Transient Stability Improvement Using UPQC

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1. Abstract

This paper deals with the improvement of transient stability using unified power quality conditioner (UPQC). The main purpose of a UPQC is to compensate for voltage imbalance, reactive power, negative-sequence current and harmonics. This paper discusses the improvement in the transient stability when a UPQC is used in detail. Experimental results obtained on a MATLAB simulation model are shown to verify the viability and effectiveness of the UPQC.

2. Introduction

The steady-state operation of multi-terminal unified power flow controller is performed in (Mwinyiwiwa, 2000). The M-UPFC has been implemented as it has an advantage over UPFC of high level of service. The operation of M- UPFC is demonstrated experimentally by a laboratory model. Ref. (Orfanogianni, 2003). focuses the use of power semiconductor technology to increase network load-ability. The steady state problem can be easily handled with the use of semiconductor based controller as they have fast response. Hydro- Quebec network is analyzed for its steady state performance due to the effect of various types of FACTS devices in (Ghahremani, 2014).

A genetic algorithm based optimization method is used to find the optimal location and values for various types of FACTS devices. The performance of the network is analyzed with and without facts devices. Results show that UPFC is the most efficient FACTS device in case when increase in network load-ability and reduce network losses are required. The effect of UPFC on a longitudinal system for the enhancement of its transient stability is analyzed in (Mihalic, 1996). A mathematical model is developed to describe the interdependence of longitudinal system parameters and operating condition with UPFC. Ref. (Fujita, 2001) told about transient flow of power in UPFC experimentally as well as theoretically. This paper shows that the outflow of active power from series device of UPFC is stored as line inductance in transient states. In order to improve the stability, (Gholipour, 2005) has designed a model of UPFC for reference identification of series part based on state variables. Here, the UPFC is connected to an infinite bus and as such control of voltage magnitude is neglected. By modulating the active and reactive powers a vast improvement in the first swing transient stability is obtained.

An H∞ scheme is applied to a single-neuron radial basis function neural network in order to design the control strategy of UPFC (Mishra, 2006). This type of controller of UPFC is providing improvement in transient stability over a broad range of operating conditions. The dynamic analysis of power system incorporating UPFC is shown in (Arabi, 2000). In this paper, UPFC is introduced using auxiliary capacitor. This design of UPFC provides smooth transition and fast convergence to ideal voltage source injection. Different control models of UPFC are developed for the stability simulation. Ref. (Ramirez, 2002) presents a technique to enhance the dynamic behavior as well as to estimate the PSS and FDS parameters. The effectiveness of the technique is examined by simulation on a three machine power system with UPFC. Results are a clear evidence of improvement in the dynamic behavior of the system.

3. Simulation model

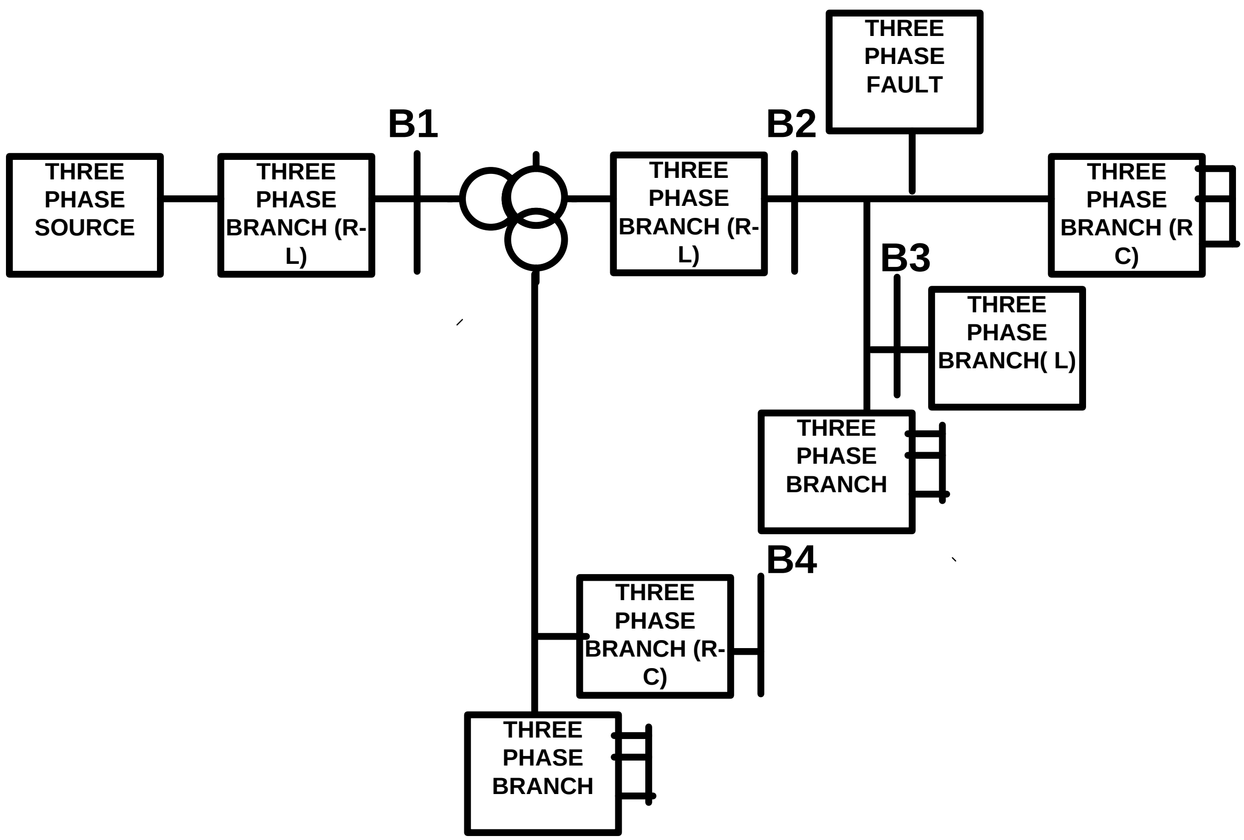

Figure 1: 3-phase system without unified power quality conditioner (UPQC)

As per figure shows in left hand side the supply voltage to Linear and non-linear IAD the two inverters are connected series APF & Shunt APF, so basically series APF is used to fed the AC voltage when the voltage swell sag was found in the utility grid, so that time inverter will provide the voltage and the waveforms are shown in the figure sag voltage now the shunt APF inverter is used when the current improvement is required due to non linear load current is distorted, and Shunt inverter will feed the current into grid. Waveform are shown as the results. Shunt APF removes all sorts of current issues such as current harmonic compensation, power factor enhancement , reactive power compensation. Series APF compensates for the voltage dip/rise such that the voltage at load side is regulated perfectly. The Shunt APF is connected in parallel\ manner with transmission line and series APF is connected in series with transmission line. UPQC is a formation of both series APF and shunt APF combined and connected back to back on DC side.

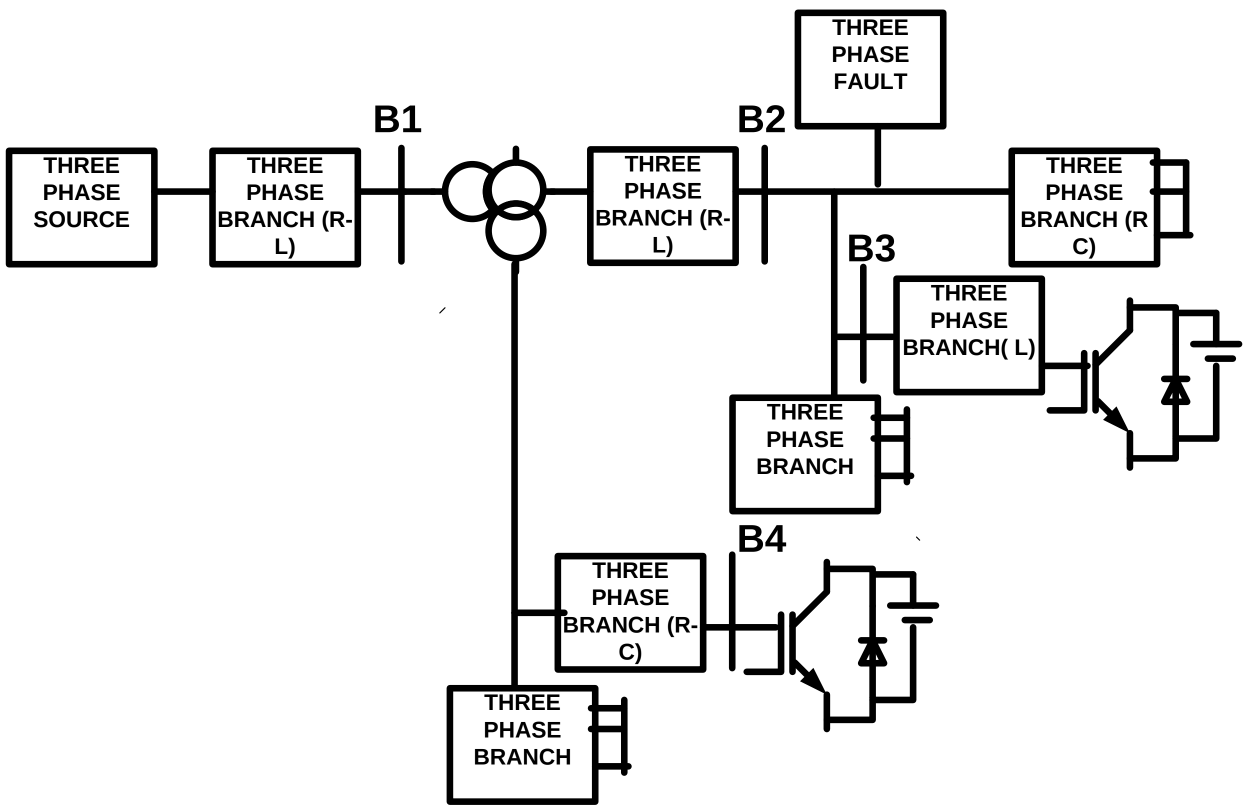

Figure 2: 3-phase system with unified power quality conditioner (UPQC)

UPQC is used to remove any problems arising due to current harmonics and voltage unbalances & distortions. It also improves the power quality of a system. UPQC is an adaptable device as it mitigates the problem of both current and voltage harmonics. In this study, power quality of system was improved by the use of UPQC.

Shunt APF is connected in parallel to transmission line to compensate for load current harmonics and to make source current completely sinusoidal and free from any harmonics or distortions. Series APF is connected in series with transmission line to alleviate the voltage distortions and unbalance which is present in the supply side and to make the voltage at load side perfectly balanced, regulated and sinusoidal. UPQC is made of two voltage source inverters connected back to back through a DC link capacitor in a single phase, three phase-three wire, three phase-four wire configuration. The inverter in shunt APF is controlled as a variable current source inverter and in series APF is controlled as a variable voltage source inverter.

Unified Power Quality Conditioner is made of shunt &series converter as described. The Series converter is used to overcome voltage fluctuations i-e Sag, Swell or flickers. It compensates the voltage to the desired magnitude taking distribution voltage as reference voltage. Series converter supplies a smooth voltage to the load and improves power quality of the systems. Dc source voltage is the capacitor and at the output of the inverter inductor connects the grid with the inverter. Shunt converter deals with Power Quality problems related to current generated by power customers having low Power Factor, unbalanced load, harmonic currents etc. it insert current equal in magnitude with the harmonic currents but out of phase (180 Degree) with the harmonic current but remains in phase with grid voltage. Shunt converter injects current on the main line, when large scale current is drawn by the Nonlinear Load. During the fault shunt inverter draws current from the Capacitor bank which is charged during the normal conditions. Inductor acts as first order filter. It improves the power quality and removes harmonics introduced by the nonlinear load.

Transformer implemented to inject the compensation voltages and currents, and for the purpose of electrical isolation of UPQC converters. The UPQC is capable of steady-state and dynamic series and/or shunt active and reactive power compensations at fundamental and harmonic frequencies. However, the UPQC main function is to protect sensitive devices which demand high power quality for operation. Transformers are used in series and shunt configuration to provide isolation to the system. They also provide gain to the duty cycle due to which it is possible to get great voltage from small voltage or small voltage from great voltage. However, UQPC is responsible for improving power quality and removing harmonics form the supply voltage and from the load side. Transformers lower the efficiency of the system however; UPQC is not concerned about this efficiency.

We take two cases, one with the UPQC connected and one where the UPQC is not connected. This is done to verify that the UPQC improves the transient stability of the circuit.

4. Simulation Results

(a) WITHOUT UPQC

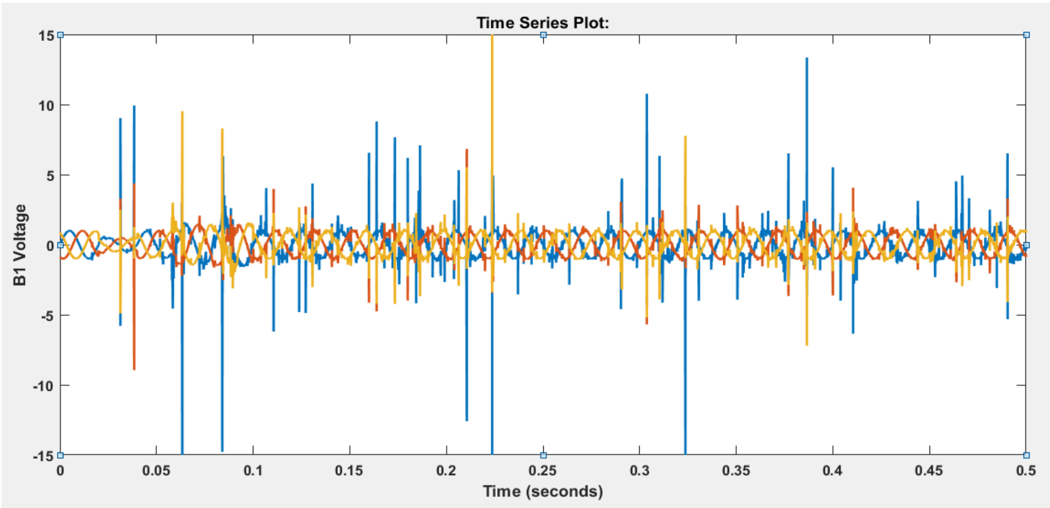

Figure 3: The voltage in Bus 1 vs Time when UPQC is not connected

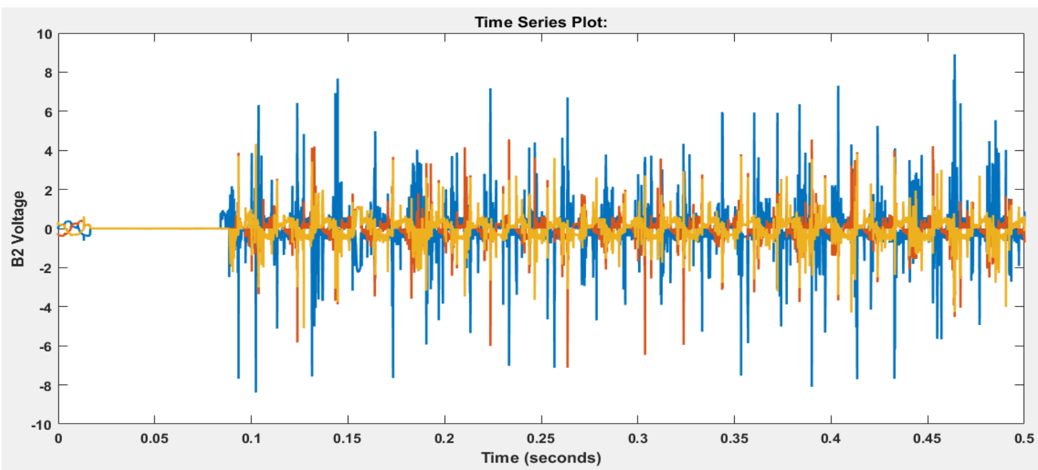

Figure 4: The voltage in Bus 2 vs Time when UPQC is not connected

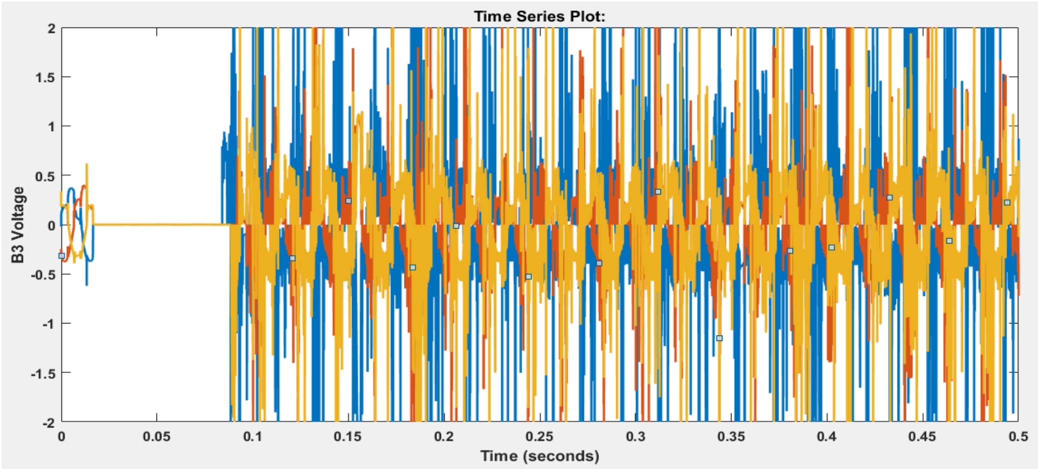

Figure 5: The voltage in Bus 3 vs Time when UPQC is not connected

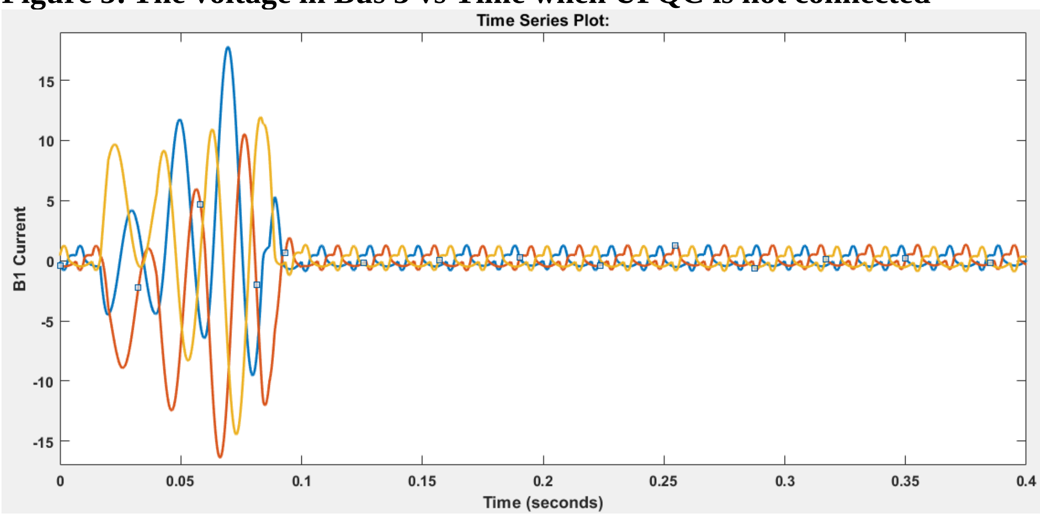

Figure 6: The current in Bus 1 vs Time when UPQC is not connected

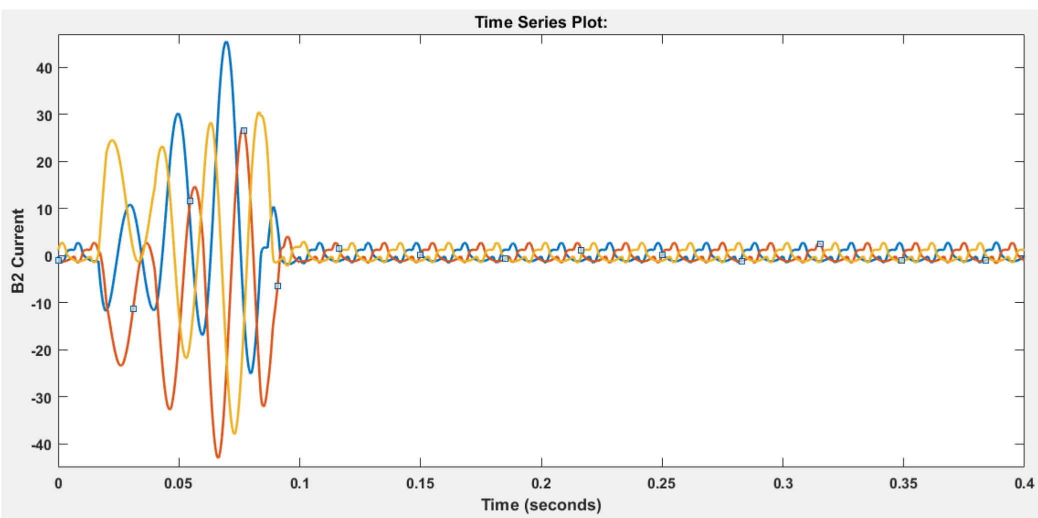

Figure 7: The current in Bus 2 vs Time when UPQC is not connected

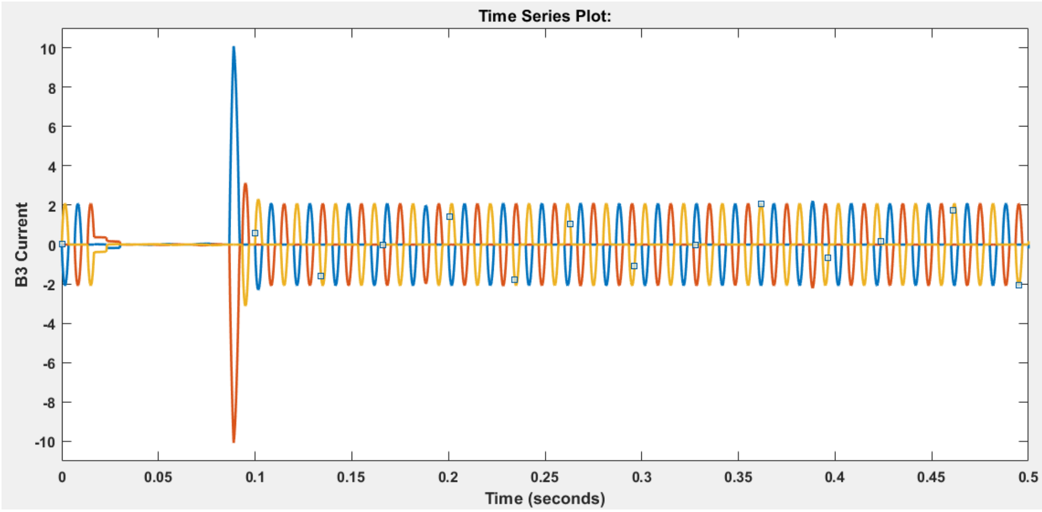

Figure 8: The current in Bus 3 vs Time when UPQC is not connected

Under normal conditions when UPQC is disconnected from supply, the reactive power is supplied from the main source completely. But when UPQC is connected with the system then the reactive power is supplied through the Shunt APF. Shunt APF provides reactive power to the load and there is no burden on main supply. Series APF has no relation with reactive power demand of load. The main causes for distortion in a system are harmonics, notching, and inter harmonics.

Distortion is that the fundamental frequency sine wave is represented as super position of all harmonic frequency sine waves on fundamental sine wave. The problems because of which distortion occur might be uninterrupted power supply, flicker, harmonics, voltage fluctuations e.t.c. There could also be PQ problems such as voltage rise/dip due to network faults, lightning, switching of capacitor banks. With the excessive uses of non-linear load (computer, lasers, printers, rectifiers) there is reactive power disturbances and harmonics in this system.

The above results show the waveforms when the UPQC is not connected. It can be seen that the waveforms are highly distorted and fluctuating, they do not follow a stable path. Voltages in B1, B2 and B3 fluctuate from very low to very high voltages. This is not a good sign as the voltages are not stable and therefore cannot be used in any beneficial manner. These voltages and currents as such without a UPQC are seen to be highly distorted and hence not useful. To solve this problem UPQCs are connected to the circuit and the results are shown below.

(b) WITH UPQC

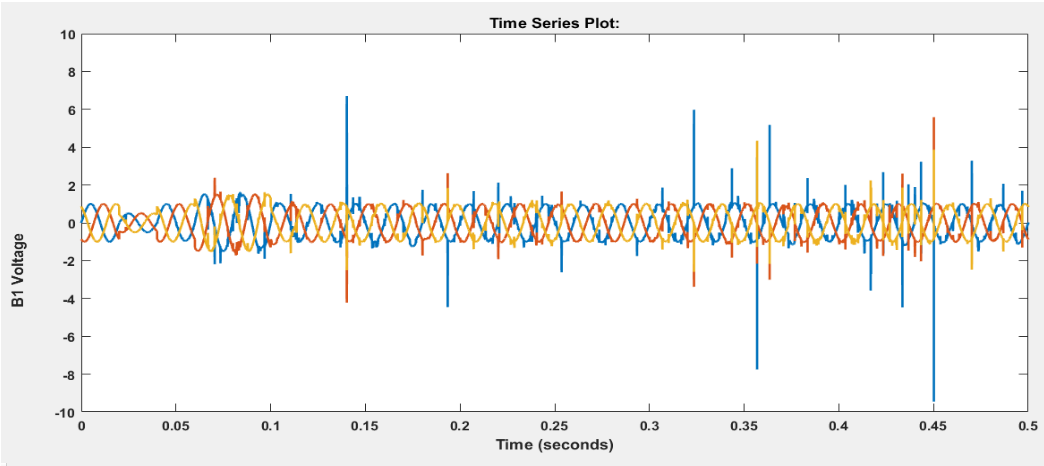

Figure 9 : The voltage in Bus 1 vs Time when UPQC is connected

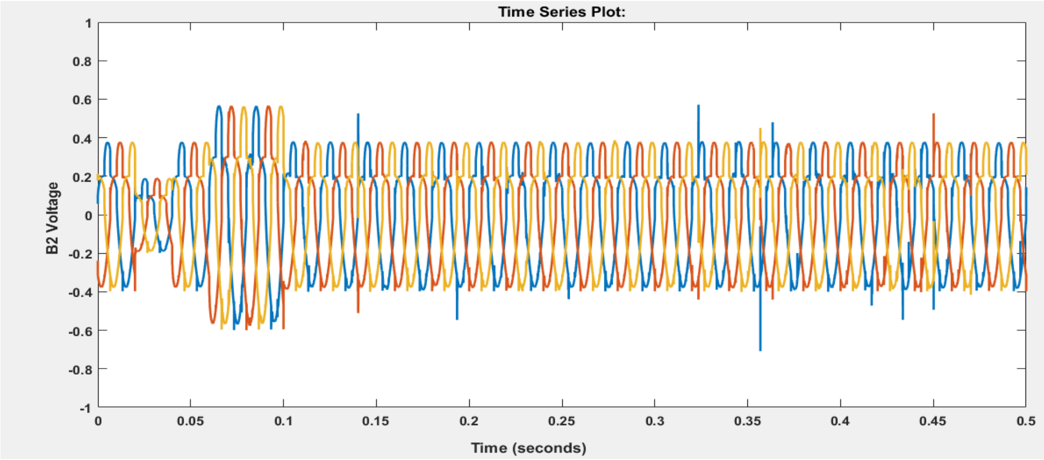

Figure 10: The voltage in Bus 2 vs Time when UPQC is connected

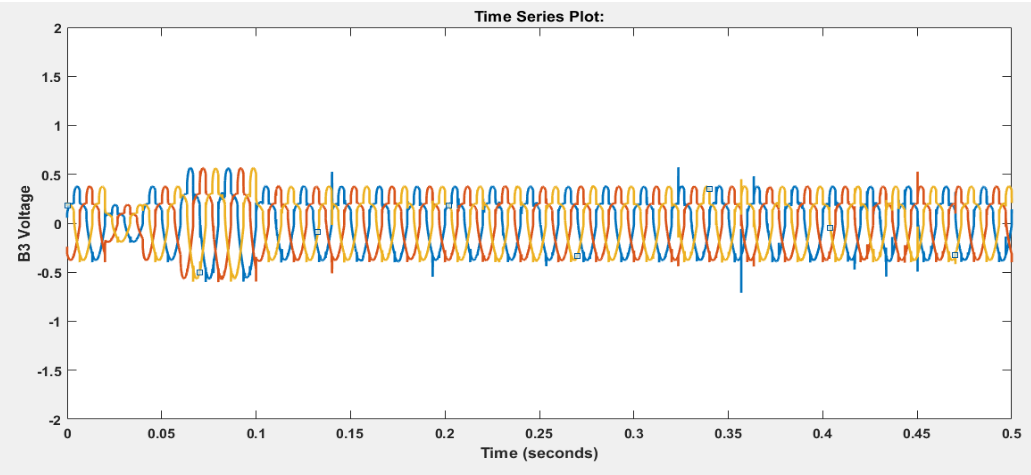

Figure 11: The voltage in Bus 3 vs Time when UPQC is connected

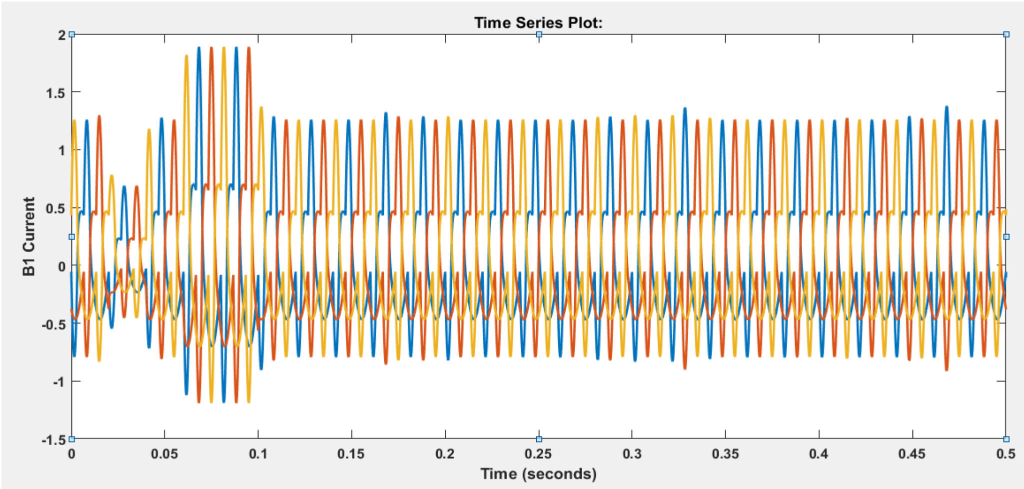

Figure 12: The current in Bus 1 vs Time when UPQC is connected

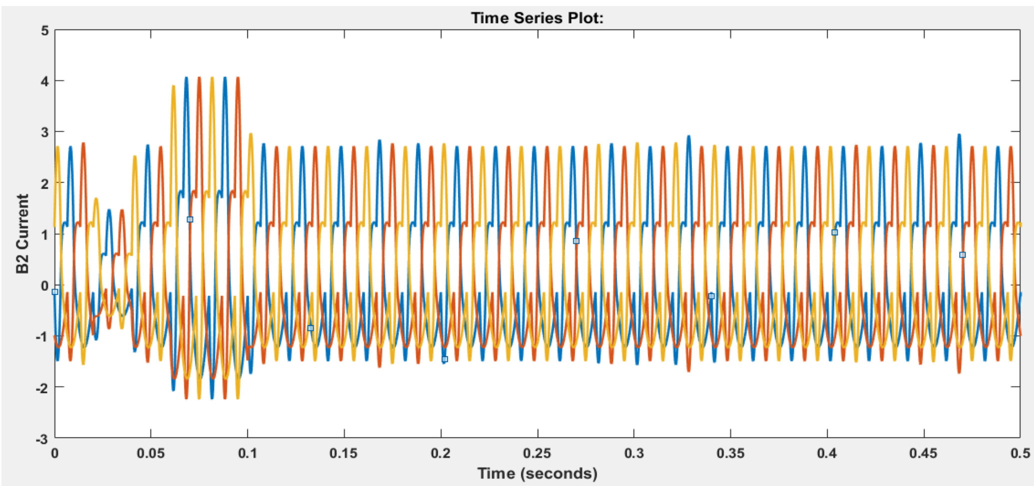

Figure 13: The current in Bus 2 vs Time when UPQC is connected

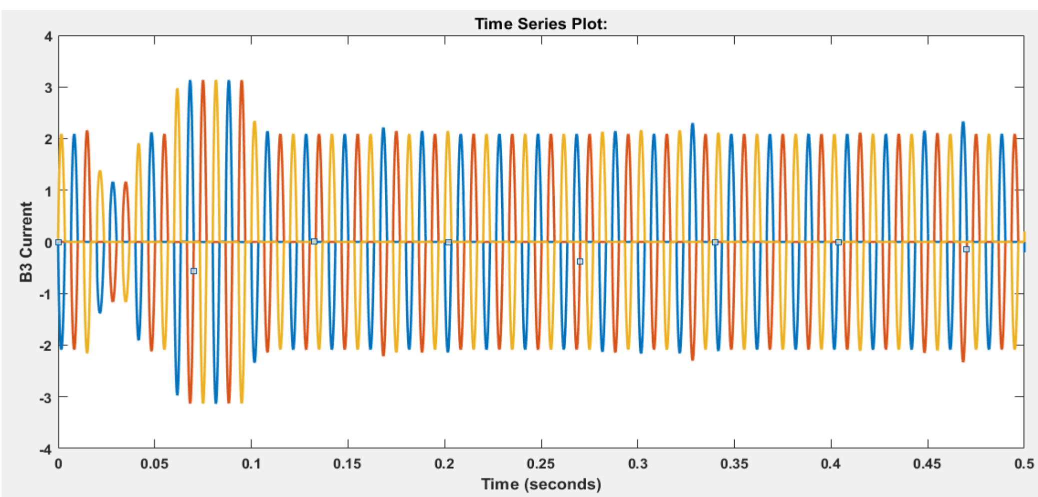

Figure 14: The current in Bus 3 vs Time when UPQC is connected

A power distribution system contains unbalance, distortion and even DC components because of the power electronic devices due to their non-linear behavior draw harmonics and reactive power from the supply source. In three phase systems, they cause unbalance and draw neutral currents. The injected harmonics, reactive power, unbalance, and neutral currents cause less system efficiency and poor power factor. In addition, the power system has various transients like voltage sags, swells, flickers etc. These transients affect the voltage at distribution levels. Excess in reactive power of loads will also increase the transmission losses in lines. Therefore, as we can see from the simulation results, the UPQC when connected increases the transient stability of the system. The main purpose of a UPQC is to compensate for supply voltage flicker/imbalance, reactive power, negative-sequence current, and harmonics. In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems.

The above results show the waveforms when UPQCs are connected. As is can be seen, the waveforms are continuous and stable. The voltages and currents of B1, B2 and B3 are regular and continuous without and fluctuations or distortions. This is a desirable characteristic as it is stable and can be used beneficially for multiple applications. This shows that the use of UPQC provides transient stability to a circuit and improves it characteristics.

5. Conclusion

This paper shows the use of a UPQC in improving the transient stability of a given system. The experimental results have shown that the proposed scheme is feasible, the control strategy proposed is valid and effective while the result of compensation is satisfactory. The UPQC, therefore, is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage flicker/imbalance. The results show how the stability is increased when a UPQC is used.

6. Reference

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