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DESIGN, MODELING AND SIMULATION OF UNIFIED POWER QAULITY CONDITIONER IN MULTI BUS SYSTEM

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ABSTRACT

The Unified Power Quality Conditioner (UPQC) is a versatile device and it mitigates both load current and supply voltage problems, simultaneously. This device combines a shunt active filter together with a series active filter in a back to back configuration, to simultaneously compensate the supply voltage and the load current or to mitigate any type of voltage and current fluctuations and power factor correction in a power distribution network. This paper deals with design, modelling and simulation of unified power quality conditioner in multi bus system to improve the power quality in a multi bus system. A sag is created by applying a heavy load at the receiving end. The sag will compensated by using the unified power quality conditioner. The harmonics required at the receiving end are supplied by the inverter part of unified power quality conditioner. The simulation results of multi bus system are presented in time domain. The unified power quality conditioner system is modelled using the elements of Simulink and it will simulated using MATLAB

KEYWORDS: Flexible alternating current transmission system (FACTS), Active power filter (APF), Unified power quality controller (UPQC), MATLAB.

INTRODUCTION

Recently, Power quality problems have become an important issues for electricity consumers at all the level of usage. The deregulation of electric power energy has boosted the public awareness toward power quality among the different categories of users. The modern power distribution system is becoming highly vulnerable to the different power quality problems. The extensive use of non-linear loads is further contributing to increased current and voltage harmonics issues. Furthermore, the penetration level of small / large-scale renewable energy systems based on wind energy, solar energy, fuel cell, etc., installed at distribution as well as transmission levels is increasing significantly [1].

Unified power quality control was widely studied by many researchers as an eventual method to improve power quality of electrical distribution system. The function of unified power quality conditioner is to compensate 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. Therefore, the UPQC is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage flicker / imbalance. The UPQC consisting of the combination of a series active power filter (APF) and shunt APF can also compensate the voltage interruption if it has some energy storage or battery in the DC link[2]. The shunt APF is usually connected across the loads to compensate all current-related problems such as the reactive power compensation power factor improvement, current harmonic compensation, and load unbalance compensation whereas the series APF is connected in a series with the line through series transformers. It acts as controlled voltage source and can compensate all voltage related problems, such as voltage harmonics, voltage sag, voltage swell, flicker, etc.

The proposed control technique has been evaluated and tested under non-ideal mains voltage and unbalanced load conditions using Matlab / simulink software. This work proposes UPQC to improve the power quality of multi bus system. This work presents the simulink model of UPQC based multi bus system.

BASIC CONFIGURATION OF UPQC

The UPQC consists of two voltage source inverters connected back to back, sharing a common dc link. The voltage

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at PCC may be or may not be distorted depending on the other non-linear loads connected at PCC. Also, these loads may impose the voltage sag or swell condition during their switching ON and/or OFF operation. The UPQC is installed in order to protect a sensitive load from all disturbances[3].

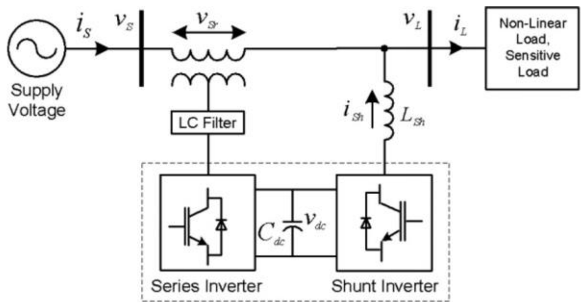

Fig1.System Configuration of a UPQC

Fig.1 shows the basic configuration of the unified power quality Conditioner. The shunt converter Of the UPQC must be connected as close as possible to the non-linear load, instead of the network side. The UPQC approach is the most powerful compensator for a scenario as depicted in Fig 1, where the supply voltage Vs is itself already unbalanced & distorted &is applied critical load that require high power quality .On the other hand, part of the total load include nonlinear loads that inject a large amount of harmonic current into the network, which should be filtered. In fig1, current $i_L$represents all nonlinear loads that should be compensated. The shunt active filter of the UPQC can compensate all undesirable current components, including harmonics, imbalances due to negative- and zero sequence components at fundamental frequency, and the load reactive power as well[4]. The same kind of compensation can be performed by the series active filter for the supply voltage, hence, the simultaneous compensation performed by the UPQC guarantees that both the compensated voltage V_L at load terminal and compensated current i_s that is drawn from the power system become balanced, so that they contains no unbalance from negative- and zero sequence components at fundamental frequency. Moreover, they are sinusoidal and in phase, if the load reactive power is also compensated. Additionally, the shunt active filter has to provide dc link voltage regulation, absorbing or injecting energy from or into the power distribution system, to cover losses in converters, and correct eventual transient compensation errors that lead to undesirable transient power flows into the UPQC. It might be interesting to design UPQC controllers that allow different selections of the compensating functionalities [6].

STEADY STATE POWER FLOW ANALYSIS

The UPQC is controlled in such a way that the voltage at load bus is always sinusoidal and at desired magnitude. In the following analysis the load voltage is assumed to be in phase with terminal voltage even during voltage sag and swell condition. In this particular condition, the series APF could not handle reactive power and the load reactive power is supplied by shunt APF alone [7]

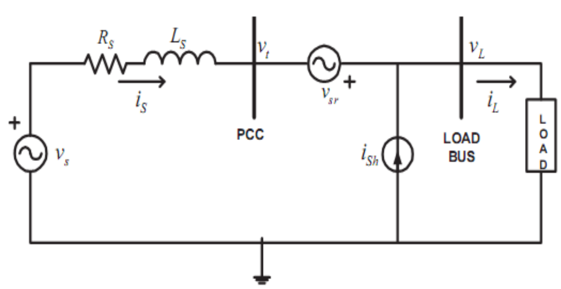

Fig2.Equivalent Circuit of a UPQC

The source voltage, terminal voltage at PCC and load voltage are denoted by Vs, V_t and V_L respectively. The source and load currents are denoted by i_s and i_L respectively. The voltage injected by series APF is denoted by V_{Sr}, whereas the current injected by shunt APF is denoted by i_{Sh}. Taking the load voltage, V_L, as a reference phasor and suppose the lagging power factor of the load is Cos Φ_L then we can write;[7]

$V_L = V_L \angle 0^0$ (1)

$I_L = I_L \angle -\Phi_L$ (2)

$Vt = V_L(1+k) \angle 0^0$ (3)

Where factor k represents the fluctuation of source voltage, defined as,

$k = \frac{Vt - VL}{VL}$ (4)

The voltage injected by series APF must be equal to,

$V_{Sr} = V_L - Vt = -kV_L \angle 0^0$ (5)

The UPQC is assumed to be lossless and therefore, the active power demanded by the load is equal to the active power input at PCC. The UPQC provides a nearly unity power factor source current, therefore, for a given load condition the input active power at PCC can be expressed by the following equations,

$Pt = P_L$ (6)

$Vt.i_S = V_L.i_L.\cos\varphi_L$ (7)

$V_L(1+k).i_S = V_L.i_L.\cos\varphi_L$ (8)

$i_S = i_L/(1+k) * \cos\varphi_L$ (9)

The above equation suggests that the source current i_S depends on the factor k, since $\varphi_L$and i_L are load characteristics and are constant for a particular type of load. The complex power absorbed by the series APF can be expressed as,

$S_{S}r = V_{Sr} .i_S *$ (10)

$P_{Sr} = V_{Sr} .i_S . \cos\varphi s = -k .V_L .i_S .\cos\varphi s$ (11)

$Q_{Sr} = VS_r .i_S .\sin\varphi_S$ (12)

$\varphi_S = 0$, since UPQC is maintaining unity power factor

$P_{Sr} = V_{Sr} .i_S = -k .V_L .i_S$ (13)

$Q_{Sr} \cong 0$ (14)

The complex power absorbed by the shunt APF can be expressed as,

$S_{Sh} = V_L .i_{Sh} *$ (15)

The current provided by the shunt APF, is the difference between the input source current and the load current, which includes the load harmonics current and the reactive current. Therefore, we can write;

$i_{Sh} = i_S - i_L$ (16)

$i_{Sh} = i_S \angle 00 - i_L \angle \ \varphi_L$ (17)

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$i_{Sh} = i_S - (i_L .\cos\varphi_L - j\, i_L .\sin\varphi_L)$ (18)

$i_{Sh} = (i_S - i_L .\cos\varphi_L) + j\, i_L .\sin\varphi_L$ (19)

$P_{Sh} = V_L .i_{Sh} .\cos\varphi s_h = V_L .(i_S - i_L .\cos\varphi_L)$ (20)

$Q_{Sh} = V_L .i_{Sh} .\sin\varphi s_h\ V_L .i_L .\sin\varphi_L$ (21)

When a sag is detected such that |Vs2| <|Vs1| (rated), then for UPQC-Q , Vinj is calculated from as.[21]

Vinj2 = (Vs12 – Vs22)

Now from PWM method √2Vinj = MI (Vdc/2), where MI is the desired modulation index (MI). Therefore,

MI = (2√2 .Vinj)/Vdc

If x is the p. u. sag to be mitigated, minimum dc link voltage would be Vdc= 2√(2)* √(x(2-x)) * Vs1, for maximum value of MI =1 (taking the injection transformer turns ratio to be 1:1).

CONTROL STRATEGY

A controller is required to control the working of UPQC whenever any fault there for this purpose pi controller is used.

For DVR control load voltage is sensed and passed through a sequence analyzer. The magnitude of the actual voltage is compared with reference voltage (Vref).Pulse width modulation (PWM) control system is applied for inverter switching so as to generate a three phase sinusoidal voltage at the load terminals. Chopping frequency is in the range of a few KHz. The IGBT inverter is controlled with PI controller in order to maintain 1p.u. voltage at the load terminals. PI controller input is an actuating signal which is the difference between the Vref and Vin.

For STATCOM control load current is sensed and passed through a sequence analyzer. The magnitude of the actual current is compared with reference current (Iref).Pulse width modulation (PWM) control system is applied for inverter switching so as to generate a three phase sinusoidal current at the load terminals. Chopping frequency is in the range of a few kHz. The IGBT inverter is controlled with PI controller in order to maintain 1p.u. current at the load terminals. PI controller input is an actuating signal which is the difference between the Iref and Iin[9].

SIMULATION RESULTS AND DISCUSSION

In this section 14 bus system is modelled using the elements of matlab simulink and the simulation results are presented. The line impedances are shown as series combination of resistance and inductance. The load at each bus is represented as series combination of load resistance and inductance. The circuit of Fourteen bus system is shown in fig 3.

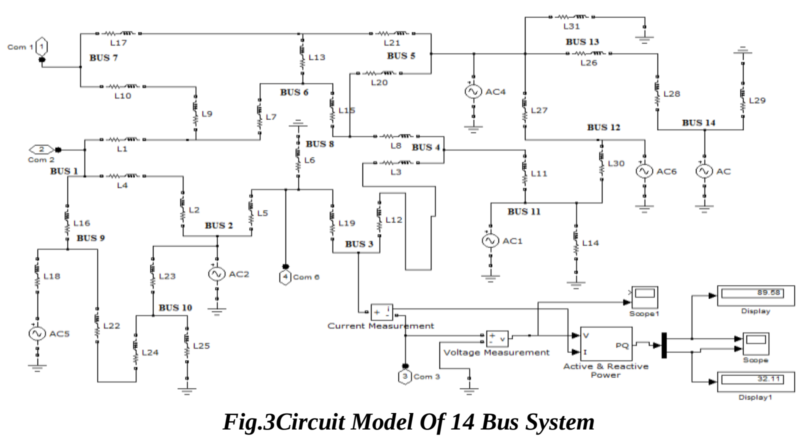

Fig.3Circuit Model Of 14 Bus System

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The circuit of Fourteen bus system without UPQC is shown in Fig. 4(a). The load 2 is connected in parallel with the load 1. The breaker is connected in series with load 2. Additional load is applied by closing the breaker at t=0.2 sec. The real and reactive powers at bus1,bus3 and bus 7 are shown in Figs.4(b) ,(c)and (d)respectively. The real and reactive power increases at t=0.2 sec, since the current drawn is increased. The voltage across load 1 and load 2 is shown in Fig. 4(e). At t=0.2 sec, the voltage across loads 1 and 2 decreases due to the addition of heavy load.

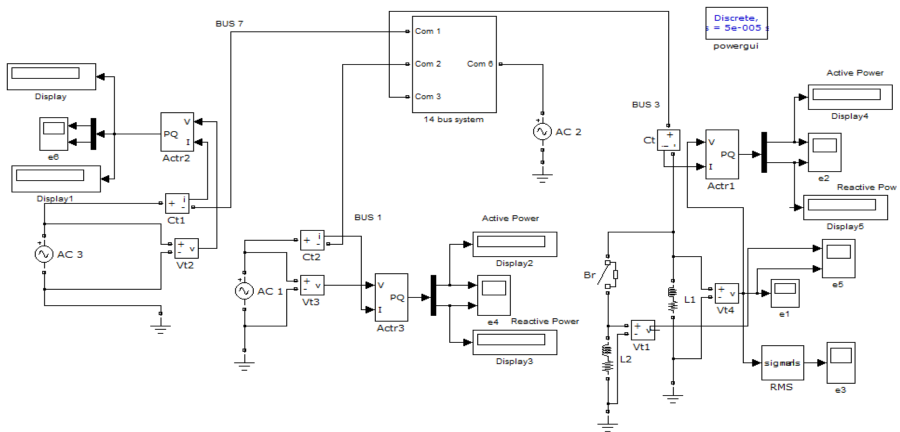

Fig4(a.)14 Bus System Without UPQC

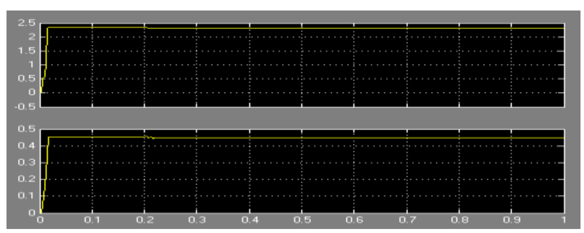

Fig4(b).Active and Reactive Power across Bus 1

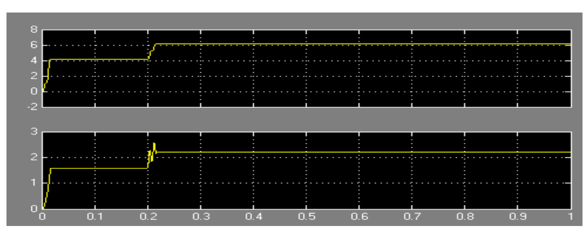

Fig4(c).Active and Reactive Power across Bus 3

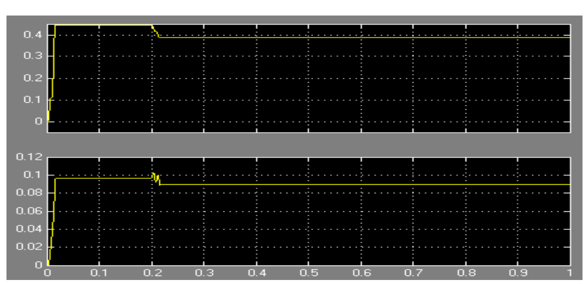

Fig4(d).Active and Reactive Power across Bus 7

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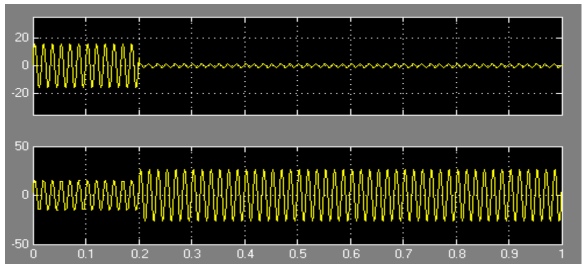

Fig4(e).Voltage Across Load 1 and Load 2

The circuit of Fourteen bus system with UPQC is shown in Fig. 5(a). The real and reactive powers at bus 3 and bus 7 are shown in Fig.5(b)and5(c) irrespectively. The load is applied at t=0.2 sec. The voltage across load 1 and 2 are shown in Fig. 5(d).

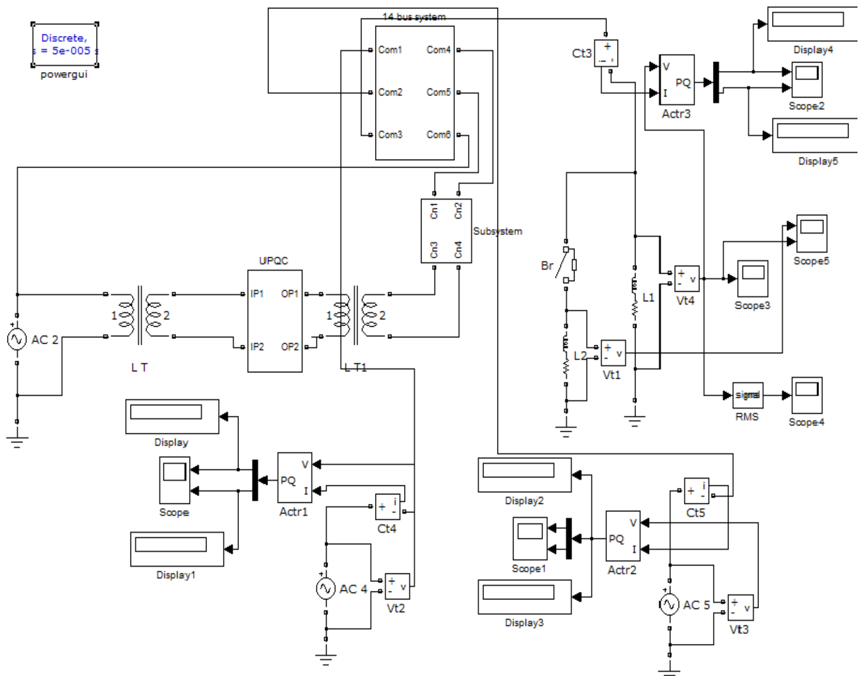

Fig5(a)14 Bus System With UPQC

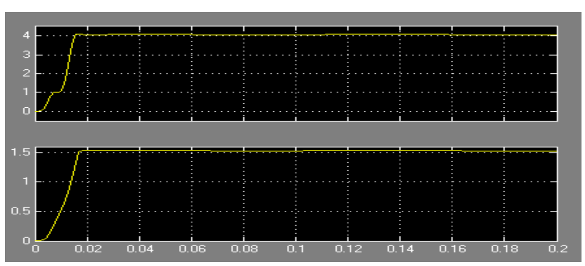

Fig5(b).Active and Reactive Power across Bus 3

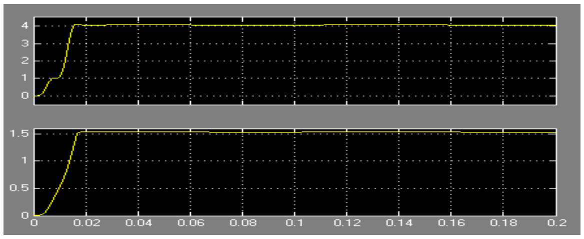

Fig5(c). Active and Reactive Power across Bus 7

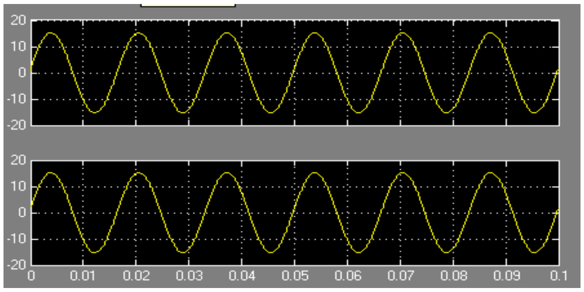

Fig5(d).Voltage Across Load 1 and Load 2

CONCLUSION

The Unified Power Quality controller has been investigated for power quality enhancement and modelled using the circuit elements of simulink.UPQC is an advanced hybrid filter that consists of a series active filter(APF) for compensating voltage disturbances and shunt active power filter (APF) for eliminating current distortions. The sag in the voltage is created by applying an additional heavy load at the receiving end. This sag is compensated by using DVR part of UPQC.

The proposed UPQChas the ultimate capability of improving the power quality at the installation point in the distribution system. The proposed system can replace the UPS, which is effective for the long duration of voltage interruption,because the long duration of voltage interruption is very rare in the present power system.

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