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Simulation of STATCOM for the Reduction of T.H.D by Using F.L.C

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Abstract: When non-linear load is connected to the grid, the non-linear load injects harmonics into the grid. The harmonics can be mitigated by introduction of STATCOM at the point of common coupling. The required pulses for the STATCOM can be generated by using Bang-bang controller along with fuzzy logic controller. The use of only bang-bang controller along with PI controller produces satisfactory results. Hence to get better results i.e's reduction in the total harmonic distortion (T.H.D) we use fuzzy logic controller in place of PI controller.

Keywords: Fuzzy Logic Controller (F.L.C), STATCOM, Total Harmonic Distortion(T.H.D),Bang-Bang Controller, Non-Linear Load,Voltage Source Inverter,Grid Synchronisation.

I. INTRODUCTION

A.ELECTRIC POWER QUALITY

Even a few years back,the main concern of consumers of electricity was the dependancy of supply.Here we define dependancy as the continuity of electric supply.Although the power generation in most advanced countries is somewhat reliable,the distribution is not always so. The transmission systems complicates the problem further as they are exposed to the vagaries of Mother Nature. It is however not only the dependability that the consumers want these days, quality is the main concern to them. For instance, a consumer that is connected to the same bus that supplies a large motor load may have to face a severe dip in his supply voltage every time the motor load is switched on.In some extreme cases, he may have to bear with blackouts. This may be quite unacceptable to most customers. There are also very delicate loads such as nursing homes(medicine , operation theatre, patient database system), raw material processing plants, air traffic control, institutions and numerous other data processing and service providers that require clean and uninterrupted power. In several processes such as semiconductor manufacturing or food manufacturing plants, a batch of product can be ruined by a voltage dip of very short duration. Such customers are very worried of such dips since each such interruption cost them a substantial amount of money. Even short dips are enough to cause contractors on motor drives to drop out. Stopping in a portion of a process can destroy the conditions for quality control of the product and require restarting of production. Thus in this changed situation in which the customers increasingly demand quality power, the term power Quality (PQ) attains increased significance.

Transmission lines are exposed to the forces of nature. moreover, each transmission line has its loadability limit that is often determined by either stability considerations or by thermal limits. Even though the power quality problem is a distribution side problem, transmission lines often have an affect on the quality of power supplied.It should be noted that while most problems associated with transmission systems arise due to the forces of nature or due to the interconnection of power systems, single customers are responsible for a more substantial fraction of the problems of power distribution systems.

B. IMPACTS OF POWER QUALITY PROBLEMS ON END USERS

The causes for power quality problems are generally complex and difficult to detect. In technical terms, the ideal ac line supply by the utility system should be pure sinewave of fundamental frequency (50/60Hz). In addition, the peak of the voltage should be of rated value. But the actual ac line supply that we receive everyday departs from the ideal specifications.

There are many ways in which the lack of quality power affects customers. Impulsive transients does not travel very far from their point of entry. An impulsive transient can give rise to an oscillatory transient. The oscillatory transient can give rise to transient overvoltage and consequent damage to the power line insulators. Impulsive transients are usually put down by surge arresters.

Short duration voltage variations have varied effects on consumers. Voltage sags (also known as dips) are the source for loss of production in automated processes since a voltage sag can trip a motor or cause its controller to malfunction.For semiconductor manufacturing industries such a loss can be substantial. A voltage sag can also force a computer system or data processing system to crash. To avoid such a crash, an uninterruptible power supply (UPS) is often used, which, in turn may give rise to harmonics. The protective circuit of an adjustable speed drive(ASD) can trip the system during a voltage swell. Also voltage swells can put weight on computers and many home appliances, thereby reducing their lives. A temporary interruption which lasts a few seconds can cause a loss of production, loss of memory etc. The cost of such interruption during peak hours can be hundreds of thousands of dollars.

The impact of long duration voltage variations is greater than those of short duration variations. A sustained overvoltage lasting for few hours can cause damage to household appliances without their ower knowing it, until it is too late. The undervoltage has the same effect as that of a voltage sag. In the case of a sag the termination of process is abrupt. But normal operation can be resumed after the normal voltage is restored. However in the case of a sustained undervoltage, the process cannot even be started or resumed. A sustained interruption is usually created by a faults. Since the loss to customers due to any sustained interruption can be in the order of millions of dollars, it becomes necessary for the utility to have a good preventive maintenance schedule and to have agreements or regulations to encourage high supply reliability.

Volage imbalance can cause temperature rise in motors and can even cause a large motor to trip. Harmonics, dc offset and notching make the waveform distortions. Harmonics are the integer multiples of fundamental frequency, fractions of the fundamental frequency (subharmonics) and at frequencies that are not integer multiples of the fundamental frequency (interharmonics). Unwanted harmonic currents passing through the distribution network can causes losses. Harmonics also can cause defect of ripple control or traffic controlsystems, malfuncting in transformers, electromagnetic interference(EMI) and interference with the communication systems. Ripple control refers to the use of a 300Hz to 2500Hz signal added to distribution lines to control switching of loads such as hot water heaters or street lighting. Interharmonic voltages can upset the operation of fluorescent lamps and television receivers. They can also cause acoustic noise in power equipment. DC offsets can cause saturation in the power transformer magnetic circuits. A notch is a periodic transient that rides on the supply voltage. It can disturbance capacitive components connected in shunt due to high rate of voltage rise at the notches.

Voltage flickers are frequent variations in voltage that can cause the light intensity from incandescent lamps to vary. This variation is perceived as disturbance by human observers,in the range of 3 to 15 times per second. The voltage flickers can have adverse effects on human health as the high frequency flickering of radiation can cause strain on the eyes resulting in headaches or migraines.The voltage flicker can also decrease the life span of electrical goods.

We can therefore conclude that the lack of standard quality power can cause loss of production,loss of equipment or appliances or can even be detrimental to human health. It is therefore important that a high standard of power quality is maintained.

II. Static Compensator(STATCOM)

This is a shunt device that does not require passive elements like inductors and capacitors. The diagram of a SMIB power system that is compensated by a shunt compensator is shown in figure 1.

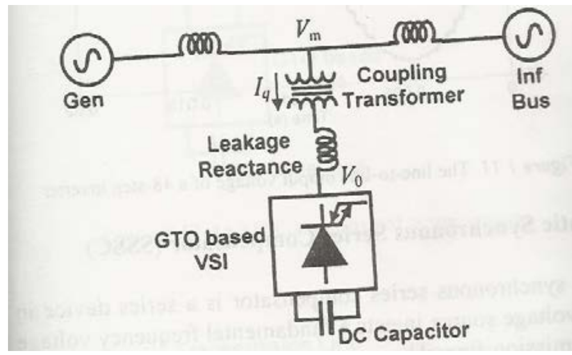

Figure 1: A STATCOM connected to an SMIB power system

The STATCOM is built around a VSI, which is supplied by a dc capacitor. The VSI consists of GTO switches which are turned on and off through a gate driven circuit.

The output of the voltage source inverter is connected to that ac system through a coupling transformer. The VSI produces a quasi sinewave voltage V_0 at the fundamental frequency. It is assumed that the losses in the inverter and the coupling transformer are negligible. The VSI is then gated such that the output voltage of the inverter V_0 is in phase with the local bus voltage V_m. In this situation two ac voltages that are in phase are connected together through a reactor, which is the leakage reactance of the transformer. Therefore the current Iq is purely reactive. If the value of the voltage V_m is more than that of the voltage V_0, the reactive current Iq flows from the bus to the inverter. Then the inverter will absorb reactive power. If, on the other hand, the magnitude of V_0 is greater than that of V_m , then that inverter feeds reactive power to the system. Therefore through this view the STATCOM can generate or absorb reactive power. In practice however the losses are not negligible and must be drawn from the ac system. This is acheived by slightly shifting the phase angle of the voltage V0 through a feedback mechanism such that the dc capacitor voltage is held constant.

The structure of the GTO-based VSI must be so chosen that the lower order harmonics are eliminated from the output voltage. The Inverter will then resemble a synchronous

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voltage source.It is Because the switching frequency of each GTOs must be kept low,and the overall switch ripple needs to be kept low without use of PWM. This is accomplished by connecting a large number of basic inverter modules.

III. CONTROL SCHEME

A. Grid Synchronisation

In the three-phase balance system, the RMS source voltage magnitude is calculated from the source phase voltages (Vsa, Vsb, Vsc) and is expressed as sample template (sampled peak voltage),V sm :

$Vsm = \sqrt{2/3(Vsa^2+Vsb^2+Vsc^2)}$…..(1)

The phase-in unit vectors are obtained from source voltage in each phases and the RMS value of unit vector is shown below.

Usa =Vsa/Vsm

Usb =Vsb/Vsm …………..(2)

Usc =Vsc/Vsm

The phase in reference currents are derived using in-phase unit voltage template as shown below.

isa*=I* Usa, isb*=I*Usb, isc*= I* Usc ..(3)

Where 'I' is proportional to magnitude of filtered source voltage for respective phases. This enables that the source current is controlled to be sinusoidal.

B.Bang-Bang Current Controller

Bang-Bang current controller is implemented in the current control mode. The reference current is generated as in (3) and the actual current are detected by current sensors and are subtracted for obtaining a current error for a hysteresis based bang-bang controller. Thus the On/OFF signals for the VSI based STATCOM are derived from hysteresis controller.

The switching function SA for phase 'a' is expressed as:

$(i_{sa} - i_{sa}^*) < HB = S_A = 1$

$(i_{sa} - i_{sa}^*) > HB = S_A = 0$

This is same for phases 'b' and 'c'.

C.Fuzzy Logic Controller

- Fuzzy logic control actually involves the derivation of a control law from imprecise rules.
- The outline of the fuzzy logic control system that is employed for designing the fuzzy controller is shown in Figure 2

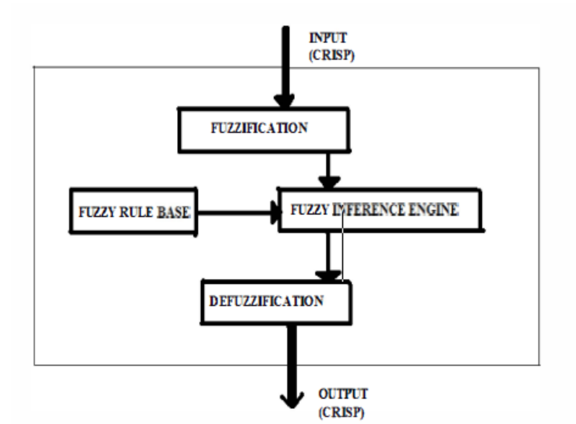

Figure 2:Fuzzy logic control

- The FLC contains four main components, they are The fuzzification interface (fuzzification),the knowledge base(fuzzy rule base), the decision making logic(Fuzzy inference engine) and the defuzzification interface (Defuzzification).

- A mamdani type Double Input Single output (DISO) is used.
- The steps involved in the designing of fuzzy logic controller are:

1.Choose the inputs to FLC(Input-crisp): The inputs to FLC used in this study are V_{dc} and $V_{dc(ref)}$.

2.Choose membership functions to represent the inputs and outputs in fuzzy set notation (Fuzzification): Triangular membership functions were selected for the study, with sevenlingistic variables choosen as PB (positive Big), PM (positive medium),PS (positive Small), ZE (zero), NS(negative Small), NM(negative medium) and NB (negative Big).

3.Develop fuzzy rules (fuzzy rule base): A set of decision rules relating the inputs to the controller with the output are complied and stored in the form of decision table. Fourty nine rules for the present study are developed as follows:

Vdc \ vdc(ref)	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NM	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Figure 3:Control rules

The control rules that associate with the fuzzy output to the fuzzy inputs are derived from general knowledge of the system behavior.
However, some of the control behaviour in the rule table are also developed using trial and error and from an intuitive feel of the process to be controlled.
4. Fuzzy Inference System: A fuzzy inference system(FIS) essentially defines a non linear mapping of the input data vector into a scalar output, using fuzzu rules. The mapping process involves input/output membership functions, FL operators, fuzzy If-Then rules, Aggregartion of output sets and defuzzification.
5.Defuzzification:It is the process of converting fuzzified output into crisp value. The method used for defuzzification is centriod method.

- Centriod defuzzification method: The centriod defuzzification method finds the “balance” point of the solution fuzzy region by calculating the weighted mean of the output fuzzy region. It is most widely used because , when it is used, the defuzzified values tend to move smoothly around the output fuzzy region.

IV. SIMULATION RESULTS

The proposed fuzzy logic controller along with bang-bang controller for STATCOM is implemented in simulink.

Due to the presence of non-linear load, the grid current contains harmonics with are reduced by using a fuzzy logic based STATCOM.

The system parameters are shown in table 1

TABLE 1:

Parameters	Ratings
1)Grid voltage	3-phase,415V,50Hz
2)Inverter Parameter	DC Link voltage-800V,DC link Capacitance=100µF, switching frequency=2KHz
3)Line series inductances	0.05e-3H
4)IGBT Rating	Collector voltage=1200V, forward current=50A, gate voltage=20V
5)Critical Load parameters	3-Phase 415V, non linear load, R=8Ω, L=12e-3H

The simulation results showing Total Harmonic Distortion without STATCOM and with STATCOM are shown in Figure 4 and Figure 5.

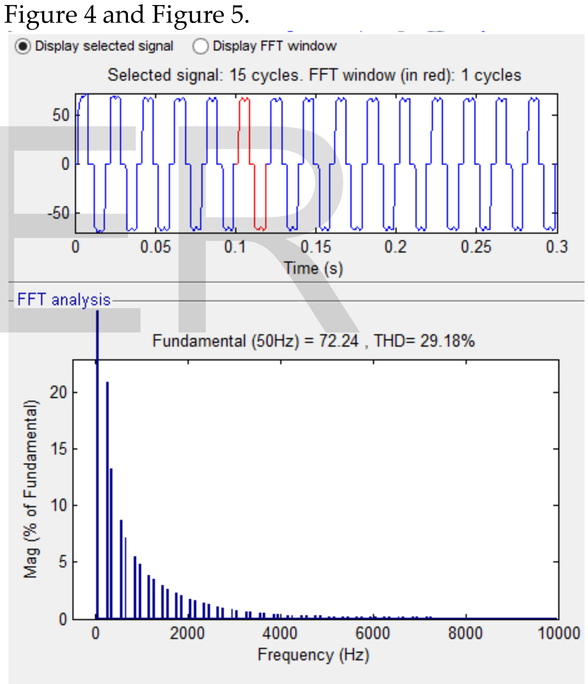

Figure 4: THD Without STATCOM

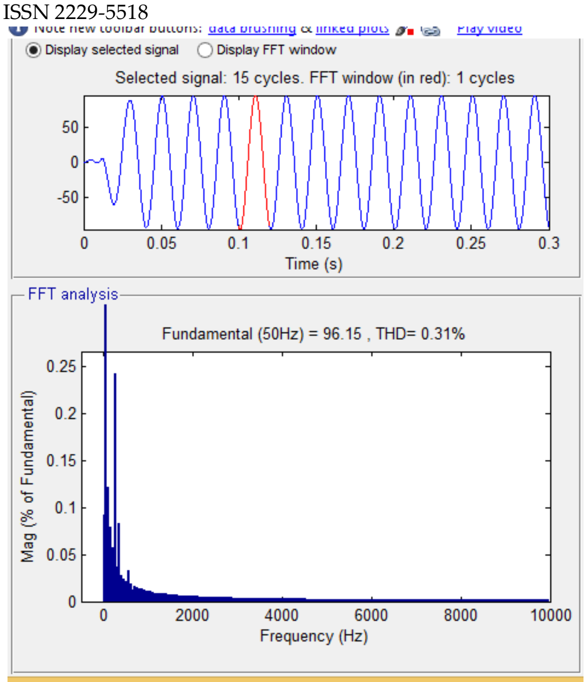

Figure 5:THD With STATCOM

V. CONCLUSION

In this paper fuzzy logic based STATCOM is presented and is implemented in simulink.

It is observed that Fuzzy based STATCOM gives better reduction in Total Harmonic Distortion than the simple Bang-Bang controller along with PI controller.

REFERENCES

[1] Shiny K.George,Fossy Mary Chacko "Comparison of different control strategies of STATCOM for power quality improvement of grid connected wind energy system" in 2013 IEEE

[2] N.Sreekanth, N.Pavan Kumar reddy, "PI & fuzzy logic based controllers STATCOM for grid connected wind generator" in Vol 2, Issue 5,September-october 2012,in IJERA

[3] P.Aruna,P Bhaskara Prasad,p.suresh babu " D-STATCOM with fuzzy logic controller for enhancing steady-state and quality performances" in IJLTET, vol 3, issue 2, November 2013.

[4] B.Ashok Kumar, Dr.N.Kamaraj,c.k.subasri "Fuzzy controller for improving voltage profile in grid connected wind energy system with FACTS devices" in JATIT , vol-63,No 2,20th may,2014.

[5] Fuzzy Logic toolbox for use with MATLAB

[6] Introduction to fuzzy logic using MATLAB , Springer publishers

[7] A textbook on " Modern Power electronics & AC Drives" by Bimal.K.Bose, PHI Publishers.

[8] k.siva kumar,Dr.Venugopal.N, "Improvement of DC link voltage in D-STATCOM based on fuzzy logic" in IJES, volume 2,issue-12,2013.

[9] S.Sabna,D.Prasad,R.siva Kumar, "Power system stability enhancement by neuro fuzzy logic based SVC for multi machine system" IJEAT, ISSN:2249-8958, volume-1,issue-4,April 2012.

[10] Marcelo Godoy simoes, Bimal.K.Bose,Ronald J.Spiegel, "Design and Performance evaluation of a fuzzy logic based variable speed wind generation system" in IEEE Transactions on Industry Applications, Vol-33,No-4, july/August 1997.

[11] R.Manikanta, S.N.V.S.K.Chaitanya, "A fuzzy logic based D-STATCOM topology with reduced VSI rating DC link voltage and filter size" in IEEJ Volume-5(2014)

[12] Prechanon Kumkratug, "STATCOM stabilizer based on fuzzy logic control for damping power oscillation" in American Journal of Applied sciences.