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# VOLTAGE SAG MITIGATION IN ELECTRIC ARC FURNACE USING FUZZY CONTROLLER BASED D-STATCOM

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## ABSTRACT

Power quality has always been an issue that is continuously increasing its importance in modern industrial and commercial applications. Voltage disturbances; for example the voltage sag, swell, noise etc are the common power quality problems that appears due to increased use of a large numbers of sophisticated and sensitive electronic equipment in industrial systems.

To overcome this problem, custom power devices are used. One of the most common device used to improve the quality of supply is the D-STATCOM which is the most efficient and effective modern custom power device used in power distribution networks. It is connected in pareallel with the power electronic based device so that they can quickly improve the voltage sag problem in the system and restore the load voltage to the pre-fault value. The primary advantage of the D-STATCOM is keeping the users always on-line with high quality constant voltage maintaining the continuity of production. Such a system is simulated using MATLAB/ SIMULINK

**KEYWORDS:** Fuzzy Controller, Voltage

## INTRODUCTION

The quality and reliability of power in distribution systems have been increasingly attracting the interest of the user in modern times and have become an area of concern for modern industrial and commercial applications. The increasing use of sophisticated manufacturing systems, industrial drives, precision electronic equipment in modern times results in the greater demand of power quality and reliability in distribution networks than ever before. Power quality problems encompass a wide range of phenomena. Voltage sag/swell, flicker, harmonics distortion, impulse transients and interruptions are a prominent few. These disturbances are responsible for problems ranging from error in one area of plant such as shut down to another one resulting in loss manufacturing capability. Voltage sags/swells can occur more frequently than any other power quality phenomenon. These sag/ swells are the most important power quality problems in the power distribution system.

Thus we can define sag as:

"Voltage Sag or Voltage Dip is defined by the IEEE- 1159 as " The decrease in the rms voltage level to 10%-90% of "nominal, at the power frequency for durations of ½ cycles to one minute."

## ARC FURNACE

The industrial application of arc furnace is melting and refining. It is used to produce steel principally by using iron. The arc furnaces are used to apply bulk power by the application of high current. Arc furnace is used as load because it is that the main source of electrical power quality problems. Therefore it is necessary to develop an accurate and easy to use ac arc furnace model.

In this dissertation, the dynamic model of Arc Furnace is constructed in two steps -:

- Using Chaotic current
- Using V-I characteristic of Arc Furnace

### Arc Furnace Operation

The Schematic of electric arc furnace is shown below

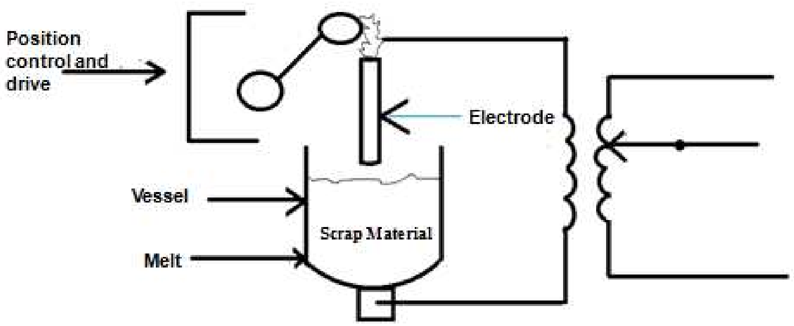


**Figure 1: Industrial Installation of Arc Furnace**

The operation of arc furnace consist of three different stages. These are

- The 1st is the one in which electric arc struck. This is accompanied by the lowering of supply electrode into the vessel charge.
- The 2nd stage is the melting stage in which the arc applies heat to the surface of the charge and the current path in the vessel charge supplies $\mathbf{i^2r}$ heating. In this stage the current may be quiet high and the current wave shape may be quiet erratic due to rapid changes in the current path.
- The 3rd is the refining stage in which the contents are heated to a very high temperature and surplus contents are either taken from bottom or from the top of the furnace or either vaporized. The heating is due to $\mathbf{i^2r}$ heating or due to current in the charge.

The typical installation of arc furnace is as shown below-:

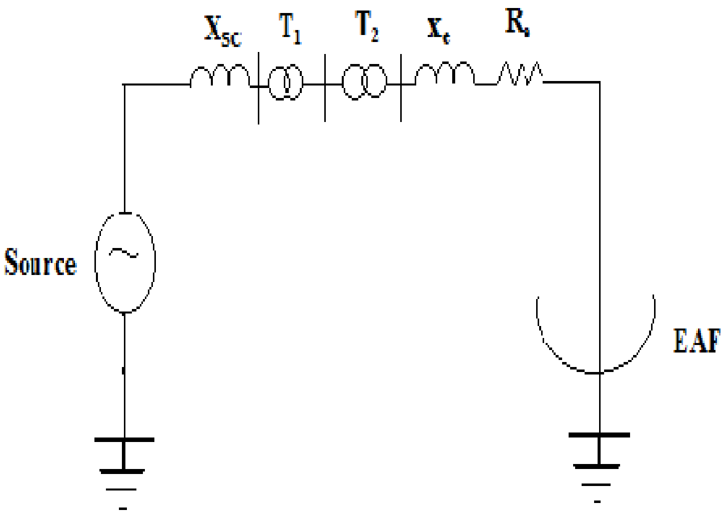


**Figure 2: Arc Furnace Installation**

Here,

$X_{sc}$ = Transmission system reactance

$T_1$ = Substation Transformer

$T_2$ = EAF Transformer

$X_e$ = Load reactance

$R_e$ = Load resistance

## DSTATCOM

### Introduction

D-STATCOM is one of the most important controller for distribution networks. It regulates system voltage, improves voltage profile, reduce voltage harmonics, reduce transient voltage disturbances and load compensation. DSTATCOM uses power electronic converter to synthesise the reactive power output.A DSTATCOM converter is controlled using PWM or other voltage/current shaping techniques. It operates on low rated power thus controlling carrier frequency much higher than FACTS controller.

The DSTATCOM is the solid – state based power converter version of the SVC. Operating as a shunt – connected SVC, its capacitive or inductive output currents can be controlled independently from its connected AC bus voltage. Because of the fast-switching characteristic of power converters, the DSTATCOM provides much faster response as compare to SVC. DSTATCOM is a shunt connected, reactive compensation equipment, which is capable of generating and or absorbing reactive power whose output can be varied so as to maintain control of specific parameters of the electric power system. DSTATCOM provides operating characteristics similar to a rotating synchronous compensator without mechanical inertia, due to the DSTATCOM employ solid state power switching devices it provides rapid controllability of the three phase voltages, both in magnitude and phase angle.

**Basic Configuration**

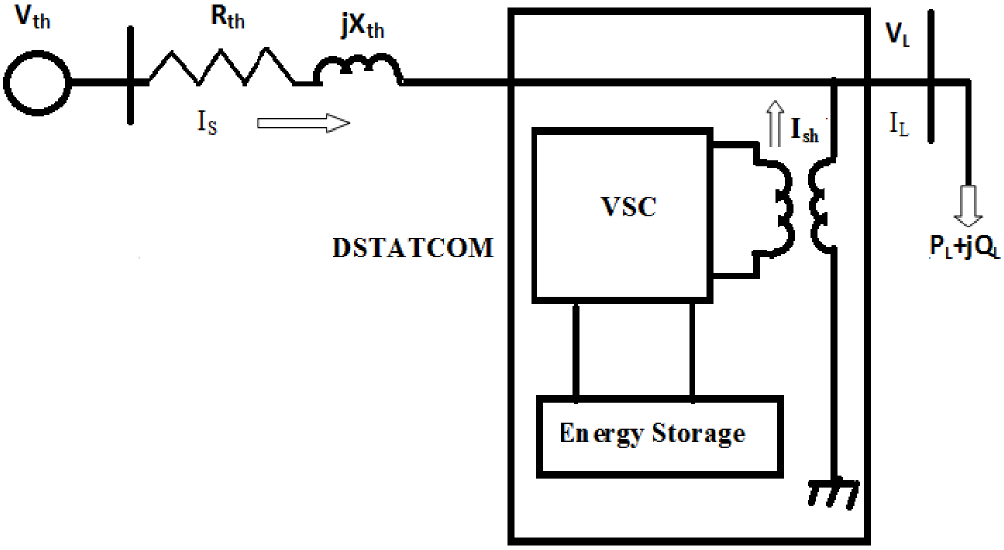


**Figure 3: Schematic of DSTATCOM**

**Principle of Operation**

The D- STATCOM is a three phase shunt connected power electronic device. It is connected near the load at the distribution systems. The major components of D-STATCOM is shown in Figure. The basic components of D-STATCOM are 12-pulse voltage source inverters composed of forced commutated power semiconductor switches which are connected in shunt with the line through a set of shunt injection transformers.

Since the D- STATCOM employs an inverter to convert the DC link voltage $V_{dc}$ on the capacitor to a voltage source of controllable magnitude and phase, it can be treated as voltage- controlled source. Figure shows the inductance L and resistance R which represent the equivalent circuit elements of the step down transformer. Let $V_s$ is the distribution system voltage, $V_i$ is the effective output voltage of the D- STATCOM and δ is the power angle. The reactive power output of the D- STATCOM either inductive or capacitive depending on the operating mode of the D- STATCOM. The controller of the D- STATCOM is used to operate the inverter in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted so that the D- STATCOM generates or absorbs the desired reactive power at the point of connection. If Vi = Vs, then the reactive power is zero and the D-STATCOM does not generate or absorb reactive power. When Vi is greater than Vs, the D- STATCOM shows an inductive reactance connected at its terminal. The current (I) flows through the transformer reactance from the D- STATCOM to the ac system, and the device generates capacitive reactive power. When Vs is greater than Vi, the D- STATCOM shows the system as a capacitive reactance. Then the current flows from the ac system to the D- STATCOM resulting in the device absorbing reactive power.

On the dc side DSTATCOM is provided with current source inductor $L_D$. This topology causes higher losses on the dc reactor. Moreover, It requires reverse blocking semiconductor switches. Hence this topology is not frequently used.

## METHODOLOGY

### Fuzzy Logic System

FL is a problem solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or work station-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based stage, in order to provide missing input information.

In fuzzy logic, basic control is determined by a set of linguistic rules which are determined by the system. Since numerical variables are converted into linguistic variables, mathematical modelling of the system is not required. The fuzzy logic control is being proposed for controlling the inverter action. The fuzzy logic controller has two real time inputs measured at every sample time, named error and error rate and one output named actuating signal for each phase. The input signals are fuzzified and represented in fuzzy set notations as membership functions. The defined 'If … Then …' rules produce output (actuating) signal and these signals are defuzzified to analog control signals for comparing with a carrier signal to control PWM inverter.

### Basic Structure of FLC

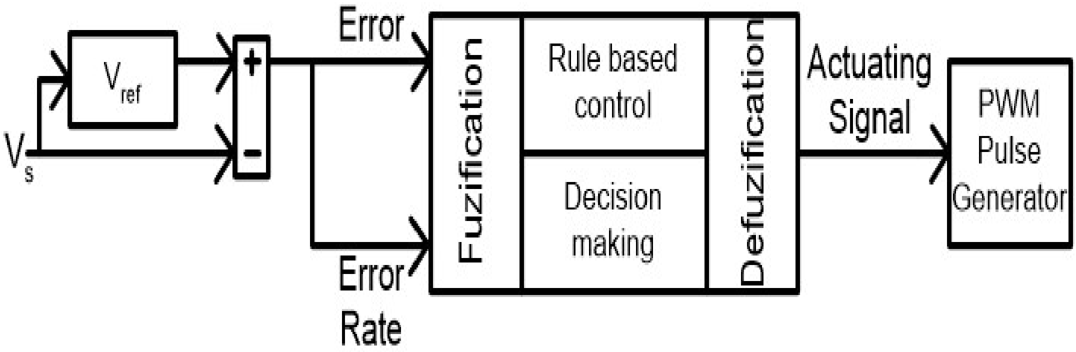


**Figure 4**

shows the basic schematic of a fuzzy logic control. Two variables, error in voltage i.e. difference between supply voltage and the reference voltage and error rate i.e. the rate of change of error of voltage are taken as input to fuzzy logic controller Error and error rate are defined as:

Error = $V_{ref} - V_S$ …. (1)

Error rate = error (n) – error (n-1)… (2)

## SIMULATION MODELS OF THE TEST SYSTEM

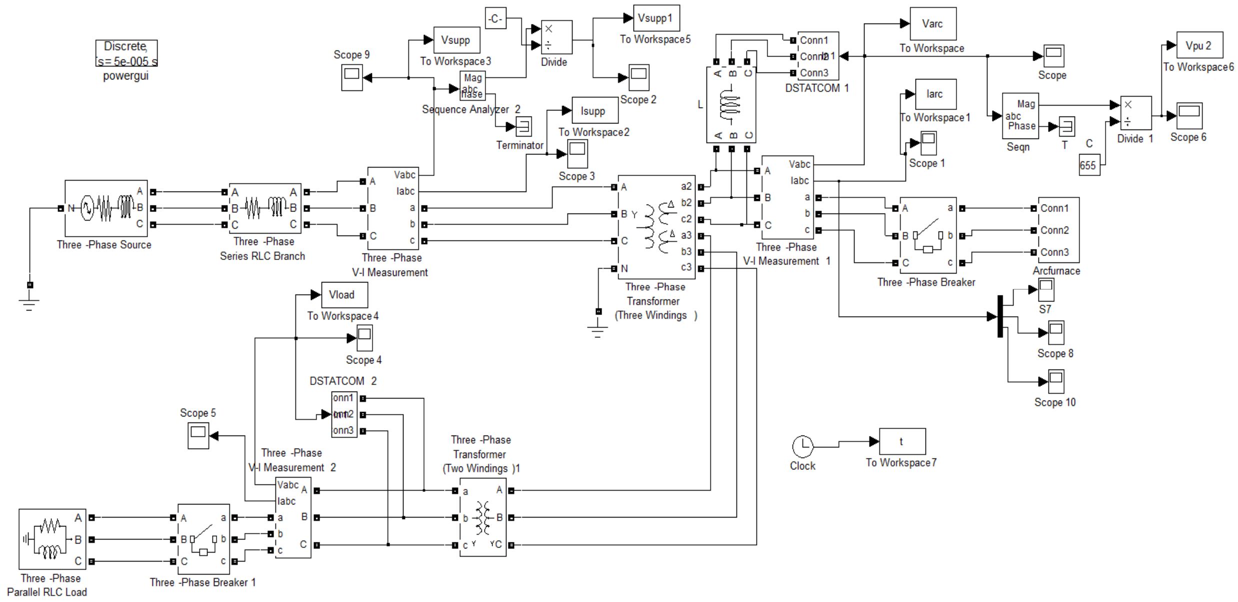

**Figure 5**

## CONCLUSIONS

This paper presents the design and simulation of fuzzy logic based DSTATCOM. The simulation is carried out for non-linear loads. The fuzzy controller is different from conventional controller as it attempts to implement the operator's knowledge rather than mathematical equations of plant .The control engineer can design the fuzzy rule base for fuzzy controller and as well as fuzzy rule base for gain updating factor according to their knowledge. The proposed fuzzy based controller is proven to improve the performance of conventional controller. Matlab based simulation results have verified the effectiveness of the design methodology. It significantly enhances the power system stability. It is clear from the simulation results that to add a fuzzy controller for DSTATCOM is potential alternative to conventional controller.

D-STATCOM is promising device which is used for voltage sag, swell mitigation at distribution side. In this work only the Vrms value is required to measure instead KVAR, so that complexity is reduced

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