Simulation Model of Inrush Current Mitigation Methods of Load Transformer for Series Voltage Sag Compensator

S.S.Kahandal[1] P.C Tapre[2] C.Veeresh[3]
[1]M.E.Student [2,3]Assistant Professor
[1,2,3]Department of Electrical Engineering
[1,2,3]S.N.D. COE and RC, Nashik

Abstract— During the alteration in heavy loads in the distribution system voltage sags are happened. These voltage sags also affect the other buses in the distribution system. The removal of voltage sags are basically done by persuading series transformers connected in the distribution lines. The series transformers are showing to unstable and disturbing voltages, which causes high inrush currents in the transformer. This paper recommends a topology to moderate the inrush current in the transformer during the series reimbursement of the distribution line. The topology includes high rating thyristors, to which the switching firing angle is organized by a state feedback controller. The complete analysis and simulation is done in MATLAB Simulink software and outputs are shown in graphical representation.
Key words: Inrush Current Mitigation Methods, MATLAB

I. INTRODUCTION

In modern years there is huge increase in load demand as the enhancement of technology is varying progressively. With the variation in load situation the power quality is concern must also be taken into attention. With the increase of globalization the manufacture is also increasing, primary to formations of new industrial and construction plants. In a grid system 92% of the voltage sags and other power quality issues are stimulated by the change in the load of these plants. In a radiated distribution system this occurrence is very common as many of the rural areas the industrial and production plants are established. These industrial loads are connected in parallel to the domestic and agricultural loads to the same distribution line (11kV or 33kV).

During the abrupt change in the load i.e., unexpected increase of load the magnitude of the current in the distribution system is amplified rapidly which leads to decrease in the voltage of the line producing a voltage sag. These voltage sags can be restored or can be maintained through series compensators including of inverter with power electronic switches. The monitoring of these power electronic switches is done through PWM technique regulating the output voltage of inverter. The attuned required voltage is fed to the series transformer which is connected in series to the line. During these processes the series transformer which is showing to the distribution line with voltage sags and interruptions the transformer itself builds high inrush currents in it leading to harm also to transformer and similarly the creating more sag in the distribution line. To circumvent these inrush currents in the transformer a new resourceful topology with thyristor control state feedback technique is presented in the system which is shown in fig. 1.

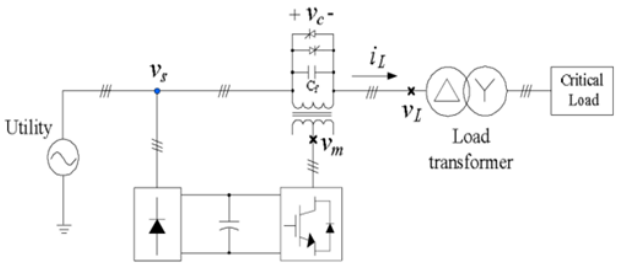

Fig. 1: Series Voltage Sag Compensator with Series Transformer

As shown in the figure the series transformer secondary is coupled in series to the line and the primary is coupled to the IGBT inverter with six switches. The IGBT inverter is linked to the DC-link capacitor and the capacitor is associated to a DBR (Diode bridge rectifier). The DBR changes the three phase AC voltage to DC voltage and the DC-link capacitance decreases the undulations in the DC voltage. The DC voltage with reduced ripple is further fed to AC inverter which is well-ordered with certain switching frequency and modulation index. The three phase inverter output is linked to the transformer secondary. The primary of the transformer has a back to back thyristor (TRIAC) connection with a soothing capacitor Cr.

The experiment system contains a three phase supply service grid with phase to phase rms voltage of 220V and a frequency of 50Hz. A load isolation transformer with 1:1 ratio is associated with delta and Yg connection. The secondary of the load transformer is associated to a non-linear load which produces harmonics and also voltage sag. The voltage profile of the line has to be enhanced by the series device linked to the transmission line.

II. CONTROL TECHNIQUE

A. Thyristor Control Technique:

The governing of the series device with thyristor connection is done through a six switch firing angle controller as each phase includes of two thyristor power electronic switches. During the process of the series device at the primary stage the firing angle of both the thyristors are 0 degrees by which we can define the complete conduction of a full cycle without the series transformer. At a certain time the firing angle slowly reductions and the thyristors partly conduct. The partly conduction of the thyristors now slowly start persuading the transformer into the system. Certain of the voltage is passed through the switches and the other residual voltage is passed through the secondary of the series transformer. The control circuit of the thyristors is shown below in fig. 2

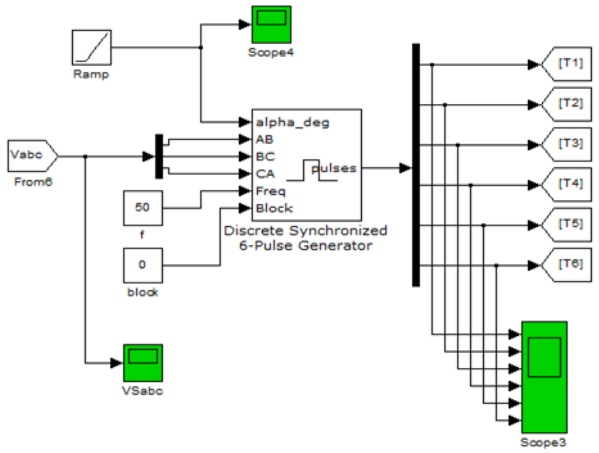

Fig. 2: Thyristor control block

B. Space Vector Pwm Control:

The space vector PWM control is active for generating a three phase AC output from the DC link of the DBR (Diode bridge rectifier). Space vector is working as it is an advanced topology from the unadventurous PWM techniques. Space vector PWM technique is an improvement of sinusoidal PWM as the pulses produced by digital switching of the fundamental waveform. Considering six switch action we divide the VSI into two portions as upper portion and lower portion. The upper portion contain the switches S1 S3 & S5 leaving the lower portion of the VSI with S2 S4 & S6.

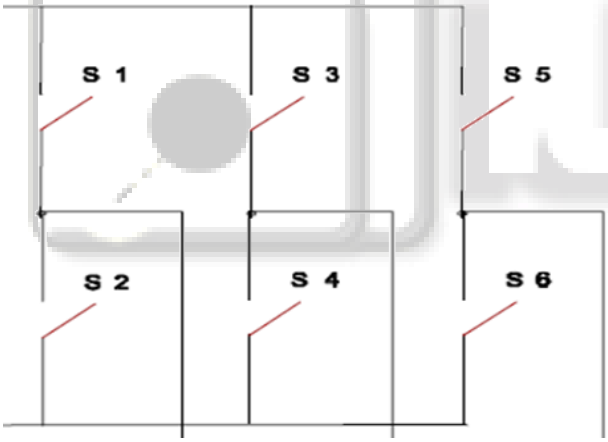

Fig. 3: switch assigning of VSI

The state of the switches are either to be ON of OFF i.e., two states. The number of probable switching states are given as 23 = 8. The 8 switching states are given below.

Switch	S1	S3	S5
1ST MODE	0	0	0
2ND MODE	0	0	1
3RD MODE	0	1	0
4TH MODE	0	1	1
5TH MODE	1	0	0
6TH MODE	1	0	1
7TH MODE	1	1	0
8TH MODE	1	1	1

Table 1: Switching States

In the overhead mentioned 8 switching modes the first and the last switching states are totally OFF and ON which is not applicable. We only consider the six states from 1st to 6th eliminating 0 and 7th mode. The last three switching states are the compliment of first three switching states, which accomplishes that we have to only generate the three switching states i.e., 1st 2nd and 3rd. The additional switching states i.e., 4th 5th and 6th are produced by applying a NOT gate to the previous modes. A simple hexagonal illustration of switching patter is shown fig. 4 below which can be called as Space vector Trajectory.

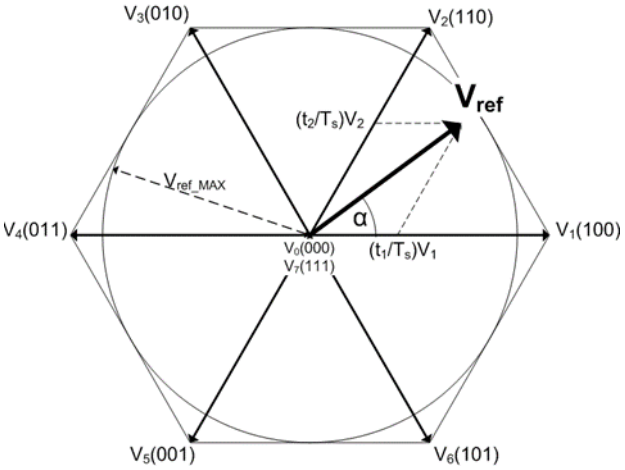

Fig. 4: Space vector trajectory

The signal generation of space vector is associated to the triangular waveform to generate three PWM pulses to which NOT gates are given to get the additional three pulses. The control signal of the space vector PWM is given blow fig. 5

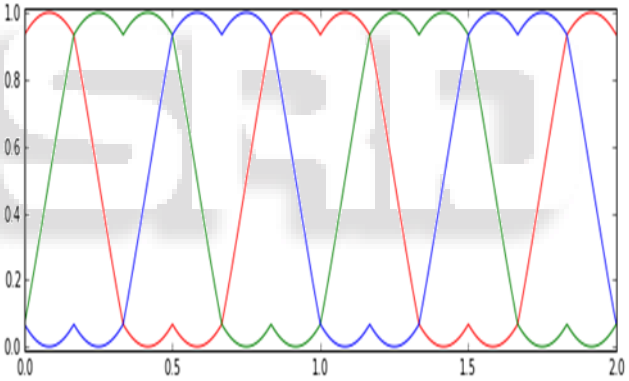

Fig. 5: Control signals of Space vector PWM

III. SIMULATION AND RESULTS

The test system in designed in MATLAB Simulink is shown below in fig. 6. The simulation is run for 3 seconds with switching of thyristors with series transformer starting from 1 second.

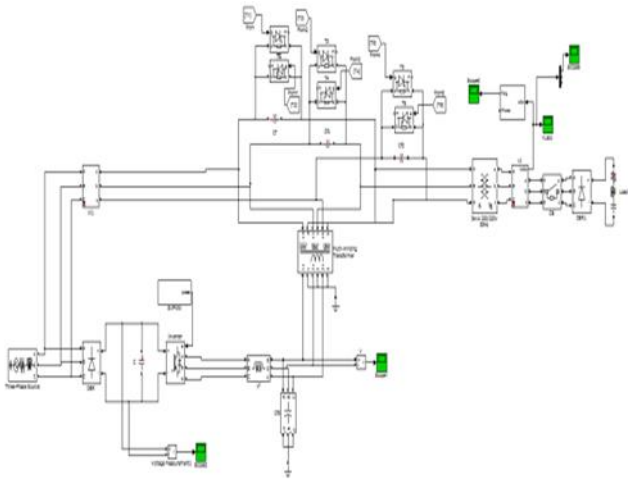

Fig. 6: Test System

The supply is divided into two different paths, together with the series voltage compensation circuit and the transmission circuit.

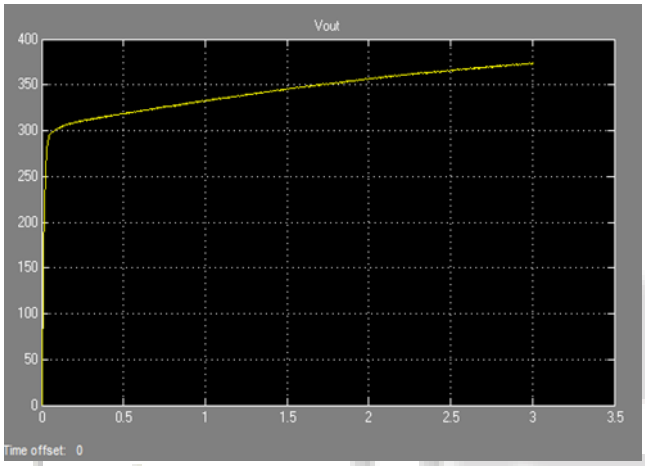

Fig. 7: DC Link Voltage

DC link voltage after rectification of the three phase voltage from the DBR is shown with slow increase in the magnitude without any disturbances and undulations.

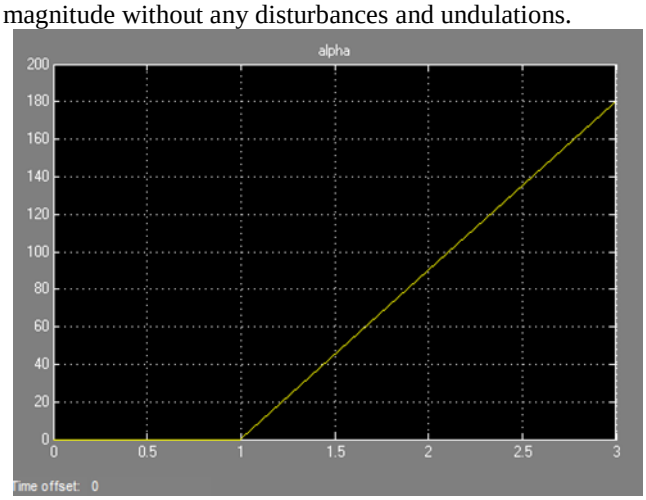

Fig. 8: Firing Angle

Change of firing angle from 0 degrees to 180 degrees in a 3 second time interval from 1 second.

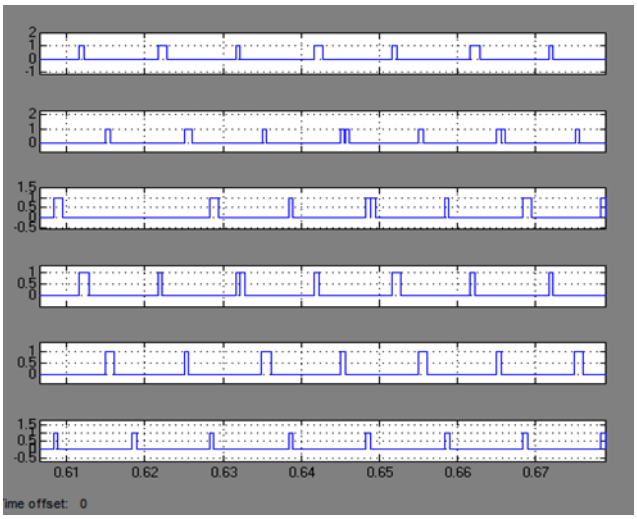

Fig. 9: Firing Pulses for Thyristors

Firing pulses of all the six thyristors in the transmission line coupled back to back as TRIAC for control in conducting voltage. All the pulses are generated with 10 degrees pulse width.

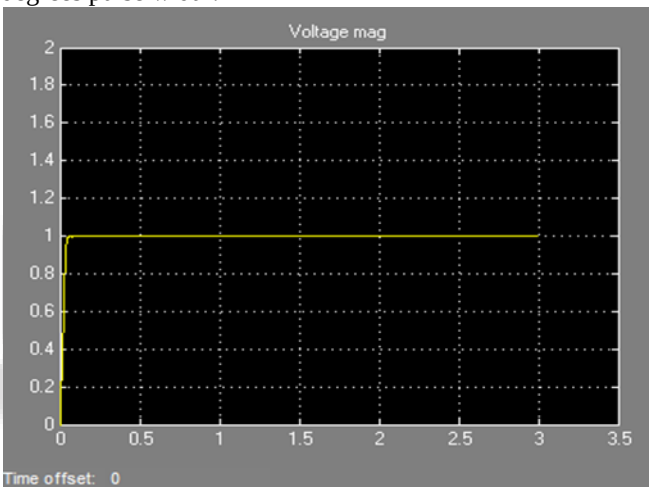

Fig. 10: Voltage Magnitude

Voltage magnitude of the three phase voltage at the load transformer secondary. As the fig.10 denotes the voltage magnitude doesn't have any voltage sags which is compensated by the series device.

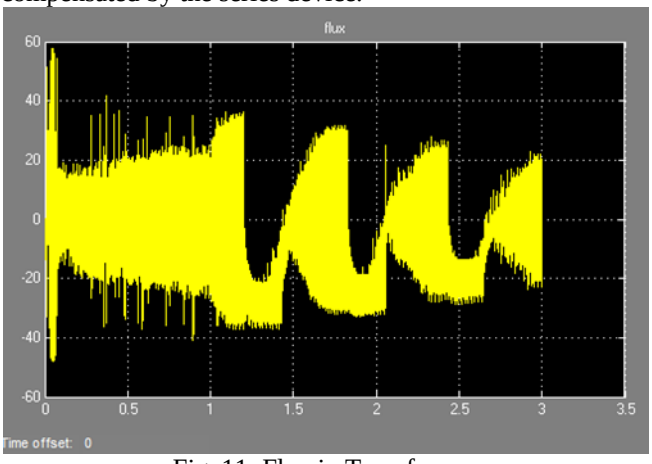

Fig. 11: Flux in Transformer

The magnetic flux and the primary current of the transformer is demonstrated with respect to time. The change in the magnitude are mitigated with the linking of the series transformer and change in firing angle of the thyristors.

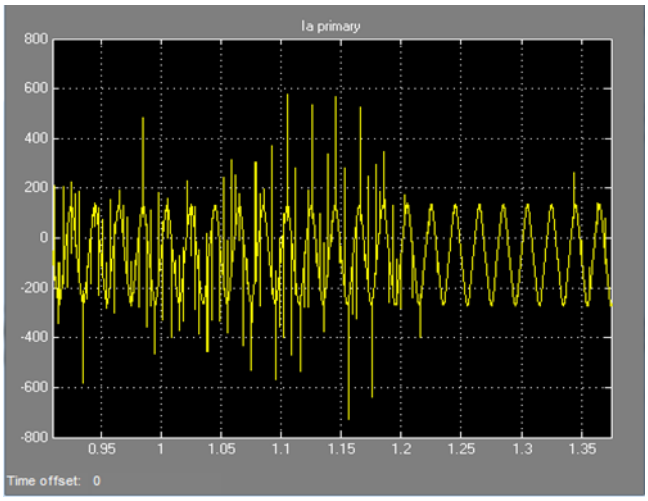

Fig. 12: Inrush Current in Phase a of Primary of Transformer

IV. CONCLUSION

The magnitude of the flux of the transformer is thus well-maintained in the system with extenuating inrush current in the transformer through series voltage compensation. With the above topology in a simple test grid system with non-linear load the voltage profile of the system is maintained even in heavy load conditions Change in firing angle of the thyristor controlled with gradual increase in firing angle removing voltage peaks in the transformer. All the parameters graphical demonstration with time reference are specified with references.

REFERENCES

[1] J. G. Nielsen, M. Newman, H. Nielsen, and F. Blaabjerg, "Control and testing of a dynamic voltage restorer (DVR) at medium voltage level," IEEE Trans. Power Electron., vol. 19, no. 3, pp. 806–813, May 2004.
[2] M. Vilathgamuwa, A.A.D. Ranjith Perera, S.S. Choi, "Performance improvement of the dynamic voltage restorer with closed-loop load voltage and current-mode control," IEEE Trans. Power Electron., Vol. 17, on 5, pp. 824 – 834, September 2002.
[3] M. J. Ryan, W. E. Brumsickle, and R. D. Lorenz, "Control topology options for single-phase UPS inverters," Industry Applications, IEEE Transactions on, vol. 33, pp. 493-501, 1997.
[4] W. E. Brumsickle, R. S. Schneider, G. A. Luckjiff, D. M. Divan, M. F. McGranaghan, " Dynamic sag correctors: cost-effective industrial power line conditioning", IEEE Transactions on Industry Applications, vol.37, pp. 212-217, Jan.-Feb. 2001.
[5] D. M. Vilathgamuwa, A. A. D. R. Perera, S. S. Choi, "Voltage sag compensation with energy optimized dynamic voltage restorer", IEEE Transactions on Power Delivery, vol.18, pp.928-936, July 2003.
[6] Chi-Jen Huang, Shyh-Jier Huang, Fu-Sheng Pai, "Design of dynamic voltage restorer with disturbance-filtering enhancement", IEEE Transactions on Power Electronics, vol.18, pp.1202-1210, Sept. 2003.
[7] P.T. Cheng; C. -C. Huang; C. –C. Pan; S. Bhattacharya, "Design and implementation of a series voltage sag compensator under practical utility conditions", IEEE Trans. Ind. Applicat., Vol. 39, pp. 844-853, May-June 2003.
[8] Omar, R. Rahim, N.A. "New Control Technique Applied in Dynamic Voltage Restorer for Voltage Sag Mitigation" Industrial Electronics and Applications, 2009. ICIEA 2009. 4th IEEE Conference on.
[9] Faisal, M.F. "Power Quality Management Program: TNB's Experience", Distribution Engineering, TNB 2005.
[10] Wahab, S.W. Yusof, A.M. "Voltage Sag Mitigation Using Dynamic Voltage Restorer (DVR) System, ELEKTRIKA, 8(2),2006, 32-37.
[11] IEEE Standard Board (1995), "IEEE Std. 1159-1995", IEEE Recommended Practice for Monitoring Electric Power Quality". IEEE Inc. New York.
[12] Kim H. "Minimal Energy Control for a Dynamic Voltage Restorer", In proceedings of the Power Conversion Conference, Osaka, Japan, 2002, pp. 428-433.
[13] V.K. Ramachandaramurthy, A. Arulampalam, C.Fitzer, C. Zhan, M. Barnes and N. Jenkins"Supervisory control of dynamic voltage restorers "IEE Proc.-Gener. Transm. Distrib. Vol. 151, No. 4, pp. 509-516, July 2004.

