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Hysteresis Control Of A Unified Power Quality Conditioner For Current And Voltage Perturbations Compensation In A Power Distribution Network

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Abstract: - Power quality problems have received a great attention nowadays because of their economical impacts on both utilities and customers. The current harmonics is the most common problem of power quality, while voltage sags is the most severe. This paper deals with a Unified Power Quality Conditioner for current and voltage perturbations compensation in a power distribution network. The topology is based on two 3-phase voltage source inverters acting respectively as a parallel active power filter and a series active power filter which share two DC link capacitors. The power flow, in the Unified Power Quality Conditioner system is analysed. This paper proposed a new efficient control system for unified power quality conditioner it is possible to reduce the voltage fluctuations like sag and swell conditions and current and voltage harmonics isolation in distribution systems. The UPQC which can be used at the PCC for improving power quality is modelled and simulated using proposed control strategy and the performance are compared by applying it to a distribution system without compensation, shunt compensation, series compensation and with UPQC. The performance of this UPQC has been evaluated with a typical industrial load with realistic parameters supplied by a polluted distribution network. Dynamic model of the UPQC is developed in the MATLAB/SIMULINK environment and the simulation results demonstrating the power quality improvement in the system are presented to different supply and load.

***Keywords*—power quality, UPFC, DC link capacitors, FACTS, DVR & DSTATCOM, VSI, Hysteresis PWM controller and MATLAB/SIMULINK.**

I. INTRODUCTION

In this chapter introduce the synchronous reference frame theory in this show the relation between a,b,c axis to d,q axis and also discussion about FACTS technology, Unified Power Quality Conditioner, MATLAB/SIMULINK Flexible AC Transmission Systems, called FACTS, got in the recent years a well known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice. Several kinds of FACTS controllers have been commissioned in various parts of the world. The most popular are: load tap changers, phase-angle regulators, static VAR compensators, thyristor-controlled series compensators, interphase power controllers, static compensators, and unified power flow controllers (IEEE/CIGRE´, 1995). The FACTS is a concept based on power-electronic controllers, which enhance the value of transmission networks by increasing the use of their capacity. In most of the applications the controllability is used to avoid cost intensive or landscape requiring extensions of power systems, for instance like upgrades or additions of substations and power lines.

FACTS-devices provide a better adaptation to varying operational conditions and improve the usage of existing installations.

The basic applications of FACTS-devices are:

- Increase of transmission capability
- Voltage control,
- Reactive power compensation,
- Stability improvement,
- Power quality improvement,
- Power conditioning,
- Flicker mitigation,
- Interconnection of renewable and distributed generation and storages.

In all applications the practical requirements, needs and benefits have to be considered carefully to justify the investment into a complex new device. The usage of lines for active power transmission should be ideally up to the thermal limits. Voltage and stability limits shall be shifted with the means of the several different FACTS devices. It can be seen that with growing line length, the opportunity for FACTS devices gets more and more important. The influence of FACTS devices is achieved through switched or controlled shunt compensation, series compensation or phase shift control. The devices work electrically as fast current, voltage or impedance controllers. The power electronic allows very short reaction times down to far below one second. These devices are mapped to their different fields of applications.

A Unified Power Quality Conditioner (UPQC) can perform the functions of both D-STATCOM and DVR. The UPQC consists of two voltage source converters (VSCs) that are connected to a common dc bus. One of the VSCs is connected in series with a distribution feeder, while the other one is connected in shunt with the same feeder. The dc links of both VSCs are supplied through a common dc capacitor. It is also possible to connect two VSCs to two different feeders in a distribution system. In, a configuration called IDVR has been discussed in which two DVRs are connected in series with two separate adjacent feeders. The dc buses of the DVRs are connected together. The IDVR absorbs real power from one feeder and maintains the dc link voltage to mitigate 40% (about 0.6 p.u.) voltage sag in the other feeder with balanced loads connected in the distribution system. It is also possible to connect two shunt VSCs to

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different feeders through a common dc link. This can also perform the functions of the two DVRs with higher device rating.

MATLAB is a software package for high performance numerical computation and visualization, the analysis capabilities, flexibility, reliability and powerful graphics makes MATLAB the premier software package for all electrical engineers.

MATLAB, developed by The Math Works, Inc., integrates computation, visualization, and programming in a flexible, open environment. It offers engineers, scientists, and mathematicians an intuitive language for expressing problems and their solutions mathematically and graphically. Complex numeric and symbolic problems can be solved in a fraction of the time required with a Programming language such as C, FORTRAN, or Java.

SIMULINK is software for modeling, simulating, and analyzing Dynamic systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. Systems can also be multi rate, i.e., have different parts that are sampled or updated at different rates. SIMULINK enables you to pose a question about a system, model it, and see what happens. With SIMULINK, one can easily build models from scratch, or take an existing model and add to it. Thousands of engineers around the world use SIMULINK to model and solve real problems in a variety of industries.

II. DESIGN OF UPQC

Block Diagram of UPQC:

Over the past few decades, the increase of non-linear loads, such as diodes or thyristor rectifiers and cyclo converters draw non-sinusoidal currents in to power system, thus contributing to the degradation of power quality or industrial power system. Notably, voltage distortion or voltage harmonics in the power systems have been serious. Recent research efforts have been made towards utilizing a device called Unified Power Quality Conditioner (UPQC) to solve almost all power quality problems.

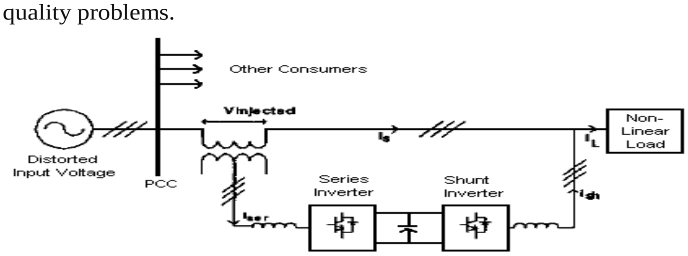

Fig2.1 Basic Block Diagram of UPQC

Basic block diagram of UPQC is shown in fig 2.1 The voltage at PCC may be or may not be distorted depending on the other non-linear loads connected at PCC. Here we assume the voltage at PCC is distorted. Two voltage source inverters are connected back to back, sharing a common dc link. One inverter is connected parallel with the load. It acts as shunt APF, helps in compensating load harmonic current as well as to maintain dc link voltage at constant level. The second inverter is connected in series with utility voltage by using series transformers and helps in maintaining the load voltage sinusoidal.

The duty of UPQC is decreasing the disturbances which effect the operation of sensitive load. UPQC is able to compensate the swell, sag and unbalanced voltage, current and voltage harmonics and reactive power, through shunt and series voltage source inverters. Voltage source inverter has to generate sinusoidal voltage with the frequency, amplitude and the phase determined by the control system as shown in fig 2.1. UPQC controller provides the compensation voltage (v_f^*) through the UPQC series inverter and provides conditioning current (i_f^*) through the shunt inverter by instantaneous sampling of load current and source voltage and current. Resulted reference currents are compared with shunt inverter output currents (i_{fa}, i_{fb}, i_{fc}), in a hystersis type PWM current controller. A suitable controlling method has been selected to simulation and the rating of series and shunt inverters has been calculated through loading calculations of these inverters applying phasor diagram to increase the design accuracy.

III. CONTROL STRATEGY OF UPQC

In The control strategy is based on the extraction of Unit Vector Templates from the distorted input supply. These templates will be then equivalent to pure sinusoidal signal with unity (p.u) amplitude. The extraction of unit vector templates is shown in the Fig3.1,

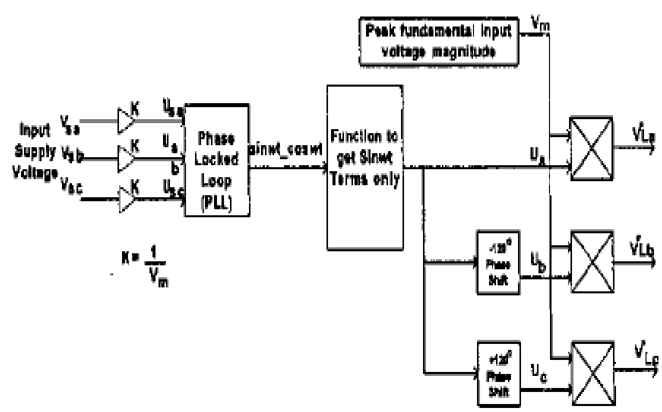

Fig.3.1: Extraction of unit vector templates

The three phase distorted input source voltage at PCC contains fundamental component and distorted component. To get unit input voltage vectors Us, the input voltage is sensed and multiplied by gain equal to I/ V_m , where V_m is equal to peak amplitude of fundamental input voltage. These unit input voltage vectors are taken to phase locked loop (PLL). With proper phase delay, the unit vector templates are generated.

$$U_a = \sin(wt)$$

$$U_b = \sin(wt - 120)$$

$$U_c = \sin(wt+120) \text{--(3.1)}$$

Multiplying the peak amplitude of fundamental input voltage with unit vector templates of equation (I) gives the reference load voltage signals,

$$U^*_{I_{abc}} = V_m\, U_{abc} \qquad (3.2)$$

In order to have distortion less load voltage, the load voltage must be equal to these reference signals. The measured load voltages are compared with reference load voltage signals. The error generated is then taken to a hysteresis controller to generate the required gate signals for series active pass filter. The overall control circuit of UPQC is shown in the Fig.3.2

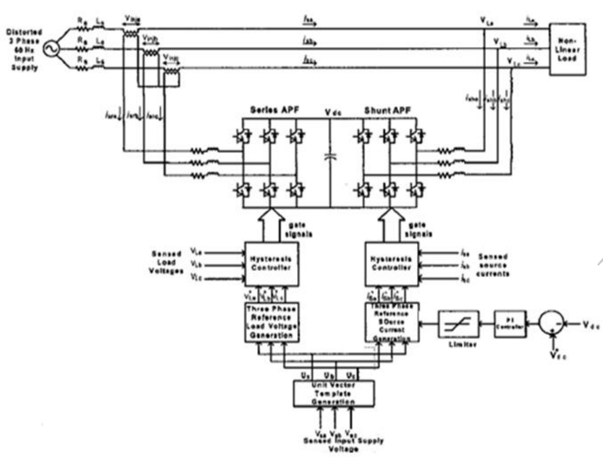

Fig.3.2: Overall control circuit of UPQC

Pulse-width modulation (PWM)

Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a commonly used technique for controlling power to inertial electrical devices, made practical by modern electronic power switches. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load.

The PWM switching frequency has to be much faster than what would affect the load, which is to say the device that uses the power. Typically switching have to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

IV. SIMULATION RESULTS

In this study power circuit is modelled as a three phase three wire system with a non linear load comprising of RL load which is connected to grid through three phase Diode Bridge. Circuit parameters used in simulation are shown in Table 4.1

Source voltage	Line-Line(rms)	415volts,50Hz
DC -Link	Capacitor	5500*uF*
	Reference voltage	750volts
Shunt Compensator	Filter L,C	2200*mH,1400uF*
Series compensator	Filter L,C	2200*mH,1400uF*
	Transformer (n1:n2),KVA	2:5 , 10kva
Load	Nonlinear load P,Q	1000kw,2460kvar

Uncompensated system

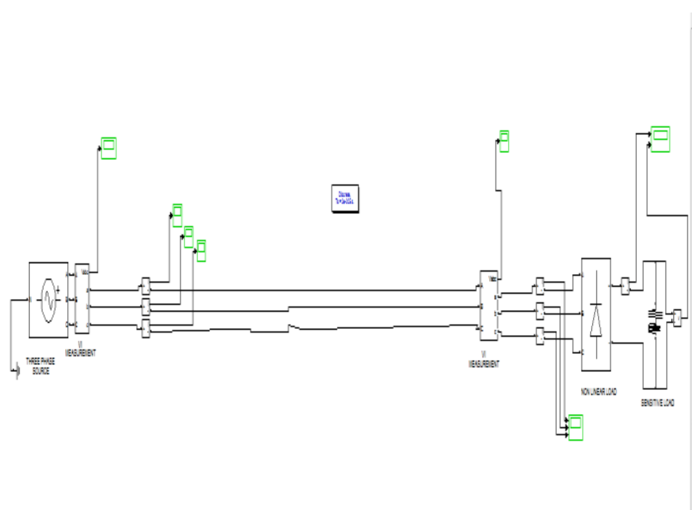

Fig.4.1.simulation diagram of uncompensated system

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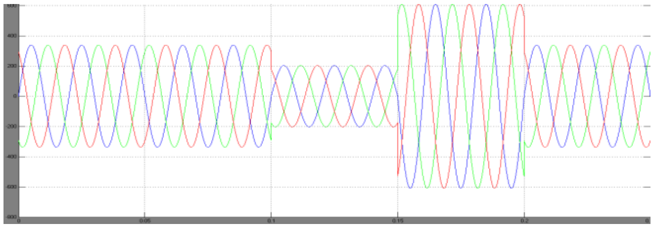
The above simulation diagram shows a source connected to nonlinear power electronic load. The diode rectifier with R-L load is used here. By using simulink in the matlab above diagram is developed.

Results for uncompensated system

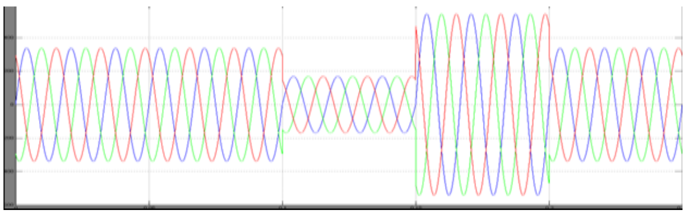
Vsource



0 0.05 0.1 time (sec) 0.15 0.2 0.25

Supply voltage is 415volts (L-L).The phase voltage is 239.60volts.The maximam phase voltage is 338.84volts.sag of o.6pu created between 0.1sec to 0.15sec in the supply voltage. Swell of 1.8pu created between 0.15sec to 0.2sec.

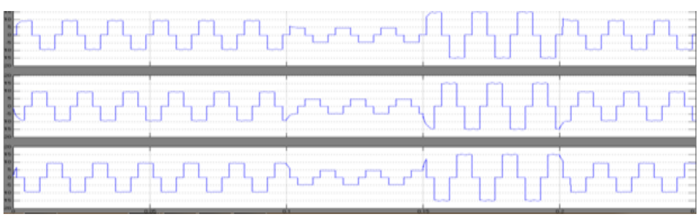
Vpcc



0 0.05 0.1 time(sec) 0.15 0.2 0.25

Three phase source voltage (V_{sabc}) and pcc voltage (V_{labc})Because there is no compensation the sag and swell is transferred to point of common coupling

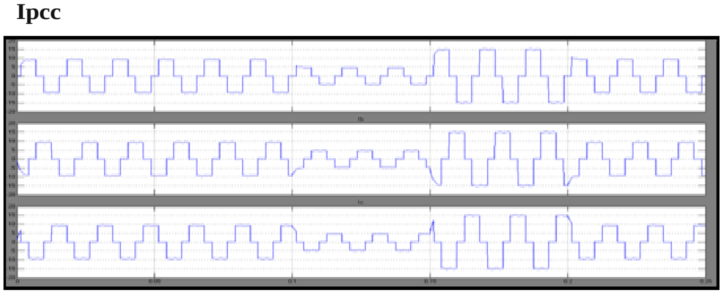
Isource



0. 0 0.5 0.1 time(sec) 0.15 0.2 0.25

Because sag and swell in the supply voltage harmonics are injected in the source current during the intervels 0.1sec to 0.15sec and 0.15sec and 0.2sec

Ipcc



0. 0 0.05 0.1 time(sec) 0.15 0.2 0.25

Fig.7.2.results of uncompensated system

Because sag and swell in the pcc voltage, harmonics are injected in the source current during the intervels 0.1sec to 0.15sec and 0.15sec and 0.2sec

UPQC compensated system

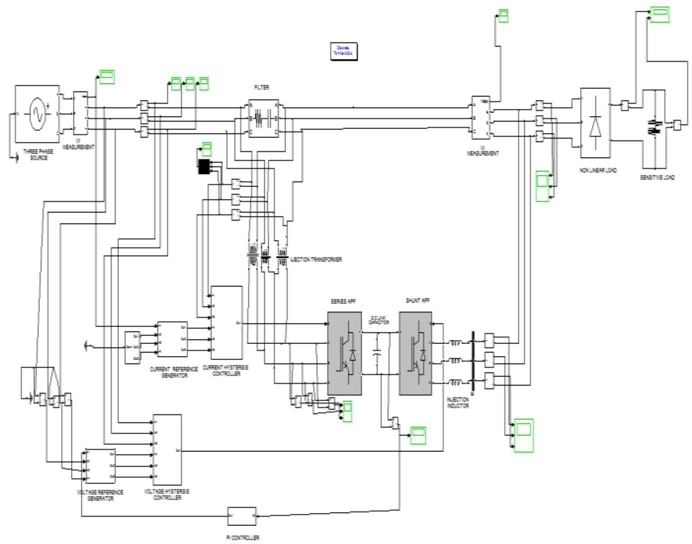


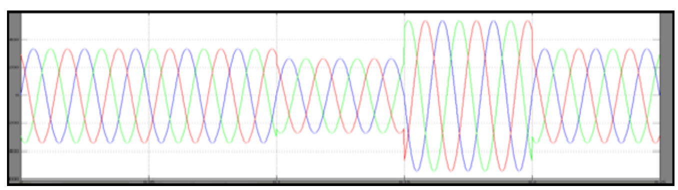
FIG: SIMULINK MODEL FOR UNIFIED POWER QUALITY CONDITIONER

Fig.4.2.simulation diagram of upqc compensated system

The above simulation diagram shows a source connected to nonlinear power electronic load. compensation is provided to improve power quality by using upqc .The diode rectifier with R-L load is used here. By using simulink in the matlab above diagram is developed

Results for upqc compensated system

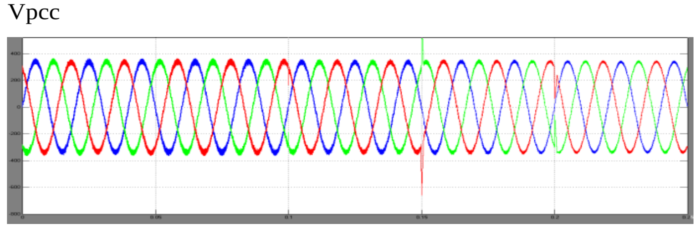
Vsource



0.0 0.05 0.1 time(sec) 0.15 0.2 0.25

Supply voltage is 415volts(L-L).The phase voltage is 239.60volts.The maximam phase voltage is 338.84volts.sag of o.6pu created between 0.1sec to 0.15sec in the supply voltage. Swell of 1.8pu created between 0.15sec to 0.2sec

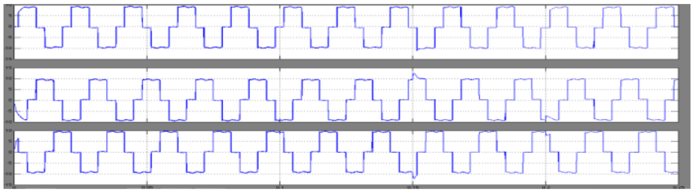
Vpcc



0.0 0.05 0.1 time(sec) 0.15 0.2 0.25

Upqc compensation eliminated the sag and swell at the pcc voltage which are previously presented due to sag and swell at source voltage.

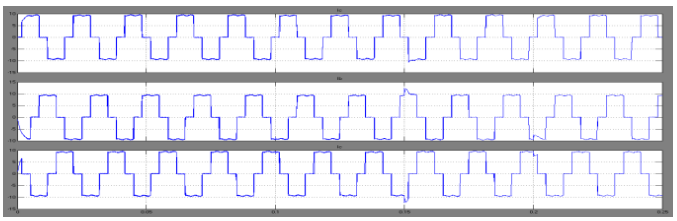
Isource



0.0 0.05 0.1 time(sec) 0.15 0.2 0.25

Source current is distorted because of sag and swell in supply, nonlinear load.

Ipcc



0.0 0.05 0.1 time(sec) 0.15 0.2 0.25

Current at the pcc is improved by upqc compensation. upqc can improved the current simultaneously with voltage. If we change percentage of load we will get same results

%THD comparisons for different compensations during sag and swell

	I source			I pcc			V source			V pcc		
	a	b	c	a	b	c	a	b	c	a	b	c
Without compensation	31.96	33.99	32.08	31.96	33.99	32.08	6.22	12.73	12.76	6.22	12.73	12.76
Upqc compensation	28.29	27.98	28.76	28.44	28.08	28.81	6.22	12.73	12.76	1.51	4.74	4.92

Table 4.2. %THD comparision

V. CONCLUSIONS

Custom power devices like DVR, D-STATCOM, and UPQC can enhance power quality in the distribution system. Based on the power quality problem at the load or at the distribution system, there is a choice to choose particular custom power device with specific compensation. Unified Power Quality Conditioner (UPQC) is the combination of series and shunt APF, which compensates supply voltage and load current imperfections in the distribution system.

In this study Unified Power Quality Conditioner (UPQC) is designed and simulated through synchronous reference frame theory. Simulation results show the proposed system's ability in voltage distortion, reactive power and current harmonics compensation. PI controller balances the power between series and shunt inverters by stabilizing DC link voltage.

A simple control technique based on h theory is proposed and the Hysteresis current control model has been simulated in MATLAB. The simulation results show that the voltage and current perturbations caused by non-linear load can be compensated effectively by the proposed control strategy. The operation of proposed system is analyzed using MATLAB/SIMULINK software. Simulation results confirm the correct operation of the proposed system.

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