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Modelling of M3C-based UPQC for Power Quality Improvement in Power Grid

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Abstract: To enhance the power system of power quality in distribution systems, a single-phase unified power quality conditioner (UPQC) based on matrix converter (M3C) is modeled The matrix converter-UPQC with filtering inductors, and capacitors are simulated then ,an integrated control method foe UPQC in which the dc circulating current is used to balance the instantaneous power of each arm and is proposed to prevent the capacitor voltages to improve effectiveness of the converter neural network controller is used and the results are shown in the mat lab simulink

Keywords: M3C-UPQC,activepower,integratedcontrol,Three phase fault,neural network.

I. INTRODUCTION

Traditionally passive filters were used for reactive power disturbances and harmonics generation but there is many problems with them like they are large in size, resonance problem, effect of source impedance on performance. Active Power Filters are used for power quality enhancement. Active power filters can be classified according to system configuration. Active power filters are of two types series and shunt. Combining both series APF & shunt APF we get a device known as UPQC. UPQC eliminates the voltage and current based distortions together. A Shunt APF eliminates all kind of current problems like current harmonic compensation, reactive power compensation, power factor enhancement. A Series APF compensates voltage dip/rise so that voltage at load side is perfectly regulated.

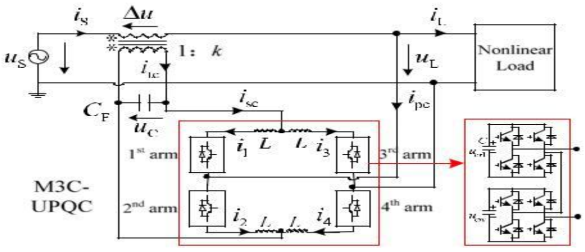
The Shunt APF is connected in parallel with transmission line and series APF is connected in series with transmission line. UPQC is formed by combining both series APF and shunt APF connected back to back on DC side. In this controlling techniques used is hysteresis band controller using “p-q theory” for shunt APF and hysteresis band controller using Park’s transformation or dq0 transformation for series APF.UPQC is made by combining both shunt APF and series APF. UPQC is used to eliminate all problems due to current harmonics and voltage unbalances & distortions and improve power quality of a system. UPQC is a very versatile device as at same time it mitigates the problem both due to current and voltage harmonics. In this thesis power quality of system was improved by using UPQC. First simulation of shunt APF was done after that series APF was done. And after that combining both device simulation of UPQC was done.

II. SYSTEM STRUCTURE AND EQUIVALENT CIRCUIT

A structure of UPQC based on the modular multi-level matrix converter (M3C) is presented, and it can be directly connected to medium/high-voltage power grid for high-power applications. The remainder of this paper is organized as follows: the system structure and equivalent circuit are presented in Section II. Detailed compensation principle and power analysis, an integrated control strategy is proposed for M3C-UPQC to ensure the sub module capacitor voltage balance.

A. Topology Structure of M3C-UPQC

UPQC coordinates the series and parallel converters to achieve comprehensive objectives. More precisely, the parallel



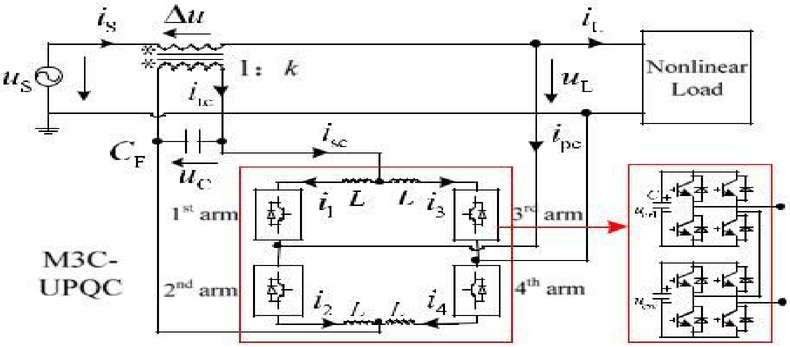


Fig1:Schematic of the single-phase M3C-based UPQC.

B. Power Quality Improvement

In our day to day life and in many industries there is very huge use of power electronics devices, Programmable logic circuits (PLC), semiconductor devices, and adjustable speed drives due to this there are power quality problems. There is also many external and internal factors that affect the quantity and quality of power delivered. Many network faults, switching of capacitor banks, voltage sag/swell, lightning, and harmonics also cause power quality problems. Mainly loads work at 50 Hz and 60 Hz frequencies. But there are many loads which work at integer multiple of 50 Hz and 60 Hz frequencies. Because of these loads there is harmonics in power system.

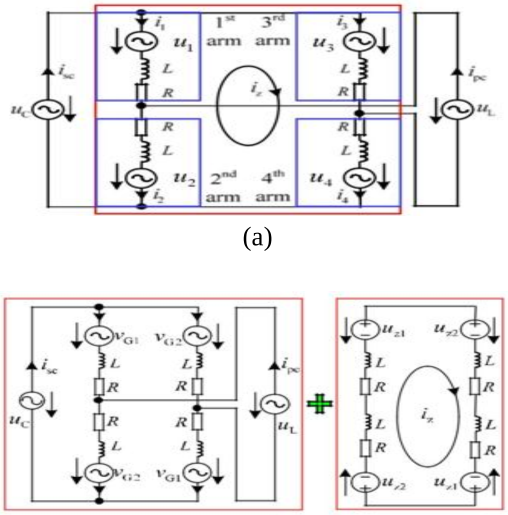
TABLE -1
COMPARSION FOUR MODULAR UPQC'S

Parameter	Modular-UPQC [32]	Modular-UPQC [33]	MMC-UPQC [35]	M3C-UPQC
SIT[1]	NR[2]	R[3]	R	R
PMT[4]	R	R	NR	NR
Switch rated voltage	800 V	800 V	800 V	800 V
Cell number	18	18	144	36
Switch number	144	144	288	144
Capacitor number	18	18	144	36

[1] SIT = Series Injection Transformer; [2] NR = Not Required; [3] R = Required;
[4] PMT = Parallel Multi-winding Transformer.

III. EQUIVALENT CIRCUIT OF M3C-UPQC

The integrated equivalent model based on controlled voltage source is established where *R* and *L* represent the series resistance and inductance of the filtering inductor, u_x and i_x represent the output voltage and current of the *x*th arm ($x = 1, 2, 3, 4$), re-spectively.i_{sc} and i_{pc} are the output current in series side and parallel side of M3C-UPQC, respectively, i_z denotes the circulating current, which only flows inside M3C-UPQC and has no effect on the output current. Generally, the mentioned circulating current should be suppressed as far as possible. However, it also can be used for the voltage balancing control under special conditions. The arm currents are described as (1) in accordance



(a)

(b)

Fig 2: Controlled voltage-source-based equivalent circuit of M3C-UPQC.
(a) Integrated model. (b) Decoupled model

with Kirchhoff current law

with Kirchhoff current law

$$i_{sc} = i_1 + i_3 = i_2 + i_4$$

$$i_{pc} = i_2 - i_1 = i_3 - i_4 \qquad (1)$$

$$i_z = (i_4 + i_3 - i_2 - i_1)/4.$$

As described in [22], benefiting from the highly symmetrical structure, the arm current i_x can be expressed as

$$i_{1,4} = \frac{i_{sc} - i_{pc}}{2} \mp i_z$$
$$i_{2,3} = \frac{i_{sc} + i_{pc}}{2} \mp i_z. \qquad (2)$$

Subsequently, the direct application of Kirchhoff voltage law results in (3), where u_C is the voltage across the ac filter capacitor C_F and u_L is the load voltage. According to Fig. 3(a), there is

$$u_1 + u_4 = u_C - u_L - L\frac{d(i_1 + i_4)}{dt} - R(i_1 + i_4)$$
$$(3)$$
$$u_2 + u_3 = u_C + u_L - L\frac{d(i_2 + i_3)}{} - R(i_2 + i_3).$$

Assuming u_{z1} and u_{z2} are the injected dc voltages, and v_{G1} and v_{G2} denote the ac components in arm output voltages, so the decoupled ac and dc model of M3C-UPQC can be established as Fig. 3(b). The desired arm voltages are defined by (4), which can be considered as an extension of equations mentioned in [22]. A key element needs to be highlighted that both injected voltages and circulating current are set as dc components, and detailed descriptions will be given in the next section. In consideration of the similarity among four arms, the first arm and fourth arm are paired as group 1, whereas the second arm and third arm are paired as group 2. By doing these, the decoupled model of M3C-UPQC can be obtained

$$u_{1,4} = v_{G1} \pm u_{z1} = \frac{u_C - u_L}{2} - \frac{L}{2}\frac{d(i_{sc} - i_{pc})}{dt} - \frac{R}{2}(i_{sc} - i_{pc}) \pm u_{z1} \tag{4}$$

$$u_{2,3} = v_{G2} \mp u_{z2} = \frac{u_C + u_L}{2} - \frac{L}{2}\frac{d(i_{sc} + i_{pc})}{dt} - \frac{R}{2}(i_{sc} + i_{pc}) \mp u_{z2}.$$

Besides, according to the voltage loop composed of four arms, the injected voltages should meet

$$u_{z1} - u_{z2} = 2L\frac{di_z}{dt} + 2i_z R. \tag{5}$$

the injected voltages and circulating current can be selected as either the dc components or the ac components with the same frequency. However, the control of dc circulating current is simpler than ac current and will not couple with ac voltages as a result of different frequencies, so it is better to set the injected voltages and current as dc components.

Parameters Design of Arm Inductance L And Sub module Of Capacitance C

As the filtering inductors and sub module capacitors are important components for M3C-UPQC, the design of them is de-rived as follows. By using the subtraction in (3), irrespective of dc injected voltages and circulating current when designing ac inductor, the following equation can be obtained:

$$L\frac{di_{pc}}{dt} = u_L - e_{pc} - Ri_{pc} \tag{6}$$

A. Major Power Quality Problems

1) *Voltage sag:-* Voltage sag is also called voltage dip . The rms line voltage decreases to 10 % to 90 % of nominal line voltage. The time interval for voltage dip is about 0.5 cycle to 1 min. The equipment which cause voltage dip are induction motor starting etc.
2) *Voltage swell:* Voltage swell is also called voltage rise. The RMS line voltage increases from 1.1 % to 1.8% of nominal line voltage. The duration for voltage rise is around 0.5 cycles to 1 min. The voltage swell is caused due to energizing the large capacitor bank and shutting down the large loads.
3) *Interruption:* Interruption is degradation in current or line voltage up to 0.1 PU of the nominal value. It is for the time period of 60 seconds and not going beyond it. The cause of interruption is failures in equipment, faults in power systems, control malfunctions.
4) *Sustained interruptions:* When there is zero supply voltage for a interval of time more than 60 sec, it is considered as sustained interruption in case of long duration voltage variation
5) *Under voltages:* It is the reduction in RMS ac voltage to lower than 90 % at power frequency for a time interval 60 sec or may be greater than it. The switching off of capacitor banks and switching on of loads cause under voltage as far as voltage regulation device on the system bring back the voltage to the given tolerance limits. The under voltage is also caused due circuits which are overloaded
6) *Over voltages:* It is the rise in RMS ac voltage to more than 110 % at power frequency for a time interval of more than 60 sec. Over voltages are caused due to the wrong tap settings of transformers and switching of loads.

IV. MULTILEVEL MATRIX CONVERTERS (M3C)

The basic configuration of the converter, in which nine switch cells are employed in the switch network, is used to demonstrate the concept. An approach to generate valid switching-device combinations from given terminal voltages is also described. Afterward, the SVM technique, which is employed for synthesizing terminal voltages, is introduced. The multilevel matrix converter can generate, at each side, 19 combinations of three-phase line-line voltages, which correspond to 19 space vectors in the coordinate six space vectors with magnitude , six space vectors with magnitude , six space vectors with magnitude and a null-state space vector. The null-state space vector and the six space vectors with magnitude under are employed in the two-level switching. The 18 non-zero space vectors are employed in the three-level switching.

A. Configurations of the Multilevel Matrix Converter

A basic configuration of the multilevel matrix converter. The multilevel matrix converter contains nine four-quadrant switches connected between each input phase and each output phase, resembling a conventional matrix converter. However, the four-quadrant switches are realized as capacitor-clamped H-bridge switch cells, each switch cell is similar to the cell

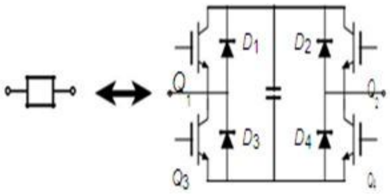


Fig.3 H-BRIDGE capacitor clamped switch cell

For the multilevel DC-link converter, except that the DC voltage sources in the H-bridge switch cells are replaced by simple DC capacitors because the use of the matrix configuration allows the converter to deliver average power without external DC voltage sources. The multilevel matrix converter synthesizes AC line-line voltages at both sides from PWM of the switch-cell capacitor voltages. This operation differs from that of the conventional matrix converter in which voltages are synthesized on one side and currents on the other side. As a result, inductors are employed as filter elements at both sides of the multilevel matrix converter. These inductors may be physically discrete elements, or they may be inductances of other system elements, such as machine-winding inductances and transformer-leakage inductances. With the symmetry structure of the multilevel matrix converter, both step-up and step-down of voltage magnitudes are possible.

B. Switching-Device Combinations

1) *Constraints for Switching-Device Combinations:* With five switch cells conducting currents at any given instant and each conducting switch cell having a potential of three different states, there are $3^5 = 243$ possible combinations of switch states for a given branch connection. As previously stated, there are 81 valid branch connections for the multilevel matrix converter. This leads to 243×81 =19,683 combinations of the switch states and branch connections, referred to as “switching-device combinations,” for the converter. Nevertheless, several switching-device combinations are not practical, and most of them can be generated by rotation of the input or output phase of previously generated combinations. This is done by operating all switch cells of the connected branches As a result of the constraint described above,the maximum instantaneous line-line voltage magnitude of the multilevel matrix converter with the basic configuration is limited to twice the capacitor voltage. In other words, for the multilevel matrix converter with N series-connected switch cells in each branch of the switch network, the possible voltage levels of the terminal line-line voltages can vary from $-2NV_{cap}$ to $+ 2NV_{cap}$ .In PWM, the above constraint implies that the multilevel matrix converter with basic configuration can operate with the instantaneous line-line voltages exceeding the capacitor voltage only when the voltage magnitudes at both sides of the converter are significantly different. The side that has line-line voltage magnitudes exceeding the capacitor voltage operates with three-level switching, while the other side operates with two-level switching.

V. UNIFIED POWER QUALITY CONDITIONER

Basically UPQC (Unified Power Quality conditioner) is a equipment which is used for compensate for voltage distortion and voltage unbalance in a power system so that the voltage at load side is completely balance and sinusoidal & perfectly regulated and also it is used to compensate for load current harmonics so that the current at the source side is perfectly sinusoidal and free from distortions and harmonics. UPQC is a combination of a Shunt Active power filter and Series Active power filter. Here Shunt Active power filter (APF) is used to compensate for load current harmonics and make the source current completely sinusoidal and free from harmonics and distortions. Shunt APF is connected parallel to transmission line. Here Series APF is used to mitigate for voltage distortions and unbalance which is present in supply side and make the voltage at load side perfectly balanced, regulated and sinusoidal. Series APF is connected in series with transmission line. UPQC consists 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. Earlier passive filters where also used for compensation of harmonics and voltage distortion but due to their many disadvantages they are not used nowadays.

A. Active Power Filter

Traditionally passive filters were used for power quality improvement, the passive filters consists of combination of capacitor, inductor and resistor. Passive filters are used for harmonic filtering. Passive filters don’t depend upon the external power source. It has many drawbacks such as it is larger in size, resonance problem, effect of source impedance on performance, fixed compensation characteristics. So active power filters (APF) came as alternate solution for passive filters. Active power filters removes harmonics and not has drawbacks such as passive filters.

VI. BASIC CONFIGURATION OF UPQC

A. Series APF

In a transmission line series APF is generally connected in series. It is connected to the transmission line with the transformer. Series APF is a voltage source inverter connected in series with transmission line. It is used to compensate or mitigate the problems which come due to voltage distortions and voltage unbalances. The series APF injects a compensating voltage so that load voltage will be perfectly balanced and regulated. Controlling of series inverter is done by PWM (pulse width modulation) techniques. Here we used Hysteresis band PWM techniques as it implementation is easy. Also its response is fast. Its details are explained in subsequent sections.

B. Shunt APF

In a transmission line shunt APF is generally connected in parallel. Shunt APF is used to compensate for distortions & harmonics which are produced due to current .Due to non- linear load there is harmonics in load current, so to keep source current completely sinusoidal and distortion free we uses Shunt APF. Shunt APF injects compensating current so that the source current is completely sinusoidal and free from distortions. Controlling of Shunt APF is done by hysteresis band PWM techniques. In hysteresis band PWM techniques output current follows the reference and current and is within the fixed hysteresis band.

VII. SHUNT ACTIVE POWER FILTER

Active power filters are devices which generates the same amount of harmonics which are generated by load but at 180^0 phase shifted. Active power filters are devices such as amplifiers etc. to remove this non-sinusoidal behavior of source current we use Shunt APF which provides the compensating current which is same as harmonic generated by load but 180^0 phase shifted and this compensating current is given at PCC which helps in removing distortions from source current and makes source current completely sinusoidal. Shunt APF is also used for reactive power compensation & it also removes all problems which arise due to current harmonics.

The control scheme used in Shunt APF is instantaneous reactive power theory also known as “p-q theory”. p-q theory is used to generate the reference current and this reference current is given to Hysteresis current controller along with compensating current (actual output current) of Shunt APF. Hysteresis current controller is used to generate gating signal which is then given to voltage source inverter.

VIII. MEDIAM AND HIGH VOLTAGE POWER GRID

An electrical grid is an interconnected network for delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers. Power stations may be located near a fuel source, at a dam site, or to take advantage of renewable energy sources, and are often located away from heavily populated areas. They are usually quite large to take advantage of the economies of scale. The electric power which is generated is stepped up to a higher voltage at which it connects to the electric power transmission network.

The bulk power transmission network will move the power long distances, sometimes across international boundaries, until it reaches its wholesale customer (usually the company that owns the local electric power distribution network).On arrival at a substation, the power will be stepped down from a transmission level voltage to a distribution level voltage. As it exits the substation, it enters the distribution wiring. Finally, upon arrival at the service location, the power is stepped down again from the distribution voltage to the required service voltage(s).

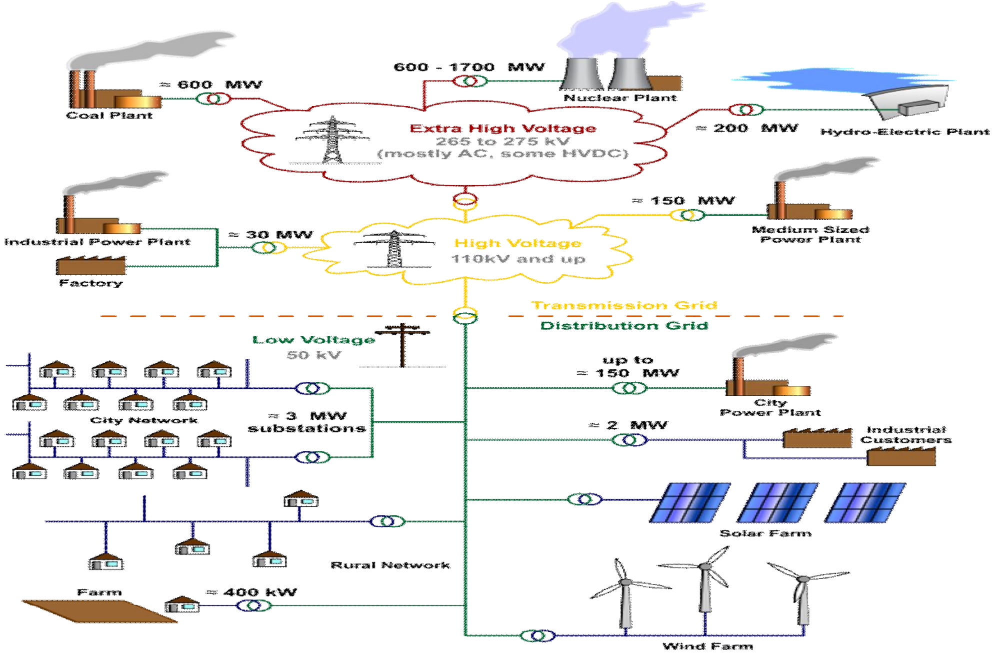


Fig 4:block diagram mediam and high voltage power grid

A. Interconnected Grid

Electric utilities across regions are many times interconnected for improved economy and reliability. Interconnections allow for economies of scale, allowing energy to be purchased from large, efficient sources. Utilities can draw power from generator reserves from a different region in order to ensure continuing, reliable power and diversify their loads. Interconnection also allows regions to have access to cheap bulk energy by receiving power from different sources. For example, one region may be producing cheap hydro power during high water seasons, but in low water seasons, another area may be producing cheaper power through wind, allowing both regions to access cheaper energy sources from one another during different times of the year. Neighboring utilities also help others to maintain the overall system frequency and also help manage tie transfers between utility regions.

IX. MODERN TRENDS

As the 21st century progresses, the electric utility industry seeks to take advantage of novel approaches to meet growing energy demand. Utilities are under pressure to evolve their classic topologies to accommodate distributed generation. As generation becomes more common from rooftop solar and wind generators, the differences between distribution and transmission grids will continue to blur. Also, demand response is a grid management technique where retail or wholesale customers are requested either electronically or manually to reduce their load. Currently, transmission grid operators use demand response to request load reduction from major energy users such as industrial plants.

With everything interconnected, and open competition occurring in a free market economy, it starts to make sense to allow and even encourage distributed generation (DG). Smaller generators, usually not owned by the utility, can be brought on-line to help supply the need for power. The smaller generation facility might be a home-owner with excess power from their solar panel or wind turbine. It might be a small office with a diesel generator. These resources can be brought on-line either at the utility's behest or by owner of the generation in an effort to sell electricity. Many small generators are allowed to sell electricity back to the grid for the same price they would pay to buy it. Furthermore, numerous efforts are underway to develop a "smart grid". In the U.S., the Energy Policy Act of 2005 and Title XIII of the Energy Independence and Security Act of 2007 are providing funding to encourage smart grid development. The hope is to enable utilities to better predict their needs, and in some cases involve consumers in some form of time-of-use based tariff. Funds have also been allocated to develop more robust energy control technologies

A. Smart Grid

The electrical grid is expected to evolve to a new grid paradigm: the smart grid, an enhancement of the 20th century electrical grid. The traditional electrical grids are generally used to carry power from a few central generators to a large number of users or customers. In contrast, the new emerging smart grid uses two-way flows of electricity and information to create an automated and distributed adanced energy delivery network.

Many research projects have been conducted to explore the concept of smart grid. According to a newest survey on smart grid,[15] the research is mainly focused on three systems in smart grid- the infrastructure system, the management system, and the protection system.

The infrastructure system is the energy, information, and communication infrastructure underlying of the smart grid that supports

1) advanced electricity generation, delivery, and consumption;
2) advanced information metering, monitoring, and management; and
3) Advanced communication technologies.

In the transition from the conventional power grid to smart grid, we will replace a physical infrastructure with a digital one. The needs and changes present the power industry with one of the biggest challenges it has ever faced.

A smart grid would allow the power industry to observe and control parts of the system at higher resolution in time and space. It would allow for customers to obtain cheaper, greener, less intrusive, more reliable and higher quality power from the grid. The legacy grid did not allow for real time information to be relayed from the grid, so one of the main purposes of the smart grid would be to allow real time information to be received and sent from and to various parts of the grid to make operation as efficient and seamless as possible. It would allow us to manage logistics of the grid and view consequences that arise from its operation on a time scale with high resolution; from high-frequency switching devices on a microsecond scale, to wind and solar output variations on a minute scale, to the future effects of the carbon emissions generated by power production on a decade scale.

The management system is the subsystem in smart grid that provides advanced management and control services. Most of the existing works aim to improve energy efficiency, demand profile, utility, cost, and emission, based on the infrastructure by using optimization, machine learning, and game theory. Within the advanced infrastructure framework of smart grid, more and more new management services and applications are expected to emerge and eventually revolutionize consumers' daily lives.

The protection system is the subsystem in smart grid that provides advanced grid reliability analysis, failure protection, and security and privacy protection services. The advanced infrastructure used in smart grid on one hand empowers us to realize more powerful mechanisms to defend against attacks and handle failures, but opens up new vulnerabilities. For example, National Institute of Standards and Technology pointed out that the major benefit provided by smart grid, the ability to get richer data to and from customer smart meters and other electric devices, also give major privacy concerns, since the energy use information stored at the meter acts as an information-rich side channel. This information could be mined and retrieved by interested parties to reveal personal information such as individual's habits, behaviors, activities, and even beliefs.

B. Grid Defection

As there is some resistance in the electric utility sector to the concepts of distributed generation with various renewable energy sources and microscope cogent units, several authors have warned that mass-scale grid defection is possible because consumers can produce electricity using off grid systems primarily made up of solar photovoltaic technology.

The Rocky Mountain Institute has proposed that there may wide scale grid defection. This is backed up by studies in the Midwest

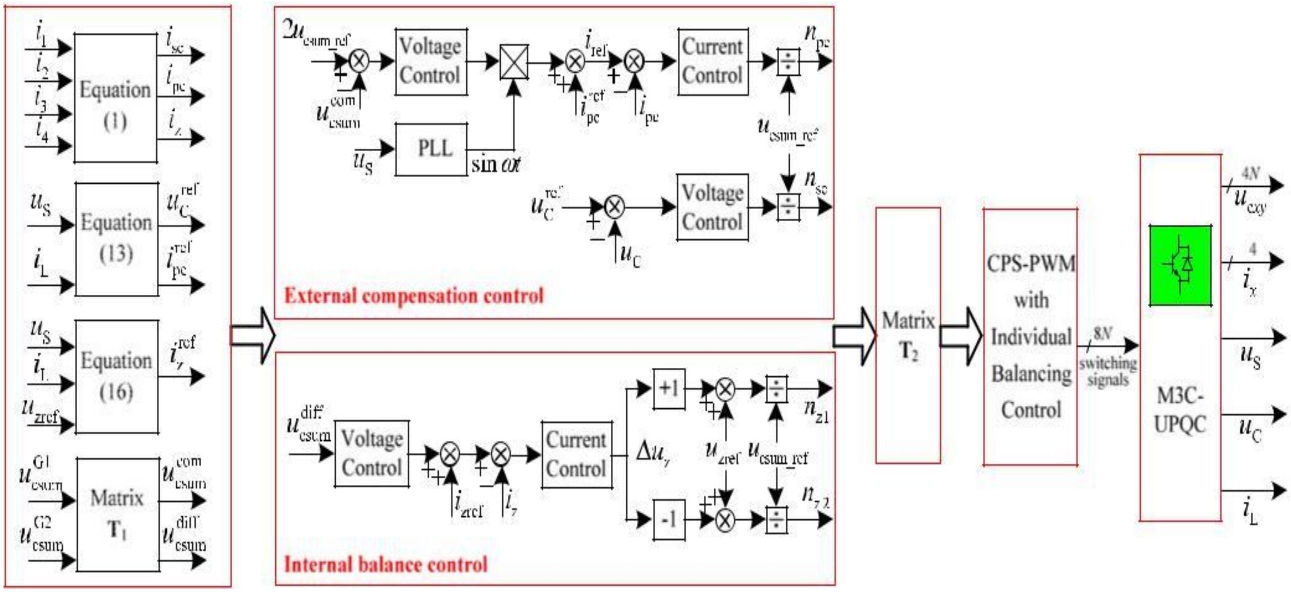
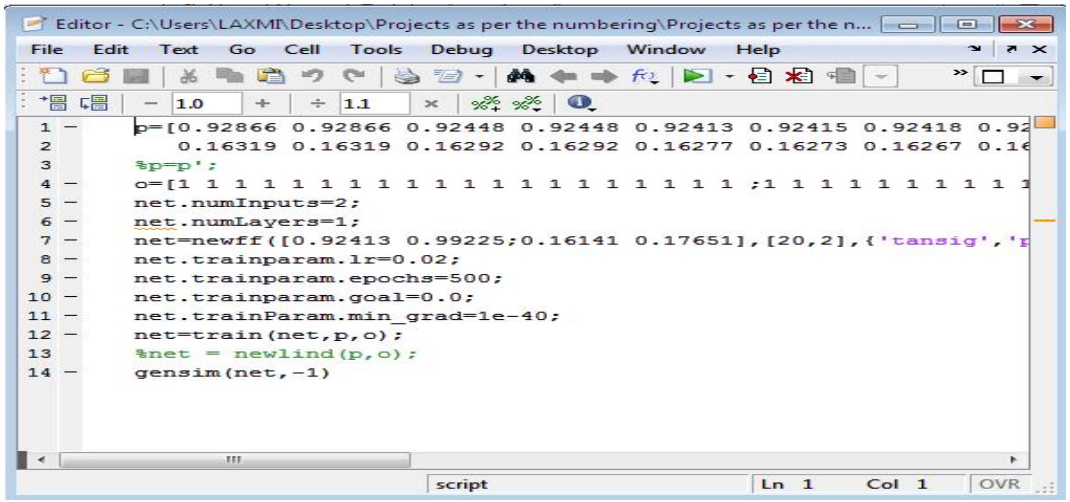


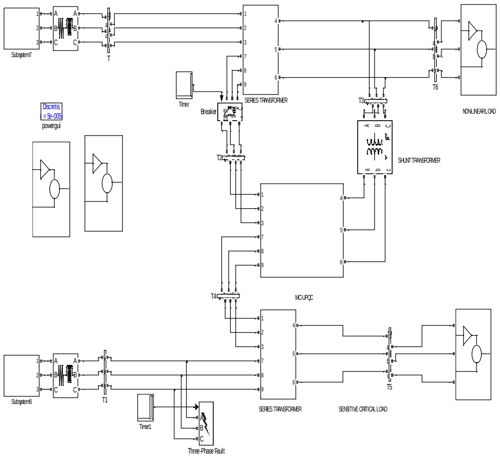
Fig: 5 Block diagram of integrated control for M3C-UPQC.

X. SIMULATION MODELS AND RESULTS

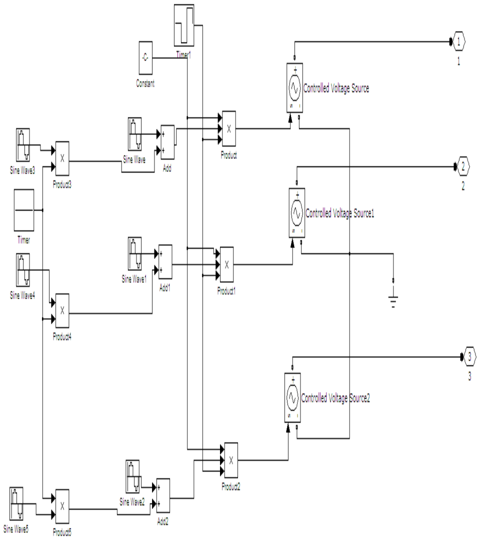


```
p=[0.92866 0.92866 0.92448 0.92448 0.92413 0.92415 0.92418 0.92
    0.16319 0.16319 0.16292 0.16292 0.16277 0.16273 0.16267 0.16
%p=p';
o=[1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 ;1 1 1 1 1 1 1 1 1 1
net.numInputs=2;
net.numLayers=1;
net=newff([0.92413 0.99225;0.16141 0.17651],[20,2],{'tansig','p
net.trainparam.lr=0.02;
net.trainparam.epochs=500;
net.trainparam.goal=0.0;
net.trainParam.min_grad=1e-40;
net=train(net,p,o);
%net = newlind(p,o);
gensim(net,-1)
```

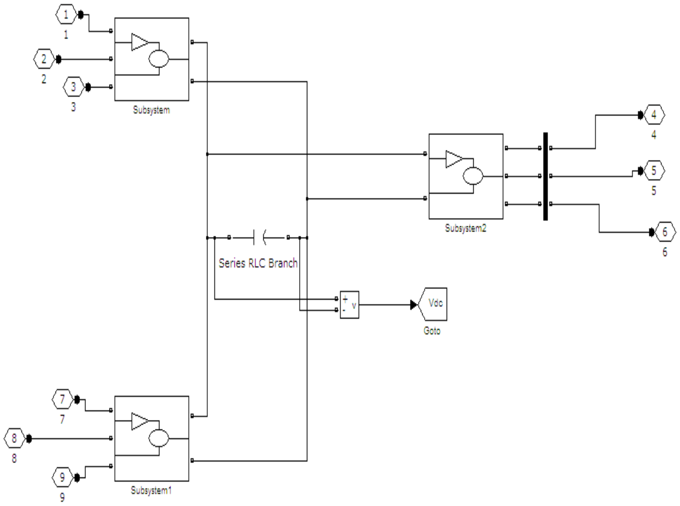
M-file program for ANN



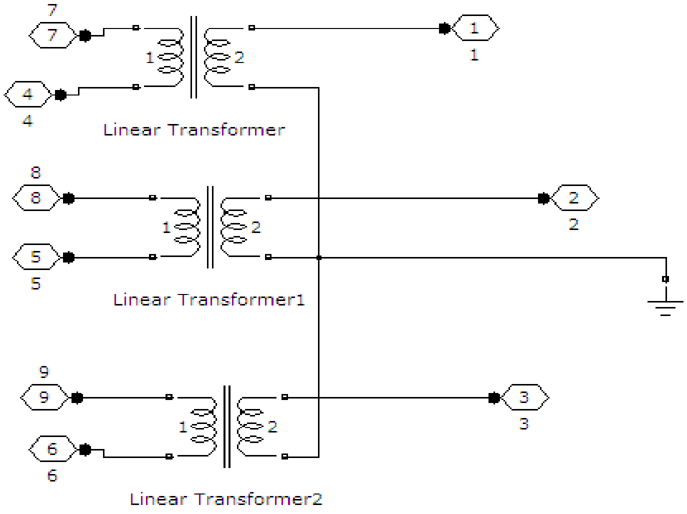
Simulation model of UPQC with Matrix converter



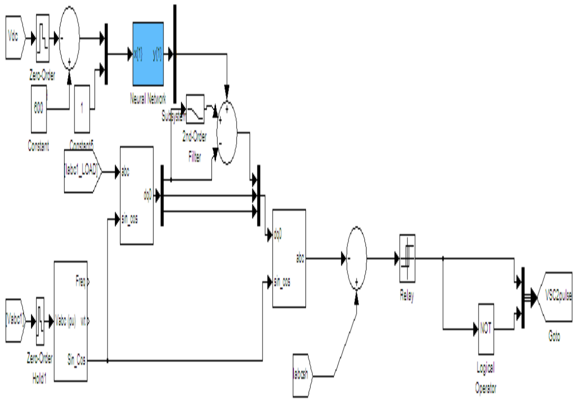
Subsystem of the Source



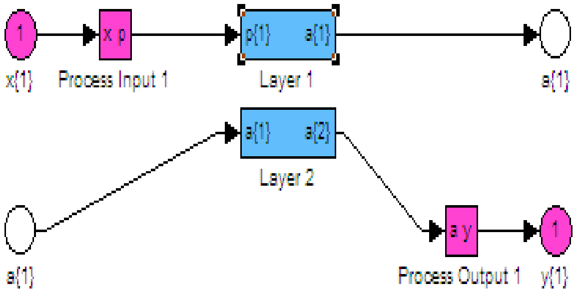
Subsystem of MC-UPQC



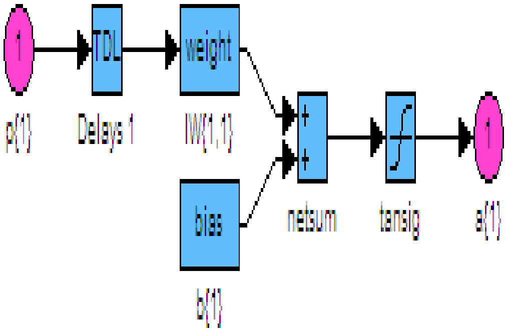
Subsystem of Linear transformer



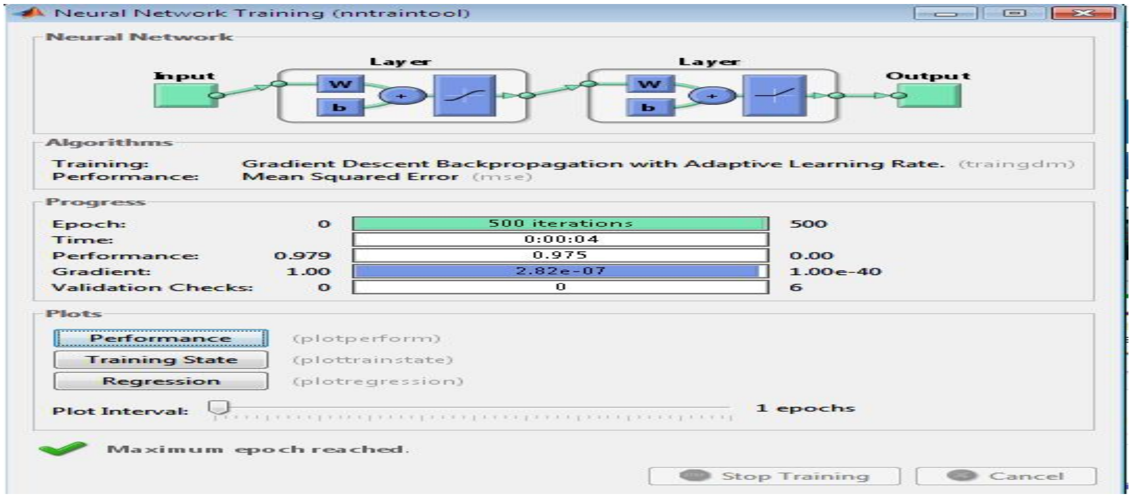
Subsystem of the Voltage control Loop using ANN



Subsystem of the Hidden layers of NN controller



Subsystem of the “net sum” of the NN controller



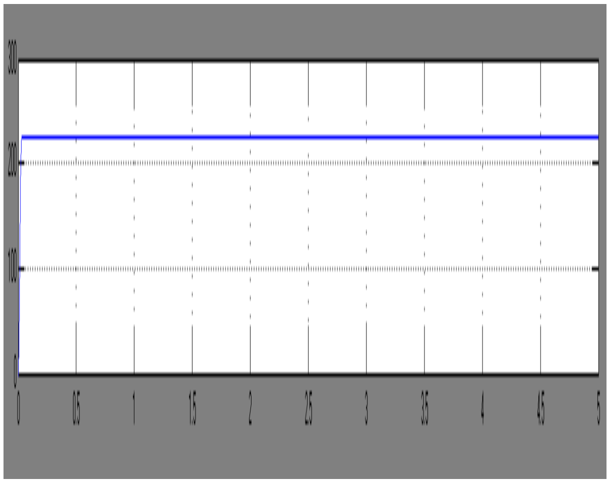
Algorithms
Training: Gradient Descent Backpropagation with Adaptive Learning Rate. (traingdm)
Performance: Mean Squared Error (mse)

Progress

Epoch:	0	500 iterations	500
Time:		0:00:04	
Performance:	0.979	0.975	0.00
Gradient:	1.00	2.82e-07	1.00e-40
Validation Checks:	0	0	6

(plotperform)
(plottrainstate)
(plotregression)
Plot Interval: 1 epochs

✓ Maximum epoch reached.



DC Voltage Versus time (secs)

The calculated results are slightly larger than the simulation results since the phase difference as well as harmonics &currents are disregarded .besides the AC fluctuations of capacitor voltages in 3rd (fourth) arm are coincidence AC fluctuations of capacitors voltages in second (first) arm but with 180 phase shifting

A. In this project the cases like

1) *Reactive Compensation and Harmonic Suppression:* The voltage and current waveforms with reactive compensation and harmonic suppression it can be found that the current drained from the grid is sinusoidal with power factors of 0.98. The THD of the load current is 40.21%, while the THD of the grid current is 5.32%, so the reactive and harmonic currents are effectively suppressed by the parallel part of UPQC
2) *Grid Voltage Sag*: In order to verify the dynamic response of M3C-UPQC, Fig. 10 depicts the experimental results during grid voltage sag, namely 20% of the rated voltage. It is observed that the M3C-UPQC can keep the load voltage at a rated value. Because of the grid voltage sag, the amplitude of grid current increases to 53 A after a fundamental period, and the THD of grid current is 3.86%. Besides, the sub modules capacitor voltages keep balance and slight voltage impulse occurs during the grid voltage step. Meanwhile, there are apparent differences among the periodic ac fluctuations of sub module capacitor voltages in first arm and second arm. The peak-to-peak value of the voltage fluctuation in first arm is 4.8 V and it is 10.1 V in second arm. So the results well coincide
3) *Grid Voltage Swell:*The experimental results during grid voltage swell It can be seen that the load voltage keeps at rated value, whereas the amplitude of grid current decreases to 36 A with the incremental THD of 13.9%. Meanwhile, the sub-module capacitor voltages keep balance with slight voltage impulse during the grid voltage step. Besides, there are remarkable differences among the periodic ac fluctuations of sub module capacitor voltages in first arm and second arms. The peak-to-peak value of the voltage fluctuation in first arm is 9.5 V and it is 4.3 V in second arm.

B. Grid Voltage Harmonic Disturbance

In order to evaluate the performance with harmonic disturbance in the grid voltage, a high-power harmonic generator is used to inject fifth and seventh harmonic voltages. From Fig. 12, it can be found that the THD of the grid voltage is equal to 6.96%, while the load voltage has THD equal to 1.57%. The THD of the grid current remains almost the same, namely 5.40%. So the harmonic voltages are effectively compensated by the series part of UPQC. The capacitor voltages in four arms remain well balanced and show little changes compared with *CASE A*. Hence, it proves that ignoring the harmonic voltages and currents has little influence on the instantaneous power calculation.

XI. CONCLUSION

A single –phase UPQC configuration based on single –phase M3C conducted and simulated in this paper .the assembling of unified modules makes it possible to use low-voltage power devices according to an adequate number of sub modules, which allows the use at M3C power grid, the intermediate dc line in the back –to-back converters is avoidable, which is beneficial to simplify the encapsulation of the overall system. In addition to this ANN, integrated control strategy is proposed to balance the power distribution among h-bridge arms

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