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Design and Analysis of Single Phase Matrix Converter for DVR Application

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Abstract: A single phase dynamic voltage restorer (DVR) is readily available to mitigate the voltage sag in the distribution system. A single phase matrix converter (SPMC) is modulated as a direct ac-ac converter replacing the voltage source inverter in a typical DVR system. The computer simulation was done using MATLAB/Simulink software to verify the SPMC performance towards the mitigating of voltage sag and to analyse the various stages of operation of the SPMC via rectification stage, inversion stage, cyclo-converter stage and cyclo-inverter stage. The sinusoidal pulse width modulation (SPWM) method is applied as the **switching technique to control the switches of the SMPC.**

Keywords: Sag, SPMC(single phase matrix converter).

Introduction

Nowadays, modern industrial devices are mostly based on electronic devices such as programmable logic controllers and electronic drives. The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Voltage dips are considered to be one of the most severe disturbances to the industrial equipments. power electronic solution to the voltage regulation is the use of a dynamic voltage restorer (DVR). DVRs are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating voltage sags/swells. The DVR applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage.

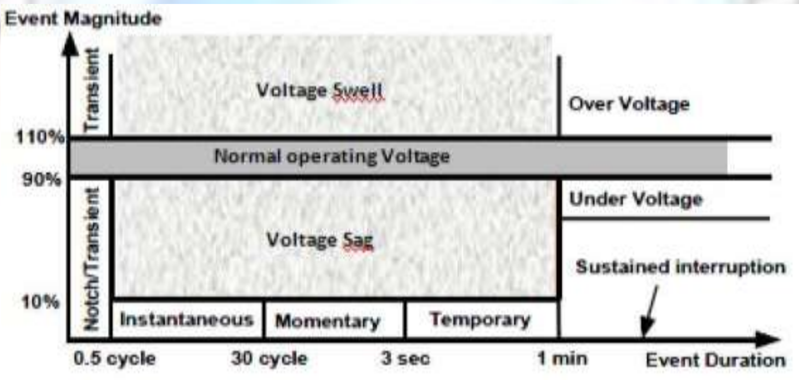

Fig 1 Sag & Swell

A. **Existing Topology**

i. The general configuration of the DVR consists of: An Injection/ Booster transformer, A Harmonic filter, Storage Devices, A Voltage Source Converter (VSC) .

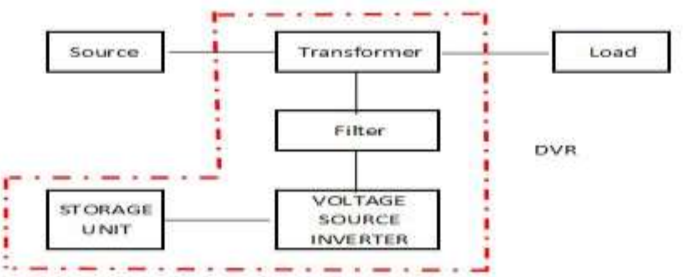

Fig 2 Conventional DVR

B. Proposed System A single phase matrix converter (SPMC) topology is used as a direct AC-AC converter to eliminate the dc link or energy storage used in a typical DVR system. DC link or energy storage is well known for its high cost and short lifespan. SPMC is used to replace the voltage source inverter since the SPMC is well known for its capabilities in producing different waveforms using different switching techniques

The Proposed configuration of the DVR consists of: An injection/ booster transformer, a harmonic filter. single phase matrix converter(spmc).

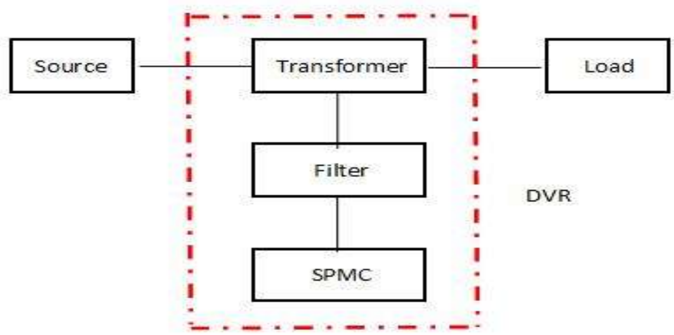

Fig 3 Proposed DVR

C. Single Phase Matrix Converter

It uses four bi-directional switches to serve as a SPMC. This arrangement has the advantage of an independent control of the current in both directions. Since these bidirectional switches are not available at present, they are substituted with two diodes and two IGBT's, connected in anti-parallel, as shown in figure 4. IGBTs are used because of their high switching capabilities and high current carrying capabilities, leading to high power applications. Diodes are included to provide the reverse voltage blocking capability

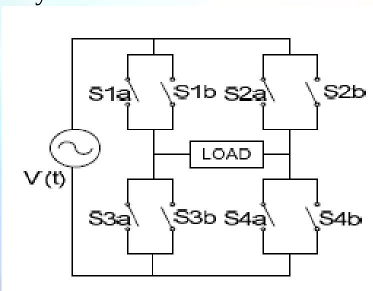

Fig 4 SPMC

D. Modelling of SPMC

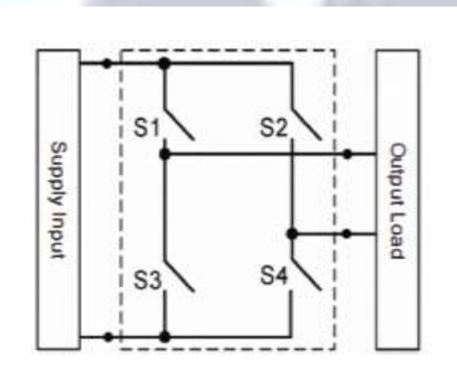

Fig 5 Single line representation of SPMC

The instantaneous input voltage is $v_i(t)$ following as

$$V_i(t)=V_m\cos\omega t \quad (1)$$

Instantaneous Input Current

$$i_i(t)= i_o(t); \text{ When } S_1 \text{ \& } S_4 \text{ are closed} \quad (2)$$
$$i_i(t)= -i_o(t); \text{ When } S_2 \text{ \& } S_3 \text{ are closed} \quad (3)$$

$i_i(t) = 0$; When S_1 & S_2 or S_3 & S_4 are closed (4)

Instantaneous Output Voltages

$v_o(t) = v_i(t)$; When S_1 & S_4 are closed (5)

$v_o(t) = -v_i(t)$; When S_2 & S_3 are closed (6)

$v_o(t) = 0$; When S_1 & S_2 or S_3 & S_4 are closed (7)

E. Modes Of Operation

SMPC may act as a

- Rectifier
- Inverter
- Cyclo-Converter
- Cyclo- Inverter

- **Mode I**

Switches 1a & 4a is in on condition and the output is Half wave rectification

Fig 6 Mode I (Positive Output)

- **Mode II**

Switches 1b & 4b is in on condition and the output is Half wave rectification

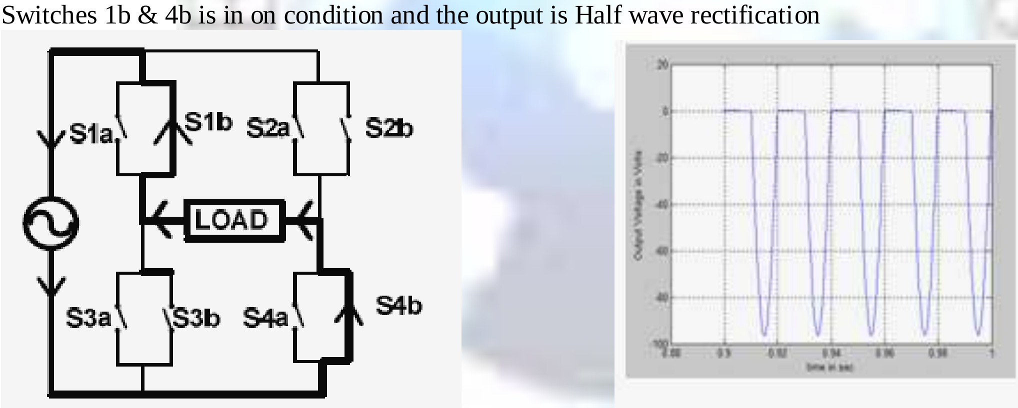

Fig 7 Mode II (Negative Output)

- **Mode III**

Switches 2a & 3a is in on condition and the output is inversion of positive half cycle and hence the output is negative.

Fig 8 Mode III (Negative Output)

- **Mode IV**

Switches 2b & 3b is in on condition and the output is inversion of negative half cycle and hence the output is positive.

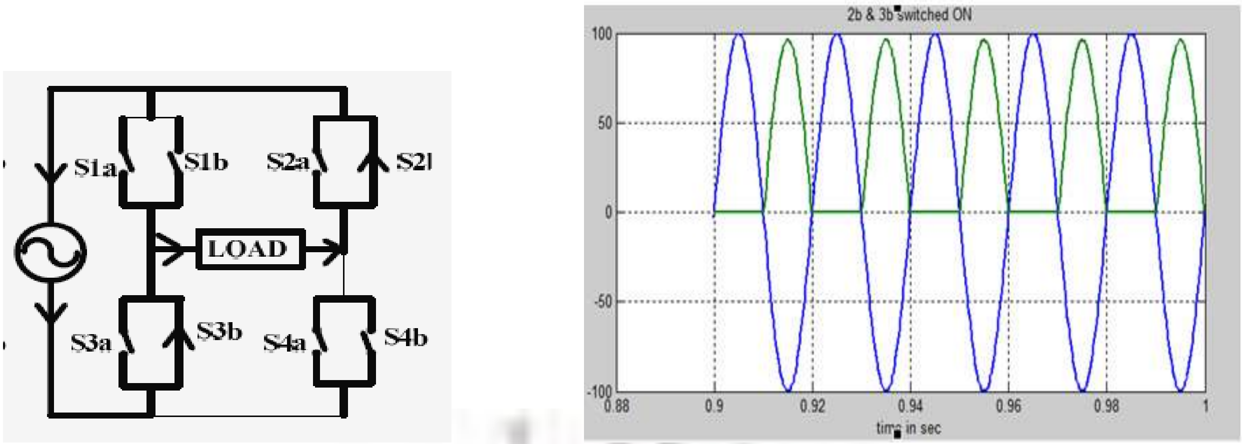

Fig 9 Mode IV (Positive Output)

- **Mode V**

It is the combination of mode I & mode IV which produces the output of full wave rectifier.

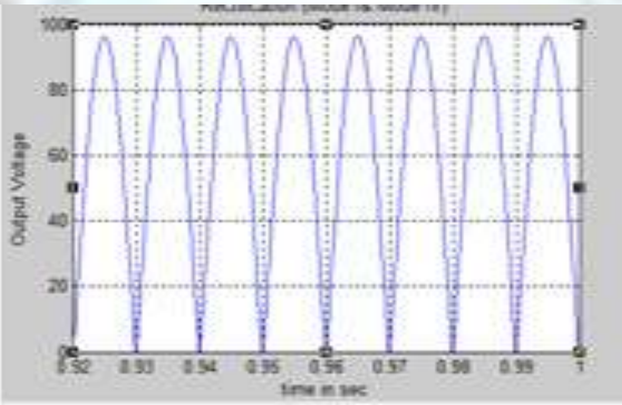

Fig 10 Mode V

- **Mode VI**

It is the combination of mode I & mode II which produces the output of Cyclo-converter

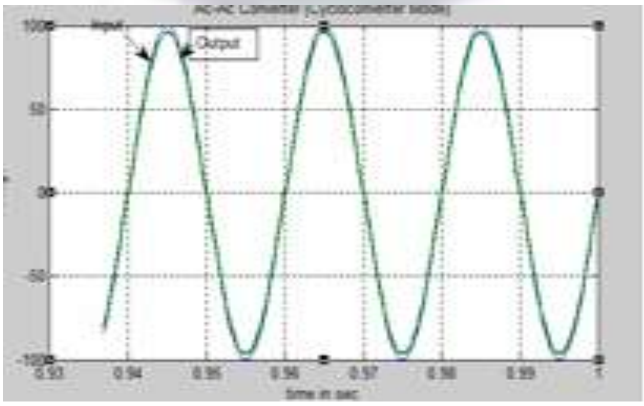

Fig 11 Mode VI

- **Mode VII**

It is the combination of mode II & mode III which produces the output of Cyclo-inverter

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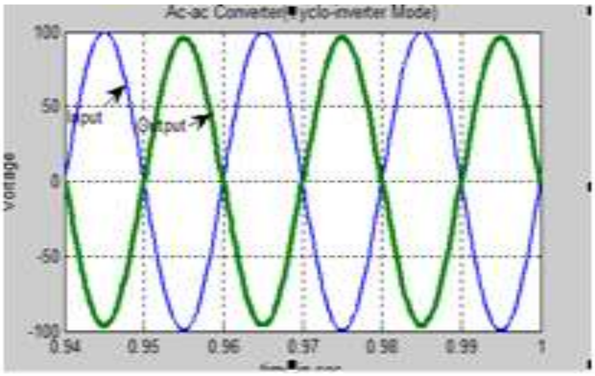

Fig 12 Mode VII

These are all the various operating modes of Single Phase Matrix Converter. Here we use mode VI to make the matrix converter to inject the voltage whenever there is sag.

Table 1 Modes of Operation

MODES	SWITCHES ON	OPERATION
I	1a&4a	Rectification (+ve Output)
II	1b&4b	Rectification (-ve Output)
III	2a&3a	Inversion(-ve Output)
IV	2b&3b	Inversion(+ve Output)
V(combination of mode I&IV)	1a & 4a 2b & 3b	Full wave rectification
VI (combination of mode I&II)	1a & 1b enabled On 4a& 4b enabled by SPWM	cycloconverter
VII (combination of mode III&IV)	2a & 2b enabled On 3a& 3b enabled by SPWM	Cycloinverter

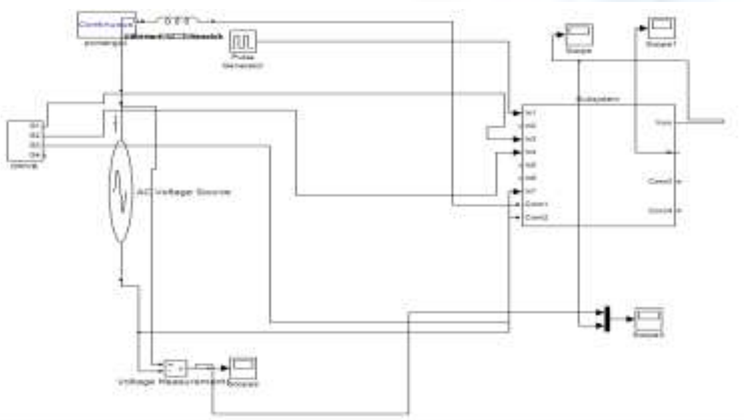

Table 2 Specification

Input Voltage(RMS)	70.71V
Input Voltage(max)	100V
Input PF	Unity
MI	0.4
Carrier Frequency	5KHz
Device Conduction loss	0.9V
Power loss	7.2mW
Output Filter	L=1mH,C=0.01micro Farad
Output Voltage	150V

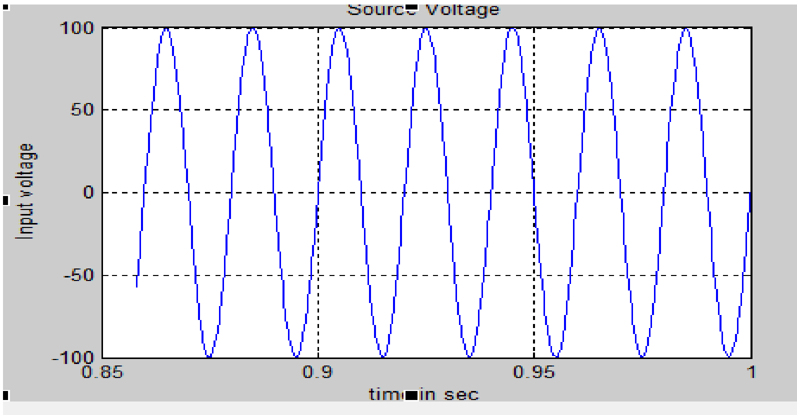

Fig 13 Input Voltage

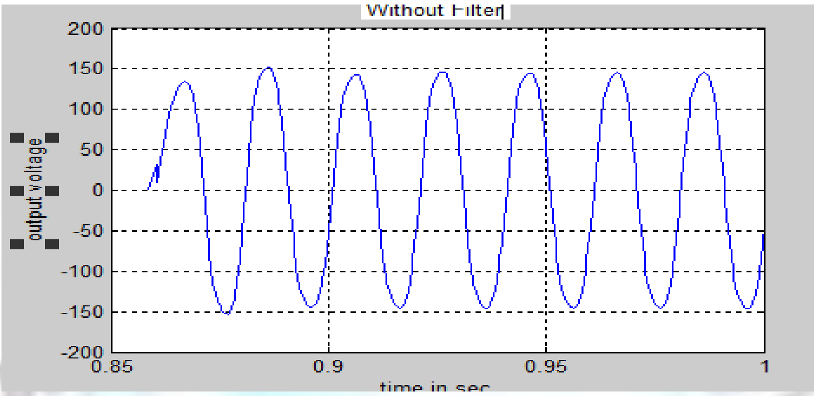

Fig 14 Output Voltage without Filter

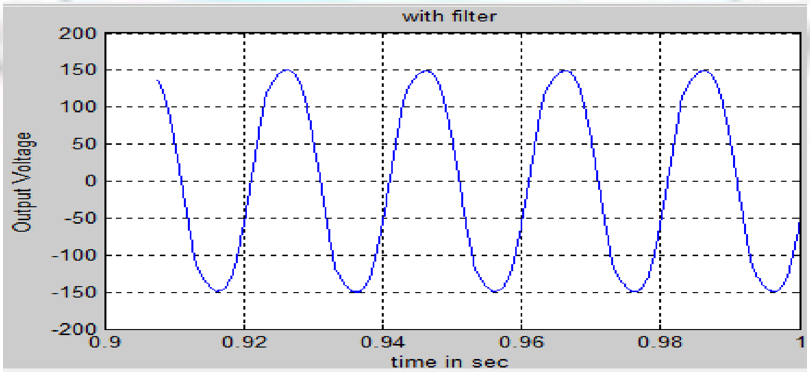

Fig 15 Output Voltage with Filter

Table 3 Output

Parameters	With Filter	Without Filter
Fundamental Component of Voltage V1m	150.56V	150.4
Fundamental Component of Load Current I1m	0.0015A	0.0015
Distortion Factor	0.86	0.935
Total Harmonic Distortion	1.76	2.65

Conclusion/Results

Operation of various modes of Single Phase matrix Converter has been analyzed to know the performance of the converter as rectifier, inverter, cyclo-converter and cyclo-inverter. A Single phase Matrix converter is simulated to produce an output of 150V by taking a input of 100V.This output voltage is fed to the system which is under fault for the mitigation of sag under open loop and closed loop conditions. Based from the result achieved, it is proven that the SPMC is capable of producing desired output through injecting transformer to the load and thus mitigate the voltage sag.

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