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ANALYSIS OF DIFFERENT LOADS WITH MULTI-TECHNIQUES USING D- STATCOM

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ABSTRACT

Due to the rapid growth of non-linear loads, such as power electronic control equipments and Electric arc furnace (EAF) power quality problems such as harmonics and voltage flicker are introduced in the power system. It occurs because of the time-varying and non- linear behaviour of the Load. Arc furnaces are used in industries for induction heating and welding. Hence an Electric arc furnace model is needed to analyze the power quality. In this paper, different non-linear loads such as a time domain model called hyperbolic model for electric arc furnace, unbalanced RL load and also three phase bridge rectifier is analyzed using MATLAB. The model is used to study its behaviour on the power system using MATLAB.

To improve the power quality D- STATCOM is proposed, in which the control strategies used are Hysteresis controller and Fuzzy Based PI controller.Hysteresis controller uses Hysteresis Bandwidth to produce the switching signals. Fuzzy based controller automatically changes the value of gain constants depending upon the requirement with the help of membership function.Control strategies used in D-statcom are simulated using MATLAB/SIMULINK.

I. INTRODUCTION

Usage of non linear loads such as EAF,three phase bridge rectifier results in voltage fluctuation which leads to the reduction in electrical equipment efficiency, interference in protection systems and grid. Hence power quality problem become a major concern for both power companies and customers. To quantify the problems, D-STATCOM is used. Distributed Static Synchronous Compensator (DSTATCOM), which consists of an IGBT- based voltage source inverter, uses advanced power switches to provide fast response and flexible voltage control at the connection for power quality improvement in distribution systems.

1.1 Advantages of D-STATCOM:

- Flexible voltage control
- Improvement in Power factor
- Harmonic contents can be reduced
- Fast response

Non linear loads such as EAF, unbalanced RL load, three phase bridge rectifier is described in Section II. Section III comprises of D-statcom and its control strategy. Section IV describes the simulation results. Section V describes about the conclusion.

II. A.ARC FURNACES

Its structure resembles to that of two electrodes with a charge placed inside a heating chamber. When the air-gap between the electrodes is subjected to maximum voltage stress, contacts between them ionized to make the flow of current which results in the form of arc. Since the electrical arc is a nonlinear and time varying phenomenon, description of its behaviour in the time domain is easier than in the frequency domain. There are different numbers of models for EAF such as

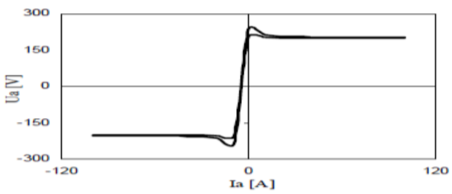
- Harmonic voltage source model
- Time domain model
- Frequency model

Time domain model is proposed here. Time domain models can be classified into V-I Characteristic (VIC), and Equivalent Circuit Methods (ECM). Based on the V-I characteristic of arc furnace, which is derived from the relationship between arc voltage and arc current VIC method is used. This method is widely used for modelling the static and the dynamic operation of EAF. This paper proposes a new model named as Hyperbolic model of EAF in the time domain. The proposed model of EAF is explained with a good approximation without need of the initial conditions of the EAF[1]. Also, it is used to describe different operating situation of the EAF and power system. The accuracy of the load model is increased by establishing random and sinusoidal noises to have a new model. An EAF flicker model based on a hyperbolic model is simulated in the first part. In the second part, the DSTATCOM with direct and indirect control is simulated.

2.1 Hyperbolic Model

Basically there are two models such as Static and Dynamic model. Simulation of arc is the important issue in the modelling of EAF. There are several methods used to describe the electric arc. Here, Hyperbolic model of EAF is discussed and simulated in the first part [4] and D-statcom with indirect,direct,Hysteresis control is proposed and simulated.

The below figure (Fig2.1) represents the VI characteristics of EAF and actual linear piecewise model [1, 2, 3 and 5]. But the Hyperbolic model discussed is a non-linear one and is modelled according to equation (2.1) & (2.2).



VI Characetristics of EAF – Fig 2.1

For static model the VIC of the EAF is considered to be in the form of V=V (i) and it can described as:

$V(i)=V_{at}+(C/D)+i$ (2.1)

Where, V - arc voltage, i - arc current per phase. V_{at} - threshold magnitude. V_{at} is the magnitude of threshold voltage to which the voltage approaches as current increases. Its value depends on the arc length which is defined by constants C and D which are of arc power and arc current respectively. Dynamic model is required for real time analysis of the effect of the arc. The dynamic arc characteristic is simulated by varying arc conductance. In general, the variation is of random nature. Two types of variation are considered for the study-sinusoidal and random. In order to study the effect of voltage flicker on the system of EAF, Vat is varied sinusoidally and randomly. In this regard Vat is modulated as follows:

The sinusoidal variation is assumed as:

$V_{at}(t) = V_{at0}[1+m.\sin(\omega ft)]$ (2.2)

Where, m is modulation index and ωf is a flicker frequency. For random flickergeneration V_{at} is modulated with a random signal with the mean of zero. Thus V_{at} is written as:

$V_{at}(t)=V_{at0}[1+m.N(t)]$ (2.3)

where, N(t) is a band limited white noise with zero mean and variance of one.

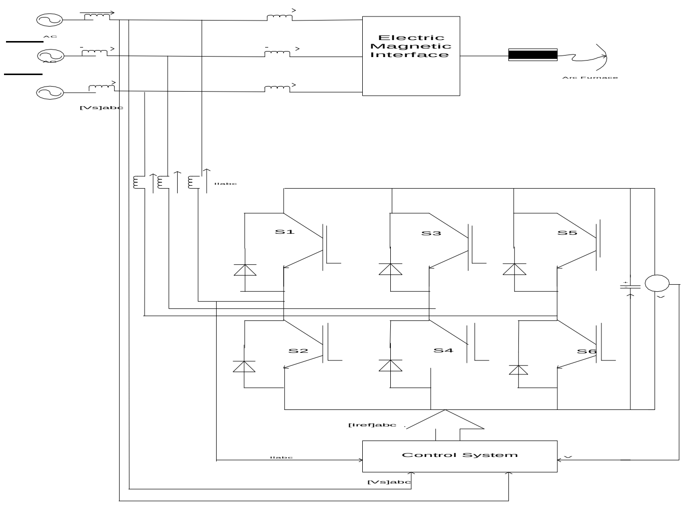
II B. UNBALANCED LOADS:

II C.THREE PHASE BRIDGE RECTIFIER:

Problems of usage of Non-linear loads:

Due to the usage of non-linear loads, it creates problems as follows:

- Harmonics
- Voltage Fluctuations
- Flickering
- Low power factor



Hence the other loads connected also gets affected and also the source voltage. Hence usage of non-linear load is considered to be the main cause of power quality degradation. Therefore we have to find a solution to improve power quality because at the load point production process gets more complicated and requirement of a bigger reliability level will occur. Hence we have to avoid this by providing energy without interruptions, without harmonic distortion and keeping the voltage in a very narrow margin. The devices which can fulfil these requirements are the Custom Power devices among wihch D-statcom is proposed here.

III. PROPOSED METHOD

IEEE defines Static Synchronous Generators as self-commutated switching power converters supplied from an appropriate electric energy source and operated to produce a set of adjustable multiphase voltages, which may be coupled to an ac power system for the purpose of exchanging independently controllable real and reactive power.

D-STATCOM compensates by generating or absorbing reactive power by using power electronic switching converters.

Algorithms based on Hysteresis Controller and fuzzy based controller is proposed. However, in STATCOM systems, the reactive power is determined by the switching converter part and reactive power can be kept constant irrespective of the supply voltage fluctuations. STATCOM systems are used in distribution and transmission systems for different purposes. STATCOMs are used in transmission systems to control reactive power and to supply voltage support to buses. STATCOM is installed in distribution systems or near the loads to improve power factor and voltage regulation. This type of STATCOM is called D-STATCOM.

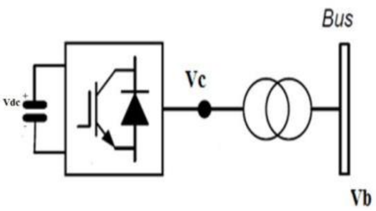
DSTATCOM (Distributed static Synchronous compensator) is the proposed model to improve the power quality[2].

Multifunction's preformed by D-statcom are:

- Voltage regulation
- compensation of reactive power.
- Correction of power factor.

Here, such a device is employed to provide continuous voltage regulation using an indirectly controlled converter[3].

Single line diagram of D-statcom is shown in Fig3.1



Single Line diagram of D-statcom - Fig3.1

Advantages:

- ✓ Simple Technique
- ✓ Robust
- ✓ Fast Response
- ✓ Good stability

3.1 Compensation Strategies

3.1.1Hysteresis Controller

Using this control, rapid switching of switch is done by using the comparison of the measurement of D-Statcom current with the reference current. Basic principle behind this is to produce the switching signals by using the comparison of error signal with the fixed value of hysteresis bandwidth.

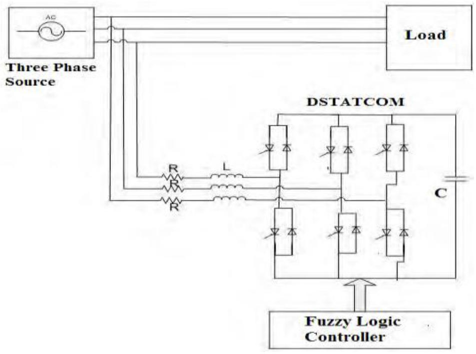
3.2 Generation of Switching signals using Hysteresis controller

Reference current signals are generated by using d-q transformation. Here the three phase current variables are transformed into synchronous reference frame to synchronize the ac main voltage with the reference frame variables. The above transformation is done by converting the three phase supply variables into d-q variable.

Reference currents produced by transformation are compared with the DStatcom current which gives the output as error signal. This signal is compared with the hysteresis bandwidth [6] to generate the switching signals. Tolerable bandwidth is taken as + 2% of reference value of current. Upper switch of that leg will be turned ON, but the lower switches will be in OFF condition when the value of the phase current exceeds the upper bandwidth. Reverse operation will take place when the phase current value falls below the lower bandwidth.

3.2 Fuzzy –Based PI Controller

Overall block diagram of system using Fuzzy based PI controller is shown in Fig 3.2



Overall Block diagram of System using Fuzzy based PI Controller –Fig 3.2

3.3 Fuzzy Based PI Controller

Controller is driven by a set of control rules rather than proportionality and integral constants. It has data base and rule base. Database provides necessary information to rule base in membership function form. Rule base represent control policy of control engineer in the form of production rules i.e. if process operates, then control output. Controller designed here is a self tuning type because it changes the gain values automatically and continuously with the outputs. It has two inputs one is error (e) and change in error (Δe) with one output as U.Domain for membership function is divided into seven regions and its shape is shown below as triangular form in figure 3.3.

NB-Negative Big

NM-Negative medium

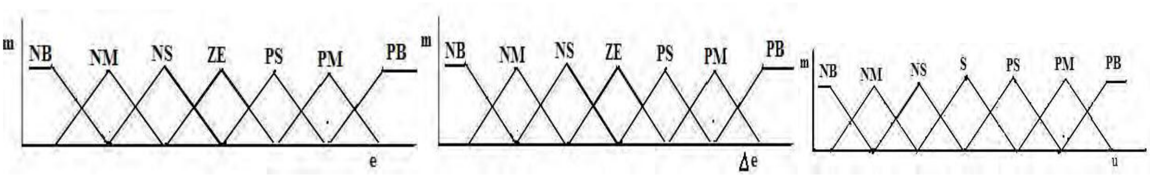
NS-Negative small

PB-Positive Big

PM-Positive Medium

PS-Positive Small

ZE-Zero

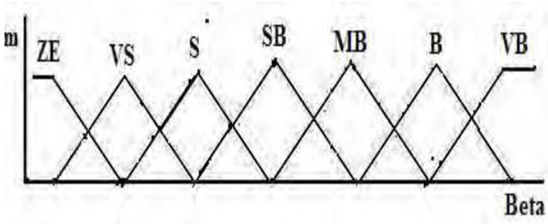


Member ship functions Fig-3.3

Fuzzy rule is represented in chart form as below . From the figure below if value of e is zero and value of Δe is NM, then the value of output U as NM.

Member ship function for gain updating factor and fuzzy rule for it is shown below in Figure 3.4

Fuzzy rule for domain membership function Fig-3.4



Membership function for Beta Fig-3.5

Δe \ e	NB	NM	NS	ZE	PS	PM	PB
NB	VB	VB	VB	VB	B	MB	SB
NM	VB	VB	VB	B	MB	SB	S
NS	VB	VB	B	MB	SB	S	VS
ZE	VB	B	MB	SB	S	VS	ZE
PS	B	MB	SB	S	VS	ZE	ZE
PM	MB	SB	S	VS	ZE	ZE	ZE
PB	SB	S	VS	ZE	ZE	ZE	ZE

Fuzzy rule for Beta Fig -3.6

Member ship function and its fuzzy rule is shown in figure 3.5 and 3.6 respectively.Using fuzzy based controller with Dstatcom simulation is done for different loads such as unbalanced RL load, three phase bridge rectifier. Here source side is protected by compensating reactive power using D-statcom with fuzzy based controller and to make the source to supply balance current .

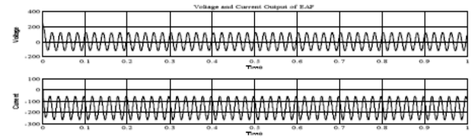
Advantages:

- ✓ Harmonics are reduced
- ✓ Settling time is faster

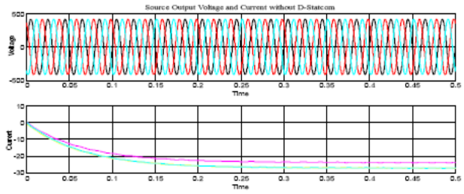
IV. SIMULATION RESULTS

Fig. 4.1 shows the EAF voltage and current. Fig 4.2 shows the source output voltage and current without Dstatcom. Fig 4.3 shows the output of source output voltage and current with Hysteresis controller of D-statcom. Fig 4.4 shows the instantaneous active power with Hysteresis controller of d-statcom. Fig 4.5 shows the instantaneous Reactive power with Hysteresis controller of d-statcom.Fig 4.6 shows the source and load output voltage and current for unbalanced RL load using Fuzzy based PI controller with D-Statcom. Fig 4.7 shows the source and load output voltage and current for three phase bridge rectifier using Fuzzy based PI controller with D-Statcom

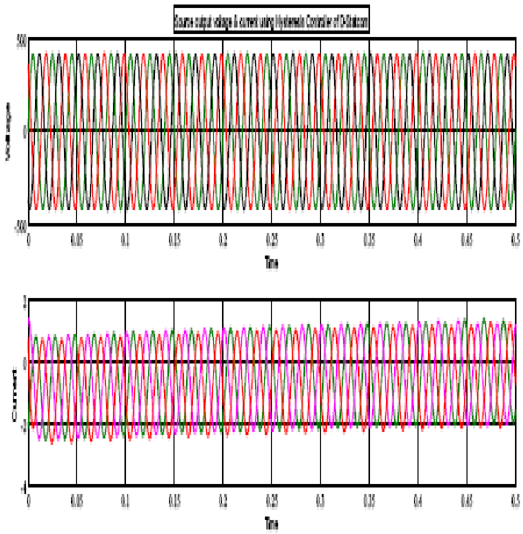
Δe \ e	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NS	NS	ZE
NM	NB	NM	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PM	PB
PB	ZE	PS	PS	PM	PB	PB	PB



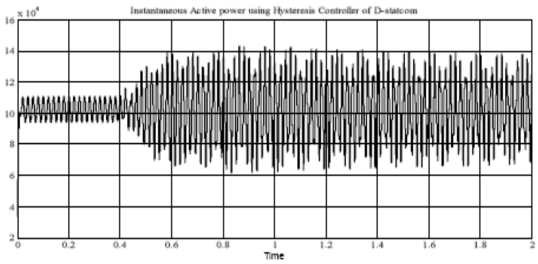
3 PHASE EAF VOLTAGE AND CURRENT OUTPUT- Fig (4.1)



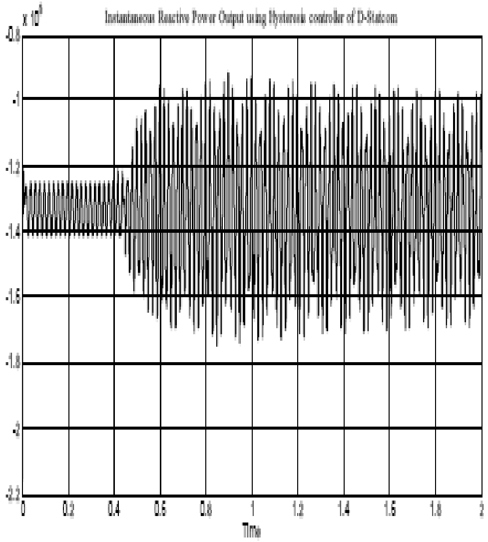
3 PHASE SOURCE OUTPUT WITHOUT D-STATCOM- Fig 4.2



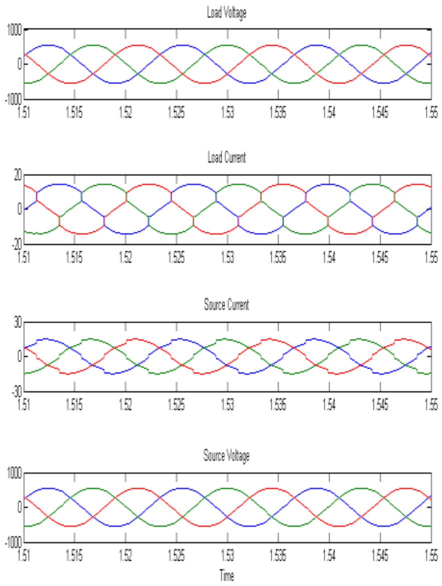
3 phase source output voltage & current using hysteresis controller with D-STATCOM –Fig 4.3



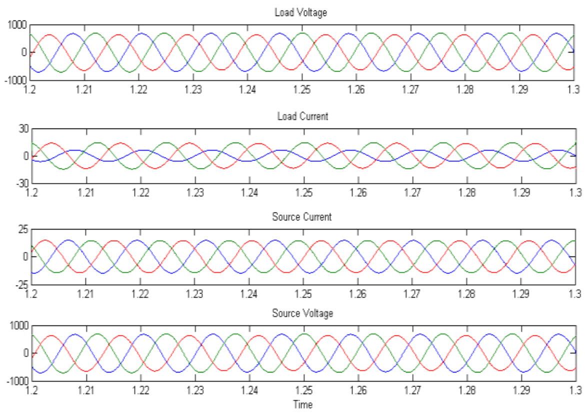
Instantaneous active power using hysteresis controller with D-STATCOM – Fig 4.4



Instantaneous reactive power using hysteresis controller with D-STATCOM – Fig 4.5



3 phase source,load output using fuzzy based pi controller for unbalanced RL load with D-STATCOM – Fig 4.6



3 Phase source,load output using fuzzy based pi controller for three phase bridge rectifier with D-STATCOM – Fig 4.7

V. CONCLUSION

Non-linear load is considered to be one of the major causes of power quality degradation. Compensation is done using D-Statcom with Hysteresis and Fuzzy Based PI controller for EAF and unbalanced RL load, three phase bridge rectifier respectively. Two techniques are discussed and simulated using MATLAB Simulink. All the controllers are proven to be effective with improved response. Source side output is compared for different non-linear loads with different techniques. Among them Fuzzy based controller is chosen to be the best one because of its quicker settling in its output. Future scope is used to simulate the Hyperbolic model of EAF using Fuzzy based PI controller.

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