

Transformer-Less Impedance Current Source Inverter for Photovoltaic Systems

¹Pratheeba.k

PG Scholar, Power Electronics & Drives,
Dr.Pauls Engineering College ,India.
Pratheebak05@gmail.com

²Dr.E.Mariappane

Dean(Academics)
Dr.Pauls Engineering College, India.
Dev_mari@rediffmail.com

³Pushpalatha.N

Asst. Prof.,EEE Department,
Dr.Paul Engineering College, India.
Pushpalatha.sundar@gmail.com

Abstract— In this paper transformer-less impedance current source inverter for photovoltaic system is proposed. Because of reduced dc-link capacitor obligation, current source inverter (CSI) grants higher reliability than the voltage source based solar inverter. Whereas, conventional three-phase pulse width modulated (PWM) current source based solar inverter introduced high earth leakage currents and IGBT used in the CSI will get overshoot. To reduce the leakage current, an isolation transformer can be used. But use of this transformer increases cost, size and decrease efficiency. For the abovementioned limitation impedance current source inverter is proposed. Impedance network reduces both earth leakage current and shoot-through problem. HBPWM controller is used because its fast transient response, direct limiting of device peak current and simple implementation thereby increasing the efficiency. The proposed system is simulated in MATLAB/SIMULINK platform.

Keywords— *Energy conversion, leakage current, photovoltaic power systems-source converter*

I. INTRODUCTION

The governmental incentives in clean distributed power, like geothermal, wind power, fuel cells, photovoltaic (PV), are growing at fast pace due to environmental concerns. For instance, the worldwide grid-connected PV systems develop every year, for the reason that of their relative small size, noiseless operation, simple installation and the possibility to put it close to the user. For protection reasons, some PV systems have a galvanic isolation, using dc-dc boost converters with high-frequency transformer or using a bulky low-frequency transformer in the grid side. Equally both solutions increase the cost and size of the whole system, reduces on the whole efficiency. Transformer-less solutions, in which the PV frames should be grounded for safety reasons, for reducing the above disadvantages due to the absence of the transformer, a large number of series modules or a voltage boost stage is necessary, in order to transfer the energy from the PV array to the grid. Such problem can be defeat by using a pattern in which the voltage boost requirement is obtained by a Z-source inverter, The ZSI for grid-connected three-phase PV systems has-been proposed. The number of switching components and the volume of the system can be reduced, decreasing the total cost. However the PV system based on ZSI (based on the traditional voltage source inverter) does not comply with the well-known German standard VDE0126-1-1 that states that ground leakage currents have to be 300mA grid connected solar PV system. Immediate disconnection of inverter is suggested if leakage current exceeds this limit.

The conventional three-phase PWM-CSI requires an intermediate isolation transformer to feed power to the grid. The use of this transformer reduces the efficiency of conversion by about two–three percentage. Furthermore, it increases the size, cost, and weight of inverter, making it unviable for module integrated or string inverter applications. a modified PWM strategy is also suggested. Therefore, this topology is suitable for module integrated inverters (low power), wherein parasitic capacitance is small and therefore the leakage current. To address the limitations modified CSI is proposed in this paper. It eliminates the high-frequency component in the common mode voltage, thereby suppressing the common mode earth leakage current. The conventional four-leg CSI I shown in Fig.1.string of PV modules I connected across the input dc capacitors. The dc link is realized by two capacitors connected in series. Midpoint of these capacitors is connected to the neutral of the grid. DC-link inductors L_{dc1} and L_{dc2} are wound on the same core and therefore have a high value of mutual coupling. To generate ac current waveforms from the dc current, eight semiconductor switching devices are used. Each device has unidirectional current flow capability and can block the reverse voltage. Either a diode connected in series with IGBT or reverse blocking (RB) IGBTs can be used to realize these switches. Output of three phases is connected to the grid through capacitor–inductor (C–L) filter and that of the fourth leg is increasing the number of witching devices and moreover IGBT used in four-leg current source inverter, shoot-through problem reduces the inverter output voltage. For the aforementioned limitation impedance current source inverter is proposed.

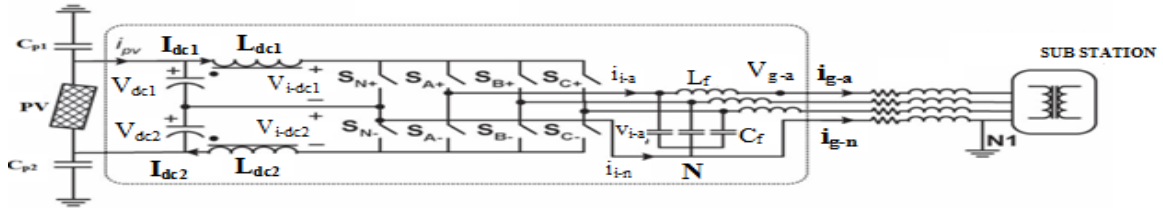


Fig.1. Conventional Four-leg CSI

II. EARTH LEAKAGE CURRENT

Metallic frames are used to provide mechanical strength and support to the PV modules. Due to large overlap surface area between PV cell and frame, parasitic capacitance is present between them (grounded) for safety [4]. Therefore, parasitic terminals of PV module and earth, value of these further, the metallic frames are connected to earth capacitors (Cp1 and Cp2) are present between negative or positive terminal of PV can be directly further, the metallic frames are connected to earth dust, and other environmental conditions. In case of transformer-less system as shown in Fig. 1, neither capacitors varies with ambient temperature, humidity, (grounded) for safety [4]. Therefore, parasitic capacitors (Cp1 and Cp2) are present between terminals of PV module and earth, value of these capacitors varies with ambient temperature, humidity, dust, and other environmental conditions.

In case of a transformer-less system as shown in Fig. 1, neither negative nor positive terminal of PV can be directly connected to earth. This is because, grid neutral is connected to earth at the substation, and potential difference between terminals of PV (either -ve or +ve terminal) and neutral depends on the conducting state of the inverter switches. Therefore, connecting PV terminals to earth will inject high earth fault currents. On the other hand, if PV terminals are not earthed, high (switching) frequency voltage appears across Cp1 and Cp2. This results in the flow of high earth leakage current. To demonstrate the generation of high-frequency common mode voltage and corresponding current, a conventional SPWM-CSI based solar PV system is used.

III. PROPOSED Z-CSI TOPOLOGY

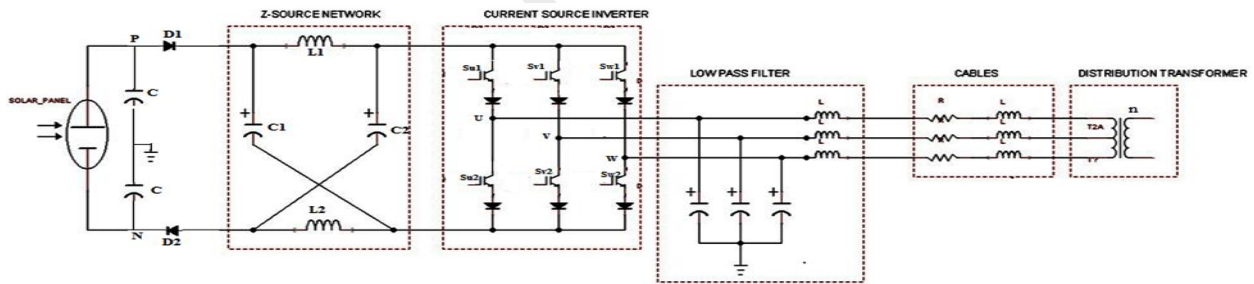


Fig.2. Circuit diagram of Impedance Current Source Inverter

The difference between the traditional ZSC and the proposed one (Fig. 2) is the additional fast-recovery diode (D), that is used to guarantee the complete isolation of both terminals of the PV array from the inverter switches during the shoot-through states it is possible to express the leakage voltage (voltage between the positive (P) or negative (N) dc bus and the grounded neutral (n) - V_{Pn} or V_{Nn}) in terms of the CMV in the inverter (V_{CM}).

$$V_{Nn} = -V_{CM}(1)$$

$$V_{Pn} = V_{PN} + V_{Nn} = V_{PN} - V_{CM}(2)$$

Where, V_{pn} is the dc link voltage.

Due to the parasitic capacitances C_{PV} in the common-mode circuit (Figure 2), the occurrence of switching in the leakage voltages, as consequence of switching in the CMV, induces undesired high spikes in the leakage current. This is the reason current. this reason for both diodes D_1 and D_2 in the ZSI-D, that open the circulating path of leakage currents during the shoot-

through states. Furthermore, during the non-shoot-through states (when both diodes are conducting), the PWM technique should maintain the CMV constant, in order to maintain the leakage voltages constant, avoiding undesired spikes in leakage currents.

A. Impedance Network

Impedance network, combined between the power source and converter circuit, to offer both buck and boost property which cannot be achieved by conventional voltage source and current source inverters. The impedance network consist of two equal inductors (L_1, L_2) and capacitors (C_1, C_2). In the network inductors are coupled in series arms and capacitors are coupled in diagonal arms. This impedance network is used to buck or boost the input voltage depends upon the boosting factor value. The network can also act as a second order filter. It should require less value of inductance and capacitance they are smaller in size. Three-phase Z-source bridge has one extra zero state when the load terminals are

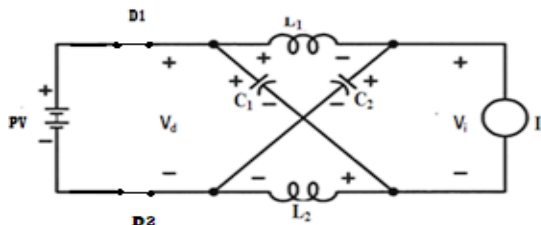


Fig.3. Equivalent circuit of ZSC-D during non-shoot through state

Shorted through in any one phase leg both the upper and lower devices i.e., both devices are gated to turn on (or) various two phase legs, or every three phase legs. Shoot-through zero state is not allowed in the traditional inverter, for the reason that it would cause a shoot-through. This third zero state is the shoot-through zero state, by seven different ways shoot through zero state is generated: shoot through via any one phase leg, combinations of any two phase legs, and every three phase legs. The shoot-through zero state possible by the use of Z-source network. It provide the buck-boost feature to the converter. When DC voltage is not sufficient to generate desired output, PWM with shoot-through zero states be will used to boost the voltage.

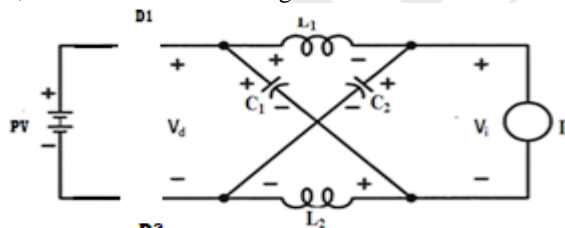


Fig.4. Equivalent circuit of ZSC-D during Shootthrough state.

It can be seen that the shoot-through period is only a tiny proportion of the switching cycle. The bridge is viewed as a ‘short-circuit’ from the dc link of the inverter. States to boost the voltage whenever the PV panel is unable to provide the enquired during this mode, no voltage appears across the load like in the zero state operation

the dc voltage of the capacitor is boosted to the required value according to the ST duty ratio. This shoot-through interval is inserted into the zero voltage or during any voltage dips due to the changing isolation (irradiance) and temperature. While in this mode the dc source (PV) is separated from the inverter bridge by the diode ($V_d > V_{pv}, V_d = 2V_c$) and the voltages across C_1 and C_2 appear across L_1 and L_2 respectively causing the inductor current.

B. Modulation technique

Hysteresis band pulse width modulation is proposed because of its simplicity. Method have uses rapid response of current loop. One more benefit is that it does not need any information of load parameters. It have irregular switching frequency. In this paper sinusoidal band hysteresis current controller with low pass filter is used. Ripple is minimize by using a low pass filter and therefore it reduces the higher order harmonics.

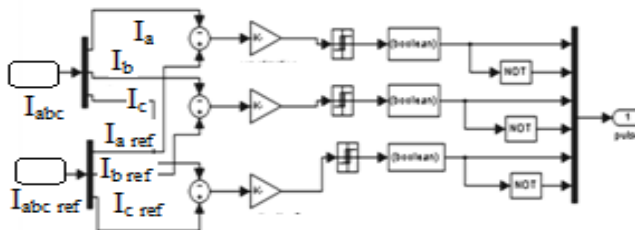


Fig.5. Block diagram of HBPWM

IV. PROPOSED HYSTERESIS CURRENT CONTROLLER

The sine reference current wave is generated by using of control circuit at desired magnitude and frequency, and it is compared with the actual phase current wave. When the current exceeds a prescribed hysteresis band limit, in the bridge the upper switch is turned off and the lower switch is turned on. As a result the output voltage transitions from +0.5Vd to -0.5Vd, and the current starts to decay. While the lower switch is turned off when current crosses the lower band limit and the upper switch is turned on. The actual current wave is thus forced to track the sine reference wave within the hysteresis band by back- and-forth switching of the upper and lower switches. The inverter then essentially becomes a current source with peak to peak current ripple, which is controlled within the hysteresis band irrespective of V_d fluctuation. The peak-to peak current ripple and the switching frequency are related to the width of the hysteresis band. The HBPWM inverter control method is shown in the Fig.6. The inputs to the HBPWM controller are three phase current errors and the outputs are the switching patterns to the PWM inverter.

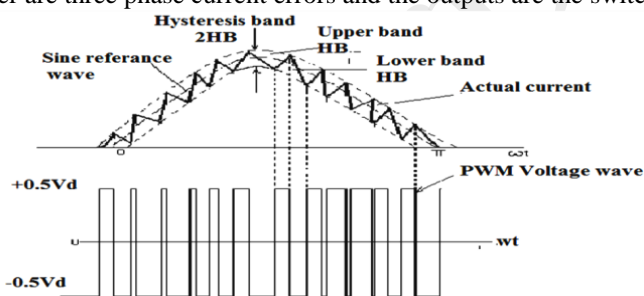


Fig.6. Hysteresis Band PWM signal generation

The quality of current wave form generated by a hysteresis current control depends on basically on below factors:

- i. The reference signal being generated.
- ii. The modulation method used.

A new adaptive hysteresis band modulation is proposed. The periodical sampling constant hysteresis band modulation is analyzed. They are compared in terms of THD of supply current, switching losses, and their flexibility of tuning. The simulation results demonstrate the viability and effectiveness of the Hysteresis band modulation method in reducing the ripple ,losses and THD of the supply.

$i_{m,ref} - i_m < \epsilon$ keeps the output pulse at the same state

$i_{m,ref} - i_m > \epsilon$ let output pulse 1 (high)

$i_{m,ref} - i_m < -\epsilon$ let output pulse =0 (low)

The algorithm for this scheme is:

$$i_{m,ref}(t) = i_{m,ref} \sin(\omega t)$$

$$\text{Upper band } i_u = i_{m,ref}(t) + \Delta I$$

$$\text{Lower band } i_l = i_{m,ref}(t) - \Delta I$$

Where

ΔI = hysteresis band limit, $m = a, b, c$ phases

i = load current, ϵ = The hysteresis band

V_{dc} = DC link voltage of the inverter

V. SIMULATION RESULTS

Simulation of proposed transformer-less impedance current source inverter is carried out in MATLAB/Simulink platform. The output waveform for impedance current source inverter using hysteresis band pulse width modulation results is shown. Peak to peak current ripple is related to the width of hysteresis band. Advantage of controller is that it does not need any knowledge of load parameters.

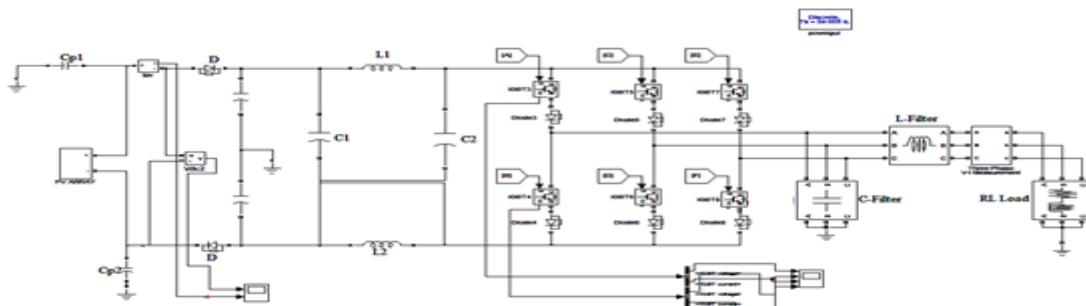


Fig.7.Simulink model of Impedance CSI

A. Output of inverter

Output of impedance current source inverter is shown in Fig.8(a). The output voltage waveform increases to 680V.

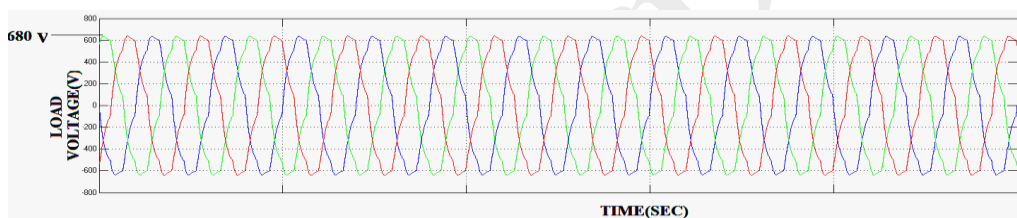


Fig.8(a)output voltage

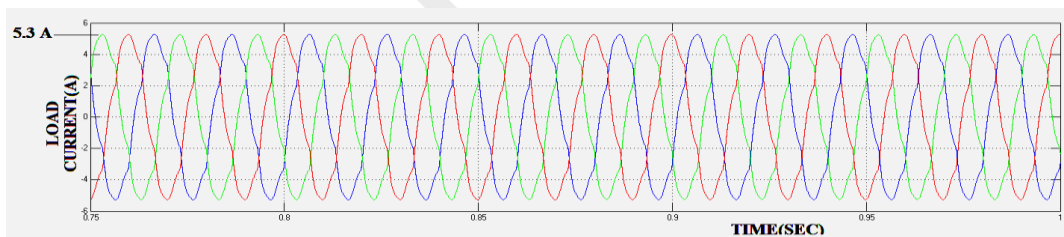


Fig.8(b)output current

Output current of inverter is increases to 5.3A is shown in Fig.8(b).

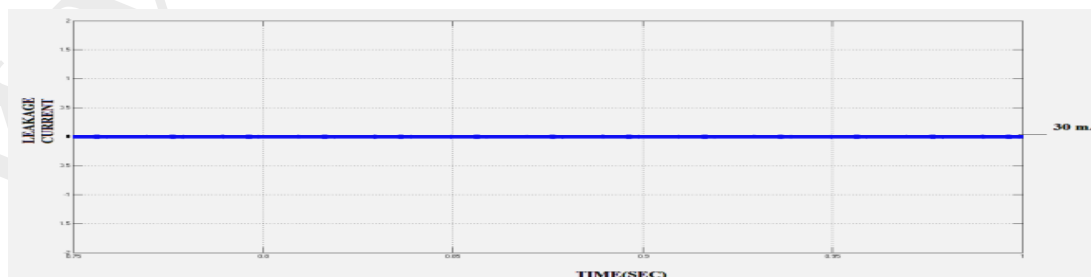


Fig.8.(c) leakage current

Leakage current is reduces to 30 mA by using the impedance current source inverter is shown in Fig.8(c).

VI. CONCLUSION

Transformer-less impedance current source inverter is proposed for photo voltaic systems. As compared with four leg CSI. The impedance based current source inverter offers higher reliability, high efficiency of output and it reduces the shoot through problem and earth leakage current. Hysteresis band pulse width modulation current controller is lower in cost and it can be easily implemented. A current source with peak to peak current ripple, which is controlled within the hysteresis band, irrespective of voltage fluctuation. Total harmonic distortion is reduced by use of hysteresis current controller when compared to proportional integral controller and it also increases the efficiency of the system.

References

- [1] SandeepAnand, saikrishna Kashyap Gundlapalli, and B. G. Fernandes, "Transformer-Less Grid Feeding Current Source Inverter for Solar Photovoltaic System"IEEETransas. IndustlElectron, Vol. 61, No. 10, October 2014
- [2] F. Bradaschia, M. C. Cavalcanti, P. E. P. Ferraz, F. A. S. Neves, E. C.dos Santos Jr., and J. H. G. M. da Silva, "Modulation for ThreephaseTransformerless Z-Source Inverter to Reduce Leakage Currents in Photovoltaic Systems," IEEE Trans. Ind. Electron., vol. PP, no. 99, pp. 1–11, 2011
- [3] Y. Huang, M. Shen, F. Z. Peng, and J. Wang, "Z-source Inverter for Residential Photovoltaic Systems," IEEE Trans. Power Electron., vol. 21, no. 6, pp. 1776–1782, November 2006.
- [4] T. Kerekes, M. Liserre, R. Teodorescu, C. Klumpner, and M. Sumner, "Evaluation of Three-Phase Transformer less Photovoltaic Inverter Topologies," IEEE Trans. Power Electron., vol. 24, no. 9, pp. 2202–2211, September 2009
- [5] F. Z. Peng, "Z-Source Inverter," IEEE Trans. Ind. Appl., vol. 39, no. 2, pp. 504–510, March/April 2003.
- [6] Y. Tang, S. Xie, C. Zhang, and Z. Xu, "Improved Z-Source Inverter With Reduced Z-Source Capacitor Voltage Stress and Soft-Start Capability," IEEE Trans. Power Electron., vol. 24, no. 2, pp. 409–415, February 2009.
- [7] M. Shen, A. Joseph, J. Wang, F. Z. Peng, and D. J. Adams, "Comparison of Traditional Inverters and Z-Source Inverter," in Proc. IEEE PESC, 2005, pp. 1692–1698.
- [8] M. C. Cavalcanti, K. C. Oliveira, A. M. Farias, F. A. S. Neves, G. M. S. Azevedo, and F. C. Camboim, "Modulation Techniques to Eliminate Leakage Currents in Transformer less Three-Phase Photovoltaic Systems,"IEEE Trans. Ind. Electron., vol. 57, no. 4, pp. 1360–1368, April 2010.
- [9] B. Sahan, S. V. Araújo, C. Nöding, and Zacharias, "Comparative evaluation of three-phase current source inverters for grid interfacing of distributed and renewable energy systems," IEEE Trans. Power Electron., vol. 26, no. 8, pp. 2304–2318, Aug. 2011.
- [10] B. Mirafzal, M. Saghaleini, and A. K. Kaviani, "An SVPWM-based switching pattern for stand-alone and grid-connected three-phase single stage boost inverters," IEEE Trans. Power Electron., vol. 26, no. 4, pp. 1102–1111, Apr. 2011
- [11] H. Xiao, S. Xie, Y. Chen, and R. Huang, "An optimized transformer less photovoltaic grid-connected inverter," IEEE Trans. Ind. Electron., vol. 58, no. 5, pp. 1887–1895, May 2011.
- [12] F. Bradaschia, M. C. Cavalcanti, P. E. P. Ferraz, F. A. S. Neves, E. C. dos Santos, and J. H. G. M. da Silva, "Modulation for three-phase transformerless Z-source inverter to reduce leakage currents in photovoltaic systems," IEEE Trans. Ind. Electron., vol. 58, no. 12, pp. 5385–5395, Dec. 2011.grid," in Proc. 22nd Annu. IEEE APEC, Feb./Mar. 2007, pp. 1733–1737.
- [13] B. Sahan, A. N. Vergara, N. Henze, A. Engler, and P. Zacharias, "A single stage PV module integrated converter based on a low-power current source inverter," IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2602–2609, Jul. 2008.
- [14] B. Ji, J. Wang, and J. Zhao, "High-efficiency single-phase transformer less PV H6 inverter with hybrid modulation method," IEEE Trans. Ind. Electron., vol. 60, no. 5, pp. 2104–2115, May 2013.
- [15] J. R. Espinoza and G. Joos, "Current-source converter on-line pattern generator switching frequency minimization," IEEE Trans. Ind. Electron., vol. 44, no. 2, pp. 198–206, Apr. 1997.

Authors Short Profile:



K.Pratheeba She completed her bachelor's degree in electrical and electronics engineering in annamalai university on 2011. She is pursuing her Post Graduation in Power Electronics and Drives at Dr.Pauls Engineering college, Tamilnadu, India.



Dr.E.Mariappane received his B.E degree in Electrical and Electronics Engineering and M.E degree in Power System Engineering from Annamalai University, Tamil Nadu, India, in 1996 and 2004 respectively. He completed the Ph.D degree in Anna University, Chennai, India (2013). He has 15 years teaching experience at various reputed institutions in and around Tamil Nadu. Currently he is working as DEAN (Academics) at Dr.Pauls Engineering College, Tamil Nadu, India, and he is a life member of ISTE in India.



N.Pushpalatha Obtained her B.E Degree from Sri Jayaram Engineering college in 2008 and her M.E (PED) from Mailam engg coll in 2012 at Anna University, Chennai. Her Area of interest is "Application of Power Electronics in Power System"