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Induction Motor Speed Control Fed by an Inverter Coupled with DSPACE Controller

Mallela Uday Kiran, Syed Sarfaraz Nawaz, PVSG Prasad

***Abstract:** The paper is design and implementation of inverter for controlling the 3-ph I.M by using DSPACE controller, the controlling objectives is PWM techniques. they are Sinusoidal PWM technique and Space vector PWM technique. SVPWM technique exhibits better overall performance than SVPWM as THD (total harmonic distortion) is much greater in SPWM modulated inverter.*

Index-SPWM, SVPWM, Induction-motor, Digital signal process for Applied and control Engineering (DSPACE).

I. INTRODUCTION

Induction-motor drives are mainly used in domestic applications because more advantages. AC motor having a light weight 20% to 40% less than DC motors and maintenance is very low. The power control is complex and more expansive. It is a adjustable speed drives. Speed control means change the speed as desired at different load. And it reduces mechanical and thermal stress. Dspace controller is been used to generate the pulses.

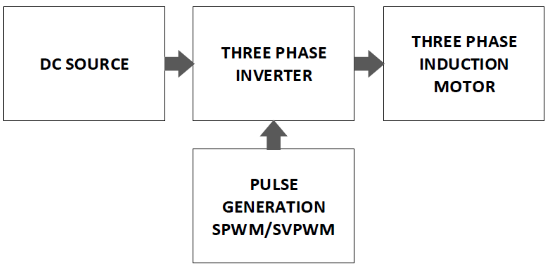

Fig. 1. 'Open-Loop' Block-Diagram

II. INVERTER

It converts fixed 'dc' input to 'variable Alternate current' output. The variation in magnitude of voltage, frequency and no of phases.

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* Correspondence Author

Mallela Uday Kiran*, PG scholar, EEE department, Gokaraju Rangaraju Institute of Engineering & Technology, Hyderabad, Telangana, India, Email: udaykiranmallela3@gmail.com.

Syed Sarfaraz Nawaz, Associate Professor, EEE Department, Gokaraju Rangaraju Institute of Engineering &Technology, Hyderabad, India Email: sarfaraz86nawaz@gmail.com.

P V S G Prasad, PG scholar, EEE department, Gokaraju Rangaraju Institute of Engineering & Technology, Hyderabad, Telangana, India, Email: pnsakpvng@gmail.com

Operating principle on forced commutation. The output wave forms are square wave forms passed through filters to eliminate the unwanted harmonics. Zeroth dc and higher frequency waves is known as harmonics. with undesired in Ac system. The 'output-voltage' made to have similar patterns in +ve and -ve cycles, therefore unwanted dc will be eliminated and also it eliminates the higher even harmonics has periodicity is full cycle. practically it is not possible to shape outputs as sinusoidal.

A) SPWM Technique

In Spwm technique, a triangle wave is compared with three phase sinusoidal waveforms for generation of gating pulses which in turn is used to control the inverter. The Pwm techniques and SPWM have been mainly used for operation is based in the inverter of the Total harmonic distortion (THD) values in the output current and voltage.

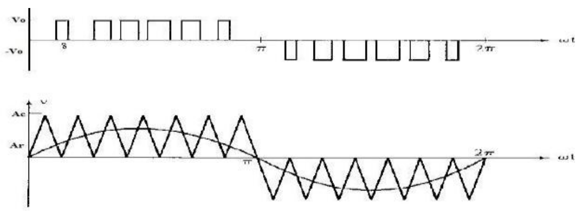


Fig. 2. Spwm pulses

$$m_a = \frac{Vref}{Vcarrier}$$

B) SVPWM Technique

There are various variations of svm the result in Different quality and computational-requirements and one main advantage in reduction of thd created by rapid switching. Because of its superior performance characteristics.it has low harmonic distortion in applied voltages and currents.

Svpwm is to implementing the voltages are a1, b1, c1 is frame to be transformed into stationary. Horizontal and vertical axis are d-q axis.

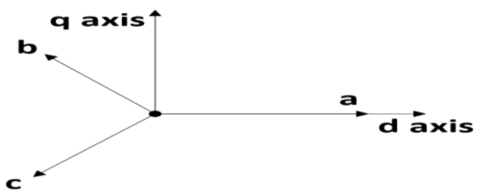


Fig. 3. 3-axis to 2-axis frame
(V_1 to V_6) divide the plane into six sectors.

V_ref is two adjoining non zero vectors.

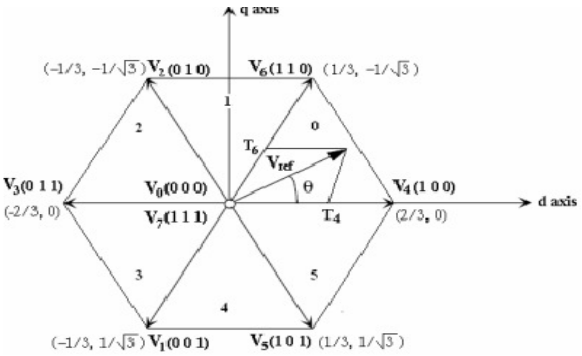


Fig. 4. switching sectors and vectors

SVPWM is implemented by the below steps:

Step 1: To resolve the Vd1, Vq1, Vref1, and an angle (α)

figure 4, the V_d1, V_q1, Vref1, and angle (α) determine:

$$V_{d1} = V_{an1} - V_{bn1}.cos(60) - V_{cn}.cos(60)$$

$$= V_{an1} - \frac{1}{2}V_{bn1} - \frac{1}{2}V_{cn1}$$

$$V_{q1} = 0 + V_{bn1}.cos(30) - V_{cn1}.cos(30)$$

$$= 0 - \frac{\sqrt{3}}{2}V_{bn1} - \frac{\sqrt{3}}{2}V_{cn1}$$

$$\begin{bmatrix} V_{d1} \\ V_{q2} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V_{an1} \\ V_{bn1} \\ V_{cn1} \end{bmatrix}$$

$$\hat{}|V_{ref1}| = \sqrt{V_{d1}{}^2 + V_{q1}{}^2}$$

$$\alpha 1 = tan^{-1}(\frac{V_{q1}}{V_{d1}}) = \omega t = 2\pi f1t$$

Where f1= frequency in fundamental

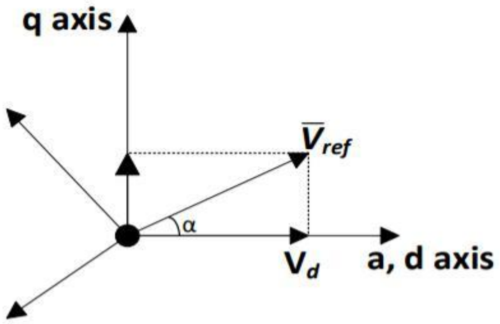


Fig. 5. d-q axis

Step 2: Resolve time duration of T3, T4, T0

$$\int_0^{T_s} V_{ref1} = \int_0^{T_3} V_3 dt + \int_{T_3}^{T_3+T_4} V_4 dt + \int_{T_3+T_4}^{Ts} V_0 dt$$

$$Ts.V_{ref1} = T_3V_3 + T_4V_4$$

$$T_s.|V_{ref1}|.\begin{bmatrix} cos\alpha \\ sin\alpha \end{bmatrix} = T_3.\frac{2}{3}.V_{dc1}\begin{bmatrix} 1 \\ 0 \end{bmatrix} + T_4.\frac{2}{3}.V_{dc1}\begin{bmatrix} cos(\frac{\pi}{3}) \\ sin(\frac{\pi}{3}) \end{bmatrix}$$

(Where, 0 ≤ α ≤ 60)

$$T_3 = T_s.a.\frac{sin(\frac{\pi}{3} - \alpha 1)}{sin(\frac{\pi}{3})}$$

$$T_4 = T_s.a.\frac{sin(\alpha 1\ )}{sin(\frac{\pi}{3})}$$

$$T_0 = T_s - (T_3 + T_4)$$

$$(\text{where} T_s = \frac{1}{f_s} \text{and } a = \frac{|V_{ref1}|}{\frac{2}{3}V_{dc1}})$$

$$T_3 = \frac{\sqrt{3}.T_s.|V_{ref1}|}{V_{dc1}}(sin(\frac{\pi}{3} - \alpha 1 + \frac{n-1}{3}\pi))$$
$$= \frac{\sqrt{3}.T_s.|V_{ref}|}{V_{dc1}}(sin\frac{n\pi}{3}cos\,\alpha 1 - cos\frac{n\pi}{3}sin\alpha 1))$$

$$T_4 = \frac{\sqrt{3}.T_s.|V_{ref1}|}{V_{dc1}}(sin(\alpha 1 - \frac{n-1}{3}\pi))$$
$$= \frac{\sqrt{3}.T_s.|V_{ref1}|}{V_{dc1}}(-cos\,\alpha 1\,sin\frac{n-1}{3}\pi + sin\,\alpha 1\,cos\frac{n-1}{3}\pi)$$

$$T_0 = T_s - (T_3 + T_4)$$

[where, n=1 to 6]

(0≤α≤60)

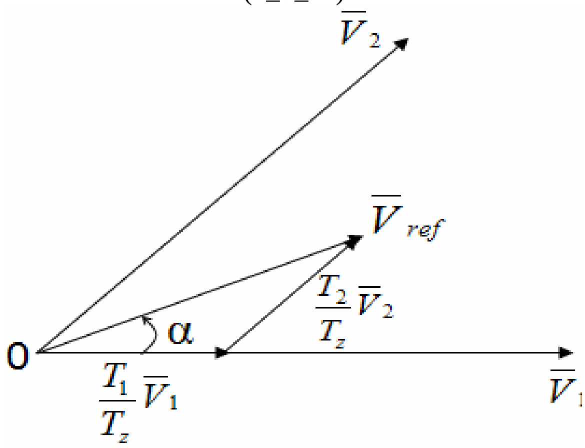


Fig.6. from mention of adjoining vectors.

III. INDUCTION MOTOR

stator winding is stationery and winding for rotor is not stationary it takes more magnetizing current. Most of times used ac drives are inverter fed 3-phase I.M. Fundamental wave is dominant, range will be $N_s(1 - S_{max})$to Ns.

Ns is the speed of Rmf with Respect to fundamental wave frequency. Induction drives are widely attracted over the world due to its less maintenance requirement.

1. The two-axis representation IM is reduced through KVL

$$V_{qs} = R_q i_{qs} + P(L_{qq} i_{qs}) + P(L_{qd} i_{ds})$$
$$+ P(L_{q\alpha} i_d) + P(L_{q\beta} i_\beta) ----(1)$$

$$V_{ds} = P(L_{dq} i_{qs}) + R_d i_{ds} + P(L_{dd} i_{ds})$$
$$+ P(L_{dd} i_d) + P(L_{d\beta} i_\beta) ----(2)$$

$$V_{\alpha} = P(L_{\alpha q} i_{qs}) + P(L_{\alpha d} i_{ds}) + R_{\alpha} i_{\alpha}$$
$$P(L_{\alpha\alpha} i_{\alpha}) + P(L_{\alpha\beta} i_{\beta}) ----(3)$$

$$V_{\beta} = P(L_{pq} i_{qs}) + P(L_{pq} i_{ds}) + P(L_{\beta\alpha} i_{\alpha})$$
$$+ R_{\beta} i_{\beta} + P(L_{\beta\beta} i_{\beta}) ----(4)$$

$$\begin{aligned} L_{\alpha\alpha} &= L_{\beta\beta} = L_{rr} \\ L_{dd} &= L_{qq} = L_{ss} \\ L_{\alpha\beta} &= L_{\beta\alpha} = 0 \\ L_{dq} &= L_{qd} = 0 \end{aligned}$$

$$\begin{aligned} L_{\alpha d} &= L_{d\alpha} = L_{sr}\cos\theta_r \\ L_{\beta d} &= L_{d\beta} = L_{sr}\sin\theta_r \\ L_{\alpha q} &= L_{q\alpha} = L_{sr}\sin\theta_r \\ L_{\beta q} &= L_{q\beta} = -L_{sr}\cos\theta_r \end{aligned}$$

w.r to fictitious rotor

$$i_{\alpha} = i_{drr}\cos\theta_r + i_{qrr}\sin\theta_r$$
$$i_{\beta} = i_{drr}\sin\theta_r + i_{qrr}\cos\theta_r$$

w.r to arbitrary reference frame $\begin{aligned} i_{ds} &= i^c_{ds}\cos\theta_c - i^c_{qs}\sin\theta_c \\ i_{qs} &= i^c_{ds}\cos\theta_c + i^c_{qs}\sin\theta_c \end{aligned}$

IM matrix eqn describing voltage analysis

$$\begin{bmatrix} V^c_{qs} \\ V^c_{qr} \\ V^c_{ds} \\ V^c_{dr} \end{bmatrix} = \begin{bmatrix} R_s + L_s P & -w_c L_s & L_m.P & w_c L_s \\ w_c L_s & R_s + L_s P & w_c L_s & L_m.P \\ L_m.P & -(w_c - w_r)L_m & R_s + L_s P & -(w_c - w_r)L_m \\ -(w_c - w_r)L_m & L_m.P & -(w_c - w_r)L_m & R_s + L_s P \end{bmatrix} \begin{bmatrix} V^c_{qs} \\ V^c_{qr} \\ V^c_{ds} \\ V^c_{dr} \end{bmatrix}$$ Tor

que: $V1 = [R]i + [L]Pi + [G]w_r i + [F]w_c i$

$$I^t.V1 = i^t[R] = i^t[L]Pi + i^t[G]w_r i + i^t[F]w_c i$$

$i^t[L]Pi$ Rate of change in stored magnet energy

$i^t[G]w_r i$ A.G power = Mech Rot speed x A.G

$$w_n T_e = P_a = i^t[G]iw_r$$
$$T_e = \frac{P}{2} i^t[G]i$$

$$[G]i = i^t \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & -l_m & 0 & -l_m \\ l_m & 0 & l_m & 0 \end{bmatrix} \begin{bmatrix} i^c_{qs} \\ i^c_{qr} \\ i^c_{ds} \\ i^c_{dr} \end{bmatrix}$$

$$I^t[G]i = L_m[i^c_{qs1} i^c_{dr1} - i^c_{ds1} i_{qr1}]$$

$$T_e = \frac{3}{2} \cdot \frac{P}{2} L_m (i^c_{qs1} i^c_{dr1} - i^c_{ds1} i^c_{qr1})$$

$$T_e = \frac{3}{2} \cdot \frac{P}{2} \cdot \frac{1}{w_b} [\psi^c_{ds1}\, i^c_{qs1} - \psi^c_{qs1} i^c_{ds1}]$$

To observing equations for speed, voltage and torque

IV. SIMULATION

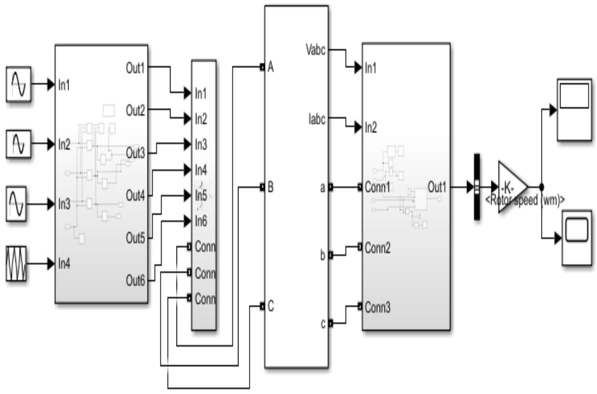


Fig. 7. Simulation diagram of 3-phase inverter driving IM

Open-loop(O.L) Three phase SPWM pulses:

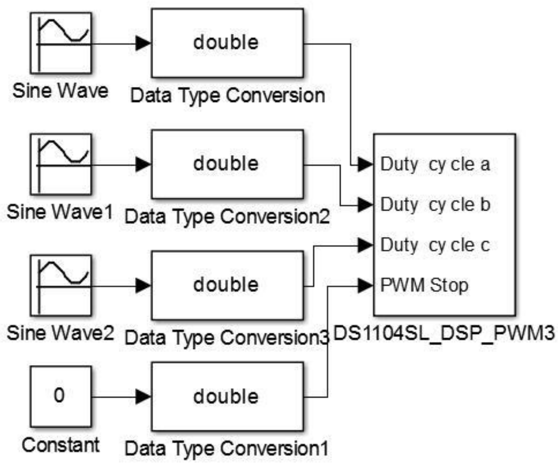


Fig. 8. O.L system 3-ph SPWM pulses in dspace

Fig

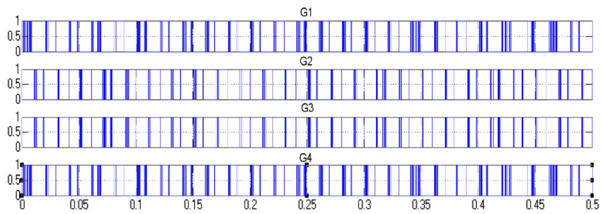


Fig. 9: gate pulses

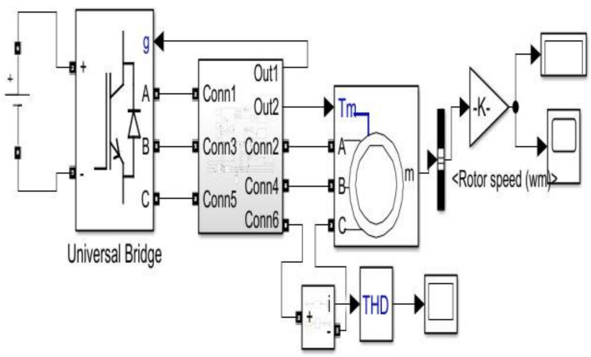
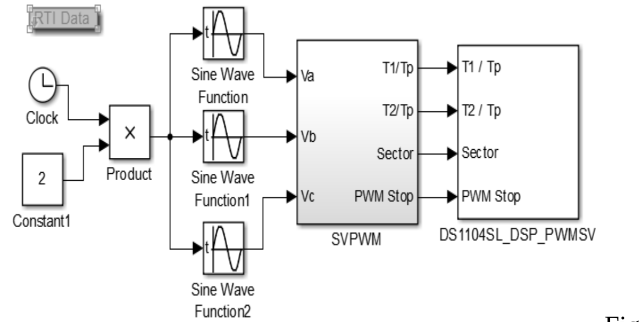


Fig. 10. Simulation diagram of 3-phase inverter driving IM in O.L

Open-loop(O.L) three phase SVPWM pulses:



Fig

fig. 11: O.L system 3-phase SVPWM pulses in dspace

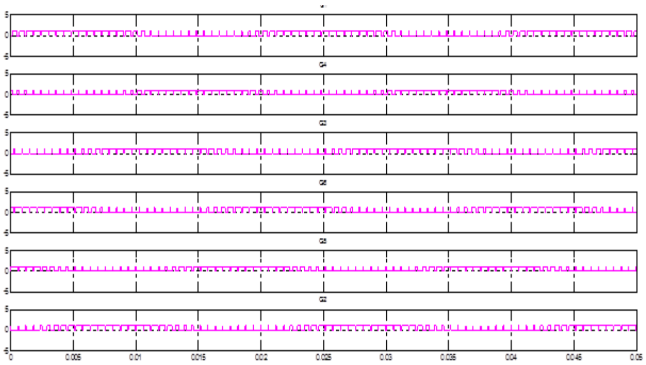


Fig. 12. gate pulses

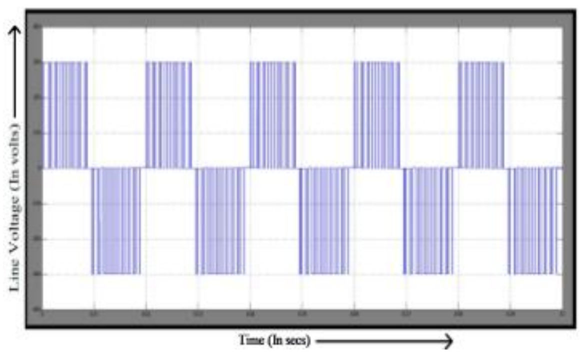


Fig. 13. o/p line voltages

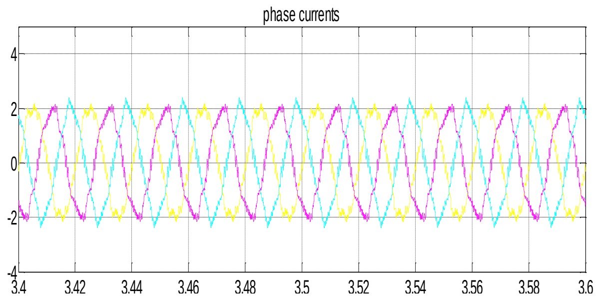


Fig. 14. o/p phase Currents

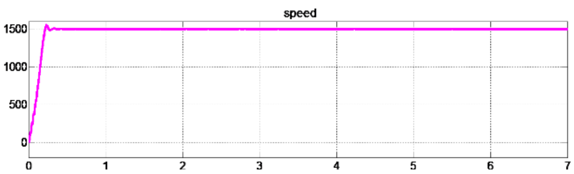


Figure15. Response of Speed in RPM

V. SPACE DS1104 CONTROLLER

Dspace full name is digital signal processer for applied voltage engineering. this is best suitable for industrial automation.

Dspace is well suited for drive control. and the cost is effective. DSpace is real time processor and it is source open software application that allows to capture and store.it is utilize control desk software because control desk is real time interface is a block set for Simulink it provides access to the input and output on dspace hardware. Implementation time is greatly reduced as it handles any continuous time, discrete time depending upon the input and output of hardware and different subsystems. It offers check that help avoid double or improper use of channels.

This is installed in desktop in the mat lab files is interfaced through package software. This unit will operate up to 250mhz.2k frequency pulse width is generated and also it consists of 8 analog and 8digital pins is there and 20 input and output signals interchanged randomly.DS1104r&d board is mainly used in research experiments in institutional labs.

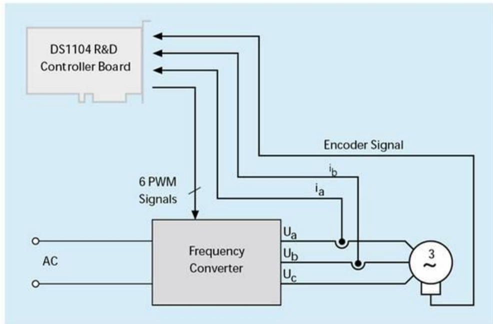


Fig. 15. IM control

VI. HARDWARE RESULTS

Figure16. DSPACE controller with IM hardware kit

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Table- II: Name of the Table that justify the values

S.No.	DC (O.V)	AC (O.V)	(RPM	THD (SVPWM)	THD (SPWM)
1	330	161.2	1128	0.45	0.45
2	330	162.0	1189	0.45	0.48
3	330	162.1	1250	0.47	0.47
4	330	163.5	1309	0.47	0.47
5	330	164.0	1410	0.47	0.47
6	330	164.6	1427	0.47	0.47
7	330	165.4	1456	0.47	0.47
8	330	166.2	1498	0.47	0.47

VI. CONCLUSION

In this paper presents using both the techniques overall performance of system speed, output voltages and currents and THD of I.M at different duty cycles are obtained. Simulation of 3-phase IM in O.L(open-loop) operation its respective output wave forms are shown. SVPWM technique exhibits better overall performance than SVPWM as THD is much greater in SPWM modulated inverter.

FUTURE SCOPE

This paper can be further extended and improvised as follows.
1. Closed loop three phase inverter can be designed where it can adjust its speed depending on the load.
2. The control technique can be further implemented to multilevel configuration.

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AUTHORS PROFILE

Mallela Uday Kiran, received B.Tech degree in Electrical and Electronics Engineering from Aurora's Research and Technological Institute, Hanmakonda. Now, he is Pursuing M.Tech Power Electronics from Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad. Interested in power electronics and drives.

Syed Sarfaraz Nawaz, currently working as a Associate professor in EEE department, GRIET -Hyderabad and He is pursuing Ph.D. from JNTUH**.** He had done his MTech from GRIET Hyderabad and his B.Tech from SSITS affiliated to JNTUH.His area of interest is power electronics, Drives and electrical machines.

P V S G Prasad, received B. Tech in Electrical and Electronics Engineering from B. V. Raju Institute of Technology, Narsapur. He is currently pursuing M. Tech in power electronics from Gokaraju Rangaraju Institute of Engineering and Technology. His area of interest is Power Electronics and Drives.