ANALYSIS OF POWER QUALITY IMPROVEMENT BY USING D-STATCOM

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ABSTRACT

Due to increasing complexity in the power system, voltage sags and swells are now becoming one of the most significant power quality problems. Voltage sag is a short reduction voltage from nominal voltage, occurs in a short time. Voltage swell is an increase in the R.M.S voltage from its nominal voltage; they are bound to have a greater impact on the industrial customers. If the voltage sag exceed two to three cycles, the manufacturing systems making use of sensitive electronic equipment's likely to be affected leading to major problems. It ultimately leads to wastage of resources (both material and human) as well as financial losses. The increasing competition in the market and the declining profits has made it pertinent for the industries to realize the significance of high power quality. This is possible only by ensuring that uninterrupted flow of power is maintained at proper voltage levels. Electric utilities are looking for solutions to ensure high quality power supply to their customers, a lot of solutions have been developed but this project tends to look at the solving the problems by using custom power devices such as Distribution static compensator(D-STATCOM). When a D-STATCOM is associated with a particular load, it can inject compensating current so that total load demand meets the specifications for utility bus from any unbalance and harmonic distortion. The aim of this paper to investigate a D-STATCOM that can perform both these tasks. In this paper, the line parameters of 415 volt industrial feeder connected with non-linear loads are considered for analysis. The distribution line and D-STATCOM are modelled using MATLAB-SIMULINK software. In this project, fuzzy logic control is used which is a simple method for implementation and control compared to other methods The effectiveness of fuzzy logic control for power quality improvement is proved by comparing results of Simulink model with and without D-STATCOM.

1. INTRODUCTION

Nowadays there is increased in concern of the power quality (PQ) at the end user mainly due to more sensitive loads, more emphasis on efficiency and awareness in them. There are many parameters upon which the power quality in distribution system determined. Out of them, voltage sag and harmonics are more observed PQ problem faced by the end user. Voltage sag is a rms amplitude reduction in the AC voltage at power frequency from half of a cycle to a few seconds duration. It has very adverse impact on the operation of the Adjustable Speed Drives (ASD), computers, induction motor and process control systems. A wide application of non-linear load has increased harmonic content at PCC. This harmonic current resulted in a non-sinusoidal wave having frequencies other than fundamental frequency. It has many impacts on power system equipment as well as on its operations. Distribution Static Compensator (D-STATCOM) is a very effective tool for improvement of power quality issue in the distribution system. Many PQ issues can be addressed by the D-STATCOM like voltage fluctuation suppression, power factor improvement, and harmonics. There are various control strategy and many converter topologies used for D-STATCOM operation. For the fast control over inductive and capacitive compensation using D-STATCOM. In this paper, six pulse [Insulated Gate Bipolar Transistor (IGBT) based Voltage Source Converter (VSC) is used. There are many methods for reference current generation. The basic diagram of D-STATCOM as shown in fig1. D-STATCOM performs following functions:

1. When Voltage at load side is greater than reference voltage, D-STATCOM injects voltage to the transmission line.
2. When Voltage at load side is less than reference voltage, D-STATCOM absorbs voltage from the transmission line.
3. When Voltage at load side is equal to than reference voltage, D-STATCOM neither injects voltage nor absorb voltage at transmission line.

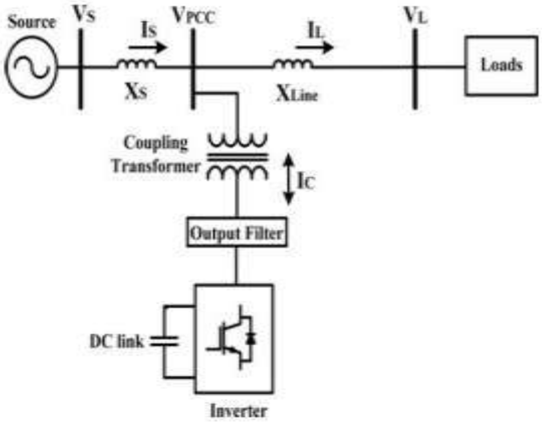

Fig. 1 Basic Configuration of D-STATCOM

1.1 Need for the New system

In our Paper we use Fuzzy logic Controller in matlab software for controlling the operation of D-STATCOM. Fuzzy logic Controller is very popular because of It's good results. In this Controller, We have to build the rules by creating the rules we can build the fuzzy logic Controller in our model. We use this Controller because it is more efficient as compare to other Controllers and It gives less THD values also. In recent years, the number and variety of applications of fuzzy logic have increased significantly. applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection. To understand why use of fuzzy logic has grown, you must first understand what is meant by fuzzy logic.

1.2 Description of fuzzy logic

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system which is an extension of multivalued logic. However In a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets; a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of FL. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalued logical systems. In Fuzzy Logic Toolbox software, fuzzy logic should be interpreted as FL,that is fuzzy logic in its wide sense. The basic ideas underlying FL are explained very clearly and insightfully.What might be added is that the basic concept underlying FL is that of a linguistic variable, that is a variable whose values are words rather than numbers. In effect, much of FL may be viewed as a methodology for computing with words rather than numbers. Although words are inherently less precise than numbers, their use is closer to human intuition. Furthermore, computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution. Another basic concept in FL, which plays a central role in most of its applications, is that of a fuzzy if-then rule or, simply, fuzzy rule. Although rule-based systems have a long history of use in Artificial Intelligence (AI), what is missing in such systems is a mechanism for dealing with fuzzy consequents and fuzzy antecedents. In fuzzy logic, this mechanism is provided by the calculus of fuzzy rules. The calculus of fuzzy rules serves as a basis for what might be called the Fuzzy Dependency and Command Language (FDCL). Although FDCL is not used explicitly in the toolbox, it is effectively one of its principal constituents. In most of the applications of fuzzy logic, a fuzzy logic solution is in reality, a translation of a human solution into FDCL. A trend that is growing in visibility relates to the use of fuzzy logic in combination with neurocomputing and genetic algorithms. More generally, fuzzy logic, neurocomputing, and genetic algorithms may be viewed as the principal constituents of what might be called soft computing. Unlike the traditional, hard computing, *soft computing* accommodates the imprecision of the real world. The guiding principle of soft computing is exploit the tolerance for imprecision, uncertainty, and partial truth to achieve tractability, robustness, and low solution cost. In the future, soft computing could play an increasingly important role in the conception and design of systems whose MIQ (Machine IQ) is much higher than that of systems designed by conventional methods. Among various combinations of methodologies in soft computing, the one that has highest visibility at this juncture is that of fuzzy logic and neurocomputing leading to neuro-fuzzy systems. Within fuzzy logic, such systems play a particularly important role in the induction of rules from observations. An effective method developed by Dr. Roger Jang for this purpose is called ANFIS (Adaptive Neuro-Fuzzy Inference System). This method is an important component of the toolbox. Fuzzy logic is all about the relative importance of precision. How important is it to be exactly right when a rough answer will do? You can use Fuzzy Logic Toolbox software with MATLAB technical computing software as a tool for solving problems with fuzzy logic. Fuzzy logic is a fascinating area of research because it does a good job of trading off between significance and precision something that humans have been managing for a very long time. In this sense, fuzzy logic is both old and new because, although the modern and methodical science of fuzzy logic is still young, the concepts of fuzzy logic relies on age-old skills of human reasoning. Fig 2 gives the example of fuzzy logic system.

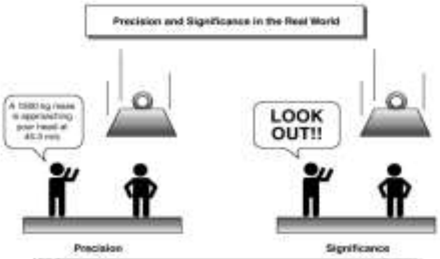

Fig. 2 Fuzzy Logic

1.3. Why Use Fuzzy Logic?

Here is a list of general observations about fuzzy logic:

- Fuzzy logic is conceptually easy to understand:- The mathematical concepts behind fuzzy reasoning are very simple. Fuzzy logic is a more intuitive approach without the far-reaching complexity.
- Fuzzy logic is flexible:- With any given system, it is easy to layer on more functionality without starting again from scratch.
- Fuzzy logic is tolerant of imprecise data:- Everything is imprecise if you look closely enough, but more than that, most things are imprecise even on careful inspection. Fuzzy reasoning builds this understanding into the process rather than tacking it onto the end.
- Fuzzy logic can model nonlinear functions of arbitrary complexity:- You can create a fuzzy system to match any set of input-output data. This process is made particularly easy by adaptive techniques like Adaptive Neuro-Fuzzy Inference Systems (ANFIS), which are available in Fuzzy Logic Toolbox software.
- Fuzzy logic can be built on top of the experience of experts:- In direct contrast to neural networks, which take training data and generate opaque, impenetrable models, fuzzy logic lets you rely on the experience of people who already understand your system.
- Fuzzy logic can be blended with conventional control techniques:- Fuzzy systems don't necessarily replace conventional control methods. In many cases fuzzy systems augment them and simplify their implementation.
- Fuzzy logic is based on natural language:-The basis for fuzzy logic is the basis for human communication. This observation underpins many of the other statements about fuzzy logic. Because fuzzy logic is built on the structures of qualitative description used in everyday language, fuzzy logic is easy to use.
- The last statement is perhaps the most important one and deserves more discussion. Natural language, which is used by ordinary people on a daily basis, has been shaped by thousands of years of human history to be convenient and efficient. Sentences written in ordinary language represent a triumph of efficient communication.

1.4 Objectives

The aim of this project is to study the various types of power quality problems and their effects on both the utility and customer’s side of the system with more emphasis on these two namely: voltage sag and voltage swells, and how they can be mitigated with the use of the D- STATCOM (Distribution Static Compensator), which are also called custom power devices and its effectiveness in mitigating the named power quality problems given above. The objectives of this project are:
I. To investigate that the mitigation techniques are suitable for voltage sags, swells and interruptions in the event of a fault in a distribution system.
II. To observe the effect on the characteristic of voltage sag, swell and interruption for the techniques.

III. To suggest on the suitability of the techniques used for the mitigation process.

1.5 Fuzzy Logic Controller

In this theory, the gradual transition between membership and non-membership function. In fuzzy logic control, there are two processes as follow Fuzzification

Fuzzy logic uses linguistic variables instead of numerical variables. The process of converting a numerical variable (real number or crisp variable) into a linguistic variable (fuzzy number) is called fuzzification. Triangular membership function is widely use function because it is simplest membership function and it is used as the reference. The fig3shows the spread of membership functions for the inputs and output. As Sugeno type of implication is considered, the singleton membership is used for the output variable namely the change in duty cycle. Actual error in speed is divided with the reference speed to calculate the error. This normalization is useful for using the fuzzy controller for any speed reference.

Defuzzification

The reverse of fuzzification is called defuzzification. A linguistic form of output will be required to produce by using inference engine. According to real world requirements, the linguistic variables have to be transformed to crisp output. In defuzzification method for Sugeno type fuzzy controller, weighted average method is best well known and is used in this work. This method has the advantage of easy implementation in simulation.

Rule Based Table

The rules are in the format - If error is Ai, and change in error is Bi then output is Ci. Here The then‟ part of the rule is called the rule consequent and logical combination of fuzzy propositions describes the control output". The rules for the designed fuzzy controller are given in the Table 1 uses seven linguistic variables for the error and change in error with 49 rules as given in table 1. The seven sets used for fuzzy variables error and change in error are negative big (NB), negative medium (NM), negative small (NS), zero (Z), positive big (PB), positive medium (PM) and positive small (PS). From the rule table, the rules are manipulated as - If error is NB and change in error is NB, then output is NB. The actual output is fed back and is compared with set output. After comparison, input to the fuzzy logic control is calculated from error signal and the change in error are calculated. In this work, the error is normalized to per unit value with respect to the set output. This helps in using the fuzzy controller for any set output. The fuzzy controller will attempt to reduce the error to zero by changing firing angle of switching signal.

Table 1 Fuzzification rule

e/ce	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

Membership Function For Evaluation

Membership functions can have different shapes. The most commonly used shapes are triangular, trapezoidal, Gaussian and bell shaped membership functions. In this work, the response of voltage of transmission line at load side is evaluated by considering the membership functions like triangular, trapezoidal, Gaussian and bell shaped. Fig. 3 shows the spread of the various functions used for seven variables

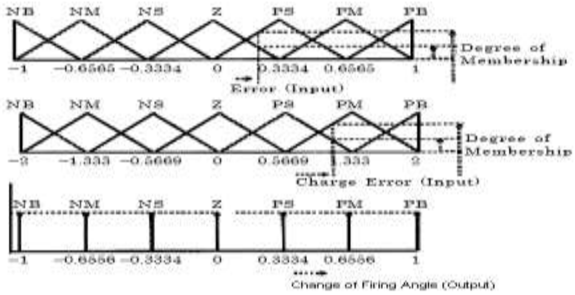

Fig. 3 Different Membership Function

2.PROPOSED WORK

In our proposed system we use the modifications that we can build the Voltage Source Inverter by using this Inverter. we can show the Five or upto 15 level output that shows the Improve power quality. Fuzzy logic Controller is very popular Because of It's good results In This Controller we have to build the rules by creating the rules we can build the fuzzy logic Controller. In our model We use this Controller because it is more efficient as compare to other Controllers and It gives less THD values also. The block diagram of proposed works as shown in fig 4.

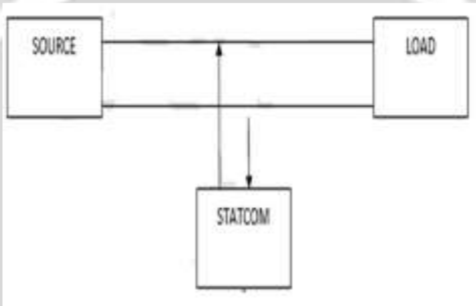

Fig. 4 Block Diagram for D-STATCOM system

3. SIMULATION MODEL

3.1 Description of Simulation Model

A distribution static compensator (D-STATCOM) is used to regulate voltage on an 11-kv distribution network. A feeder (100 km) transmits power to loads connected at bus. The performance of D-STATCOM is evaluated by using the MATLAB/SIMULINK 2016 as a simulation tool. A D-STATCOM is connected in shunt between a three phase voltage source with 11 KV line to line RMS voltage,50 HZ. A load of 15KVA & 25KVA load is connected between 1.5 to 2s and also at the same time, nonlinear load is connected.We compensate for source side voltage and current. Test parameter of the system as shown below. The first set of simulation was done with no D-STATCOM and then the nonlinear load connected with fuzzy logic control duration of transition time 1.5 to 2s. Below figures shows the RMS voltage at load point when the system operates with no D-STATCOM and without fuzzy logic. When the D-STATCOM is in operation the voltage interruption is compensated almost completely and the RMS voltage at the sensitive load point is maintained at normal condition. To analyse voltage dip, a additional load is connected near the system load, as shown in Fig. 5 is created. The time duration for this load is 0.5 seconds (500-10000 MS). The additional nonlinear load causes observable voltage sag during this time, as shown in Fig.7. The voltage sag value is about 0.5 per unit. The D-STATCOM can compensate the source voltage sag effectively. The voltage sag mitigation with D-STATCOM is shown in Fig 9. The current swell mitigation for this case can be observed from the given below figures. Also by using Fuzzy logic control, less THD values can be obtained.

Table 2 Test Parameter of system

Sr.No	SYSTEM QUANTITY	STANDARD
1	Source Voltage	415V
2	Frequency	50Hz
3	Capacitancefor D-Statcom	3000microfarad
4	Referance for Dc Voltage	700V
5	Non linear load	Three phase rectifier with 50Ω resistance
6	Active power for main load	20KW
7	Reactive power for main load	20KVAR
8	Active power for switching load	15KW
9	Reactive power for Switching load	25KVAR

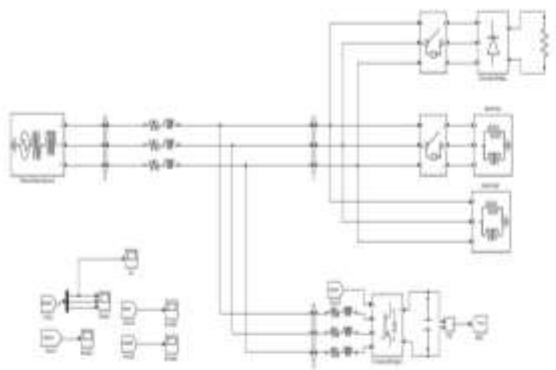

Fig 5 Simulation Model

3.2 Controller Scheme

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a fuzzy logic control which offers simplicity and good response. Since custom power is a relatively low-power application, fuzzy logic methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favoured in FACTS applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses. The controller input is an error signal obtained from the reference voltage and the value rms of the terminal voltage measured. Such error is processed by a fuzzy logic controller. Note that in this case, indirectly controlled converter; there is active and reactive power exchange with the network simultaneously: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The fuzzy controller process the error signal generates the required angle to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage. Fuzzy logic controller in matlab simulation is as shown in fig.6

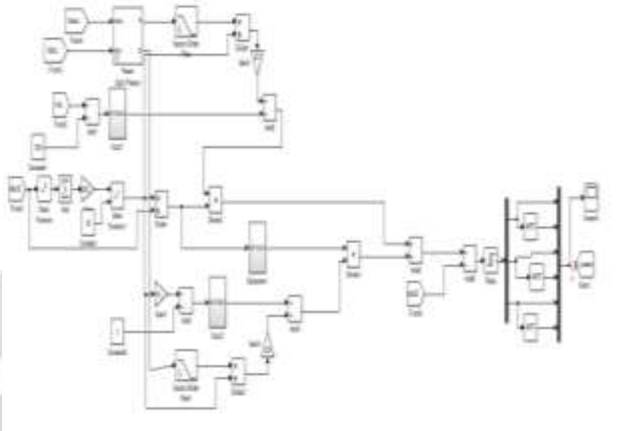

Fig. 6 Fuzzy logic controller

3.3 Simulation Results

In this paper, results are obtained by comparing the voltage and current by considering following way

Case I:

In this case, The results of voltages and currents at source side as well as load side are obtain without D-STATCOM. In this, one load having 20kw&20kvar are connected continuously and one load having 15 kw & 25KVAR and another nonlinear load connected for 1.5 to 2s. After the simulation, the voltage and current waveforms at load side are observed as shown in fig 7 & 8. due to additional load, there is reduction in voltage.

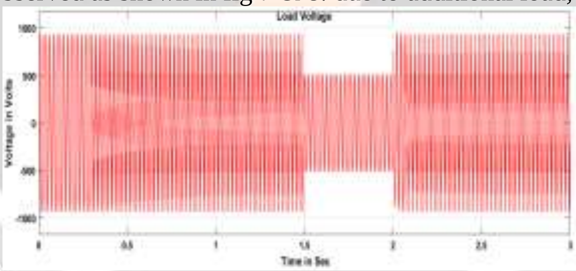

Fig. 7 Load voltage without D-STATCOM

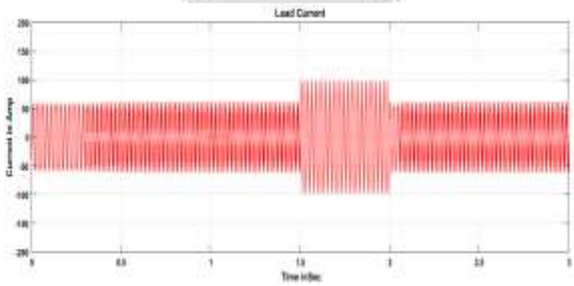

Fig. 8 Load current without D-STATCOM

Case II:

In this case, The results of voltages and currents at source side as well as load side are obtainned with

D-STATCOM. In this, one load having 20kw&20kvar are connected continuously and one load having 15 kw & 25KVAR and another nonlinear load connected for 1.5 to 2s. After the simulation, the voltage and current waveforms at source side and load side are observed as shown in fig 9 & 10. Due to the additional load, Voltage sag created which will be reduced by using D-STATCOM. The Voltage waveform shown in fig indicates that after connecting D-STATCOM, voltage sag improved to maintain constant voltage at load side.
In this, Fuzzy logic control strategy is used. In this, due to the use of fuzzy logic control, less value of THD can be obtained as compared to other controller load, Voltage sag created which will be reduced by using D-STATCOM. Also D-STATCOM Voltage and current waveform as shown in fig 9 & 10.

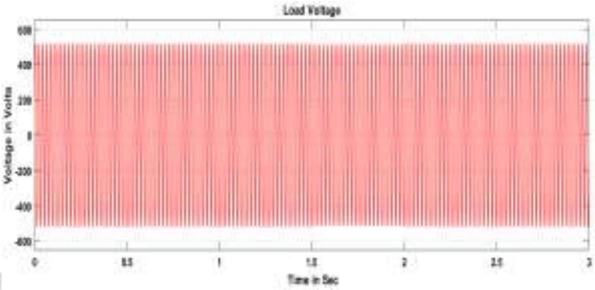

Fig. 9 Load voltage with D-STATCOM

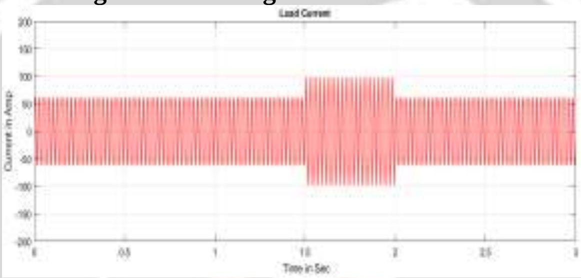

Fig. 10 Load Current with D-STATCOM

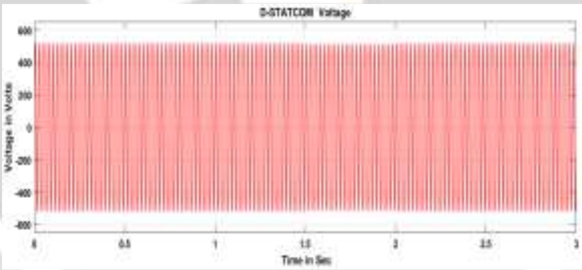

Fig. 11 D-STATCOM Voltage with nonlinear load

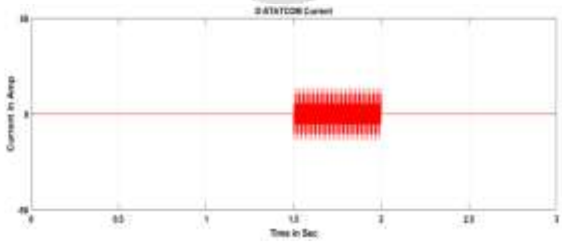

Fig. 12 D-STATCOM Current with nonlinear load

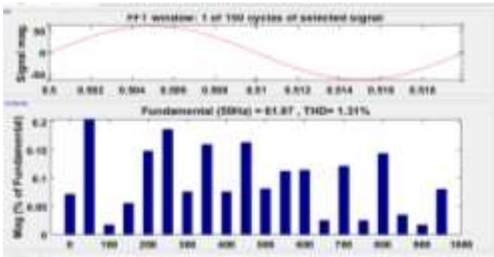

Fig. 13 Total harmonic distortion (WITHOUT FUZZY)

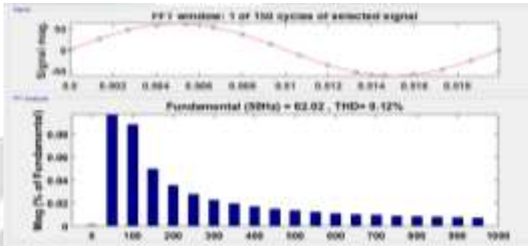

Fig. 14 Total harmonic distortion (WITH FUZZY)

Harmonic Distortion Result(FFT ANALYSIS):

Table 3 Harmonic Distortion Result

WITHOUTD STATCOM	**WITH D STATCOM**
LOAD CURRENT(THD)=**1.21%**	LOAD CURRENT(THD)=**0.12%**

The load voltage and load current harmonic analysis using fast Fourier transform (FFT) of power GUI window by using Simulink as shown in table 3.it can be seen that after implementation of D-STATCOM in the system the odd harmonic are reduced within acceptable range, that is Total harmonic distortions (THD) of source voltage and source current and also at load side.

4 CONCLUSION

In this work modeling and simulation of D-STATCOM with necessary control strategy is implemented. The simulation results showed clearly the performance of the DSTATCOM in mitigating the voltage sag and swell. A new fuzzy based control scheme is implemented to control the operation of the power electronic switches in VSC which is used in the DSTATCOM .The control scheme will measure only the voltage magnitude but not the reactive power. The source voltage and source current harmonic analysis using FFT are reduced after implementation of D-STATCOM in the system. The total harmonic distortions of load side also reduced. A fuzzy based control scheme is implemented. As opposed to fundamental frequency switching schemes already available in the MATLAB/SIMULINK, this fuzzy control scheme gives less THD values as compared to other control strategy. This characteristic makes it ideally suitable for low-voltage custom power applications. D-STATCOM has shown the efficiency and effectiveness on voltage sag compensation hence it makes D-STATCOM to be an interesting power quality improvement device. In this thesis, custom power park concept has been studied. Advantages of custom power devices have been pointed out. CPP has been modelled by using MATLAB SIMULINK program.

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