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Genetic Algorithm Optimizing Technique for Power Quality Enhancement

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ABSTRACT

Unified Power Quality Control commonly known as UPQC can be a better option to mitigate the power quality issues like voltage & current abnormalities on the demand side. UPQC is a combination device that contains two voltage source converters connected with a DC link. Moving towards sustainable development, a classic architecture of the UPQC with PV Arrays as a renewable energy resource is considered using MATLAB/SIMULINK software. The results were optimized using Genetic Algorithm Optimizing Technique. GA is one of the soft computing techniques that helped to enhance the power quality of the system containing transient supply for variable speed drives.

Keywords- UPQC, Shunt and Series Active Filters, PV Arrays, Soft computing Techniques & Genetic Algorithm.

I.INTRODUCTION

These days, advanced power electronic devices have many uses in the home, workplace, and marketplace. Power converters, variable-speed drives, and cyclo-converters all affect the quality of electric power as they draw distorted currents waveform from the source. Poor power factor, with reduced efficiency, sensitive electronics malfunctions, increase in losses of transformer, and so on are all consequences of quality degradation [1]. Moreover, distribution systems frequently experience an uneven load. In a 3P-4W distribution system, this results in an excess of neutral current. So a new measure of success for power distribution utilities in the current trend toward deregulation is the quality of the power that can be provided to customers.

In the past, people used passive filters to reduce harmonics. But because passive filters have problems like static compensation, resonating source impedance, tuning issues, and filter parameters changing over time [2–4], active and hybrid filters became necessary. Existing Distribution Systems have serious power related issues, like reactive power compensation, low power factor, unbalanced loads, abnormalities in voltage and current, such as voltage sag , swell and overcurrent. You can use these active and hybrid filters to address specific power quality issues.

Recently a technology named bespoke power arose with the aiming of improving the distribution systems' power supply dependability and quality [5–6]. The types of custom power devices that are used to make up for power losses are mostly UPQC [11–13], DVRs [9–10], and static shunt compensators, also known as D-STATCOMs [7-8]. In order to reduce distortions caused by current, the DSTATCOM is a shunt device; in contrast, the DVR is a series device that is used to reduce the distortions caused by voltage. Thus, an UPQC is a device that includes a sequencing of APFs and a connection of common DC link voltage between them. The shunt inverter adjusts the load current to mitigate the adverse effects of harmonic content, imbalances, and reactive components on power systems. If the source voltage has harmonic or asymmetrical components, flicker, sag, or swelling, the series APF can compensate.

The article focuses on integrating UPQC into the distribution system using multiple PV arrays. UPQC often employs two voltage-source converters. Harmonic mitigation in between transmission and distribution systems is the main function of a series converter. The series converter can additionally regulate voltage and adjust for harmonics at the utility-consumer PCC; it can also compensate for voltage flicker and imbalance. On the other hand, the shunt converter's main job is to manage the dc-link voltage between the two converters, smooth out the current, and fix problems with reactive power and negative sequence current [14]. However, without energy storage, UPQC is unable to compensate for power interruptions. In this work, we present an alternative setup for UPQC.

Fig. 1 illustrates the proposed system's topology. A DC link goes to the Battery Energy Storage System (BESS), which then goes to the MISO, which is a DC-DC converter, as well as the two UPQC converters. For periods of insufficient solar radiation, such as at night or on overcast days, the BESS maintains the battery voltage. Simultaneously the photovoltaic panels continuously charge the BESS throughout the day. In this section, we will go over each part of the proposed system. The next sections will provide a concise overview of the different parts of the proposed system.

II.PROPOSED UPQC SYSTEM

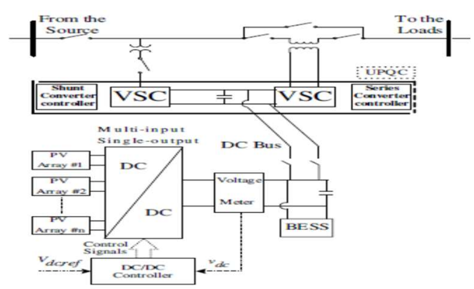


Figure.1 UPQC System to be considered.

III. UPQC CONNECTED WITH MORE THAN ONE PV ARRAY:

Several recent studies have concentrated on the connection of distributed generators with the grid using shunt active filters, a topic that has gained significant attention. This context places greater emphasis on grid interface shunt inverters, as DGs are less susceptible to grid factors. A novel UPQC architecture with Photovoltaic arrays with battery energy storage system is considered here. We link boost converters in series to connect the inputs of the photovoltaic array components (Vpv1, Vpv2, Vpv3, and Vpvn) with DC bus. The voltage source inverter at output side takes the DC-DC converter's single output and turns it into AC power for the distribution system. We can manage the solar array parts' power flow and output voltage by varying the triggering cycles of the nth switches (Spv1, Spv2, Spv3, and Spvn) These switches are designed using IGBT. The model used here consists of three PV arrays as multi-inputs to DC-DC Boost converter.[15–19]IV.DC-DC converter with more than two inputs

Since the converter absorbs power from the photovoltaic array, it must meet the standards of the array's ripple current and avoid injecting any negative current. To get a higher, more regulated output voltage, the novel DC-DC converter is helpful to integrate many DG sources that vary in capacities for power and/or voltage levels [14]. Fig. 3 depicts the converter configuration that combines the DC voltages of photovoltaic array units. The output voltage of this Boost converter, Vdc, is represented as shown in (1).

$$V_{dc} = V_{dc1} + V_{dc2} + V_{dc3} + \ldots\ldots + V_{dcn}$$

$$= \frac{V_{pv1}}{1-D_{pv}} + \frac{V_{pv2}}{1-D_{pv2}} + \frac{V_{pv3}}{1-D_{pv3}} + \ldots\ldots\ldots + \frac{V_{pvn}}{1-D_{pvn}} \quad (1)$$

Where

Duty cycles of boost converters are: D_{pv1}, D_{pv2}, D_{pv3} and D_{pvn} & Output voltages of boost converters are: V_{dc1}, V_{dc2}, V_{dc3} and V_{dcn}

INow consider the converter with equal number of inputs and duty cycles and their inputs then,

Output voltage of this DC-DC converter, i.e., V_{dc}, can be derived as;

$$V_{dc} = \frac{n}{1-D_{pv}} V_{pv} \quad (2)$$

Where

V_{dc} is the output voltage of MSO converters; D_{pv} represents duty cycle of one boost converters; V_{pv} is the low input voltage of each photovoltaic array unit having very low value.

The value of capacitor of each boost converter is given by C:

$$C = \frac{n^2}{(1-D_{pv})} \frac{V_{pv}}{Rf\Delta V_{pv}} \quad (3)$$

Where

f_s represents switching frequency, ; *Equivalent load resistance is R* and ΔV_{dc} is the output ripple voltage of converter. Numerical Value of the inductor in each boost converter is calculated using following equation (4):

$$L = \frac{(1-D_{pv})^2 D_{pv} R}{2nf_s} \quad (4)$$

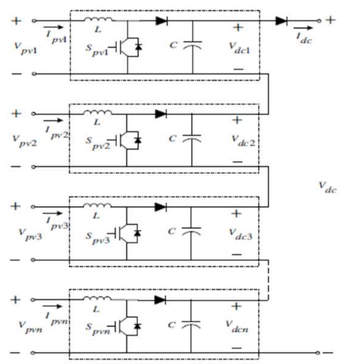


Figure3. TISO DC - DC Converter

A PI-controller receives an error signal based on a comparison of the output voltage of this DC-DC converter to a reference value. This controller's output signal adjusts the duty cycle through a single input of pulse width modulation (PWM). This work provides an example of the construction and study of a specific TISO DC-DC converter.

V. CONTROLLING SCHEME USED IN THE SYSTEM

The proposed system's control is using the principle of theory of instantaneous power. This strategy incorporates photovoltaic (PV) energy resource, which powers loads, maintains the DC link voltage, and executes other conditional tasks. The theory is based on the definition of a well-known transfer matrix. The three-axis parameters are reduced to two axes. We can break down different components of the real(active) and imaginary (reactive) power at the desired instant into DC and AC harmonic components, respectively. The alternating current distorted components are composed of a negative sequence component and a harmonic component.

When used on 3P-4W networks, suggested method should fully make up for power p0. More real power component needs to be injected from the supply because 0-sequence power is not capable to give a continuous direct current component unless and until it is related with AC component.

$$P = \bar{p} + \tilde{p}$$
$$Q = \bar{q} + \tilde{q}$$
$$p_0 = \bar{p}_0 + \tilde{p}_0 \quad (5)$$

$p_{control} = p_0 + \tilde{p}$ $\quad\quad q_{control} = \bar{q} + \tilde{q}$ (6)

Where:

P is active power ; $p_0$represents active power with zero sequence. ; $\tilde{p}$ is AC harmonic component of active power with negative sequence.

Q is reactive power; $\bar{q}$ is reactive power with direct component.; $\tilde{q}$ is another reactive power component containing reactive component with some harmonics.

When both the inverters are used at the same time for reactive harmonic component compensation & negative harmonic compensation, the α-β axes for current reference & voltage reference are represented as the equations given below respectively:

$$\begin{bmatrix} i^*_{c_\alpha} \\ i^*_{c_\beta} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} -p_{control} \\ -q_{control} \end{bmatrix} \quad (7)$$

$$\begin{bmatrix} v^*_{c_\alpha} \\ v^*_{c_\beta} \end{bmatrix} = \frac{1}{i_\alpha^2 + i_\beta^2} \begin{bmatrix} i_\alpha & -i_\beta \\ i_\beta & i_\alpha \end{bmatrix} \begin{bmatrix} -p_{control} \\ -q_{control} \end{bmatrix} \quad (8)$$

When using the proposed shunt converter to control battery charging, active reactive power control becomes critical. The system under consideration meets the output's compensatory needs, such as negative and sinusoidal compensation. The equation given provides the value of reference current along the α-β axis is given as (9).

$$\begin{bmatrix} i^*_{c_\alpha} \\ i^*_{c_\beta} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p_{control} + p_{pv} \\ q_{control} \end{bmatrix} \quad (9)$$

Where, P_{pv}: PV represents delivered power to loads by parallel converter.

Parameters like size of load and transformer turns ratio heavily influence the design of the filters. So it is considered that the reactive power compensation and current harmonic mitigation with solely series converters is quite challenging.

VI. Techniques Used to optimized the output:-

Optimization means tuning of controller parameters to appropriate values. In control systems,many methods are available for tuning of PI controller. The main purpose of every optimization technique is to minimize the lengthy calculations and time of conversion to get output with higher accuracy. This can be achieved using different methods as per the load side requirement. Normally, an optimization algorithm is applied through an objective function which is to be minimize or maximize is used. Shunt and Series Active Filter are utilizing PI controller for proportional value conversion from voltage to current or vice versa. The value of THD is taken as mean and utilized. Different Optimization Techniques for PI controller tuning are Particle Swarm Optimization (PSO), Gravitational Search Algorithm (GSA),Genetic Algorithm (GA) and many more. Here we will be discussing the use of GA Optimizing technique for PI controller tuning.

VI. Genetic Algorithm:-

To find the optimal solution on a global scale, genetic algorithms rely on three stages of evolution: crossover, reproduction, and mutation. At the outset, the algorithm does not know the exact solution. There are two parts to a genetic algorithm. A genetic algorithm considers both the encoding technique and the evaluation function. Every genetic evaluation cycle produces a new generation from the chromosomes of the reference population. After that, we employ the encoding system to provide potential solutions to the problems.

This work achieves two main objectives through the implementation of GA. This work aims to identify the optimal Kp and Ki settings for the SAPF PI controllers. As a fitness function for GA optimization.

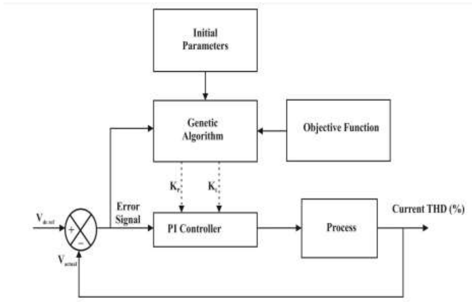


TABLE I
OPTIMIZATION PARAMETER OF THE GA

Parameters	
Objective Function	Mean (THD) in %
No of Iterations	50
No of variables	04
Population Size	20
Number of generations	20
Mutation type	Uniform mutation
Execution Time	57195.3652 seconds

GA based PI controller tuning circuit & optimization parameters

VII. TEST SYSTEM SINGLE LINE DIAGRAM

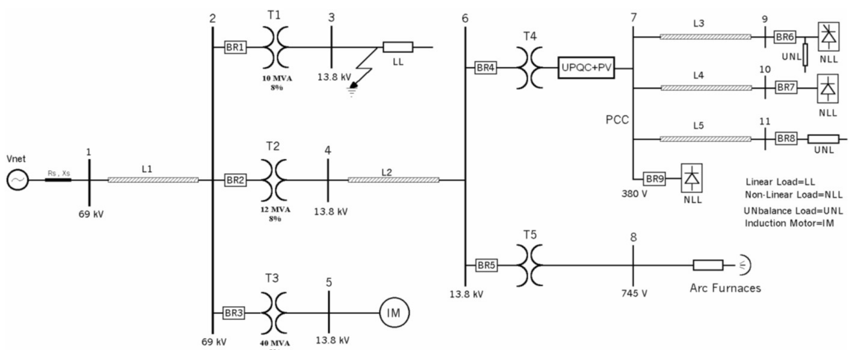


Figure 4. UPQC connected at PCC in single line test diagram

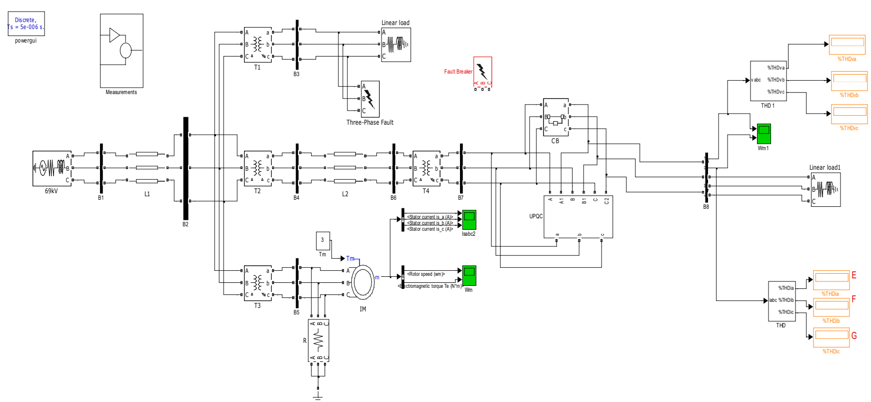
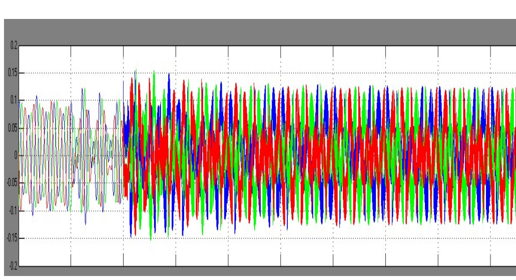


Figure 5.Test system under consideration

VII. Simulation results of the Test System

Following section shows the comparative analysis of SIMULINK model of the test system with floating THDs. FFT Analysis during simulation of the system was also considered under three conditions as mentioned: Without UPQC ; With UPQC and UPQC with Optimized PI controller using GA Optimization Technique



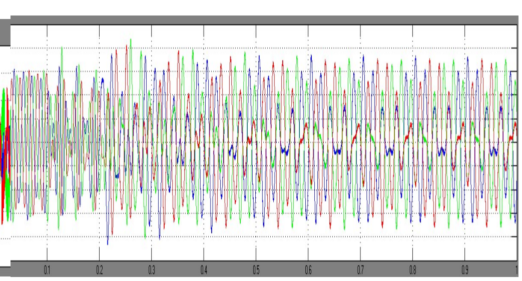
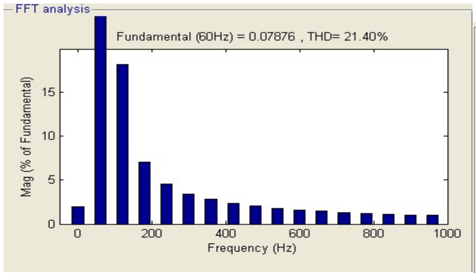


Figure 7.Test System output without UPQC Figure 8.Test System output with UPQC



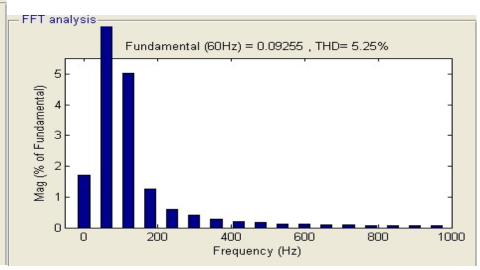


Figure 9.Test system without UPQC (FFT Analysis) Figure 10. Test system with UPQC (FFT Analysis)

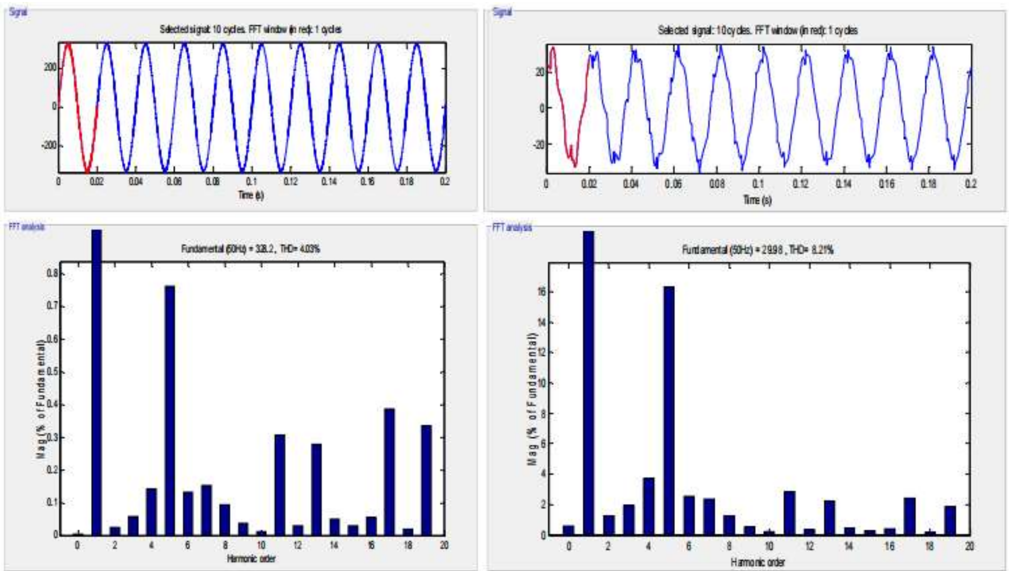


Figure 10. FFT Analysis of system for Voltage and Current for UPQC with optimized PI controller using Genetic Algorithm.

VIII. CONCLUSION

Here, we propose the UPQC model with a TISO DC converter on the output side of the distribution transformer in the test system. This section demonstrates the potency of the UPQC. Test system has reduced its THD level from 21.40% to 5.25%. We analyzed the proposed system's performance using MATLAB SIMULINK simulations, validated by the enhancement in the power quality of the VSD loads. This paper proposes a classic UPQC model connected to multiple PV arrays with a MISO DC DC converter on the secondary side. Results obtained show the effectiveness of UPQC with PI controllers and optimized PI controllers using genetic algorithms.THD of the test system under consideration has decreased from 21.40% without UPQC connected in the system at PCC to 5.25% with UPQC and a normal PI controller. Connecting an optimized PI controller using GA again reduces this level from 5.25% to 4.03%.

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