

Application HER Vague Harmonic Immunity VSC HVDC Transmission

1. M. SWAPNA, 2. N. PUNNA RAO

¹PG Scholar, Department Of EEE, Sri Sai Educational Society's Group of Institutions, Kodad.

²Assistant Professor, , Department Of EEE, Sri Sai Educational Society's Group of Institutions, Kodad.

Abstract: The objective of this paper is to discuss the effectiveness of optimized modulation based on pre calculated SHE-PWM in a two-level three-phase VSC to make the ac side immune from the fluctuations of the dc link without the use of passive components. However, since the VSC studied here does not include a closed-loop controller, strategies to compensate unbalances are not addressed in this paper. Control methods based on selective harmonic elimination pulse-width modulation (SHE-PWM) techniques offer the lowest possible number of switching transitions. This feature also results in the lowest possible level of converter switching losses. For this reason, they are very attractive techniques for the voltage-source-converter-(VSC) based high-voltage dc (HVDC) power transmission systems. The paper discusses optimized modulation patterns which offer controlled harmonic immunity between the ac and dc side. The application focuses on the conventional two-level converter when its dc-link voltage contains a mix of low-frequency harmonic components. Simulation and are presented to confirm the validity of the proposed switching patterns. Simulation is carried out using Matlab software.

Keywords: *Amplitude Modulation (AM), Dc-Ac Power Conversion, Harmonic Control, HVDC, Insulated-Gate Bipolar Transistor(IGBT), Power Electronics, Power Transmission System, Pulse-Width Modulation, Voltage-Source Converter (VSC).*

I. INTRODUCTION

The Continuous growth of electricity demand and ever increasing society awareness of climate change issues directly affect the development of the electricity grid infrastructure. The utility industry faces continuous pressure to transform the way the electricity grid is managed and operated. On one hand, the diversity of supply aims to increase the energy mix and accommodate more and various sustainable energy sources. On the other hand, there is a clear need to improve the efficiency, reliability, energy security, and quality of supply. With the breadth of benefits that the smart grid can deliver, the improvements in technology capabilities, and the reduction in technology cost, investing in smart grid technologies has become a serious focus for utilities. Advanced technologies, such as flexible alternating current transmission system (FACTS) and voltage-source converter (VSC)-based high-voltage dc (HVDC) power transmission systems, are essential for the restructuring of the power systems into more automated, electronically controlled smart grids. The most important control and modeling methods of VSC-based HVDC systems and the list of existing installations are also available.

The first generation of utility power converters is based on current-source converter (CSC) topologies. Today, many projects still use CSCs due to their ultra-high power capabilities. With the invention of fully controlled power semiconductors, such as insulated-gate bipolar transistors (IGBTs) and integrated gate-commutated thyristors (IGCTs),

the VSC topologies are more attractive due to their four-quadrant power-flow characteristics. A typical configuration of the VSC-based HVDC power transmission system is shown in Fig. 1. The multilevel topologies for high-voltage high-power VSCs are also briefly discussed. Multilevel converters can be more efficient but they are less reliable due to the higher number of components and the complexity of their control and construction. Increasing the number of levels above three is a difficult task for the industry. The multilevel converters are beyond the scope of this paper.

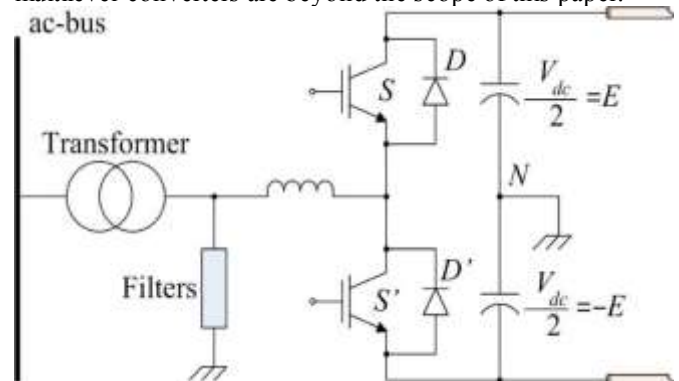


Fig.1. Phase of the two-level VSC for the HVDC power transmission system.

This paper focuses on the conventional three-phase two-level VSC topology (Fig. 2) and associated optimized modulation. In most cases, the voltage of the dc side of the

converter is assumed to be constant and the ac network is assumed to be balanced. However, fluctuations at various frequencies often occur on the dc side which usually appears as harmonics of the ac-side operating frequency. The most significant harmonic introduced to the dc-side voltage spectrum by an unbalanced three-phase ac-network is the 2nd harmonic. Inverters with 2nd harmonic on the dc bus generate the third harmonic on the ac side. The elimination of inverter low-order harmonics with fluctuating input voltage is described. The proposed M-type modulation technique allows 33% reduction in the switching transitions without lowering the order of the predominant harmonic. The geometrical technique of proposes a numerical calculation by modifying the pulse width to cancel the harmonics produced by the dc-side ripple voltage.

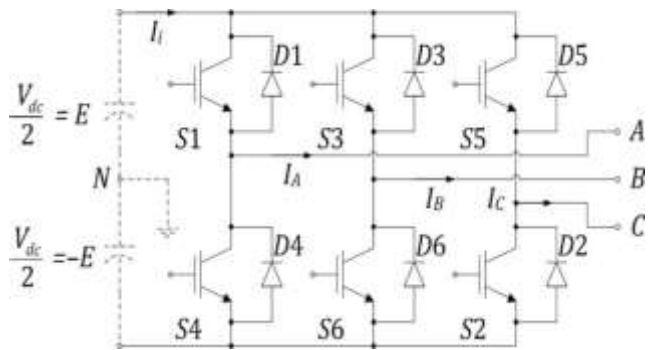


Fig. 2. Three-phase two-level VSC.

It has lower total harmonic distortion (THD) when compared with the conventional triangular sinusoidal PWM in the case where the dc-link voltage also fluctuates. However deal with sinusoidal-PWM techniques, which require a relatively high number of transitions per cycle to eliminate the low-order harmonics. Selective harmonic elimination pulse-width modulation (SHE-PWM) is the harmonic control with the lowest possible switching to give tightly controlled voltage spectrum and increase the bandwidth between the fundamental frequency and the first significant harmonic.

II. ANALYSIS OF THE PWM CONVERTER AND SHE-PWM

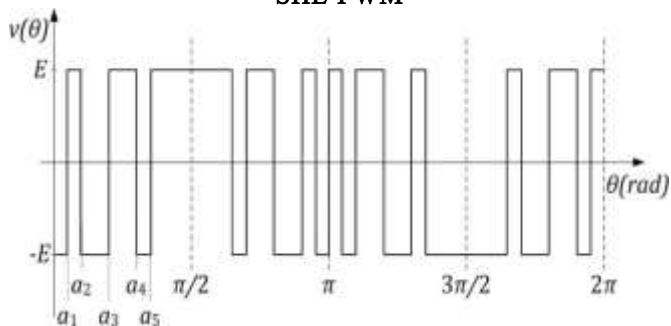


Fig. 3 Typical two-level PWM switching waveform with five angles per quarter cycle.

The optimized SHE-PWM technique is investigated on a two level three-phase VSC topology with IGBT technology, shown in Fig.2. A typical periodic two-level SHE-PWM waveform is shown in Fig.3. The waveforms of the line-to-neutral voltages can be expressed as follows:

$$V_{LN} = \begin{bmatrix} V_{AN} \\ V_{BN} \\ V_{CN} \end{bmatrix} = V_{dc} \begin{bmatrix} \sum_{n=1}^{\infty} A_n \sin n\omega_0 t \\ \sum_{n=1}^{\infty} A_n \sin n(\omega_0 t - \frac{2\pi}{3}) \\ \sum_{n=1}^{\infty} A_n \sin n(\omega_0 t + \frac{2\pi}{3}) \end{bmatrix} \quad (1)$$

Thus, the line-to-line voltages are given by

$$V_{LL} = \begin{bmatrix} V_{AB} \\ V_{BC} \\ V_{CA} \end{bmatrix} = \sqrt{3} \cdot V_{dc} \begin{bmatrix} \sum_{n=1}^{\infty} A_n \sin n(\omega_0 t + \frac{\pi}{6}) \\ \sum_{n=1}^{\infty} A_n \sin n(\omega_0 t - \frac{\pi}{6}) \\ \sum_{n=1}^{\infty} A_n \sin n(\omega_0 t + \frac{5\pi}{6}) \end{bmatrix} \quad (2)$$

The SHE-PWM method offers numerical solutions which are calculated through the Fourier series expansion of the waveform

$$M = 1 + 2 \sum_{i=1,2,3,\dots}^{N+1} (-1)^i \cos(\alpha_i) \quad (3)$$

$$0 = 1 + 2 \sum_{i=1,2,3,\dots}^{N+1} (-1)^i \cos(k\alpha_i) \quad (4)$$

Using five switching angles per quarter-wave in SHE-PWM, $k=5, 7, 11, 13$ to eliminate the 5th, 7th, 11th, and 13th harmonics. During the case of a balanced load, the third and all other harmonics that are multiples of three are cancelled, due to the 120 symmetry of the switching function of the three-phase converter.

III. RIPPLE REPOSITIONING TECHNIQUE

In this section, the technique to reposition the low-order harmonics produced by the dc-link ripple voltage of a VSC is described. The switching angles are pre-calculated for every available modulation index to obtain the trajectories for the SHE-PWM, as shown in Fig. 4. The complete sets of results are presented. The intersections of the trajectories shown in Fig. 4 with any horizontal straight line, called the modulating signal (i.e., an imaginary line of 0.75 p.u.), give the switching angles of the specific modulation index. Those switching angles are identical to the solution of the conventional SHE-PWM method, so when the dc bus voltage is constant, all harmonics before the 17th one are eliminated. However, when the dc bus voltage is fluctuating, other harmonics are introduced. When the dc link has a ripple voltage of constant frequency and amplitude times the dc-side voltage, the line-to-neutral voltage is represented as

$$V'_{LN} = V_{LN} (1 + k \sin \omega_r t) \quad (5)$$

According to Fourier transform properties, multiplication in one domain corresponds to convolution in the other domain. So even if one frequency is removed from the

modulated signal, it is expected to appear as sidebands of the switching frequency.

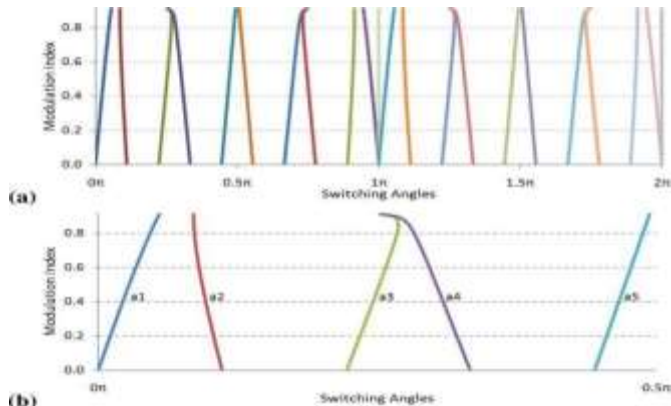


Fig.4. Solution trajectories. (a) Per-unit modulation index over a complete periodic cycle. (b) Five angles in radians.

Therefore, the modified line-to-line voltage of(2) becomes

$$\begin{aligned}
 V'_{AB} &= V_{AB} (1 - k \sin \omega_r t) \\
 &= \sqrt{3} \cdot V_{dc} \sum_{n=1}^{\infty} \left\{ A_n \sin n \left(\omega_o t + \frac{\pi}{6} \right) \right. \\
 &\quad \left. + \frac{k}{2} A_n \cos \left[(\omega_r - n\omega_o) t - n \frac{\pi}{6} \right] \right. \\
 &\quad \left. - \frac{k}{2} A_n \cos \left[(\omega_r + n\omega_o) t + n \frac{\pi}{6} \right] \right\}. \quad (6)
 \end{aligned}$$

IV. SIMULATION RESULTS

The Matlab/Simulink software is used to demonstrate the dc-link ripple-voltage repositioning technique as shown in Figs.5 to 13.

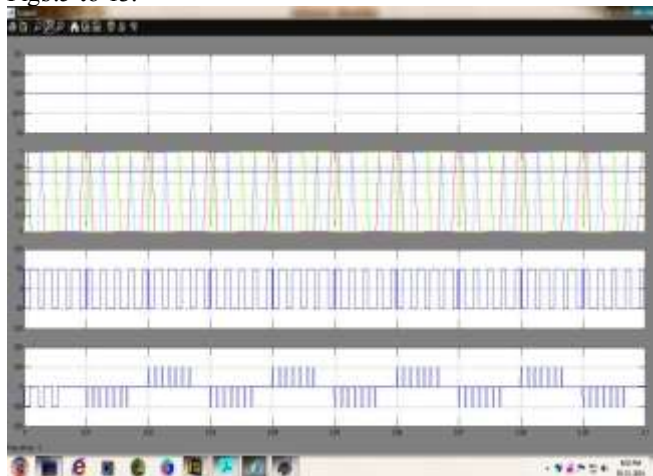


Fig.5. Simulation results for SHE-PWM eliminating 5th, 7th, 11th, and 13th harmonics. (a) DC-link voltage. (b) Solution trajectories to eliminate harmonics and intersection points with the modulating signal (M=0.75). (c) Line-to-neutral voltage. (d) Line-to-line voltage.

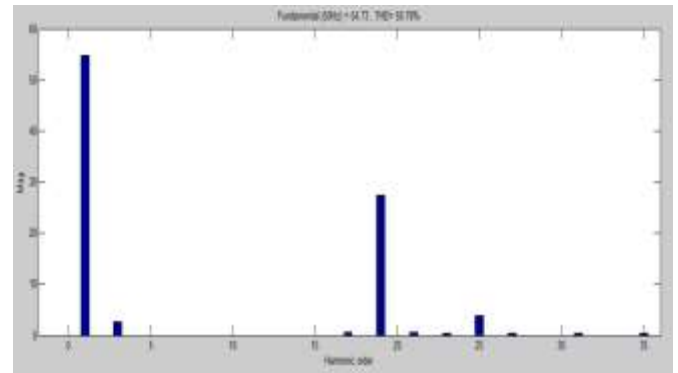


Fig. 6. Positive sequence line-to-line voltage spectra.

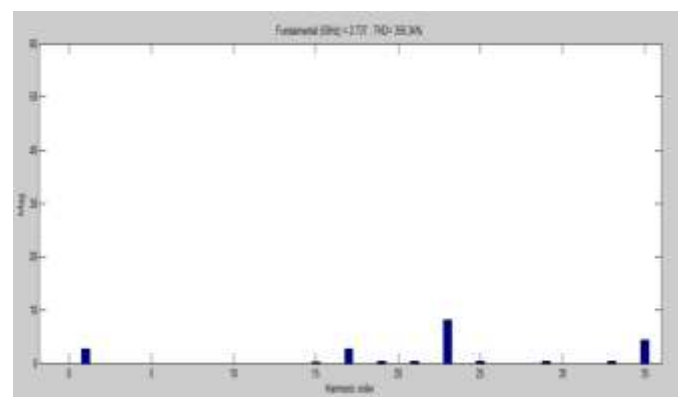


Fig.7. negative-sequence line-to-line voltage spectra.

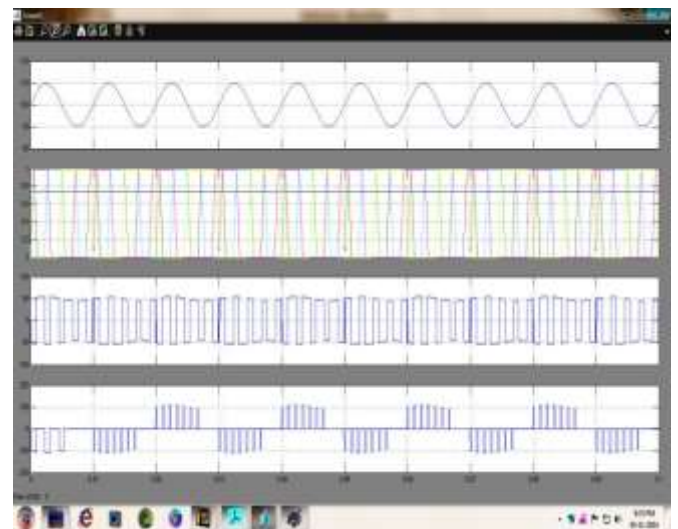


Fig. 8. Simulation results for conventional SHE-PWM with 10% ripple of 2nd harmonic at the dc bus (without the repositioning technique). (a) DC-link voltage with 10% ripple. (b) Solution trajectories to eliminate harmonics and intersection points with the modulating signal (M=0.75). (c) Line-to-neutral voltage. (d) Line-to-line voltage.

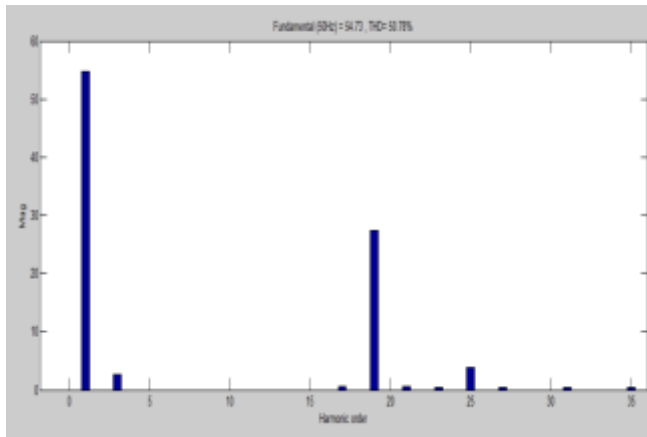


Fig. 9. Positive sequence line-to-line voltage spectra.

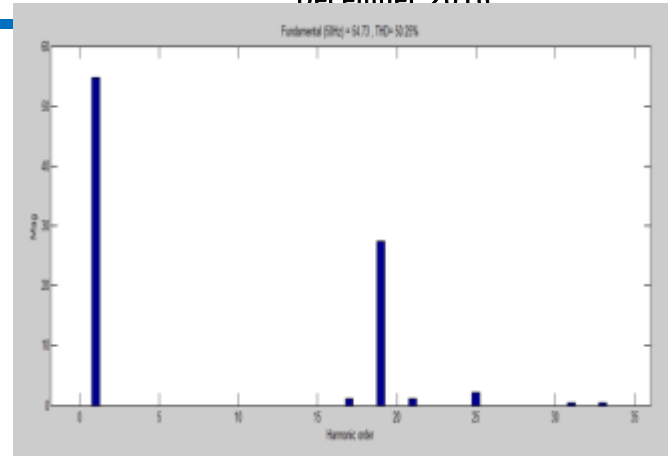


Fig. 12. Positive sequence line-to-line voltage spectra.

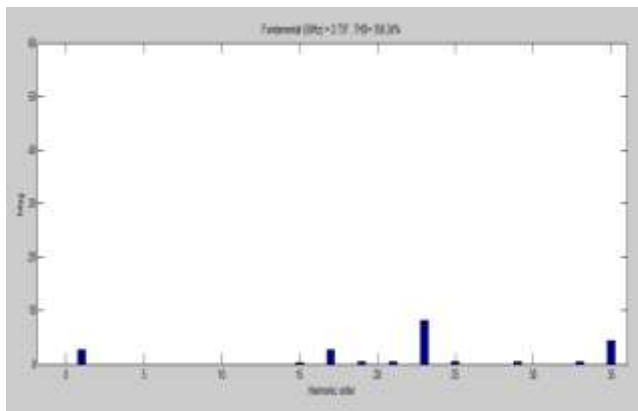


Fig.10. negative-sequence line-to-line voltage spectra.

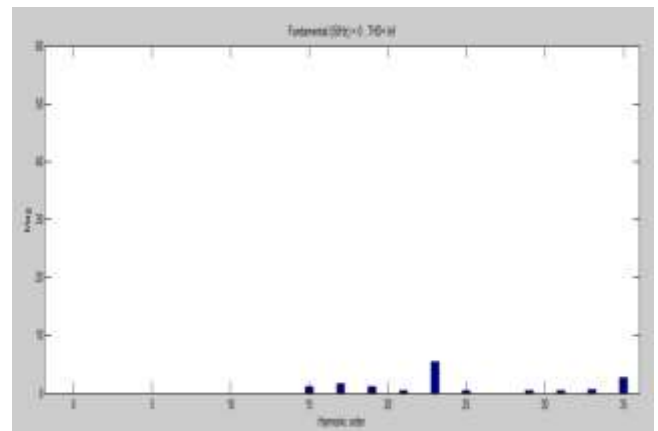


Fig.13 negative-sequence line-to-line voltage spectra.

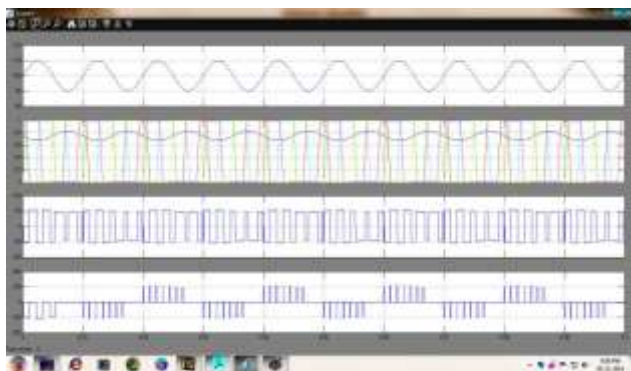


Fig. 11. Simulation results for 10% ripple of the 2nd harmonic at the dc bus by using the repositioning technique. (a) DC-link voltage with 10% ripples. (b) Modified modulating function and its intersection with the solution trajectories. (c) Line-to-neutral voltage. (d) Line-to-line voltage.

V. CONCLUSION

An optimized SHE-PWM technique, which offers immunity between the ac and dc side in a two-level three-phase VSC, is discussed in this paper. The technique is highly significant in HVDCs due to the elimination of every low-order harmonic of the ac side produced by the dc-link ripple voltage. The dc-link ripple repositioning technique regulates the magnitude of the fundamental component and eliminates the low-order harmonics of the ac side even when the dc bus voltage fluctuates. This is an online method which can be applied for eliminating any low-order harmonic frequency regardless of amplitude or phase shift of the ripple. There are some limitations related to the maximum modulation index available for SHE-PWM angles. The repositioning technique also causes a reflection with respect to the midpoint between the fundamental component and the first significant harmonic. There are cases where the technique is not beneficial. On the other hand, it eliminates all low-order ac-side harmonics for every dc-bus ripple voltage of frequency below the midpoint harmonic.

VI. REFERENCES

- [1] J. McDonald, "Leader or follower [The business scene]," IEEE Power Energy Mag., vol. 6, no. 6, pp. 18–90, Nov. 2008.
- [2] N. Flourentzou, V. G. Agelidis, and G. D. Demetriades, "VSC-based HVDC power transmission systems: An overview," IEEE Trans. Power Electron., vol. 24, no. 3, pp. 592–602, Mar. 2009.
- [3] A. A. Edris, S. Zelingher, L. Gyugyi, and L. J. Kovalsky, "Squeezing more power from the grid," IEEE Power Eng. Rev., vol. 22, no. 6, pp. 4–6, Jun. 2002.
- [4] B. K. Perkins and M. R. Iravani, "Dynamic modeling of high power static switching circuits in the dq-frame," IEEE Trans. Power Syst., vol. 14, no. 2, pp. 678–684, May 1999.
- [5] P. Steimer, O. Apeldoorn, E. Carroll, and A. Nagel, "IGCT technology baseline and future opportunities," in Proc. IEEE Transm. Distrib. Conf. Expo., Oct. 2001, vol. 2, pp. 1182–1187.
- [6] V. G. Agelidis and G. Joos, "On applying graph theory toward a unified analysis of three-phase PWM inverter topologies," in Proc. IEEE Power Electronics Specialists Conf., Seattle, WA, Jun. 1993, pp. 408–415.
- [7] J. Arrillaga, Y. H. Liu, and N. R. Watson, Flexible Power Transmission: The HVDC options. Hoboken, NJ: Wiley, 2008.
- [8] G. Asplund, "Application of HVDC light to power system enhancement," in Proc. IEEE Power Eng. Soc. Winter Meeting, Singapore, Jan. 2000, vol. 4, pp. 2498–2503.
- [9] P. N. Enjeti, P. D. Ziogas, and M. Ehsani, "Unbalanced PWM converter analysis and corrective measures," in Proc. IEEE Industry Applications Soc. Annu. Meet., San Diego, CA, Oct. 1989, pp. 861–870.
- [10] P. N. Enjeti and W. Shireen, "A new technique to reject dc-link voltage ripple for inverters operating on programmed PWM waveforms," IEEE Trans. Power Electron., vol. 7, no. 1, pp. 171–180, Jan. 1992.
- [11] J. Y. Lee and Y. Y. Sun, "Adaptive harmonic control in PWM inverters with fluctuating input voltage," IEEE Trans. Ind. Electron., vol. IE-33, no. 1, pp. 92–98, Feb. 1986.
- [12] S. Funabiki and Y. Sawada, "Computative decision of pulse width in three-phase PWM inverter," in Proc. IEEE Industry Applications Soc. Annu. Meet., Pittsburgh, PA, Oct. 1988, pp. 694–699.
- [13] T. Kato, "Precise PWM waveform analysis of inverter for selected harmonic elimination," in Proc. IEEE Industry Appl. Soc. Annu. Meeting, Piscataway, NJ, Sep. 1986, vol. 1, pp. 611–616.
- [14] B. P. McGrath and D. G. Holmes, "A general analytical method for calculating inverter dc-link current harmonics," in Proc. IEEE Ind. Appl. Soc. Annu. Meeting, Edmonton, AB, Canada, Oct. 2008, pp. 1–8.
- [15] A. M. Cross, P. D. Evans, and A. J. Forsyth, "DC link current in PWM inverters with unbalanced and nonlinear loads," Proc. Inst. Elect. Eng., Elect. Power Appl., vol. 146,

no. 6, pp. 620–626, Nov. 1999.

AUTHOR'S PROFILE:

1. M. SWAPNA

PG Scholar, Department Of EEE. Gandhi Academy Of Technical Education, Ramapuram (kattakommu Gudem), Chilkur(M), Kodad, Telangana 508206.

2. N. PUNNA RAO

Naladi Punna Rao was born in Andhra pradesh, INDIA in 1981. He received his B.Tech degree from SRIT Engg College ,JNTU Hyderabad in 2007, M.Tech degree in Power Systems & High Voltage from JNTK Hyderabad in 2015. Since July 2016 he has been working as an Assistant Professor Department of Electrical and Electronics Engineering in SSESGL, Kodad JNTUH, Telangana. His areas of interest are Electrical Machines, Power Electronics and Drives, Power Systems.