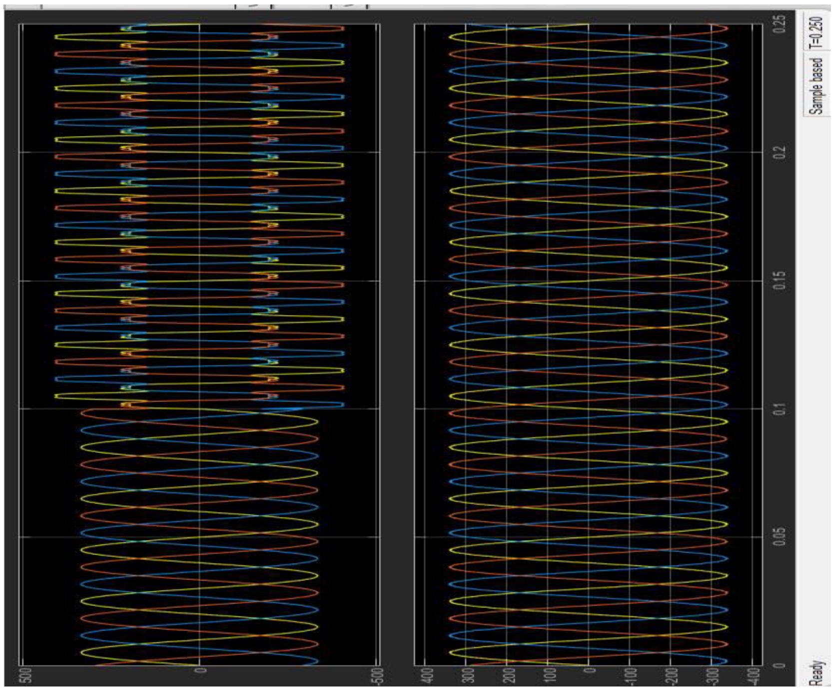

Figure.2 linear load with harmonics

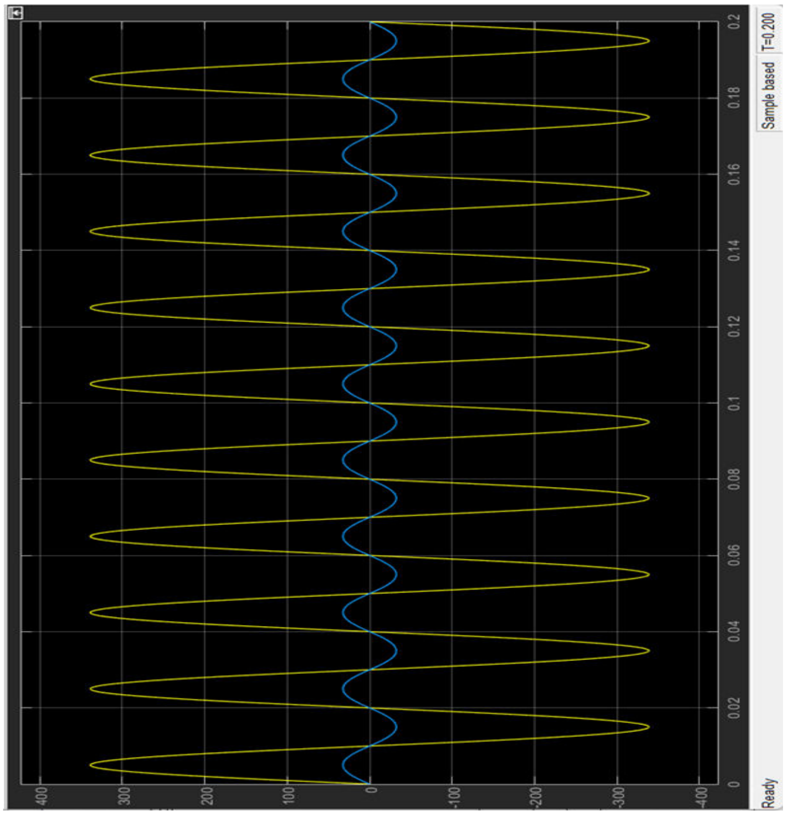

Figure 3 Non-linear load condition

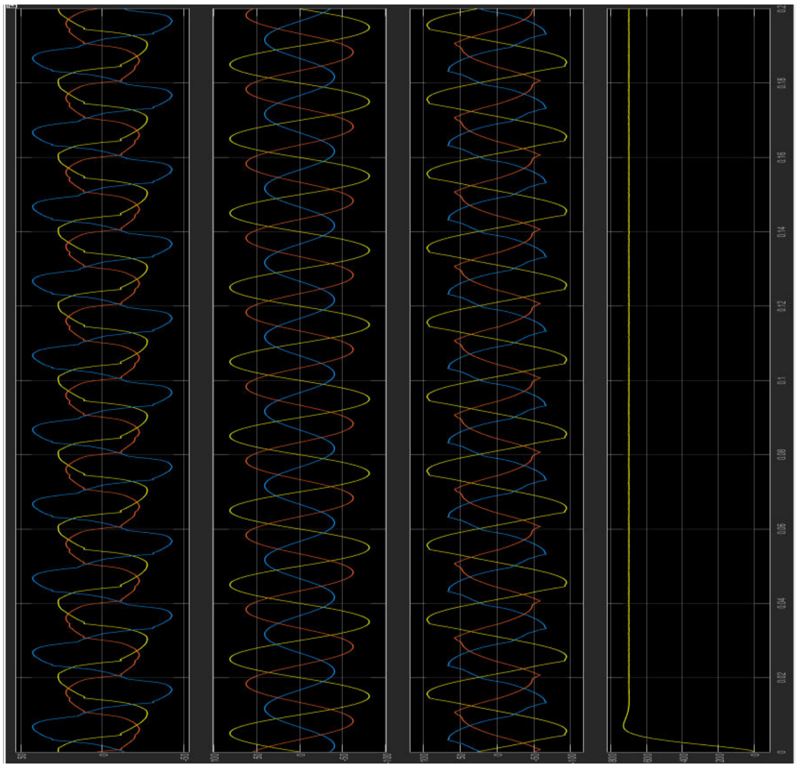

Figure .4 Non-linear unbalanced load

6. CONCLUSION

This paper presents a technique of Fuzzy logic based control statergy for PV-fed UPQC is presented here. The overall performance and efficiency of the system are investigated through simulation.The shunt compensator is working satisfactorily under suddenly varying load and load unbalanced conditions and makes the grid current sinusoidal by successfully compensating for load reactive power demand, load harmonics.series compensator effieciently compensates higher order harmonics in source voltage.The load terminal is maintained at the rated value by the series compensator under sudden variation in grid voltage level (sag and swell). Also, the series compensator successfully eliminates the harmonics presentin thr source side and prevents it from reaching to the load side.The performance of the proposed scheme is further enhanced by the incorporation of PV array.Burden on the grid is reduced due to the interconnection of pv array.Under load defict condition, PV array feeds extra generated power to the source.Under voltage swell, the performance of UPQC is improved.

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