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# A Fuzzy Logic Controlled Based Protection Scheme for HVDC Converters against DC-Side Faults with Current Suppression Capability

**S. Anupama**[1]
*Assistant professor*

**K. Harinath Reddy**[2]
*Assistant professor*

**S. Chandrakanth**[3]
*PG scholar*

[1-3]*Department of Electrical and Electronics Engineering,*
*AITS College, Rajampet, India.*

**Abstract**

In this paper Two-level voltage-source converters and half-connect modular multilevel converters are the highly used popular types of HVDC converters. One of their serious disadvantages is their helpless nature to dc-side faults, because the freewheeling diodes act as a bridge rectifier and supply current to the dc side faults. The seriousness of dc-side faults can be restricted by associating two fold thyristor switches over the semiconductor devices. By turning them on, the ac current contribution into the dc side is wiped out and the dc-link current will openly rot to zero. The fundamental inconveniences of this strategy are: high dv/dt stresses crosswise over thyristors amid ordinary conditions, and not having the bypassing for the freewheeling diodes amid dc shortcomings since they are sharing the deficiency current with thyristors. The extension plan has expanded to fuzzy logic controller compare to the HVDC converters.

**Keywords:** DC-side faults, double thyristor switch, fault current suppression, protection of HVDC converters, Fuzzy logic.

## I. INTRODUCTION

Until recently, the classic HVDC transmission based on thyristors was used for power conversion from ac to dc and vice versa. Appearance of Voltage Source Converter (VSC) makes use of more advanced semiconductor technology instead of thyristors. The VSC-based HVDC installation has several advantages compared to classic HVDC transmission such as independent control of active power and reactive power.

Whenever fault occurred in the dc side the higher currents flowing through the freewheeling diode. At that time the diode is going to be a damaged. This fault is overcome by doing some arrangements to the following figure 1(a) and figure 1(b).

The initially developed single thyristor switching scheme is shown in figure 2(a).In this scheme the single thyristor is arranged across a sub module in each module of modular multi level converter.

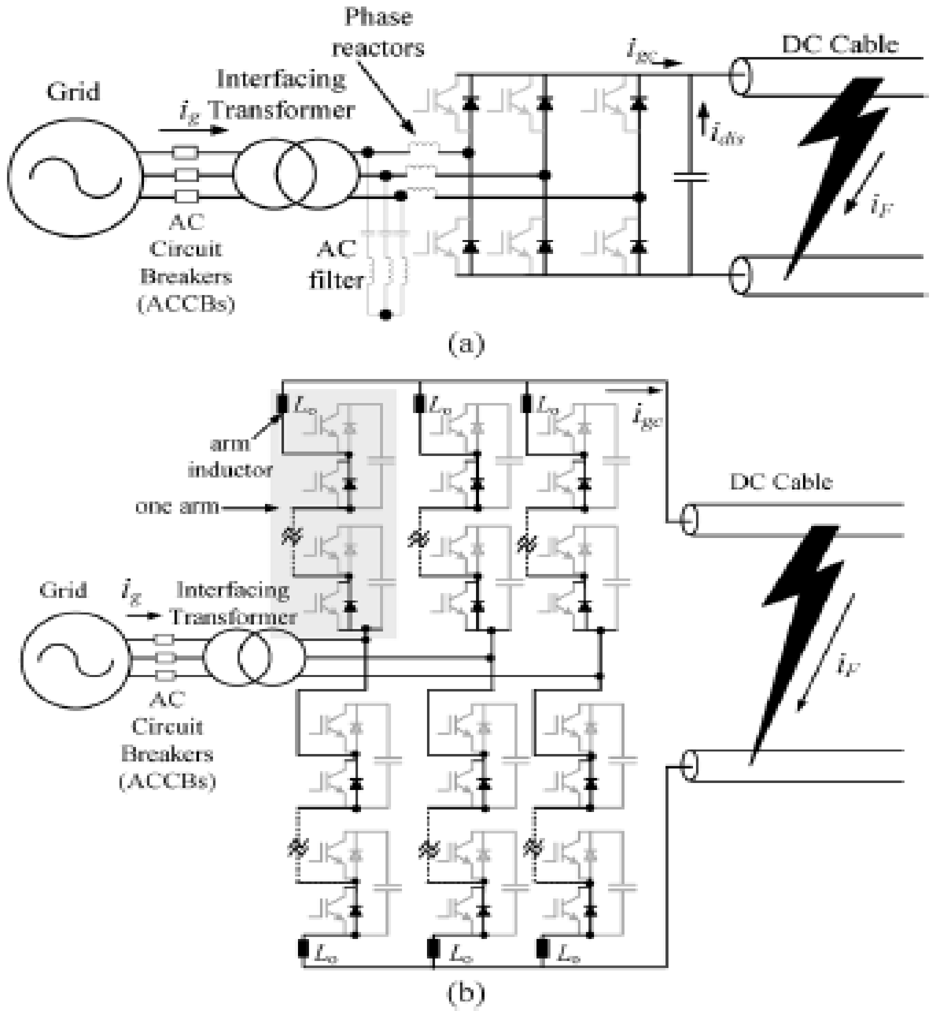


**Figure 1.** (a) 2-level VSC arrangement during dc-side faults and (b) MMC arrangement during dc-side faults.

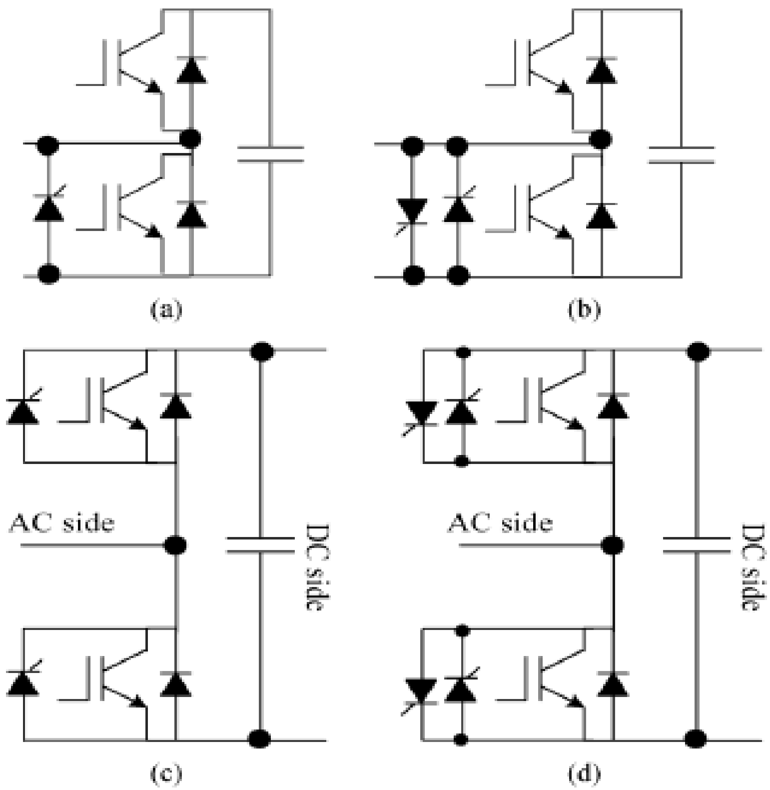


**Figure 2.** Converters protection arrangements: (a) STSS arranged in MMC of each sub module, (b) DTSS arranged in MMC of sub module, (c) STSS for the two level VSC , and (d) DTSS for the two-level VSC.

Here the thyristor is going to be sharing some fault current to with freewheeling diode, or as such, to decrease the over current weights on semiconductor devices pending the tripping of the AC Circuit Breakers. This can be done the thyristor is on at the time of dc side fault occurred. This thyristor has must have higher withstanding ability at the the time fault occurred dc side by contrasted with the freewheeling diode. The double thyristor switch scheme (DTSS) proposed can be utilized to ensure the semiconductor devices by imparting the current to the freewheeling diodes furthermore, all the while keep the system current commitment which permits the dc-link current to freely decay. In the double thyristor switching scheme two thyristors are connected anti parallel across the each module of modular multi level converter. By this scheme also we have a some draw back as mentioned below:

1) The two thyristors must have the withstanding capability for the high dv/dt stress.
2) This scheme is needed a snubber circuit. Why because it should protect from high dv/dt stresses and from the over currents.
3) Still the freewheeling diode is taking fault current.

The double thyristor switching scheme is shown in figure 2(b) and figure 2(d).

## II. EXISTING PROTECTION SCHEME

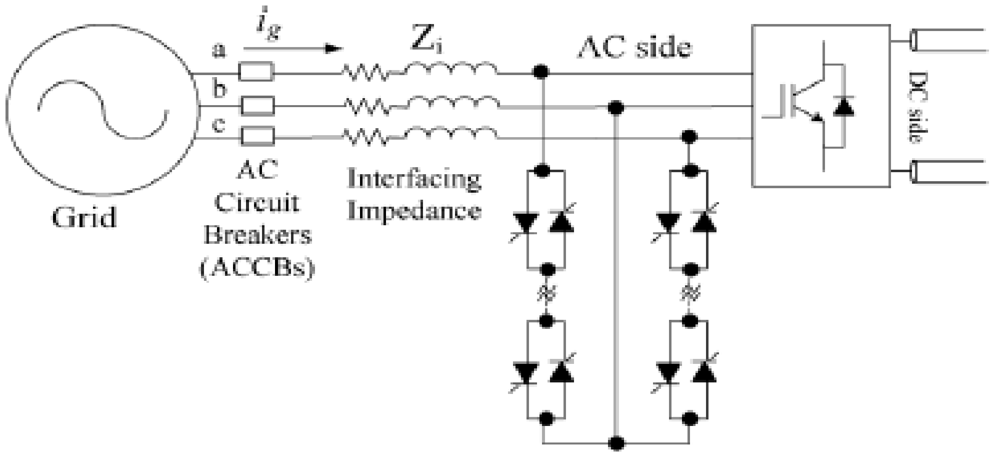


**Figure 3.** Existing protection scheme the double thyristor switches are arranged across ac output terminals.

In the existing protection scheme the double thyristors are connected across the AC output terminals. This existing protection scheme is simulated by using PI controllers. Here we get complete segregation between AC output terminal and converter. But in this scheme the controlling of gain is little difficult. The figure 3 is simulated by using PI controllers.

## III. COMPARISON BETWEEN THE EXISTING SCHEMES AND PROPOSED SCHEME

**1) Single-Thyristor Switch Scheme (STSS):**

In the STSS, the thyristor are connected across the semiconductor device. Under natural operating conditions, the voltage across semiconductor devices varies between 0 and $V_{sw}$. In case of a 2-level Voltage source converter,$V_{sw}$,is nearly equals to the dc-link voltage$V_{dc}$,hile it is equal to the voltage of each submodule's capacitor($\frac{V_{dc}}{n}$) in case ofthe MMC; where is the number of submodules per arm. The $\frac{dv}{dt}$on the single thyristor switch for the two-level VSC andMMC is given by (1) and (2), respectively

$$\text{For single, VSC } \frac{dv}{dt} = \pm \frac{V_{sw}}{T_{\frac{on}{off}}} = \pm \frac{V_{dc}}{T_{\frac{on}{off}}} \tag{1}$$

$$\text{For single, MMC} \frac{dv}{dt} = \pm \frac{(\frac{V_{dc}}{n})}{T_{\frac{on}{off}}} \tag{2}$$

Where $T_{\frac{on}{off}}$ is the need a time for the thyristors to change its state from ON to OFF or vice-versa. Six and 6n single thyristor switches with a voltage rating of $V_{dc}$ and$(\frac{V_{dc}}{n})$ will be needed for the two-level VSC and MMC configurations, respectively.

**2) DTSS (Double-Thyristor Switching Scheme):**

In this Double Thyristor Switching Scheme ,the back-to-back thyristor switch are connected across each semiconductor device, that is, it will have the same as the STSS as follows: So also, six and double thyristor switches with a voltage rating of and will be required for two-level VSC and MMC arrangements, separately.

$$\text{For double, VSC}\frac{dv}{dt} = \pm\frac{V_{sw}}{T_{\frac{on}{off}}} = \pm\frac{V_{dc}}{T_{\frac{on}{off}}} \quad (3)$$

$$\text{For double, MMC}\frac{dv}{dt} = \pm\frac{(\frac{V_{dc}}{n})}{T_{\frac{on}{off}}} \quad (4)$$

**3) Existing Scheme:**

In previous method the back-toback thyristors utilized as a part of the DTSS are consolidated and separated into two gatherings (i.e., there are 3 and consecutive thyristor switches per bunch for the two-level VSC and MMC, individually). Every gathering is associated over the air conditioner terminals of the converter as appeared in Figure 3. Accordingly, the converter line voltage is connected over every gathering.

In the established two-level VSC case, there is a voltage step of$\pm V_{dc}$in every adjustment in converter line voltage. Since, the voltage step is shared between three arrangement consecutive thyristor switches; the comparing $\frac{dv}{dt}$over each thyristor in the proposed plan can be computed from

$$\text{proposed VSC}\ \frac{dv}{dt} = \pm\frac{\frac{V_{dc}}{3}}{T_{\frac{on}{off}}} \quad (5)$$

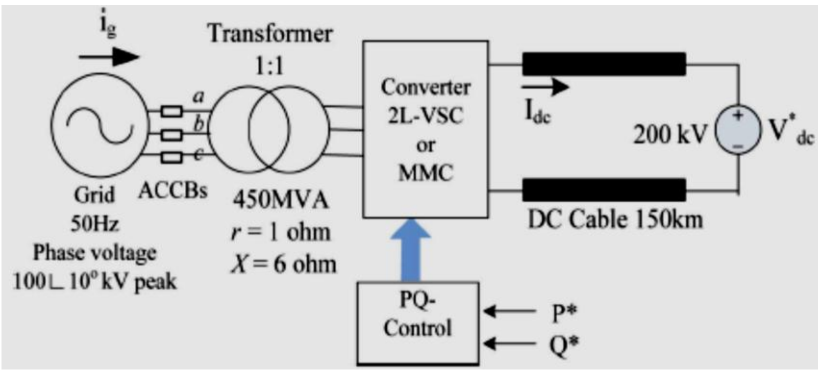


**Figure 4.** Description of the simulated case study.

comparing (3) and (5) shows that the thyristor $\frac{\mathrm{dv}}{\mathrm{dt}}$ decreasesby 66% using the proposed scheme. The thyristors required with a lower voltage rating may be used. During normal conditions,the highest instantaneous value of line voltage$\frac{V_{dc}}{3}$is shared between three series back-to-back thyristor switches,which means a thyristor with a voltage rating of maybe used, that is, the voltage rating of thyristors also decreases by 66% with the proposed configuration.

In the MMC case, there is a voltage step of $\pm V_{sw}$with eachchange in the converter line voltage. Since, the voltage step is shared between series back-to-back thyristor switches, the corresponding $\frac{dv}{dt}$ across each thyristor of the existing scheme is expressed using

$$\text{proposed MMC } \frac{\mathrm{dv}}{\mathrm{dt}} = \pm \frac{\frac{V_{dc}}{3n}}{T_{\frac{on}{off}}} = \pm \frac{\frac{V_{dc}}{3n^2}}{T_{\frac{on}{off}}} \qquad (6)$$

## IV PROPOSED PROTECTION SCHEME

**Fuzzy logic:**

Normally fuzzy rationale control system is made from four noteworthy components exhibited on Figure fuzzification interface, fuzzy induction motor, fluffy principle grid and defuzzification interface. Every part alongside fundamental fuzzy rationale operations will be depicted in more detail below.

Receiving one or expansive number of estimations or other appraisal of conditions existing in some system that will be dissected or controlled. Processing all got inputs as indicated by human based, fuzzy "assuming then" standards, which can be communicated in basic dialect words, and consolidated with conventional non-fuzzy preparing.

**Multi level inverter**

Various mechanical applications have started to require higher power contraption as of late. Some medium voltage engine drives and utility applications require medium voltage and megawatt power level. For a medium voltage framework, it is troublesome to interface stand out power semiconductor switch specifically. Therefore, a multilevel power converter structure has been presented as an option in high power and medium voltage circumstances.

## V. SIMULATION RESULTS

The existing simulation results is got by the simulating the figure 4. This existing scheme is simulated by using PI controller. But the proposed simulation results are got by replacing the PI controller with the Fuzzy logic controller. Here the fault is taking at time t=0.1s.

**i) Two-level VSC existing results:**

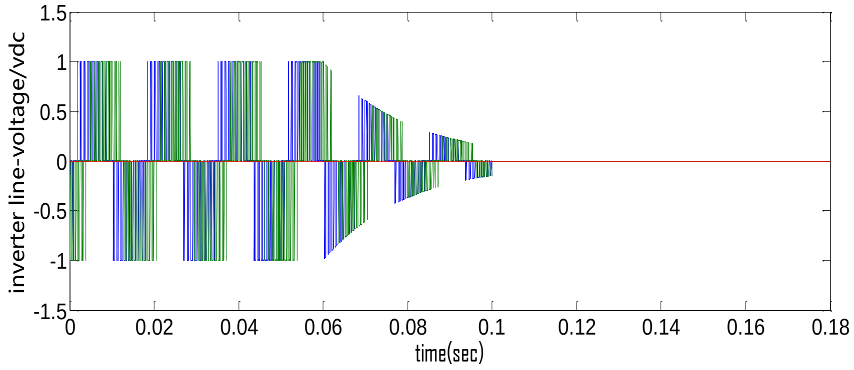


**Figure 5 (a)** Converter line voltage for the 2- level VSC

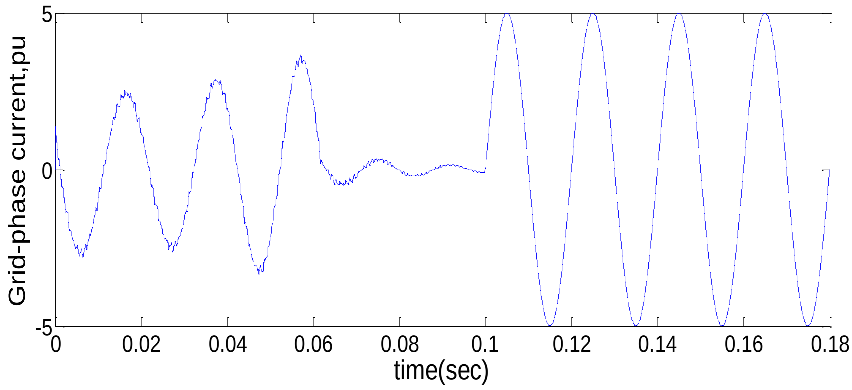


**Figure 5(b)** Per-phase grid current for the 2- level VSC

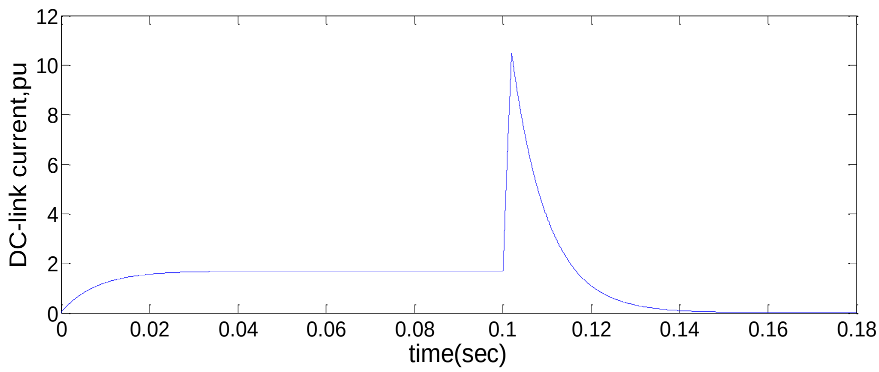


**Figure 5(c)** Dc-link current for the 2-level VSC

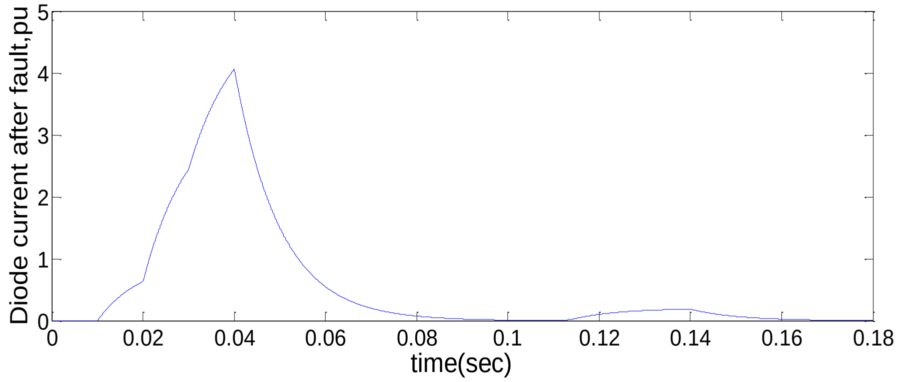


**Figure 5(d)** Freewheeling diode current for protection scheme during the dc fault

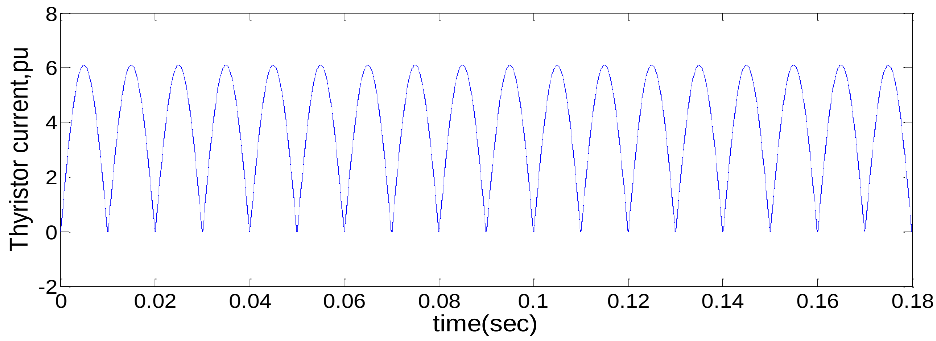


**Figure 5(e)** Thyristors current for Protection scheme during the dc fault

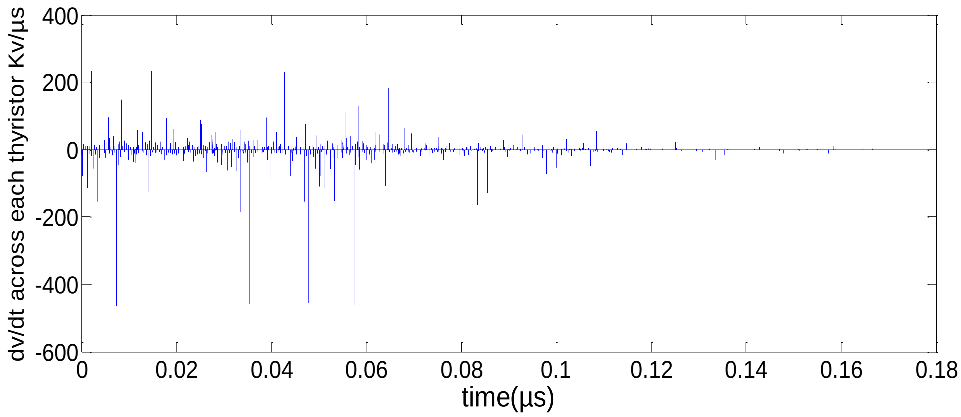


**Figure 5.** (f)dv/dt stresses across each thyristor for different protection schemes during normal operating conditions

**ii)Two-level VSC proposed fuzzy based results:**

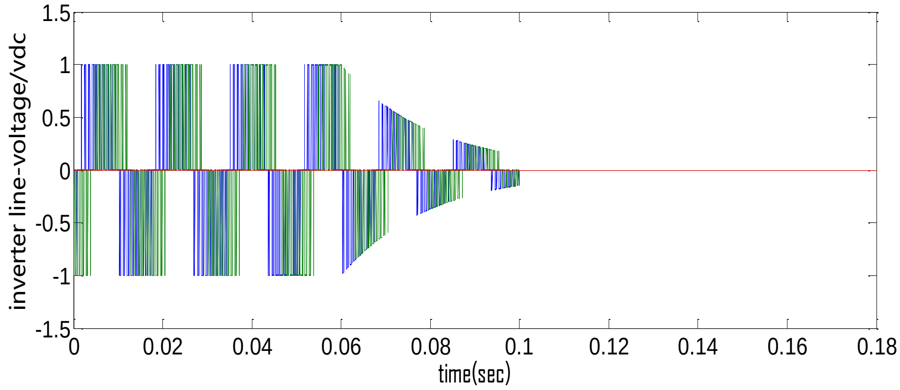


**Figure 6(a)** Converter line voltage for the 2-level VSC

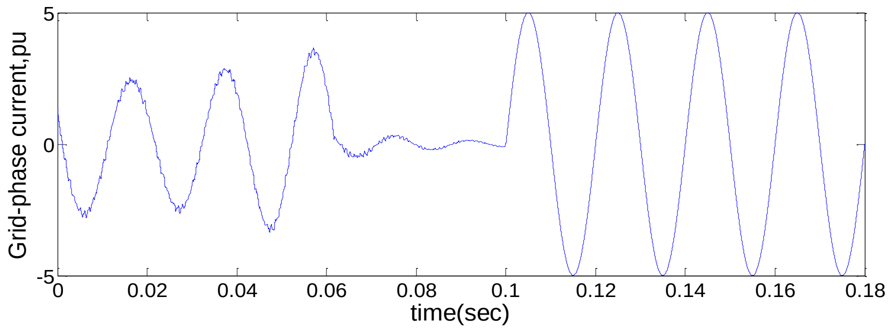


**Figure 6(b)** Per-phase grid current for the 2-level VSC

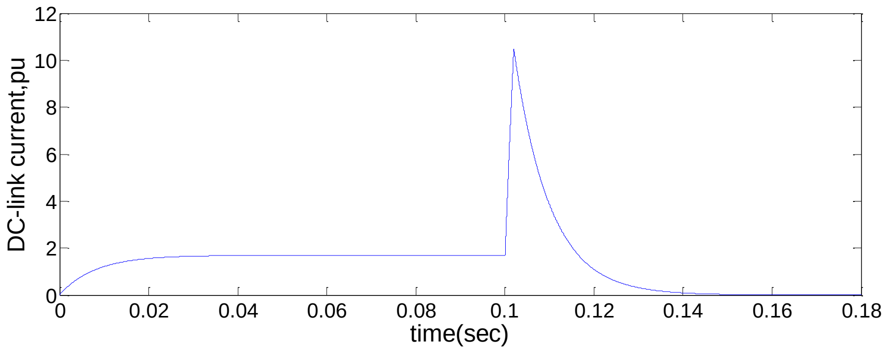


**Figure 6(c)** Dc-link current for the 2-level VSC

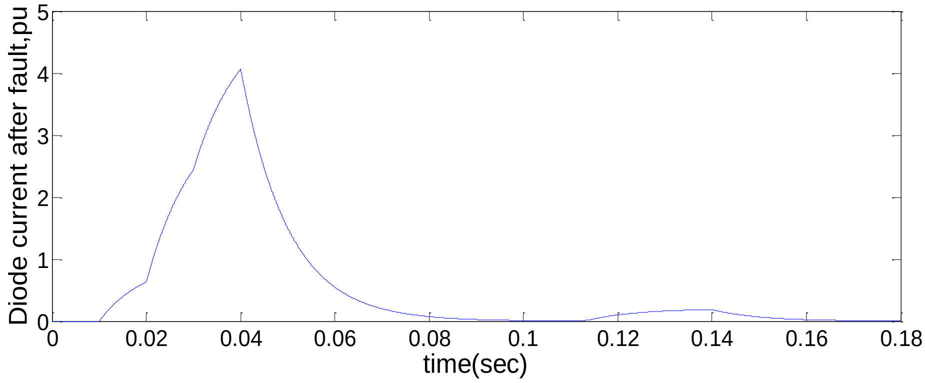


**Figure 6(d)** Freewheeling diode current for protection scheme during the dc fault

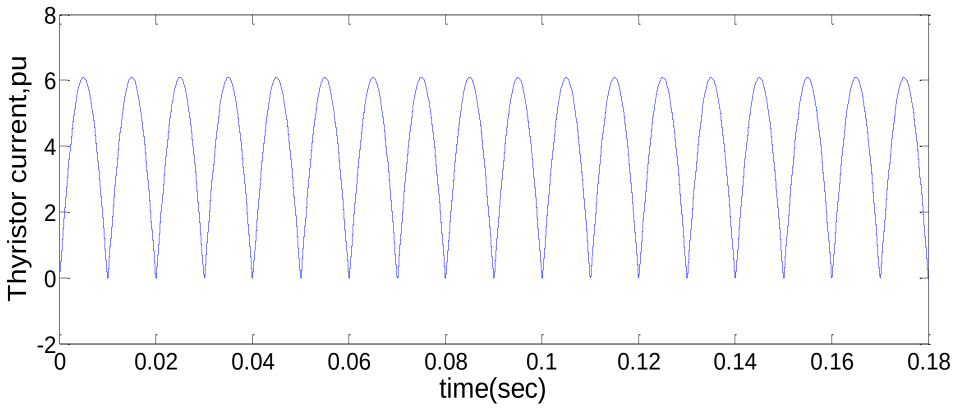


**Figure 6(e)** Thyristors current for Protection scheme during the dc fault

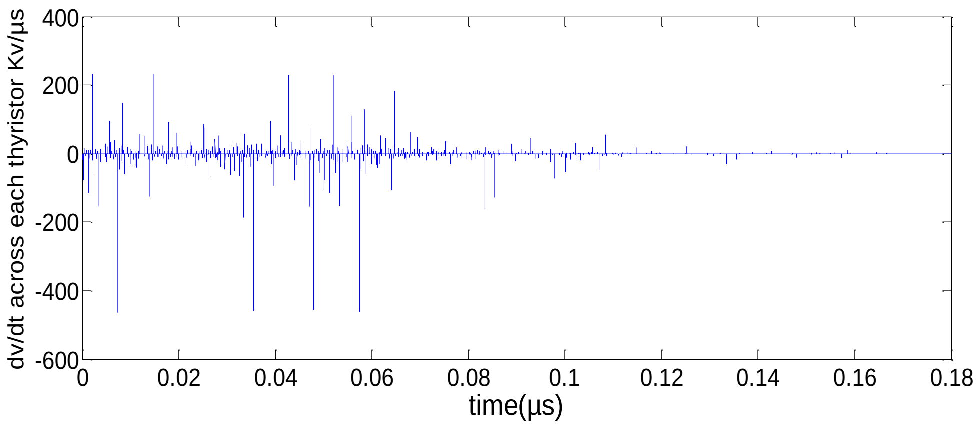


**Figure 6(f)** dv/dt stresses across each thyristor for different protection schemes during normal operating conditions

**iii) Existing three-level MMC results:**

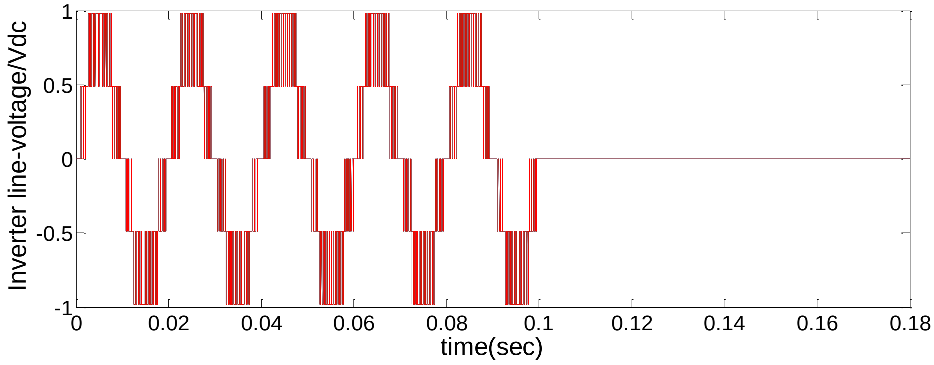


**Figure 7(a)** Converter line voltage

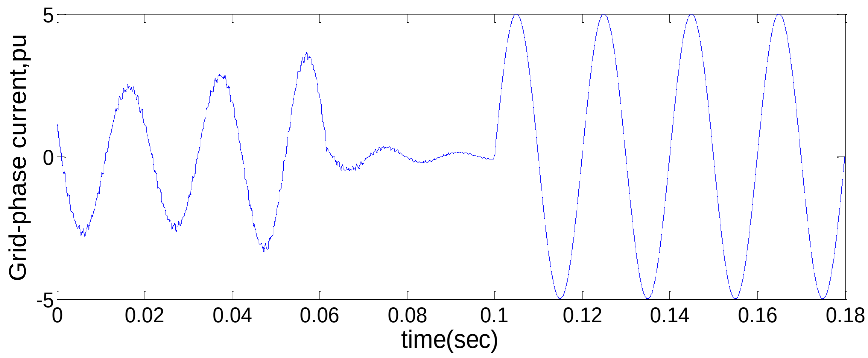


**Figure 7(b)** Per-phase grid current

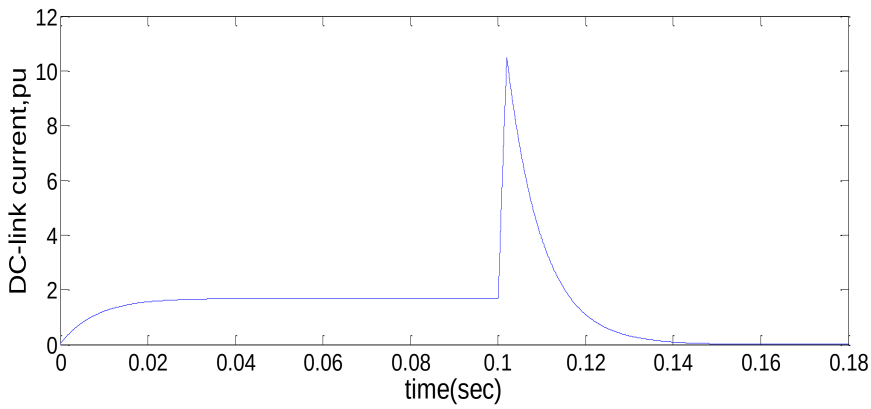


**Figure 7(c)** Dc-link current

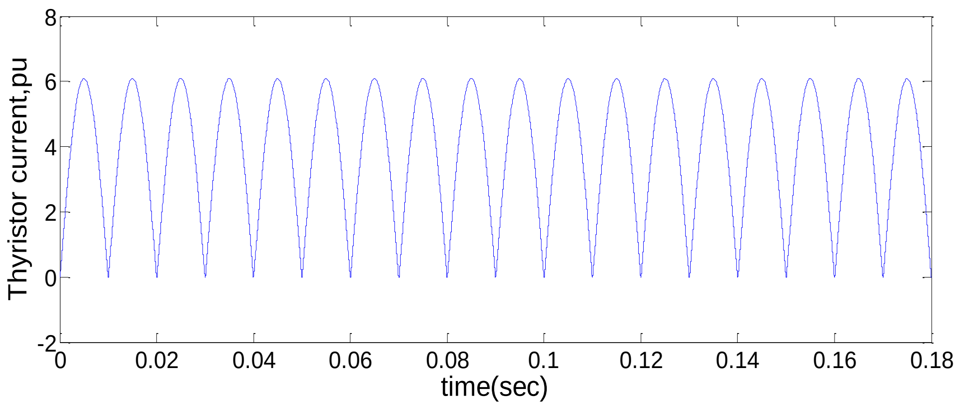


**Figure 7(d)** Thyristors currents for differentProtection schemes during the dc fault

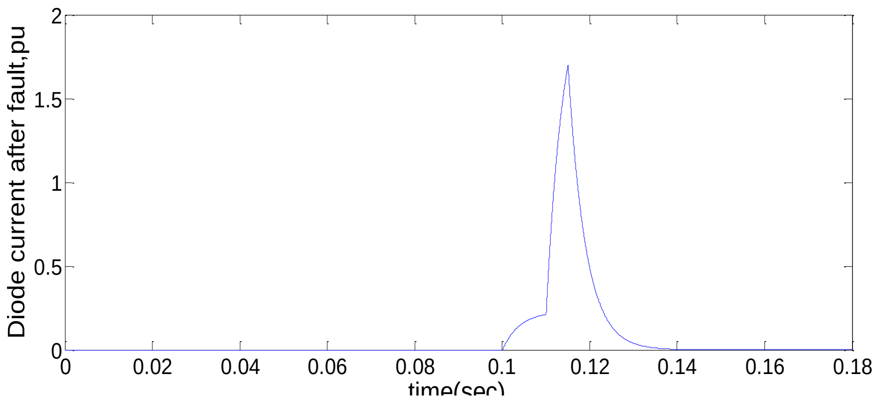


**Figure 7(e)** Freewheeling diode current for different protection schemes during the dc fault

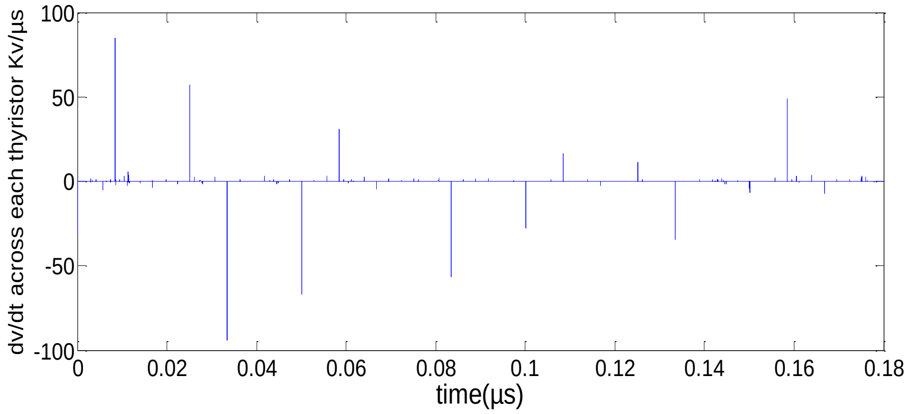


**Figure 7(f)** dv/dt stresses across each thyristor for different protection schemes during normal operating conditions.

**iv) Three-level MMC proposed fuzzy based results:**

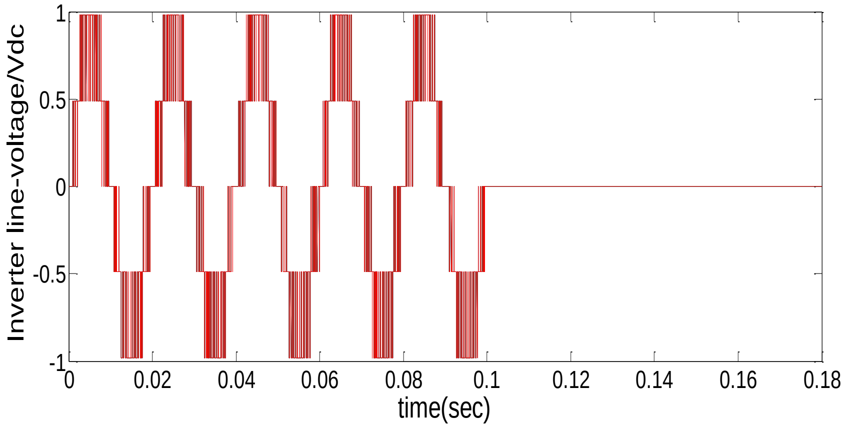


**Figure 8(a)** Converter line voltage

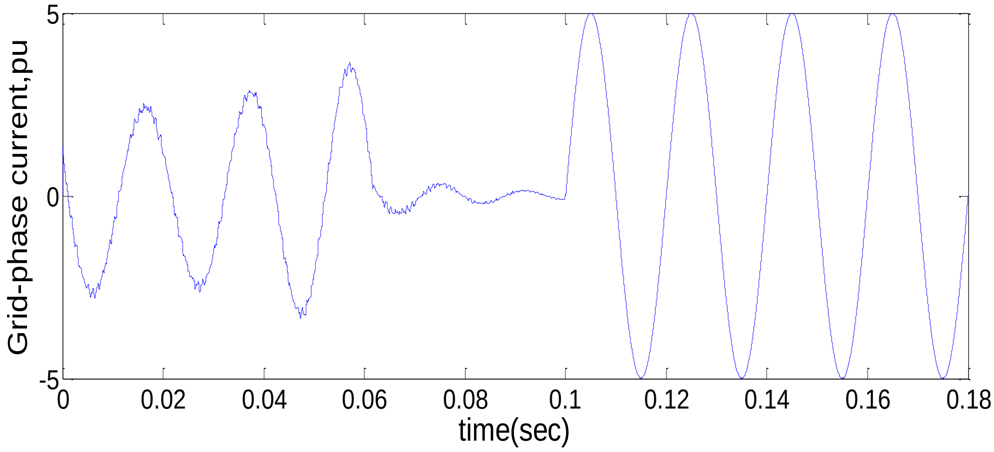


**Figure 8(b)** Per-phase grid current

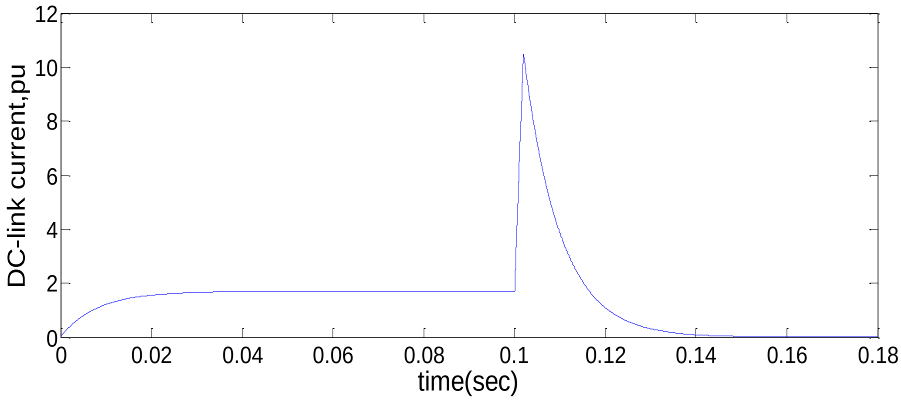


**Figure 8(c)** Dc-link current

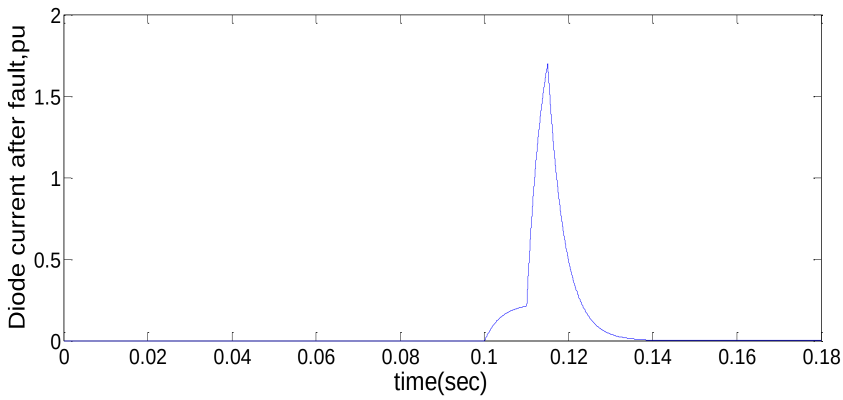


**Figure 8(e)** Freewheeling diode current for different protection schemes during the dc fault

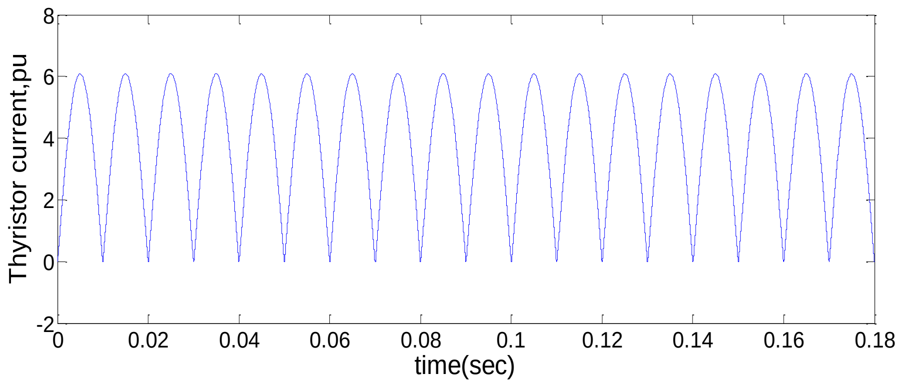


**Figure 8(d)** Thyristors currents for different Protection schemes during the dc fault

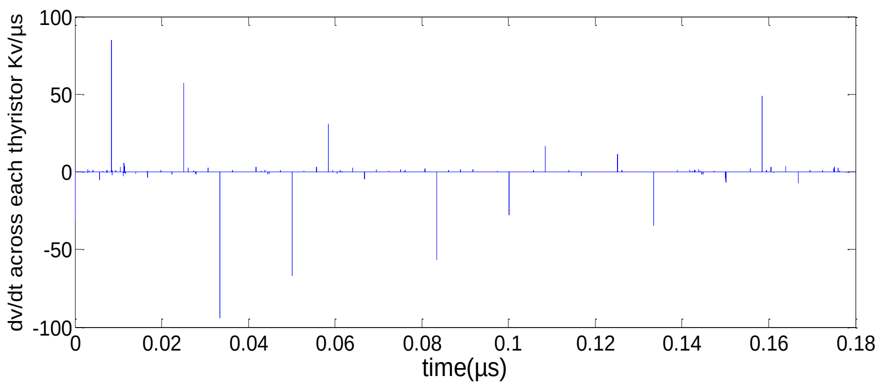


**Figure 8(f)** dv/dt stresses across each thyristor for different protection schemes during normal operating conditions.

## CONCLUSION

In an AC circuit breaker protection scheme, whenever fault occurred at the dc-side the circuit breaker will take some time to trip. So during this period the fault current flowing through the freewheeling diode. At that time the freewheeling is going to be damaged. Similarly in the single thyristor switching scheme and double thyristor switching scheme the fault current is sharing with the freewheeling diode. For eliminating the sharing of fault current with the freewheeling diode developed one scheme i.e DTSS are connected at the AC output terminals. But in this scheme the PI(proportional-integral) controller are used. In this controller the gain controlling is difficult. But in PI controller the Boolean rationale, reality estimations of variables may just be 0 or 1. But in Fluzzy rationale is a type of numerous esteemed rationale in which reality estimations of variables might be any genuine number somewhere around 0 and 1. The proposed scheme has designed fuzzy logic controller compare to the HVDC converters is Efficiency is higher for at fundamental frequency switching.

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