Simulation of Interline Unified Power Quality Conditioner (IUPQC) with Artificial Neural Networks

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Abstract: Interline Unified Power Quality Conditioner (IUPQC) is combo of Series and shunt connected second order devices for enhance the power quality (PQ) in distribution system. The role of an IUPQC, which provides both shunt and series compensation, in enhancing the ride through capability is investigated under both full and partial voltage restoration also used for harmonic reduction. This paroject compares total harmonic distortion of IUPQC with Fuzzy Logic (FL), Artificial Neural Networks and Proportional Integral (PI) Controller in PQ enhancement in two feeder utilization system. The proposed IUPQC provides compensation in Voltage disturbances like sag/swell and reduction in Total Harmonic distraction. The efficiency of the proposed configuration has been verified and compared with PI, FL and ANN Controllers configuration through simulation studies using MATLAB/SIMULINK.

KEYWORDS: IUPQC, Harmonics, Fuzzy logic controller, Artificial Neural Networks

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INTRODUCTION

Now a days industries and industrial applications are widely required the power electronic loads. These loads can operate with the help of power electronic devices. As the amount of load increase the number of converters will be more. As know that the increasing power electronic converters will increase the power electronic devices like IGBT, GTOs and MOSFET switches. But the increasing number of switches faces the problem of abnormal current harmonics and harmonic distributions in the converters, In order to reduce or eliminate this situation. Power electronic devices draw harmonics and reactive power from the supply side due to non linear loads. Generally Series active power filter and shunt active power filter are used to solve the voltage and current based distortions [1-4].

VOLTAGE-SOURCE CONVERTER (VSC)-based custom power devices are increasinglybeing used in custom power applications for improving the power quality (PQ) of powerdistribution systems. Devices such as distribution static compensator (DSTATCOM) anddynamic voltage restorer (DVR) are the facts devices. A DSTATCOM can compensate fordistortion and unbalance in a load such that a balanced sinusoidal current flows through thefeeder. It can also regulate the voltage of a distribution bus. A DVR can compensate forvoltage sag/swell and distortion in the supply side voltage such that the voltage across asensitive/critical load terminal is perfectly regulated.A unified power-quality conditioner(UPQC) can perform the functions of both DSTATCOM and DVR. The UPQC consists oftwo voltage-source converters (VSCs) that are connected to a common dc bus. One of theVSCs is connected in series with a distribution feeder, while the other one is connected inshunt with the same feeder. The dc links of both VSCs are supplied through a common dccapacitor. It is also possible to connect two VSCs to two different feeders in a distributionsystem.In,aconfigurationcalledIDVRhasbeendiscussedinwhichtwoDVRsareconnectedinseries with twoseparateadjacentfeeders.Thedcbuses of theDVRs areconnected together. The IDVR absorbs real power from one feeder and maintains the dc linkvoltage to mitigate 40% (about 0.6 p.u.) voltage sag in the other feeder with balanced loadsconnectedin thedistribution system.ItisalsopossibletoconnecttwoshuntVSCs todifferent feeders through a common dc link. This can also perform the functions of the twoDVRsmentionedabove,albeitwithhigherdeviceratin g.

IUPQC SYSTEM WITH CONTROL METHODS

UPQC mainly includes three parts: the series active power filters, shunt active power filters and energy storage capacitors.

The series and shunt active power filter couples together through the DC-link energy storage capacitors. Series APF connected to the grid and load by coupling transformer is mainly used to adjust the load voltage amplitude and compensate the power supply voltage sag in the controlled voltage source mode. Shunt active filter connected to the load is used to compensate load currents.

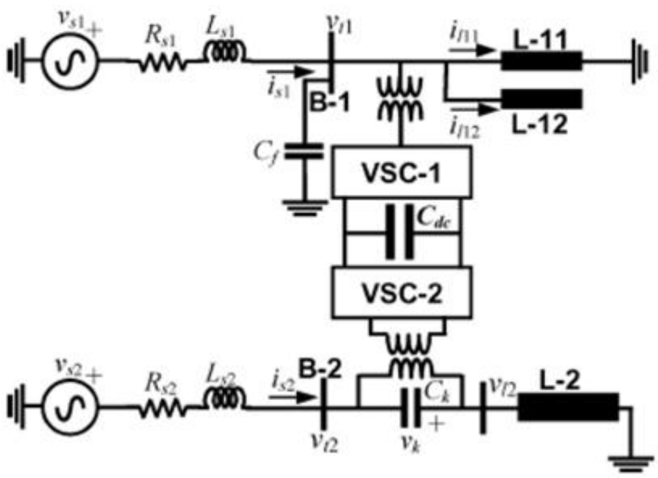

Fig 1: Topology of IUPQC

ACTIVE POWER FILTERS

Current Source Inverter (CSI) Active Power Filter [Fig 2] and Voltage SourceInverter (VSI) Active Power Filter [Fig 3] are two classifications in this category.Current Source Inverter behaves as a non-sinusoidal current source to meet the harmoniccurrentrequirementofthenonlinearloads.Adiodeisusedinserieswiththeself-commutatingdevice(IGBT)forreversevoltageblocking.However,GTO-basedconfigurations do not need the series diode, but they have restricted frequency of switching.They are considered sufficiently reliable, but have higher losses and require higher values ofparallel ac power capacitors. Moreover, they cannot be used in multilevel or multistep modestoimproveperformanceinhigherratings.

The other converter used as an AF is a voltage-fed PWM inverter structure, as shownin Fig 3.It has a self-supporting dc voltage bus with a large dc capacitor. It has becomemore dominant, sinceitislighter,cheaper,andexpandable tomultilevel andmultistepversions, to enhance the performance with lower switching frequencies. It is more popular inUPS-based applications, because in the presence of mains, the same Inverter Bridge can beusedasanAFtoeliminate harmonics ofcriticalnonlinearloads. AF'scanbeclassifiedbasedonthetopologyused asseriesorshuntfilters,andunifiedpowerqualityconditionersuseacombinationofboth.Combinationsofactiveseries and passive shunt filtering are known as hybrid filters. An example of an activeshuntfilter,whichismostwidely usedtoeliminatecurrentharmonics,reactivepowercompensation also known as STATCOM, and balancing unbalanced currents. It is mainlyused at the load end, because current harmonics are injected by nonlinear loads. It injectsequalcompensatingcurrents,oppositeinphase,tocancelharmonicsand/orreactivecomponents of the nonlinear load current at the point of connection. It can also be used as astaticVARgenerator(STATCOM)inthepowersystemnetworkforstabilizingandimprovingthevoltageprofile.

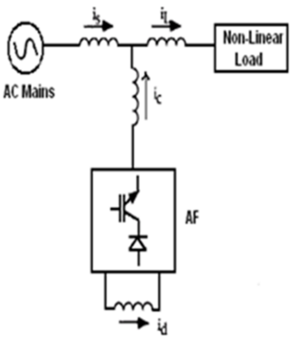

Fig 2: Current fed type AF

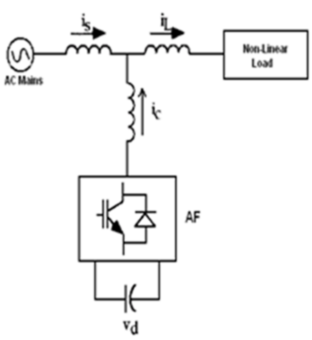

Fig 3: Voltage fed type AF

Power Quality (PQ) is generally defined as any change in power (voltage, current, or frequency) that interferes with the normal operation of electrical equipment.Power quality may also be defined as the degree to which both the utilization and delivery of electric power affects the performance of electrical equipment. From a customer perspective, a power quality problem is defined as any power problem manifested in voltage, current, or frequency deviations that result in power failure or disoperation of customer of equipment.

The definition of power quality given in Institute of Electrical and Electronic Engineers (IEEE) dictionary originates in IEEE Std 1100: "the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment."

Power quality problems concerning frequency deviation are the presence of harmonics and other departures from the intended frequency of the alternating supply voltage [4]. On the other hand, power quality problems concerning voltage magnitude deviations can be in the form of voltage fluctuations, especially those causing flicker. Other voltage problems are the voltage sags, short interruptions and transient over voltages. Some common reason for voltage sags are lightning strikes in power lines, equipment failures, accidental contact power lines, and electrical machine starts [5].

Non-ideal sinusoidal waveforms were produced by synchronous generators in the past; however modern generators are far more advanced. Generators nowadays have excellent control systems which allow them to produce almost perfect sinusoidal waveforms. Nonetheless transformer saturation is still a cause of harmonics on systems while the main cause of harmonics is non-linear loads. This is due their tendency to draw a current that is far from being sinusoidal.

With advances in power electronics, harmonics is a problem that is becoming quite severe in almost every power system.

Common causes of harmonics are:

1. Fluorescent Lighting
2. Arc Furnace
3. Power Supplies and Converters
4. Adjustable Speed Drives
5. Cycloconverters

FUZZY LOGIC CONTROLLER

Step1:Fuzzificationofinputvariables.

Step2:ApplicationofFuzzyoperator.(AND, OR,NOT)IntheIF(antecedent)partoftherule.

Step3:Implication fromtheantecedent to theconsequent(Thenpart ofthe rule).Step4:Aggregationofthe consequents acrosstherules.

Step5:Defuzzification.
Generally therewillbeamatrixofrulessimilartotehESrulematrixfor Ex:Thereare7MFforinputvariables'x'and MFfor inputvariable 'y'thentherewillbe alltogether35rules.

Implicationmethod

Theimplicationstep (3)wasintroduced fortheevaluationofindividualrules.Methods:

1) MAMDANI
2) SUGENO
3) LUSINGLARSON.

The sugeno or Takgi-Sugeno-Kang method of implication was first introduced in1986. Thedifference here is that unlike the Mamdani and Lusins Larson methods, the output MFS areonlyconstantsorhavelinearrelationswiththeinputswithaconstantoutputMF (Singleton),it is defined as the Zero-order Sugeno method; whereas with a linear relation, it is known asfirst order Sugeno method. The outputs of the sugeno method have a constant minimum valueintheinput.

InferenceEngine

There are two basic types of approaches employed in the design of the inference engine offuzzylogiccontroller:

Compositionbasedinference(firing)

Inthiscase,thefuzzyrelationsrepresentingthemeaningofeachindividualruleareaggregated into one fuzzy relation describing the meaning of the overall set of rules. Theninterference of firing with this fuzzy relation is performed via the operation compositionbetween the fuzzified crisp input and the fuzzy relation representing the meaning of theoverall set of rules. As resultof the composition one obtains the fuzzy setdescribing thefuzzyvalueoftheoverallcontroloutput.

Individual-rulebasedinference:

Inthiscase,firsteachsingleruleisfired,Thisfiringcanbesimplydescribedby:(1)computing the degree of match between the crisp input and the fuzzy sets describing themeaning of the rule – antecedent and (2) "clipping" the fuzzy set describing consequent to thedegree towhich the rule-antecedenthasbeen matchedbuy the crispinput.Finally,the"clipped" values for the control output of each rule are aggregated, thus forming the value ofthe overall control output. Usually, the second type of inferenceis preferred sinceitiscomputationallyoverefficientandsaves alotofmemory.

DefuzzificationandDenormalization:-

The functionofadefuzzificationmodule(DM)isas follows:

Performs the so-called defuzzification,which converts the setof modified control outputvaluesintosingle point–wisevalues.

Performs an output denormilization,which maps the point-wise value of the control outputonto itsphysicaldomain.Thisstep innot neededifnonnormalizedfuzzysetsisused.

Adefuzzificationstrategyisaimedatproducinganon-fuzzycontrolactionthatbestrepresents the possibility of an inferred fuzzy control action. Seven strategies in the literature,among the many thathave been proposed by investigators, are popularfor defuzziffyingfuzzyoutputfunctions.

ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks are relatively crude electronic models based on the neural structure of the brain. The brain basically learns from experiences. It is natural proof that are beyond the scope of current computers are indeed solvable by small energy efficient packages. This brain modeling also promises a less technical way to develop machine solutions. These biologically inspired methods of computing are thought to be the next major advancement in the computing industry. Even simple animal brains are capable of functions that are currently impossible for computers. Computers do rote things well, like keeping ledgers or performing complex math. But computers have trouble recognizing even simple patterns much less generalizing those patterns of the past into action of the future.

Now, advance in biological research promise an initial understanding of the natural thinking mechanism. This research shows that brain stores information, as patterns. Some of these patterns are very complicated and allow us the ability to recognize individual faces from any different angles. This process of storing information as patterns, utilizing those patterns, and then solving problems encompasses a new field in computing. This field does not utilize traditional programming but involves the creation of massively parallel networks and the training of those networks to solve specific problems. This field also utilizes words very different from traditional computing, words like behave, react, self-organize, learn, generalize, and forgot. An artificial neural network (ANN), often just called a "neural network" (NN), is a mathematical model or computational model based on biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. In more practical terms neural networks are non-linearstatisticaldata modeling tools. They can be used to model complex relationships between inputs and outputs or to find patterns in data. A neural network is an interconnected group of nodes, akin to the vast network of neurons in the human brain.

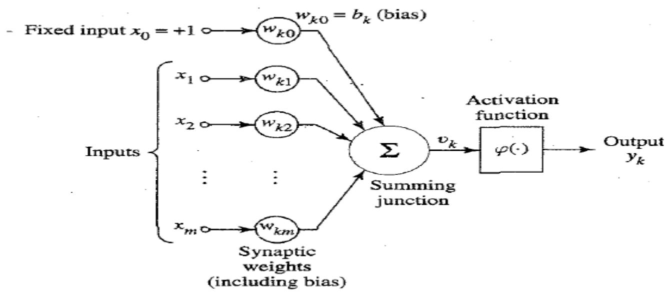

Fig 4: Artificial Neural Networks

SIMULATION RESULTS

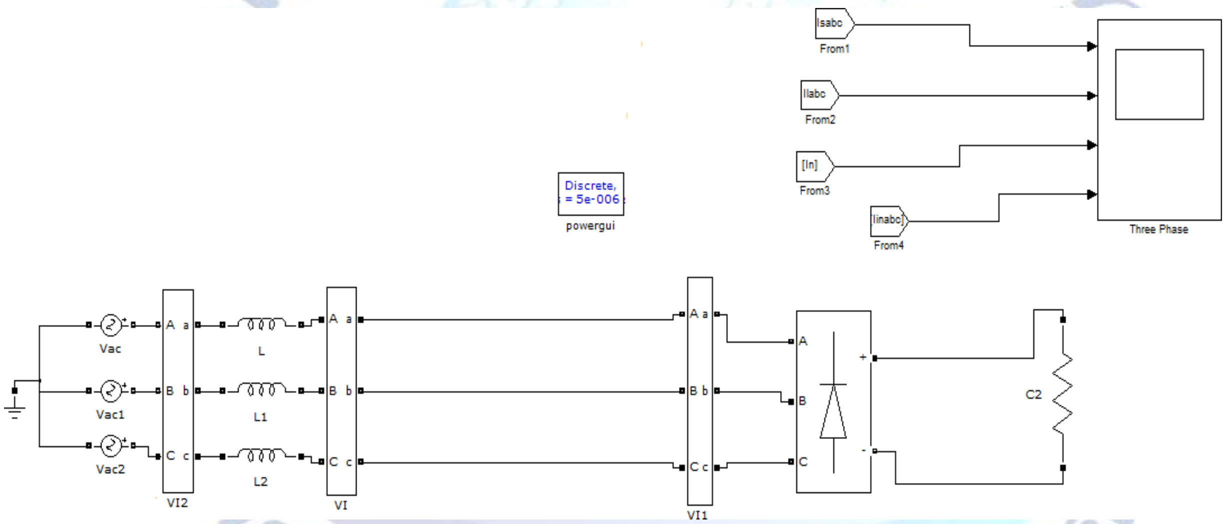

Fig. 5: Simulationofsourcecurrentwithnonlinearload

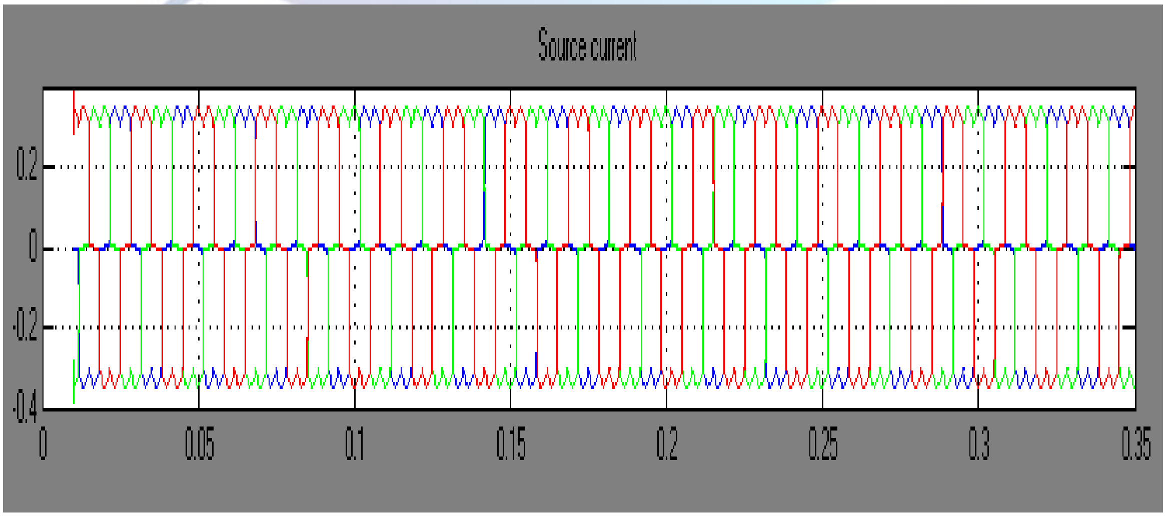

Fig. 6: Sourcecurrentharmonicsdue tononlinearload

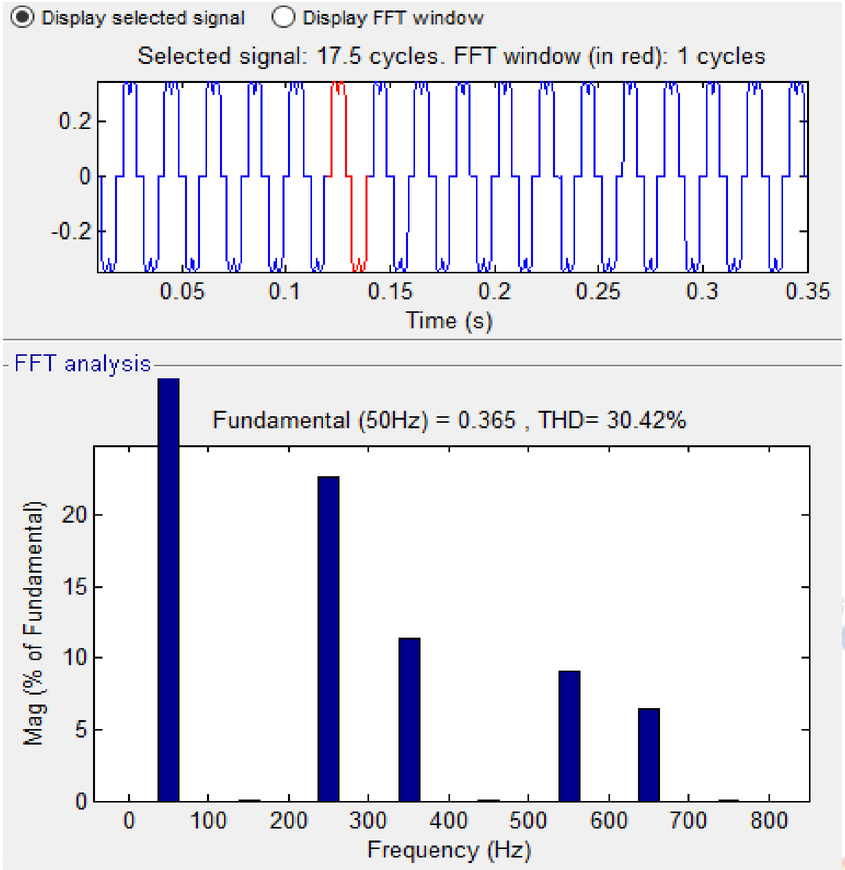

Fig.7. SourcecurrentharmonicswithoutIUPQC

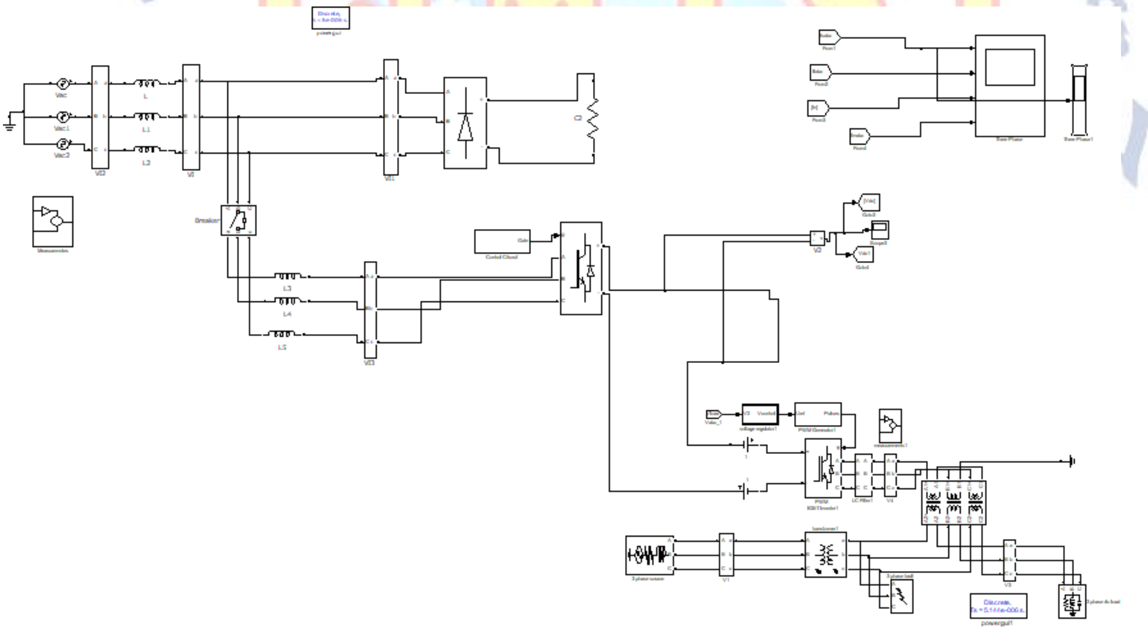

Fig. 8: IUPQCwithPIcontroller

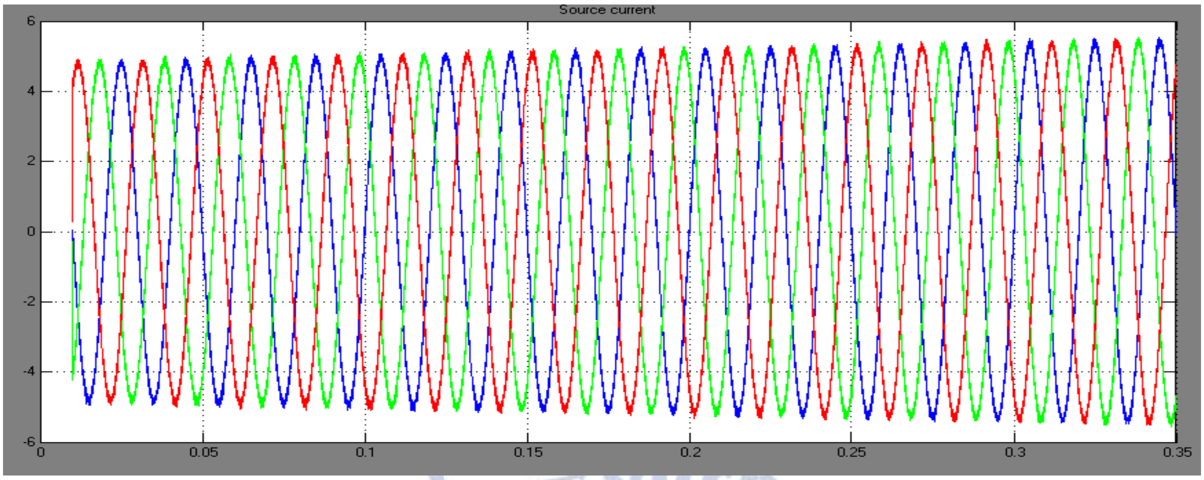

Fig. 9: SourcecurrentwithPIcontroller

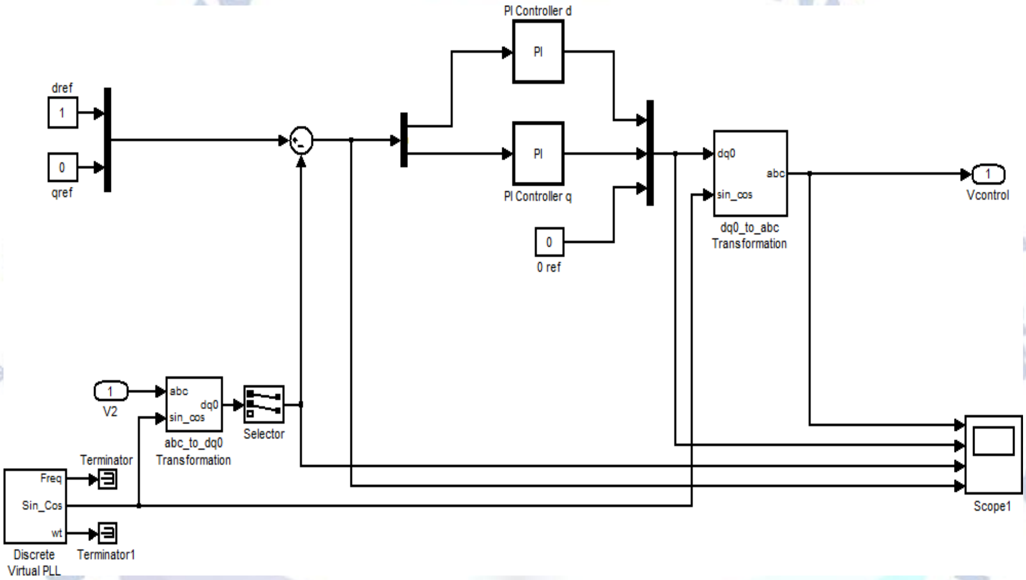

Fig.10. ShuntfilterwithPIcontroller

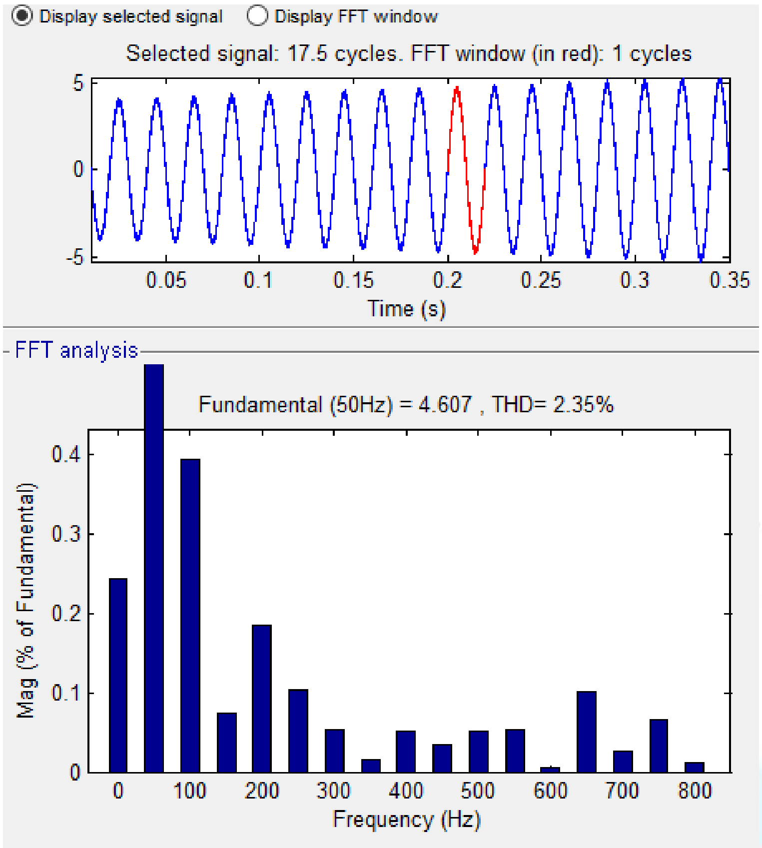

Fig11. THDwith PI Controller

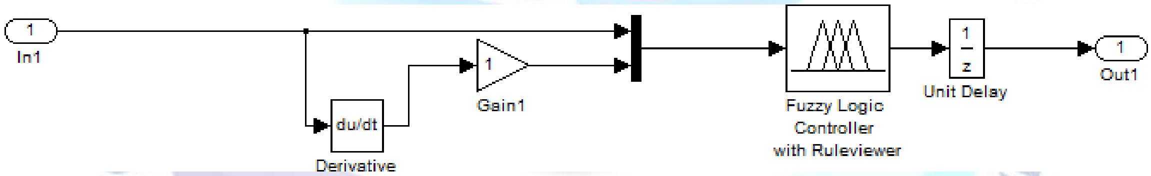

Fig.12. Shuntfilterwithfuzzycontroller

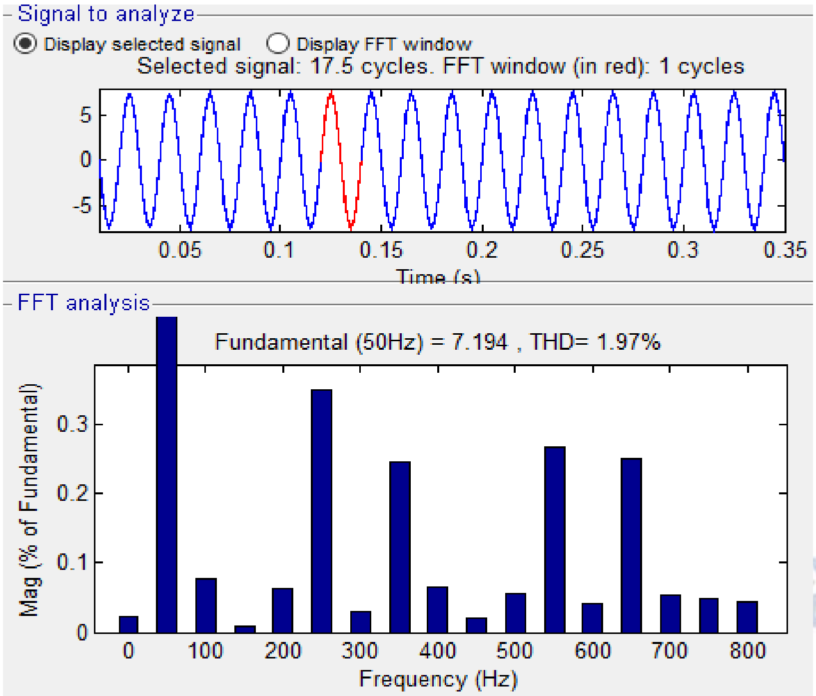

Fig.13. THDofShuntfilterwithfuzzy

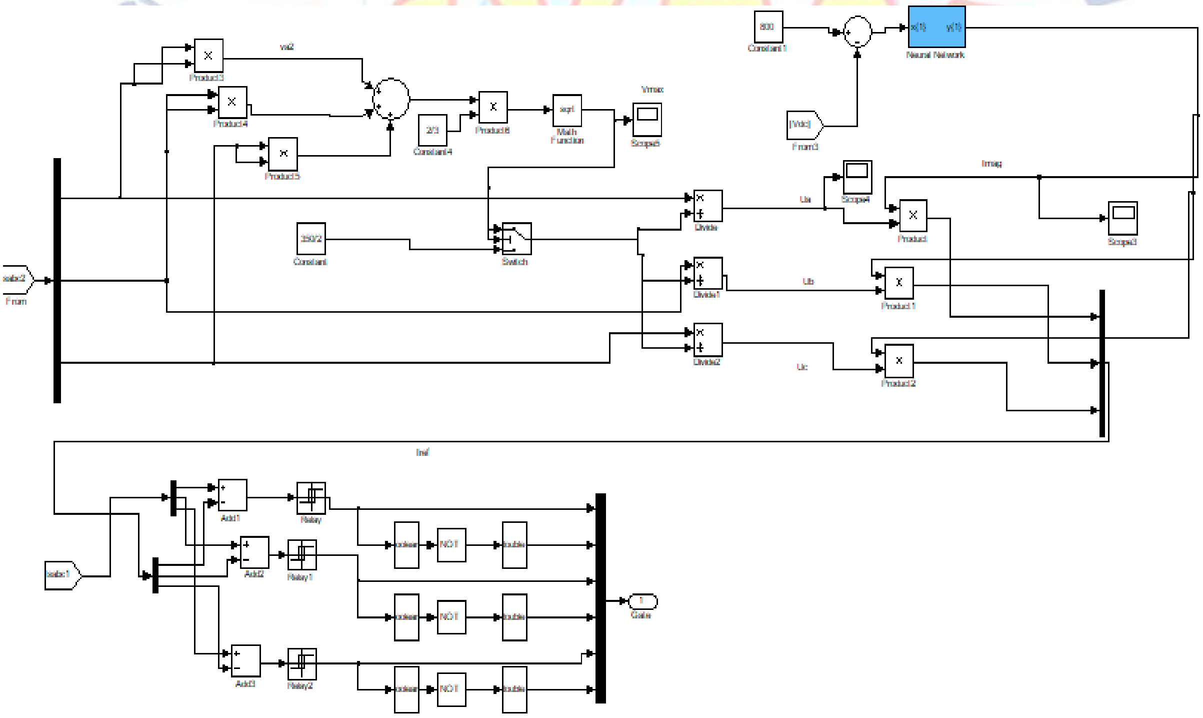

Fig.14. ShuntfilterwithANN

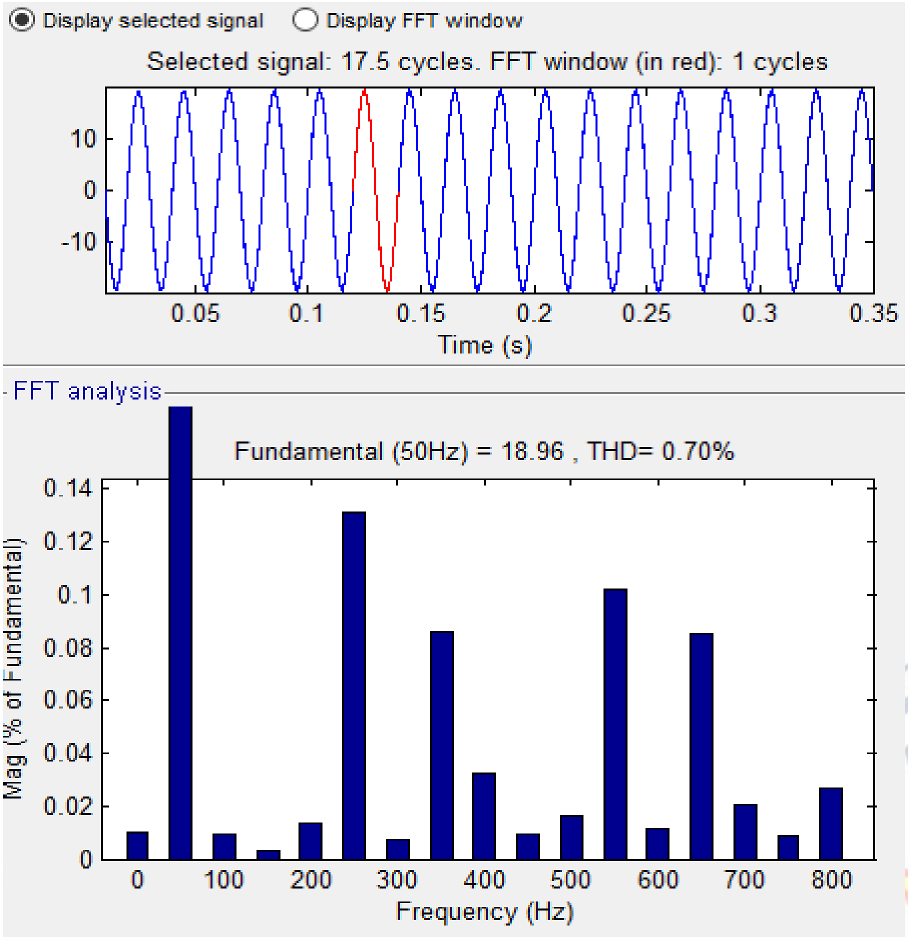

Fig.15. THDwithANN

MATLAB basedmodelseriescontroller

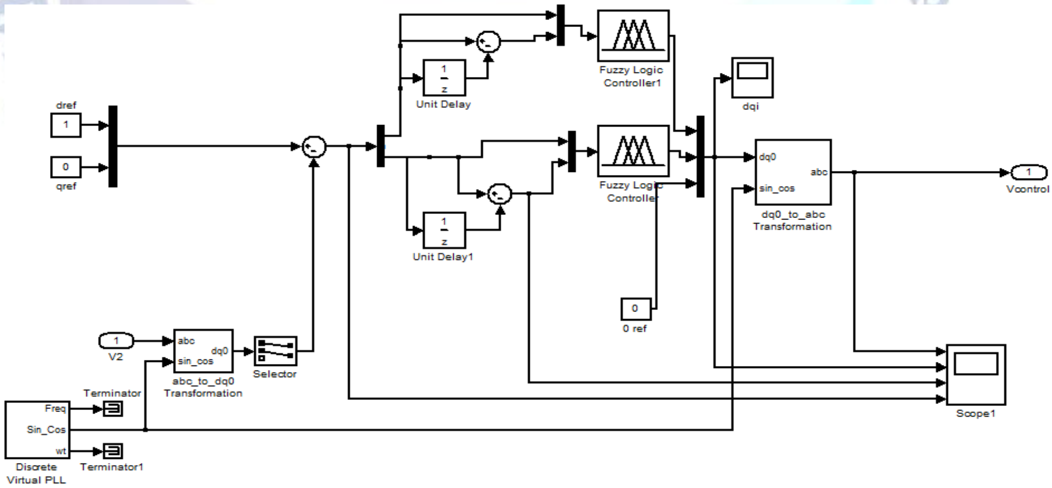

Fig.16. Seriescontrolusingfuzzylogiccontroller

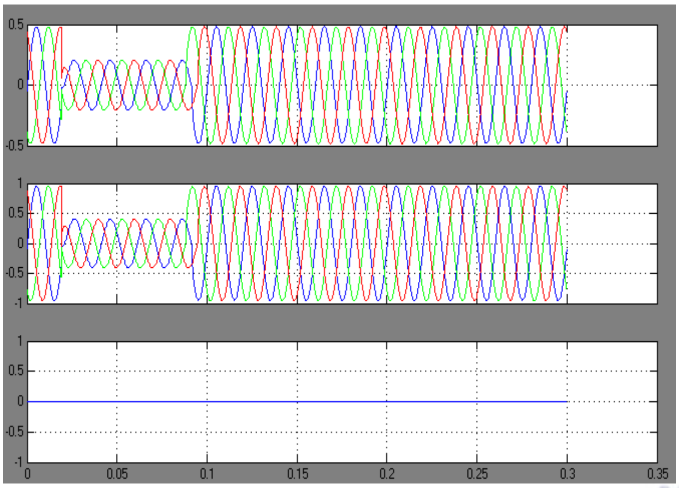

Fig.17. WithoutIUPQCsourcevoltageandinjectedvoltage

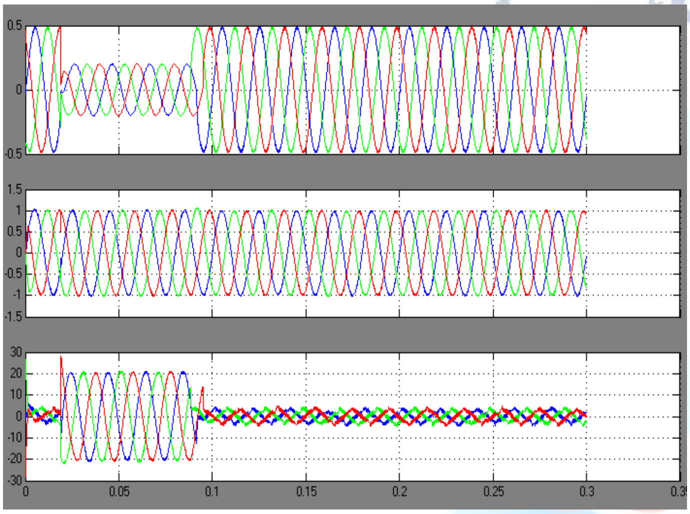

Fig.18. IUPQCresultswithPI controller

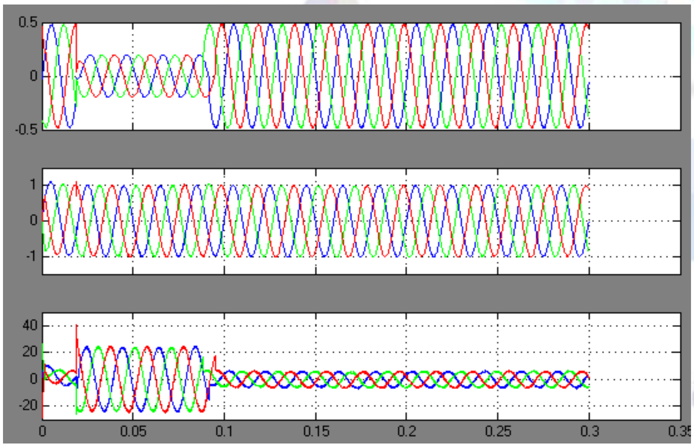

Fig.19. IUPQCusingfuzzycontroller

CONCLUSION

Thisprojectillustratestheoperationandcontrolofaninterlineunifiedpowerqualityconditioner (IUPQC). The device is connected between two feeders coming from differentsubstations. An unbalanced and non-linear load L-1 is supplied by Feeder-1 while a sensitiveload L-2 is supplied through Feeder-2. The main aim of the IUPQC is to regulate the voltageat the terminals of Feeder-1 and to protect the sensitive load from disturbances occurringupstream. The performance of IUPQC is simulated matlab simulink the IRP theory and abc todqtheoryhavebeenusedforDSTATCOMandDVRrespectively.Toenhancetheperformance under unbalanced, nonlinear and faulty conditions it observes that the proposedIUPQC effectively protect the sensitive loads from sag conditions and current harmonics. InDSTATCOM to adjust the dc link voltage PI, fuzzy and ANN controllers. ANN based controltechnique providesbetterresults.

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