POWER QUALITY IMPROVEMENT USING UPQC WITH DIFFERENT CONTROL TECHNIQUES

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Abstract:

Demand for power electronic devices is increasing day-by-day, whose performance is very sensitive to the quality of power supply. So, one of the major concerns in electricity industry today is power quality. The power quality problems include voltage sag, voltage swell, flickers, interruptions, harmonics and load unbalance etc. This paper presents the simulation of the unified power quality conditioner (UPQC) to mitigate voltage sag and voltage swell. The UPQC consists of series active power filter and shunt active power filter (APF), which are connected via a common dc link capacitor. This paper presents the simulation done to improve the power quality using different control techniques like PI controller and Fuzzy controller for compensation of voltage sag and voltage swell. The MATLAB/SIMULINK results of the two different controllers are compared and are presented.

Key words: Ben Okri, Nigeria, natural resources, forest, tradition, globalization, modernization,

INTRODUCTION:

Power quality is commonly defined as the power grid's ability to supply stable and clean power flow as a constantly available power supply. The flow of power should have a pure sinusoidal wave form and it should remain within specified voltage and frequency tolerances. Power quality (PQ) is most important term of any power delivery system today. Poor power quality may affect end consumers in terms of loss of production, damage of equipment, and also affects the overall performance of the power systems. Good power quality saves both energy and money, but this might not be the ideal case in real life. Using the non-linear loads (Ex: televisions, printing and fax machines, rectifiers, inverters, speed drives, AC, etc.) will degrade the power quality and will introduce harmonics into the lines due to excess use of these loads on daily basis which will lead to low power-factor, less efficiency, overheating of motors and many other issues such as voltage sag, voltage swell, interruptions, distortions and harmonics. Earlier passive filters tuned with LC components were used to improve the power quality by mitigating voltage and current harmonics. But due to the drawbacks such as high cost, resonance problems, large size, etc. these filters have become obsolete. The advanced alternative for these passive filters was active power filter (APF). A new technology called custom power (CP) emerged to mitigate the different power quality issues. One important CP device is Unified Power Quality Conditioner (UPQC) which compensates current and voltage related issues.

UPQC is one of the active power filters (APF) which contained series APF (used for solving only voltage harmonics problems like voltage sag, swell, flickering etc.) and shunt APF (used for solving only current harmonics problems and maintain DC link voltage at constant level). The series and shunt APF's are coupled together through the DC-link energy storage capacitor.

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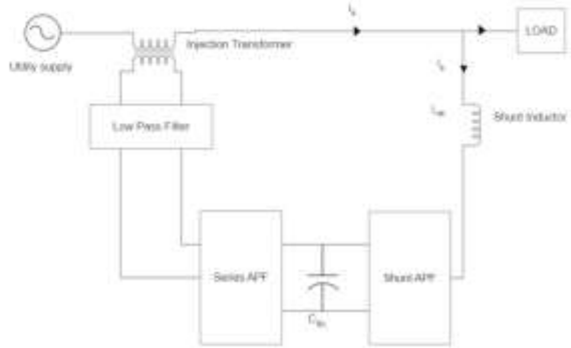

Fig. 1 Schematic Block Diagram Of UPQC

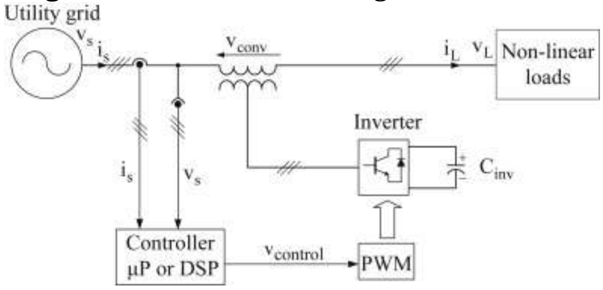

Fig. 2 Block Diagram Of Series APF

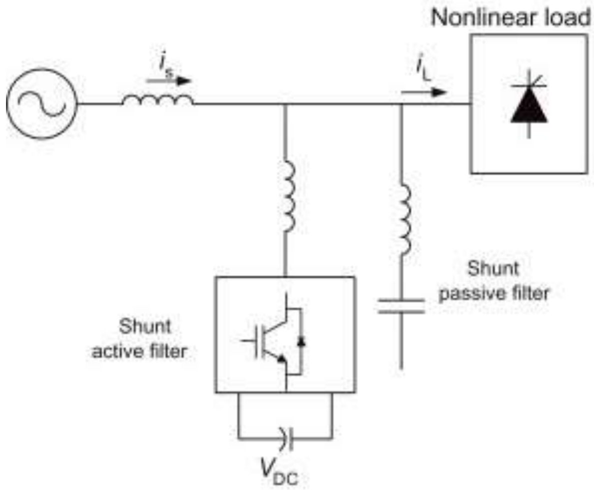

Fig. 3 Block Diagram Of Shunt APF

The Fig.1.0 shows the series APF is connected in series with utility supply voltage through a series injection three-phase transformer and a series low pass filter. The series APF compensates the supply voltage related problems by injecting voltage in series with line to achieve voltage without distortion at load terminal.

The series low pass filter is mainly used to filter out high frequency switching ripples on converter output voltage.

The shunt APF (with or without transformer) is connected to shunt inductor and in parallel with the non-linear load which helps in compensating load harmonic current and also maintains dc-link voltage at constant level. In order to mitigate the harmonics generated by non-linear load, shunt converter should inject a compensating harmonic current in order to have sinusoidal input current.

The shunt inductor is used to smoothen the current wave shape. The main objective of shunt APF is to inject a current which is equal in magnitude but in phase opposition to harmonic current.

The DC link capacitor is mainly used for two purposes. One, to maintain the dc voltage with a small ripple in the steady state, and it is used as an energy storage element to supply a real power difference between the source and load during the transient period.

VOLTAGE SAG:

Voltage sag is defined as the decrease in RMS voltage level by 10%-90% of nominal, at power frequency for duration of ½ cycle to one (1) minute (IEEE definition).

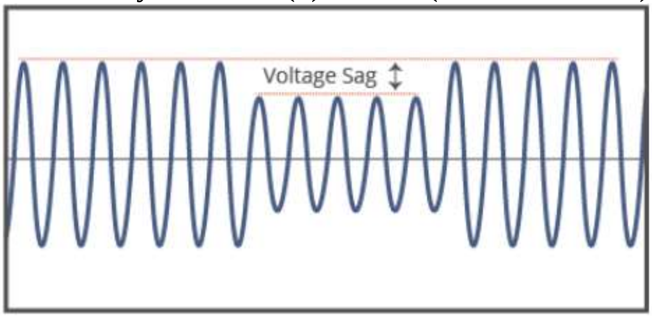

Fig. 3 Voltage Sag

The main reasons due to which the voltage sag needs to be mitigated are, relay getting tripped, loads malfunctioning, damage or failure of the equipment found at load end.

VOLTAGE SWELL:

Voltage swell is defined as the increase in RMS voltage level by 110%-180% of nominal, at power frequency for duration of ½ cycle to one (1) minute (IEEE definition).
The effects of voltage swell are similar to that of voltage sag.

Fig. 4 Voltage Swell

PHASE LOCKED LOOP:

Phase Locked Loop is used to generate reference currents and voltages (PLL). The extraction of Unit Vector Templates is used as the control strategy.
Reference currents and voltages are created BY utilizing the Phase Locked Loop (PLL). Unit Vector Templates are extracted from the distorted input supply as part of the control approach. These templates will then be compared to a pure sinusoidal signal with amplitude of unity (p.u.).

$$U_a = \sin(\omega t)$$
$$U_b = sin(\omega t - 120) \quad (1)$$
$$U_c = sin(\omega t + 120)$$

PCC, the 3-ph distorted input source voltage has both fundamental and distorted components. The input voltage is sensed and multiplied by gain equal to 1/Vm, where Vm is the peak amplitude of the basic input voltage, to obtain unit input voltage vectors Uabc.

$$V_{abc} = V_m * U_{abc} \quad (2)$$

CONTROL STRATEGIES:

The controllers that we are using to enhance the power quality improvement process are:

(i) PI controller
(ii) Fuzzy controller

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PI CONTROLLER:

The PI controller is a generic control loop feedback mechanism. The PI controller is used for regulating the voltage of DC link capacitor. The output of PI controller is applied to current control system of the shunt inverter, to maintain the DC capacitor voltage by drawing the required amount of active power from the grid.

PI controller contains two parameters, P which is proportional component and I which represents integral component. In order to obtain a desirable smooth waveform at the output, the switching frequency must be constant and should be independent of output frequency and this can be obtained by PI Control.

The proportional component determines the reaction to current error whereas integral component determines the reaction based on the sum of recent errors

The main aim of the proportional controller (P) is to generate an output proportional to error difference signal e(t).

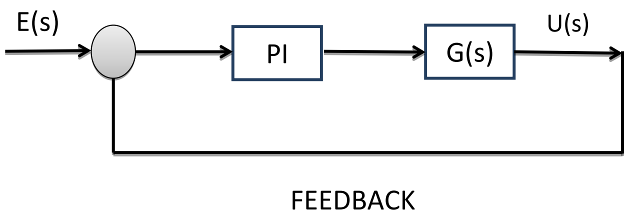

Fig. 5 Diagram of UPQC PI CONTROLLER

Integral controller is basically used to remove the steady error. Then the integral controller integrates the error value until the error value reaches zero.Usually PI controller does not reach Zero-error as it improves the system time constant, and hence makes the device produce unstable output.

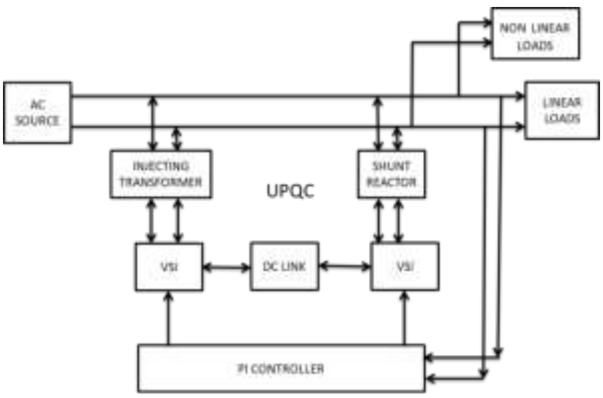

Fig. 6 Connection of UPQC to PI controller

FUZZY LOGIC CONTOLLER:

Fuzzy logic is the part of artificial intelligence or machine learning which interprets the human actions. Fuzzy logic theory is recognized as a qualitatively defined mathematical multivalued logic that employs artificial intelligence and probability theory to provide solutions to issues by simulating the human brain and then use probabilistic reasoning. The set of linguistic principles then explains the FLC, the basic control method. Those regulations are established by the system. The mathematical variables like numerical variables are converted into linguistic variables.

Fuzzy logic is a rule-based system. The rules of fuzzy logic are stored in knowledge base of system. The input given to the system is always a fuzzified scalar value.

The fuzzy logic controller basically has three parts:

(i) Fuzzification
(ii) Decision Making

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(iii)Defuzzification

FUZZIFICATION:

PS (Positive Small), PM (Positive Medium), PB (Positive Big), NB (Negative Big), NM (Negative Medium), NS (Negative Small), and ZE (Zero) are the seven fuzzy subsets used to give Membership function values to linguistic variables (Zero). Partition take the structure of the fuzzy subsets and the membership function up to the appropriate system.

DEFUZZIFICATION:

Using a Mamdani-type-inference system, input signal computation in a fuzzy control system is understood as a fuzzy singleton, with linguistic variables (input and output) presumed to be given as fuzzy variables. The assembly of indicator functions in the classical sets is known as a fuzzy membership function set. The membership functions determine fuzzy variables, which are subsequently characterized by their location, shape, width, or total overlap.

DECISION MAKING:

Several composition methods have been proposed in the literature, including Max-Min and Max-Dot. The Max-Min approach is employed in this work. The minimum and maximum operators determine the output membership function of each rule.

ANT COLONY:

The Ant Colony Optimization (ACO) method is basically a system of agents that imitate natural behavior of ants, including cooperation and adaptability processes. It's made to mimic ant colonies' abilities to figure out the fastest routes to food. Real ants may use pheromone information to communicate without utilizing visual sign and can discover the quickest path between food sources and their nests. While walking, the ant deposits pheromone on the trail and other ants follow the pheromone trails with a probability proportional to the pheromone density. Ants will finally locate the shortest path using this approach. Artificial ants follow the way used by actual ants seek for food, but they can solve a lot of problems.

The following concepts underpin ACO algorithms:

(i) Each path taken by an ant corresponds to a potential solution to a particular problem.

(ii) The amount of pheromone deposited on a path is proportional to the quality of the related candidate solution for the target issue when an ant pursues it.

(iii) When an ant is forced to pick between two or more pathways, the path(s) with the most pheromone have a higher chance of being chosen.

This method is simple and only has a very few stages for discovering difficult solutions in even the most complicated domains. The fuzzy membership functions for UPQC control are found using ACO.

SIMULATION RESULTS:

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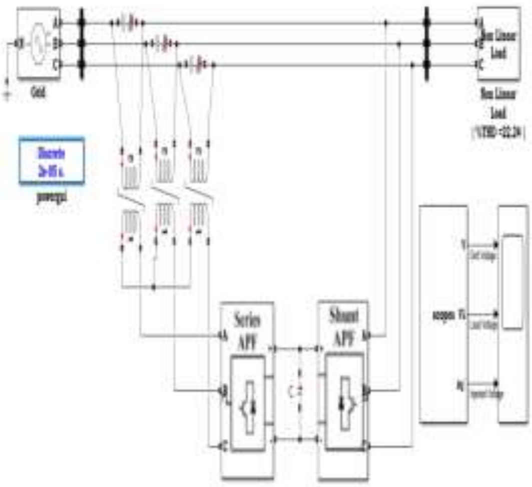

Fig. 7 Simulation of UPQC

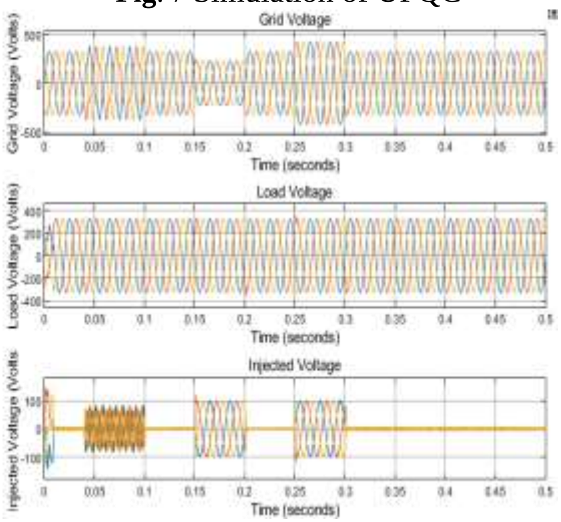

Fig. 8 Load voltage compensation with FUZZY Controller

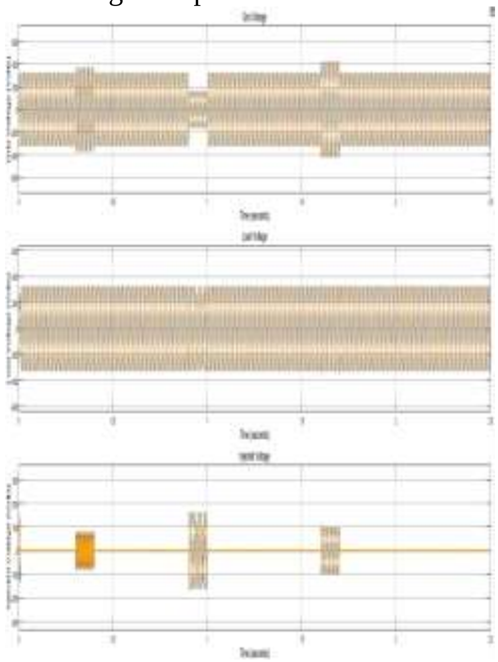

Fig. 9 Compensation of load voltage with PI Controller

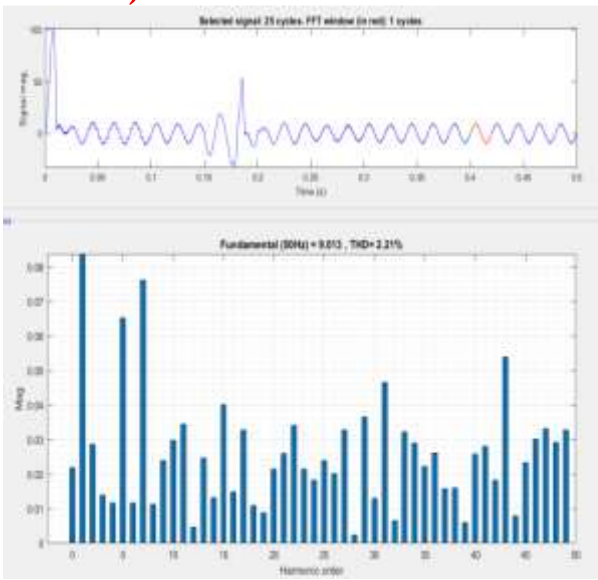

Fig. 10 THD for PI Controller

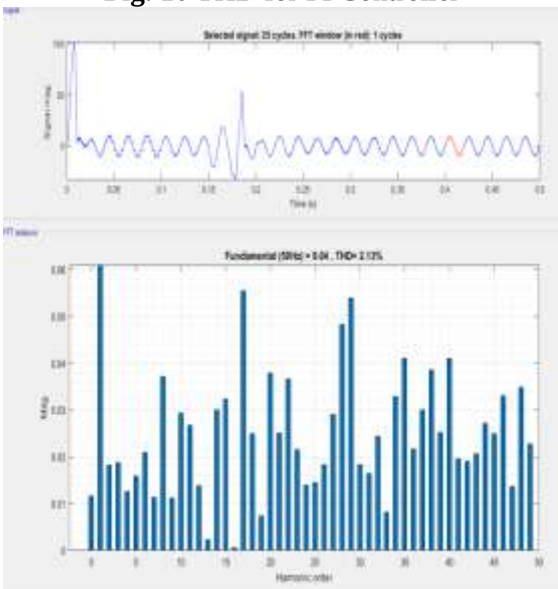

Fig. 11 THD for FUZZY Controller

PARAMETERS OF THE SIMULATION SYSTEM:

S.No	Components		Parameters
1	Grid Side	Voltage	400V
2		Frequency	50Hz
3		DC Link Capacitor	100 µF
4		Amplitude values(in p.u) in PI controller	[1 0.5 1 1.3 1]
5		Amplitude values (in p.u) in Fuzzy controller	[1 0.7 1 1.3 1]
6	Load Side	Diode Resistance	0.001Ω
7		Forward voltage	0.8V
8		Load resistance	0.4Ω
9		Load inductance	15mH

COMPARISION OF PI AND FUZZY CONTROLLER:

S.No	PARAMETERS	PI Controller	FUZZY Controller
1	Voltage Sag	Voltage sag is not mitigated for <0.5 p.u	Voltage sag is not mitigated for <0.6 p.u
2	Voltage Swell	By increasing the value of	By increasing the value of voltage

		voltage swell small disturbances are occurring during mitigation	swell to >1.6 p.u small disturbances are occurring during mitigation
3	THD	2.21%	2.13%

Note:

1) These values are considered with a reference of 1 p.u
2) The THD percentage of nonlinear load is 22.4%

CONCLUSION:

This paper provides a control method based on PI and Fuzzy Logic that is utilized in the UPQC to correct voltage and current harmonics, under non-ideal mains voltage and unbalanced load-current circumstances. There are problems related to sag, swell, and harmonic distortion without UPQC. We can address this issue with the usage of PI control and fuzzy logic controller. These techniques are advocated in the UPQC system to address this difficulty. The simulation results shows that, sag, swell and harmonics power distortion under fault conditions. The PI control eliminates the impact of distortion on supply voltage and unbalances of load current on the power line, restoring power factor unity. The Fuzzy controller is used for the same purpose. Meanwhile, in unbalanced and distorted load conditions, the series APF isolates the loads and source voltage; while the shunt APF compensates reactive power and delivers three-phase balanced and rated currents for the mains. Simulation results generated using Matlab/Simulink software to efficiently minimize power quality problems through the use of an appropriate UPQC PI controller.

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