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Power Quality improvement of Unbalanced Distribution System Using Fuzzy based D-STATCOM

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Abstract: *The power quality is a more serious problem for consumers and power companies. In this paper to mitigate power quality problems such as voltage swell and voltage sag of unbalanced distribution system, a fuzzy controller based D-STATCOM is proposed. The performance of proposed fuzzy based D-STATCOM is tested on 13 bus IEEE test feeder, a D-STATCOM is introduced at bus no-632. The performance of proposed fuzzy based D-STATCOM is compared to D-STATCOM with PI control mechanism using MATLAB-simulink to address power quality issues.*

I. Introduction

Now a day's power quality is a more serious problem for consumers and power companies. The power quality issues such as voltage swell and voltage sag leads to economic impact on consumer utility sectors like induction furnaces and process control of bulk manufactures[1-4].An Electrical distribution system is a connection between utility sector and Power Company, to provide quality of supply to consumer by maintains good voltage profile at consumer premises[5].

Causes of Power quality problems in Electrical distribution system [6]

Sag and swell, which varies from 10% to 90% of the rat-ed voltage.
Harmonic distortion in distribution system due to har-monic currents.
Due to lower power factor causes heating of electrical equipment, results heating losses.
It also causes vibration and noise in machines and mal-function of the sensitive equipment.
Due to unbalanced voltages.

There are two methods to resolve power quality problems. The first approach is from source side and next approach is from load side to diminish well known power quality problems such as voltage swell and voltage sag.

If there is sudden increase in the load then the voltage in the line decreases rapidly due to the decrease in the terminal voltage at the receiving end or the utility side. This sudden change in the terminal voltage appears as sag.

If there is a sudden decrease in the load then the voltage in the line increases rapidly due to the increase in the terminal voltage at the receiving end or the utility side. This sudden change in the utility side terminal voltage appears as voltage swell in the line[8].

There are different ways to enhance power quality problems in transmission and distribution systems. D-STATCOM is a suitable custom power device to address the power quality issues of an unbalanced distribution system and efficient device to resolve power quality issues, D-STATCOM consisting of a Voltage Source Converter (VSC) and a shunted DC link capacitor[9-10]. A D-STATCOM is reactive source, generating and absorbing reactive power. In this paper a 13-bus unbalanced distribution system is considered to address power quality problem and a D-STATCOM is connected at bus number 632.

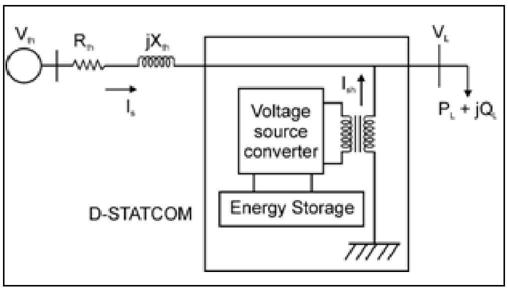

Fig.1: Block diagram of D-STATCOM

This paper is organized as follows the D-STATCOM with PI control mechanism is discussed in section II. The D-STATCOM with fuzzy control mechanism is discussed in section III. In section IV simulation results are presented where, the performance of D-STATCOM with fuzzy control technique is compared to PI control mechanism. Finally conclusions are given in section V.

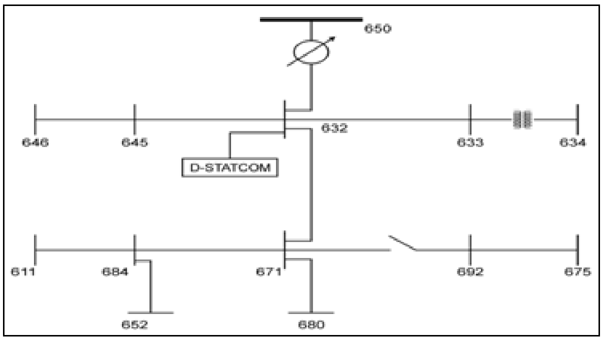

Fig-2: IEEE-13 bus unbalanced distribution system with D-STATCOM

II. Conventional Control Of D-Statcom

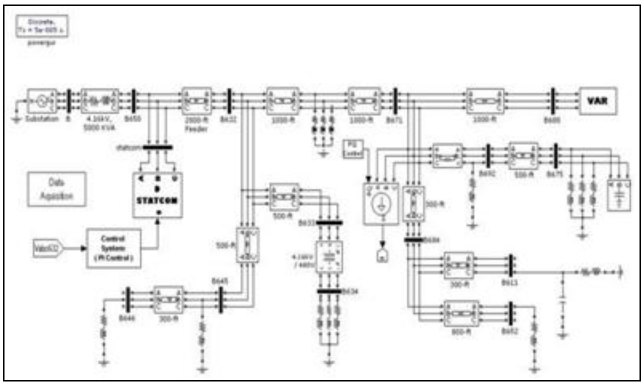

Fig-3:13 Bus unbalanced Distribution System with D-STATCOM with PI Control Mechanism

iii. d-statcom with fuzzy control mechanisam

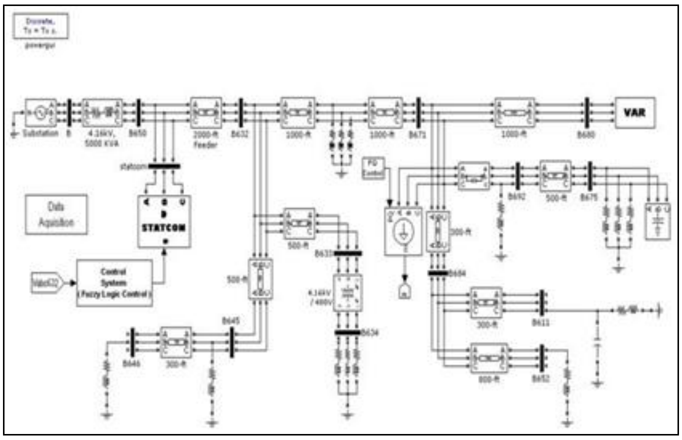

Fig. 4:13 bus unbalanced distribution system with D-STATCOM with Fuzzy control mechanism

The main objective behind this intelligent controlled strategy is to provide experience to power system engineer in the implementation of fuzzy controller [12]. The controlled strategy implemented by the engineers are prepared as set of rules that are simple to carry out manually but difficult to implement by using conventional control strategy. This approach is a convenient method for constructing nonlinear controllers via the use of heuristic information.

In this proposed fuzzy controller approach the inputs are error (e) and change in error (Δe) generates required control signal.

The design procedure of FLC consists of the following modules: 1) Fuzzification 2) Fuzzy Rule- base 3) Fuzzy Inference Engine (Decision Making Logic) and 4) Defuzzification.

A Fuzzy controller operates by repeating a cycle of following four steps. First, measurements are taken of all variables that represent relevant conditions of the controlled process (Universal Discourse). Next, these measurements are converted into appropriate fuzzy sets to express measurement uncertainties (Fuzzification). The fuzzified measurements are the used by the inference engine (Decision Making Logic) to evaluate the control rules stored in fuzzy rule base . The result of this evaluation is a output fuzzy set (or several fuzzy sets) defined on the universe of possible actions and the degree of membership of the output fuzzy set can be calculated by using Root Sum Square Method. This fuzzy set is then converted, in the final step of the cycle, into a crisp (single) value that, in some sense, is the best representative of the fuzzy set (Defuzzification). The defuzzified value represents the actions taken by the fuzzy controller in individual control cycles. Now, in the following Sections we develop the various components of FLC to solve power quality problem. Fuzzy controller is developed to generate required control signal it receives the input signal from the system and processing the data in different stages and generate required output.

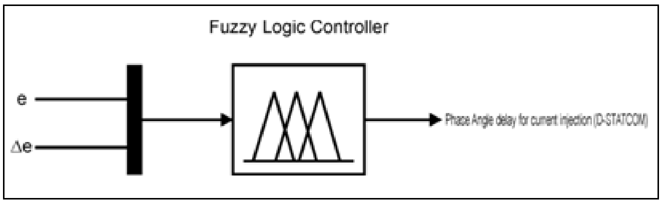

Fig-5: Input and output of FLC controller

Selection of inputs and outputs:

In the design of fuzzy controller to address power quality problem the input variables selected as error (e) and change in error (delta e). It takes fuzzy input from fuzzifier in form of membership value matrix and uses fuzzy rule base to decide the fuzzy value of output. The control signal which represents rule base in terms of membership function. The upper limit and the lower limit of the error, change in error is specified on the previous experience of power system engineer.

Fuzzification:

Fuzzification is a process of converting crisp value of input data into suitable linguistic values through membership function [12].

Development of fuzzy decision rules

The construction of rule base involves [12]:

Based on the Expert Experience and Control Engi-neering Knowledge the rules are formed in the form of "if-then " and for the present two inputs –One output case, and for two number fuzzy input parti-tions, the maximum number 3*3=9 rules are to be formed.

After forming all the rules they will be tabulated in the Decision Table.

Fuzzy decision rules developed based on previous experience of power system engineer a set of control rules can be developed these set of rules are vary person to person depends on personal experience in any particular field. There are two fuzzy variables for each input variable; therefore 4 decision rules are possible. This decision table consisting of

linguistic numeric consequents of the rules. The number of rules depends on number of input variables, here we considered input variables are three so maximum of 9 rules can be possible. For example

1. If "error" is negative and "change in error" is negative than output is negative.
2. If "error" is negative and "change in error" is zero than output is negative.
3. If "error" is negative and "change in error" is positive than output is zero.
4. If "error" is zero and "change in error" is nega-tive than output is negative.
5. 5. .If "error" is zero and "change in error" is zero than output is zero.
6. If "error" is zero and "change in error" is posi-tive than output is positive.
7. If "error" is positive and "change in error" is
   negative than output is zero.
8. If "error" is positive and "change in error" is zero than output is positive.
9. If "error" is positive and "change in error" is positive than output is positive.

e \ Δe	N	Z	P
N	N	N	Z
Z	N	Z	P
P	Z	P	P

N - Negative, P - Positive, Z – Zero

Fig. – 6: Decision rules for the implementation of FLC controller

Fuzzy inference system

Fuzzy inference is the process of mapping from a given input to output using fuzzy logic. There are two types of fuzzy inference systems that can be implemented using fuzzy logic. There are two fuzzy inference systems for implementation of fuzzy logic one is mamdani type and sugeno type these two types of inference system differs somewhat in the way output are determined.

Aggregation of fuzzy rule:

The fuzzy rule based system may contain more than one rule. the process of formulating overall conclusions from the individually specified consequents contributed by each rule the fuzzy rule is known as aggregation of the rule(or) computation of IF part of the rule is called aggregation(or)calculation of IF part of the rule is called aggregation.

Composition:

Calculation of THEN part of the rules is called composition.

Aggregation:

To represent in logical convenience new logical operators AND, OR, NOT are widely used in most of fuzzy logic applications

$AND: \mu_{A \wedge B} = \min\{\mu_A, \mu_B\};$

$OR: \mu_{A \vee B} = \max\{\mu_A, \mu_B\}$

$NOT: \mu_{\neg A} = 1 - \mu_A$

Composition:

Each rule defines an action has to be taken in THEN part.

The degree which action is valid is given by the satisfactory of rules. This satisfactory is calculated by aggregation as degree of IF part.

Decision table: The above 9 rules become the entries of decision table and are shown in shown in below.

III. Algorithm For Design Of Flc

The following algorithm is proposed for designing of Fuzzy logic controller to mitigate power quality problem of four bus system.

Step 1: Select the input variables to enhance power quality issues like swell, sag. error and change in error are selected as fuzzy inputs and the output of the FLC is proposed as the phase angle of injected current(D-STATCOM)

Step 2: Selected input and out variables are then partitioned in to 2 regions and their membership functions have been defined.

Step 3: With the knowledge of the power quality issue like voltage swell and voltage sag (through the method, “Expert Experience and Control Engineering Knowl-edge”), 9 rules are framed to decide the membership function value of the output variable. The rules are then tabulated in the Decision-Table.

Step 4: Fuzzy output sets are formed and the strengths of each of the output membership function is estimated by Root Mean Square method.

Step 5: By applying defuzzification, Crisp output is obtained. Step 6: With the crisp value, output signal is generated.

IV. Simulation Results

In this work a D-STATCOM with fuzzy control mechanism have been proposed to improve power quality (voltage swell, voltage sag) of 13-bus IEEE distribution system. Simulations are performed using

MATLAB SIMULINK.The performance of proposed D-STATCOM with fuzzy logic control technique is compared to D-STATCOM with PI control technique.

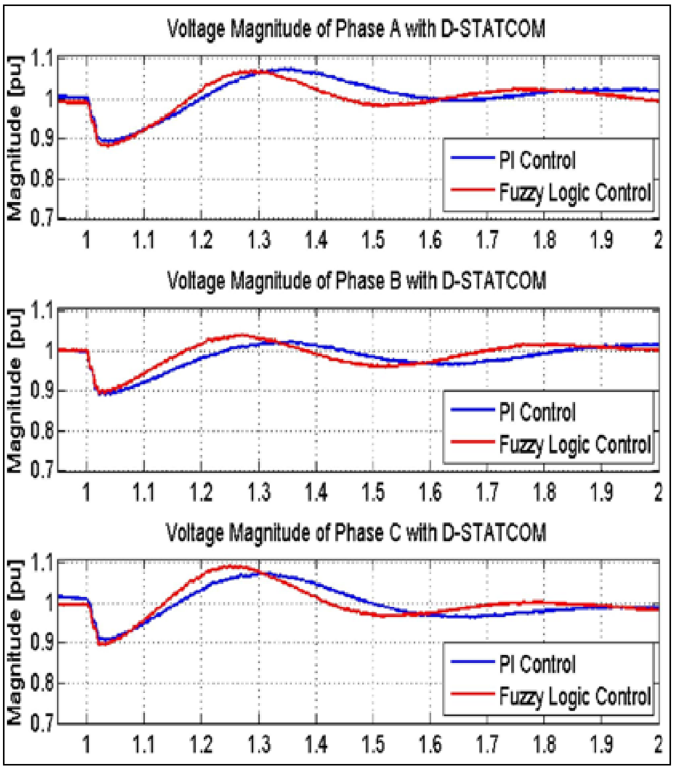

Fig-7: Illustrates the Voltage sag mitigation from source side using D-STATCOM with PI & fuzzy control

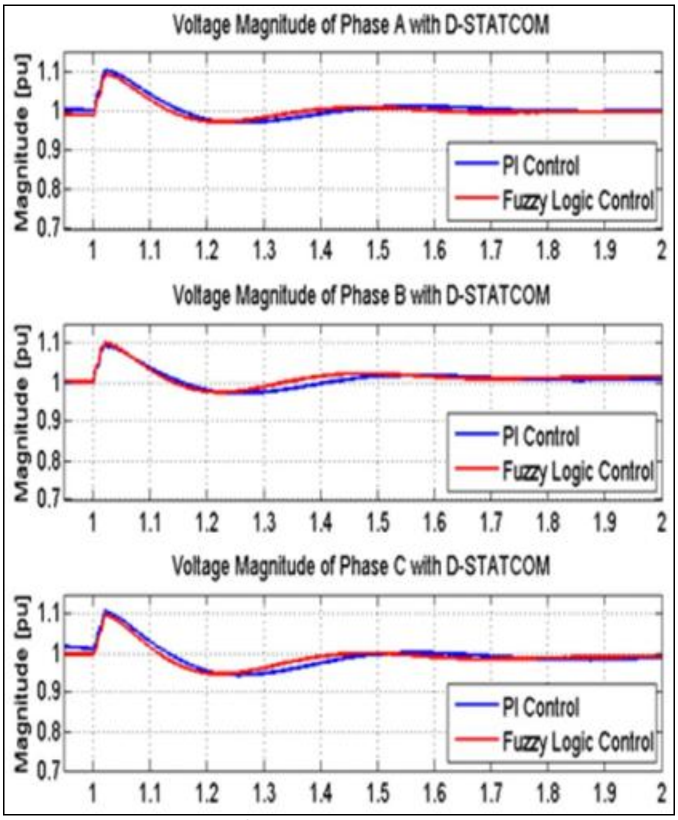

Fig-8: Illustrates Voltages swell mitigation from source side using D-STATCOM with PI & fuzzy control

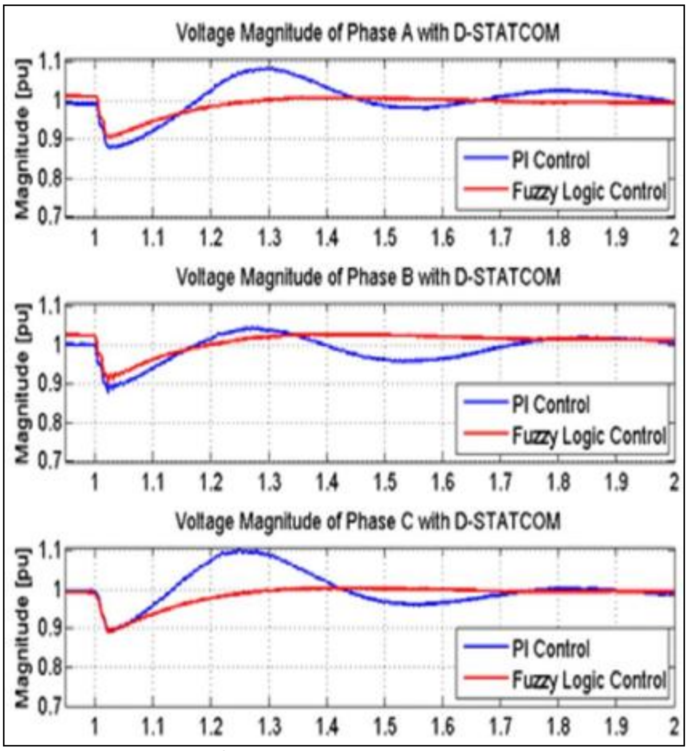

Fig-9: Illustrates the Voltage sag mitigation from load side using D-STATCOM with PI & fuzzy control

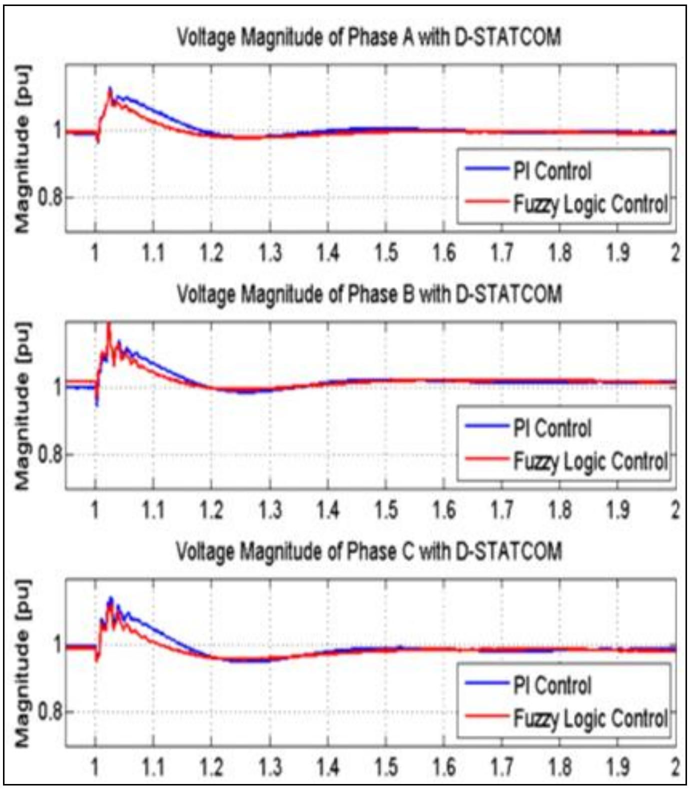

Fig-10: Illustrates Voltages swell mitigation from load side using D-STATCOM with PI & fuzzy control.

V. Conclusion

In this paper for enhancement of power quality of distribution system a 13- bus unbalanced distribution system is considered. A fuzzy control based D-STATCOM is introduced at bus number-632 of 13-buses IEEE test feeder system. The performance of proposed method is compared with PI based D-STATCOM. Simulation results revealed that the proposed model free intelligent control(fuzzy) methodology based D-STATCOM tackle power quality issues such as voltage sag, voltage swell at all bus considerable by introducing fuzzy controller based D-STATCOM at bus no 632.The fuzzy based D-STATCOM is quite capable of suppressing voltage swell and voltage sag compared to PI based D-STATCOM.

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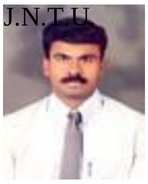

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