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Research Article

Performance Of Pd, Pod And Apod Based Modular Multilevel Converter For Single Phase Grid Connected Pv System

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Abstract

A Control Method Is Proposed In This Work Whichpermits The Extrication Of Maximum Power From Each Individual Pvarraylinked To The Five Level Modular Multilevel Converter (Mmc) And Feedbalanced Power To The Ac Grid. In Five Level Mmc, The Pv Arrayis Directly Linked To Half Bridge Sub Module (Sm) And It Does Not Need Additional Dc-Dc Converters For Mppt. Comparatively Mmc Based Half Bridge Sm Is Superior Than Full Bridge Sm Because The Power Loss And Cost Of Mmc Based Half Bridge Sm Is Lesser Than Full Bridge Sm. Depending On The Switching Modes Of S_1, S_2, The Output Voltage Of Half-Bridge Sm Is Either Equal To Its Capacitor Voltage Or Zero. Various Multicarrier Modulation Techniques Such As Phase Disposition(Pd), Phase Opposition Disposition (Pod) And Alternate Phase Opposition Disposition (Apod) Are Used To Control Mmc Which Reduces Switching Losses And Thd Of Ac Side Voltages. This Proposed Work Aims To Bring Out The Paramount Technique Among The Above Mentioned Techniques By Comparing All Of Them. The Voltage Obtained In Proposed Converter Is Fed To Single Phase Grid Through Single Phase Voltage Source Inverter. Artificial Neural Network (Ann) Is Used To Control The Grid Power And The Output Of Ann Is Fed To Multicarrier Pd, Pod And Apod That Compares Reference Signal With These Carrier Signals Achieves Grid Synchronization. Thus It Reduces Total Harmonic Distortion.

Keywords: Modular Multilevel Converter, Pv Panel, Half Bridge Sub-Module, Grid Synchronization, Artificial Neural Network, Pd, Pod And Apod.

1. Introduction

The Photovoltaic (Pv) Power Which Is Given To The Utility Grid Is Gradually Becoming Extremely Apparent, As The World's Power Demand Has Risen Significantly Over The Years Due Tofossil Fuel Scarcity And Greenhouse Effects. As Pv Panels Have Easy Maintenance And Pollution Free Utilization, They Have Been Used In Multiple Applications. Owing To The Reduced Price Of Pv Panels, Solar Power Is Gradually Getting Low-Priced That Inspires The Integration Of More Pv Array Into The Grid [1] – [3]. Mppt Algorithm Is Utilized To Overcome The Limitation Of Uncertainty Regarding The Obtainability Of Solar Energy Due To Environmental Aspects Of Cloud Passage And Weather Conditions [4]. A Family Of Flying Capacitor Transformerless Inverter Is Presented That Reports The Problem Of Leakage Currents[5]. A Switched Pv System Is Utilizedthat Improvesthe Power Extricated From Solar Panel Under The State Of Partial Shading [6]. A Grid Tied 1Φ Transformerless Inverter Extricates Maximum Power From Two Solar Pv Panelsunder Mismatched Workingstate Is Discussed In [7]. In Order To Extricate Frequency And Phase Angle Of Distorted Load Currents And To Regulate Pv Grid Which Is Connected With Voltage Source Converter, A Pll For Grid Connected Is Proposed [8].

A New Adaptive Current Controller Is Used For Grid Integratedvsiwhich Overcomes The Limitation Of Harmonics Present In Distribution System Of Solar Pv Panel. The Systemhas Variousadvantages Like Improved Harmonic Alleviation, Enhanced Stability, And Lower Settling Time [9].A Two-Stage Solar Pv Grid Connected System Is Utilized To Extricate Maximum Power From The Solar Panel That Is Given To The Grid, Retaining An Appropriate Dc-Link Potential [10].To Regulate Dc-Link Potential, An Improved Voltage Controller Is Utilized In Feedback Linearization System With Feed-Forward Solar Current Signal Is Discussed In [11]. A 3Φ Tri-Level Buck–Boost Integrated Inverter Is Utilized For Grid Integrated Pv System Is Discussed In [12].For Solar Panel Characterization, A Buck-Boost Converter Model Is Used For The Prediction Of Output, Estimation Of Efficiency And Fault Detection In Pv Industry [13].A New Grid Connection Interface Based On Modular Multilevel Converter For Utility-Scale Solar Array Employs Dc-Dc Boost Converters And

Integrates An Energy Storage Device [14].A Robust Continuous Time Model Predictive Control Is Instigated For Dc-Dc Boost Converter To Regulate The Output Potential Of Solar Panel And In The Occurrence Of Uncertainty Model And It Improves Steady State Performance [15]. Based On The Combination Of The Cuk And Sepic Converters, An Improved Dc-Dc Converter For Solar Pv Array Is Presented That Reducing The Ripple Of Current Input And Thus Greatly Enhancing The Extricated Power From The Solar Pv Panel [16]. Space Vector Pulse Width Modulation Is Instigated To Regulate The Output Voltage And Minimize The Harmonics For Grid Linked Pv Panel. The Lc Filter Is Applied To The Device To Get Enhanced Performance [17].

The Output Power Of Non-Shaded Pv Modules Will Be Reduced Through Partial Shading And The Effect Of Shaded Pv Modules [18]. A Module Integrated Converters (Mics) Is Used, This Arrangement Enhances The Authenticity, Redundancy And Output Power Of Solar Distributed Generators [19]. A Novel Structure Of Utility-Scale Pv Connected Grid System Based On Dc-Based Mmc Is Employed For High Voltage Dc Transmission [20].The Fault Tolerant Control Allows Continued Working And Retains The Balance Of Dc Voltage Capacitor Throughout The Failure Of Bridge Cells That Improves The Reliability And Availability Of The System [21].An Enhanced Phase Disposition Pwm For Modular Multilevel Inverter Is Employed For The Integration Of Pv Grid That Achieves Dynamic Balance Voltage Capacitor Without The Aid Of An Additional Compensation Signal [22].Grid Synchronization Is Achieved Using Pi Controller Take So Much Time, Inadequate Reference Tracking In Voltage Source Inverter [23].

The Pv Panel Voltage Is Varied Due To Change In Temperature And Intensity. In Order To Maintain Constant Voltage And Also Boost Up The Voltage, Boost Converters Are Used. By Using These Converters Leakage Reactance Problem Occurs Due To The Presence Of Inductance And Capacitance. To Overcome This Drawback, Mmc Is Proposed In This Work Where The Pv Is Directly Integrated With A Half Bridge Sub-Module And It Does Not Require Any Additional Dc-Dc Converters. Various Multicarrier Techniques Such As Pd, Pod And Apod Are Used To Control Mmc. Artificial Neural Network (Ann) Is Used To Control The Grid Power And The Output Of Ann Is Fed To Multicarrier Pd, Pod And Apod That Compares Reference Signal With These Carrier Signals Achieves Grid Synchronization. Thus It Reduces Total Harmonic Distortion.

II. Proposed System

The Pv Integrated Grid System Uses A Modular Five Level Converter Configurations Is Depicted In Fig 1. Normally Pv Integrated Grid System Uses A Dc-Dc Converter Which Is Followed By A Dc-Ac Inverter And Here Replaces Traditional Converter With Modular Multilevel Converter. A Mmc Is Selected In Proposed System Because Of Its High Power Application And Scalability Is Simple. A Modular Five Level Converter Is Utilized With Half Bridge Sub-Modules (Hbsm) And For Each Phase Two Sm Are Connected In Series With A Switching Frequency Of1 KHz. This Set Up Is Linked To A 1Φ Vsi And Through 3Φ Transformer The Output Is Given To The Grid.

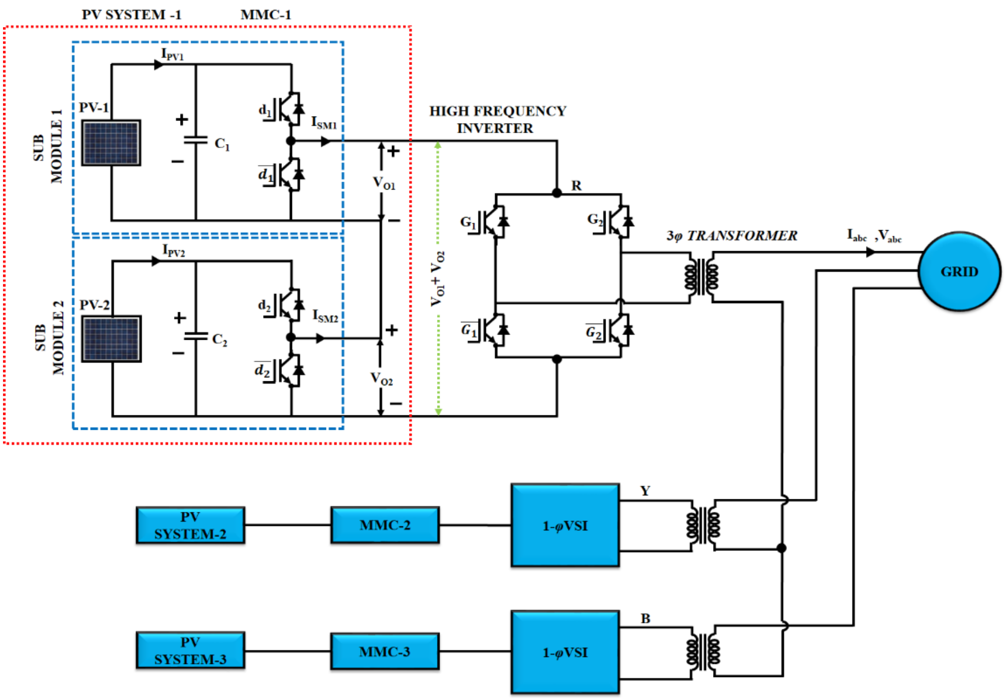


Fig 1 Proposed System Configuration

The Output Voltage From Pv Panel Is Fed To Half Bridge Sub-Modules Of Modular Five Level Converters. Number Of Switches Used In Half Bridge Sub-Module Is Less And Therefore The Pwm Techniques Are Easily Controlled By Hbsm. The Output Of Mmc Is Given To Single Phase Vsi That Converts Dc Into Ac. Various Multicarrier Techniques Such As Phase Disposition, Phase Opposition Disposition And Alternate Phase Opposition Disposition Are Used To Control Mmc. Artificial Neural Network (Ann) Is Used To Control The Grid Power And The Output Of Ann Is Fed To Multicarrier Pd, Pod And Apod That

Compares Reference Signal With These Carrier Signals Achieves Grid Synchronization. Thus It Reduces Total Harmonic Distortion.

III. Modeling Of Proposed System

A. Pv Panel

The Interface Utilized For Theextrication Of Solar Energy Is Pv Cells.Since The Output Attained From A Single Pv Cell Is Low, The Solar Cells Are Linked In Various Connectionsto Rise The Output. The Pv Effect Is Defined As The Transformation Of Light Energy Into Electrical Energy. The Energy That Is Transformed Is In The Form Of Dc Voltage. The Quantity Of Current Produced By Pv Cell Is Controlled By Solar Radiation, While Voltage Is Controlled By Temperature. The Pv Cell's Electrical Equivalent Circuit Is Depicted In Fig 2

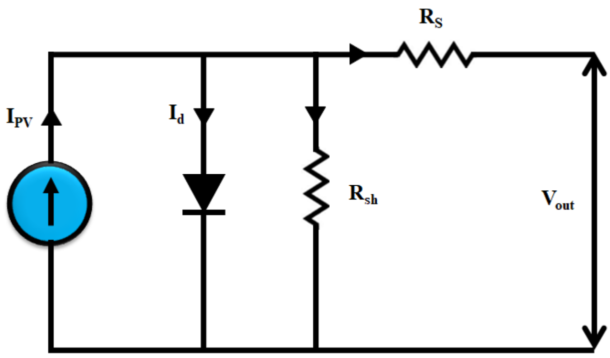


Fig 2electrical Equivalent Circuit Of Pv Cell

The Current Equation's For Solar Module Is Expressed As,

$$I = I_{pv} - I_o \left[exp \left(\frac{q(V+IR_s)}{\alpha KT} \right) - 1 \right] - \frac{V+IR_s}{R_{sh}} \quad (1)$$

$$I_o = I_o, n \left(\frac{T_n}{T} \right)^3 exp \left[\frac{qE_g}{\alpha K} \right] \left(\frac{1}{T_n} - \frac{1}{T} \right) \quad (2)$$

$$I_{pv} = [I_{sc} + K_i(T - T_n)] \frac{G}{G_n} \quad (3)$$

Where K Denotes Boltzmann's Constant, q Denotes Electric Charge, $I \ and \ V$ Denotes Cell Output Current And Voltage, I_o Denotes Cell Reverse Saturation Current, T Denotes Cell Temperature In Celsius, α Denotes Ideality Factor Between 1.0 to 1.5, I_{pv} Denotes Light Generated Current, G Denotes Solar Radiation In W/m^2, K_i Denotes Temperature Coefficient, G_n Denotes Nominal Solar Radiation In W/m^2, E_g Denotes Energy Gap Of Silicon, I_o, n Denotes Nominal Saturation Current, T_n Denotes Nominal Temperature In Celsius, $R_s \ and \ R_{sh}$ Denotes Series And Shunt Resistances.

B. Modular Multilevel Converter (Mmc)

Pv Panels Are Directly Linked To Sub-Modules (Sm) Of Modular Multilevel Converter To Make Use Of Modularity, Improves Efficiency, And Reliability Of Mmc. The Benefit Of Mmc Comprises Redundancy, Operates Under Fault Tolerant And Improves The Performance Of Total Harmonic Distortion. The Solar Panel Is Linked With A Capacitor And Half Bridge Sm Forms Mmc With $(2N + 1)$ Voltage Levels. The Output Voltage Of Hbsm Is Either Equal To Its Capacitor Voltage V_c Or Zero. Here, Five Level Mmc Is Used And Therefore Two Sub-Modules Are There For Every Phase And For Analysis Only One Sm Is Used For Easy Simplification. The Maximum Power Is Extricated By Controlling The Capacitor Voltage, Because Of Irradiance There Are Variations In The Capacitor Voltage, And It Is Observed That The Variance Is Muchfewer For One Sm, But Since There Are Numbers Of Smlinked In Series, This Should Not Be Ignored.Fig 3 (A) Represent The Simplified Circuit For One Submodule And Fig 3(B) Represents Its Equivalent Circuit.

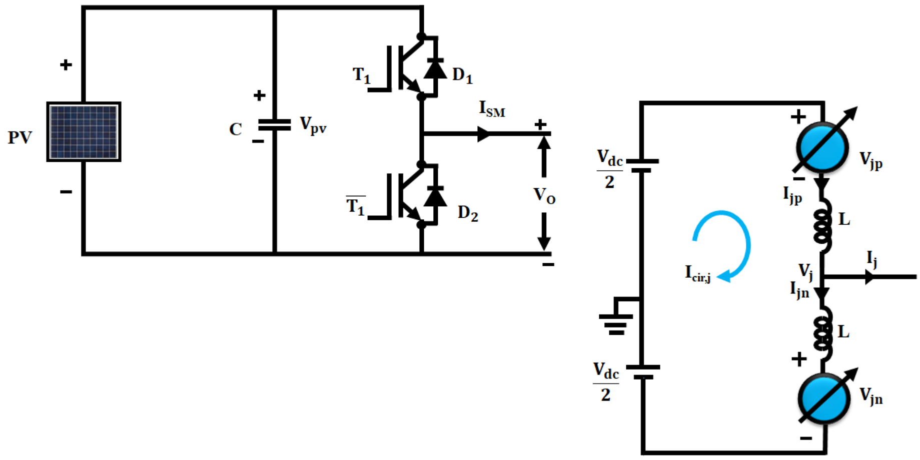


Fig 3 (A) Representation Of A Submodule (B) Equivalent Circuit

The Mathematical Model For Fig 3 (B) Is Expressed As,

$$\begin{cases} 2V_j = (V_{jn} - V_{jp}) + L\frac{d(I_{jn}-I_{jp})}{dt} \\ I_j = I_{jp} - I_{jn} \\ I_{circ,j} = \frac{I_{jp}+I_{jn}}{2} \end{cases} \quad (4)$$

Where, V_j *and* I_jDenotes Output Voltage And Current Of Phase j, Voltage Of Upper Arm And Bottom Arm Are Denoted As V_{jp}*and* V_{jn}, Current Of Upper Arm And Bottom Arm Are

Denoted As $I_{jp} and\ I_{jn}$, Circulation Current Is Denoted As $I_{circ,j}$, Buffer Inductor Is Denoted As L.

Equation (4) Becomes

$$\begin{cases} V_j = \frac{1}{2}\left(V_{jn} - V_{jp}\right) + \frac{1}{2}L\frac{dI_j}{dt} \\ V_{dc} = \left(V_{jn} - V_{jp}\right) + 2L\frac{dI_{circ,j}}{dt} \end{cases} \tag{5}$$

Where The Dc Side Voltage Of Modular Multilevel Converter Is Denoted As V_{dc}. Let Us Assume That,

$$\begin{cases} e = \frac{1}{2}\left(V_{jn} - V_{jp}\right) \\ V_{circ,j} = L\frac{dI_{circ,j}}{dt} \end{cases} \tag{6}$$

Now V_j Is Represented As,

$$V_j = e + \frac{1}{2}L\frac{dI_j}{dt} \tag{7}$$

The Expression For Reference Voltage Of Upper And Bottom Arms Are Obtained By Combining Equations (6) & (7)

$$\begin{cases} V_{jp} = \frac{1}{2}V_{dc} - e - V_{circ,j} \\ V_{jn} = \frac{1}{2}V_{dc} + e - V_{circ,j} \end{cases} \tag{8}$$

Here The Sm Are Operated Under Phase-Shifted Pwm And The Phase Shift (θ_{ph}) In Carrier Signals Among Two Sub-Modules Are Expressed As,

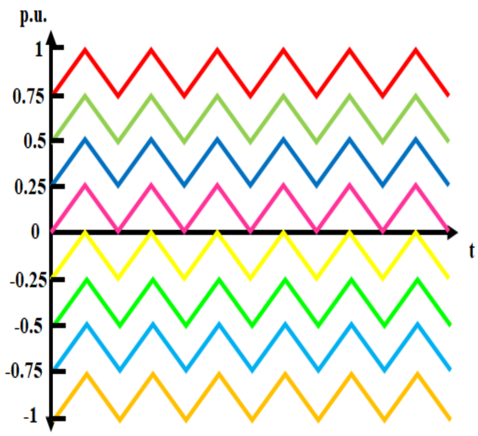
$$\theta_{ph} = \frac{360^0}{N} \tag{9}$$

Where The No. Of Sub-Modules Is Denoted As N. From Equation (8) It Is Observed That The Reference Voltage For Mmc Is Attained For Every Arm In Every Phase. Similarly, The Voltage For Other Phase Also Easily Obtained. Here The Mmc Is Controlled With The Help Of Various Multicarrier Techniques Based On Using Single Reference Waveform.

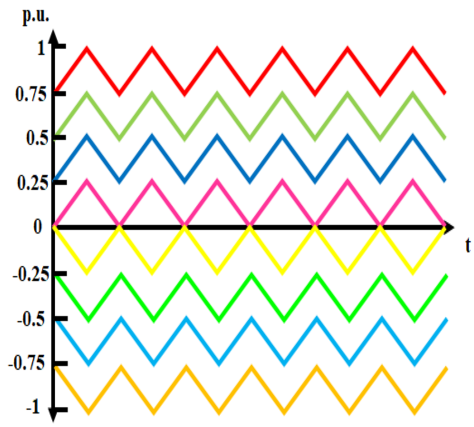
C. Multilevel Carriers Of Pd, Pod And Apod

Depending On Phase Shift Carrier Waveform, The Multicarrier Modulation Techniques Namely Phase Disposition (Pd), Phase Opposition Disposition (Pod) And Alternate Phase Opposition Disposition (Apod) Are Used To Control Mmc That Reduces Switching Losses

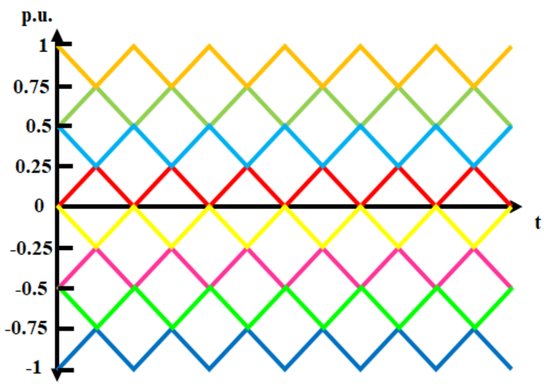
And Thd Of Ac Side Voltages.These Pwm Techniques Need*N*number Of Uniformed Triangular Carrier Waveforms That Is Displaced Symmetrically W.R.T Zero Axis. On Comparing Phase Voltage Reference With Carrier, This Generates Desired Level Of Switched Phase Output Voltage. The Insertion Of A Specific Sm Is Aligned With Voltage Transitions Which Is Equivalent To A Triangular Carrier Waveform.



(A)



(B)



(C)

Fig 4 (A), (B) And (C) Multilevel Carrier Waveforms Of Pd, Pod And Apod

Fig 4 (A), (B) And (C) Shows Multilevel Carrier Waveforms Of Pd, Pod And Apod. A Simple Carrier Rotation And Modified Carrier Rotation Method Is Utilized To Balance The Distribution Of Voltage Across All Sm Capacitors, Also It Improves Harmonic Distortion On Ac Side Voltage.The Benefit Of These Technique Is Additional Reference Signals Are Not

Present To Regulate Sm Capacitor Voltages. In This System, Each Mmc's Sm Is Controlled Individually, And Smsvoltage Balancing Is Spilt Into An Averaging And Balancing Controls. In Case Of Upper As Well As Lower Arms, The Reference Waveforms Of Every Sm Is Expressed As,

$$m_{p,i,j} = \frac{\frac{V_{dc}}{2N} - \frac{v_{j,ref}}{N} + v_{a,i,j} + v_{b,i,j}}{v_{cp,i,j}} \quad (10)$$

$$m_{n,i,j} = \frac{\frac{V_{dc}}{2N} - \frac{v_{j,ref}}{N} + v_{a,i,j} + v_{b,i,j}}{v_{cn,i,j}} \quad (11)$$

Where The Averaging And Balancing Controller Outputs Is Denoted As$v_{a,i,j}$ and $v_{b,i,j}$. This Controller Controls The Average Sub-Module Voltage Capacitor In Every Phase-Leg And Separate Sub-Module Voltage Capacitor Accordingly. The Drawbacks Of Using Pod And Apod Techniques Contain Unequal Voltage Distribution Which Leads To Harmonic Distortion. These Drawbacks Are Overcome By Pd Technique Which Equalizes The Voltage Distribution Through That, It Reduces The Total Harmonic Distortion.

D. Artificial Neural Network (Ann)

Ann Is Utilized To Regulate The Grid Power In Pv Integrated Grid System. Generally, Ann Is Used To Rectify Difficult Problems. Conventionally Pi Controller Is Used To Generate Reference Signal And It Takes Maximum Time. To Overcome This Drawback Ann Is Used To Generate Reference Signal, The Output Of Ann Is Fed To Multicarrier Pd, Pod And Apod Which Is Compared With Reference Signal Achieves Grid Synchronization. Ann Looks Identical To Human Brain Cells And Their Interconnections. These Networks Have Excellent Patternrecognition And Learning Skills. The General Structure Of A Four Inputs Ann Is Depicted In Fig 5.

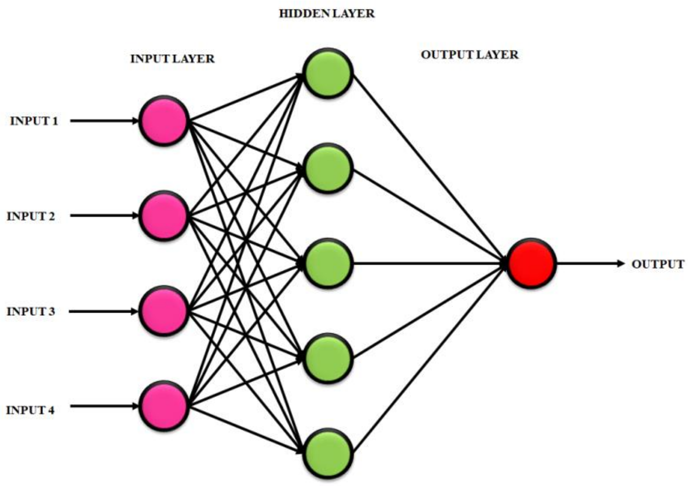


Fig 5 General Structure Of A Four Inputs Ann

Ann Comprises Input And Output Layers, These Layers Are Linked To The Outside Perimeter Of Network. Additionally A Hidden Layer Is Used In This Network Because This Layer Is Not Linked To The Outside Perimeter Of Network. The Input Layer Attains Data From Ann Inputs And Spreads Them To Hidden Layer Neurons To Be Increased By Weight Vectors. The Output Layer Attains Last Ann Output After The Multiplication Process. From The Input To Output Layer, The Hidden Layer Achieves Ann Intermediate Estimations. The Number Of Neurons In Input Layer As Well As Output Layerf Is Calculated Based On The Number Of Input And Output Issues, While The Number Of Neurons In The Hidden Layer Depends On The Required Accuracy And Computational Time.

E. Grid Synchronization In Single Phase Pv System

Grid Synchronization Is An Important Task Whichgivesrobustlya Dynamic Behaviour And Stability Of Complete Control System. In 1ф Systems, Even Grid Synchronization Is Challenged, Since There Is Only One Parameter I.E. Grid Voltage Is Utilized For Synchronization. However, Variousmethods Are Utilized To Extricate The Grid Voltage Such As Zero-Crossing Method, Filtering Of Grid Voltage Method And Phase Locked Loop (Pll) Method, These Methods Are Employed In Grid Synchronization. The Structure Of Phase Locked Loop Based Synchronization Scheme Is Depicted In Fig 6.

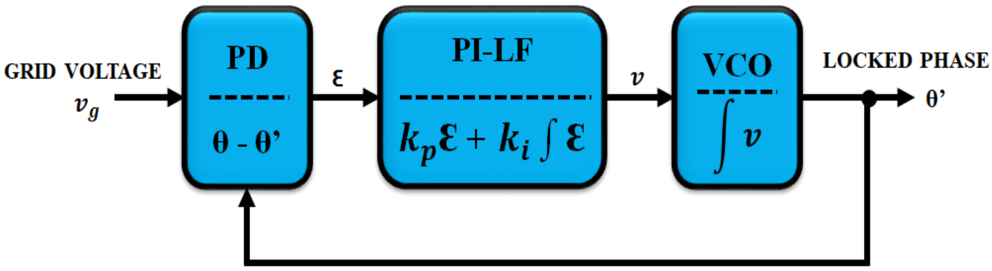


Fig 6 Structure Of Pll Based Synchronization System

The Pll System Comprises Phase Detector (Pd), Pi Based Loop Filter (Pi-Lf) And Voltage Controlled Oscillator (Vco). Pd Is Used To Detect Phase Difference And Pi-Lf Is Used To Smooth The Output Frequency. The Transfer Function Of Pll System Is Expressed As,

$$G_{pll}(s) = \frac{\theta'(s)}{\theta(s)} = \frac{k_p s + k_i}{s^2 + k_p s + k_i} \quad (12)$$

Where The Proportional And Integral Gain Of Pi-Lf Are Denoted As $k_p and\, k_i$. Later, Damping Ratio (ζ) And Undamped Frequency (ω_n) Are Expressed As,

$$\zeta = \frac{k_p}{2\sqrt{k_i}}\, and \omega_n = \sqrt{k_i} \quad (13)$$

Pi-Lf Is Utilized To Tune The Parameters Of Settling Time And Overshoot. Among Several Pll Methods, The Main Difference Occurs Only In Phase Detector Unit And It Uses Sinusoidal Multiplier Whose Output Is Double Line Frequency Which Needs More Efforts To Design Lpf To Filter It Out. The Input Grid Voltage Is Expressed As,

$$v_g = V_g \operatorname{Cos}(\theta) = V_g \operatorname{Cos}(\omega t) \quad (14)$$

Where The Input Voltage Amplitude Is Denoted As V_g, Grid Angular Frequency Is Denoted As ω. The Grid Voltage Is Practically Not Purely Sinusoidal Because Of Its Various Extreme Circumstances Such As Lightning Strikes, It May Be Distorted Or Sagged. This Greatly Challenges The Synchronization Of Grid Integrated Systems. Grid Synchronization Is Achieved By Comparing Reference Signal With Carrier Signal And Therefore It Reduces Total Harmonic Distortion.

IV. Results And Discussions

Presently, Energy Conservation Paves The Way For The Intensive Use Of Pv And High Power Applications Are Also Needed. Normally Pv Integrated Grid System Uses A Dc-Dc

Converter Which Is Followed By A Dc-Ac Inverter And Here Replaces Traditional Converter With Modular Multilevel Converter. A Mmc Is Selected In Proposed System Because Of Its High Power Application And Scalability Is Simple. The Output Voltage From Pv Panel Is Fed To Half Bridge Sub-Modules Of Modular Five Level Converters. The Output Of Mmc Is Given To Single Phase Vsi That Converts Dc Into Ac. Various Multicarrier Techniques Such As Phase Disposition, Phase Opposition Disposition And Alternate Phase Opposition Disposition Are Used To Control Mmc. Artificial Neural Network (Ann) Is Used To Control The Grid Power And The Output Of Ann Is Fed To Multicarrier Pd, Pod And Apod That Compares Reference Signal With These Carrier Signals Achieves Grid Synchronization. The Simulink Model Of Proposed System Is Depicted In Fig 7, Which Is Simulated Through Matlab Software.

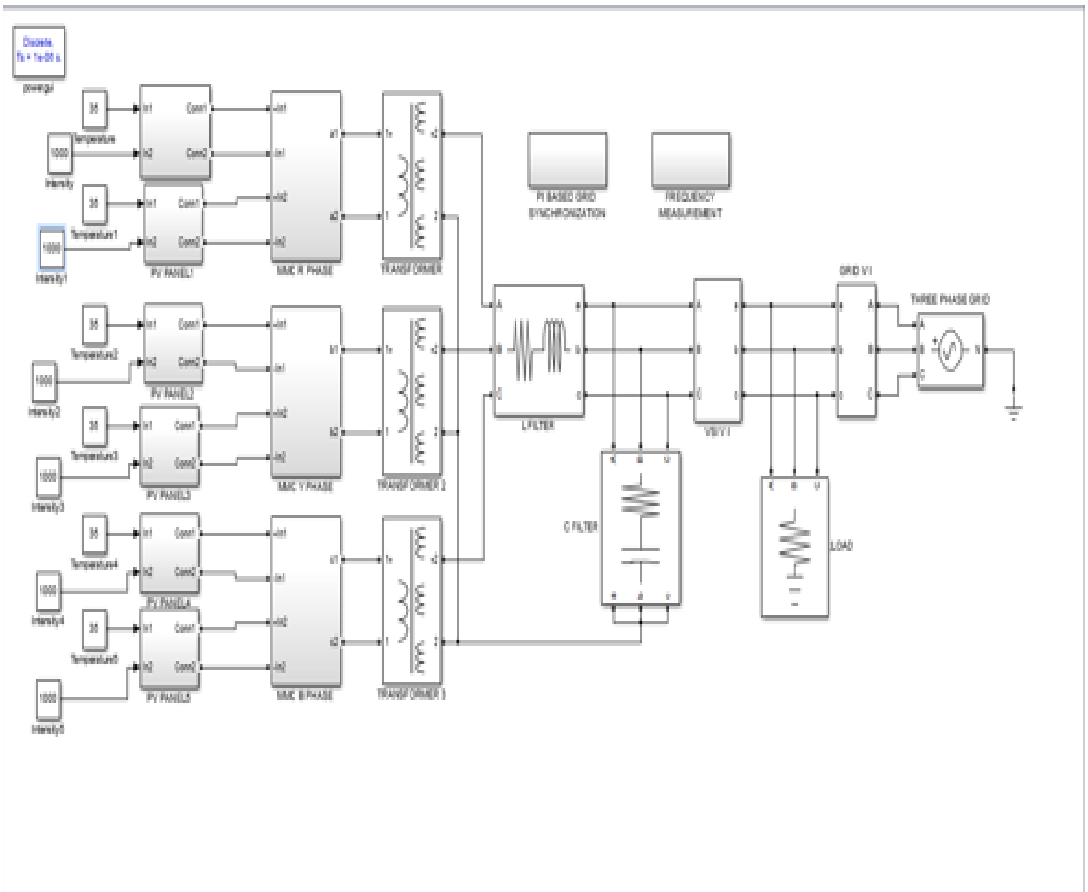


Fig 7 Simulink Model Of Proposed System

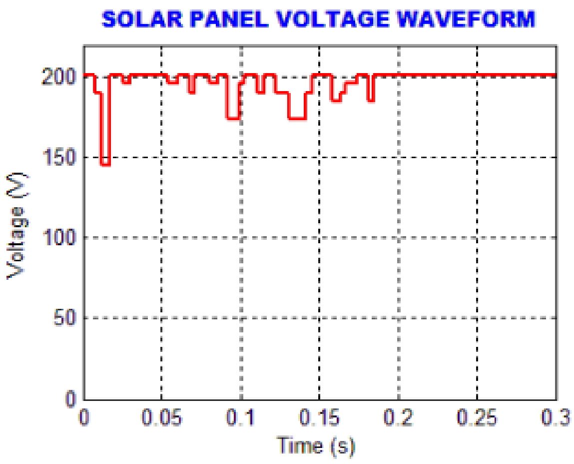


Fig 8 Solar Panel Voltage Waveform

Solar Panel Voltage Waveform Is Depicted In Fig 8. Due To Temperature Variations The Solar Panel Voltage Also Varied. From This Waveform It Is Observed That, After The Time $0.18s$ It Remains Constant At The Voltage Of$200V$.

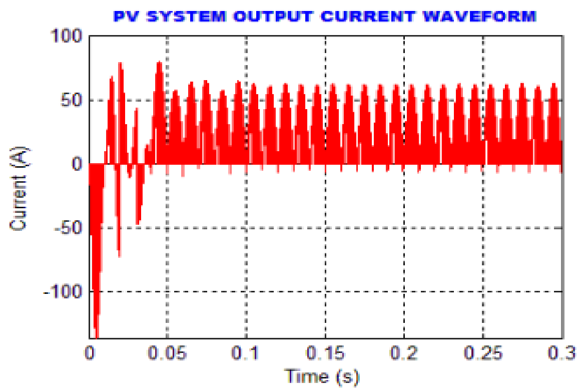


Fig 9 Pv System Output Current Waveform

Pv System Output Current Waveform Is Depicted In Fig 9. Due To Temperature Variations The Pv Panel Voltage Also Varied. If The Voltage Varies Means,The Output Current Also Varied That Is Shown In Above Figure.

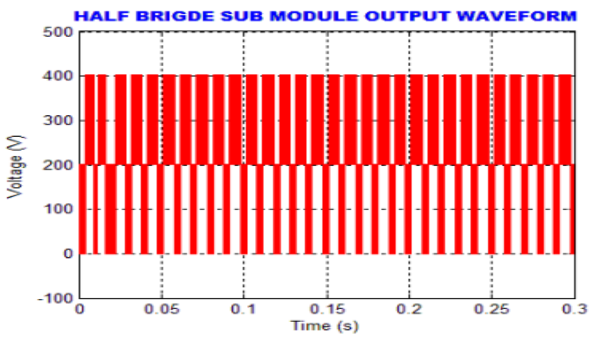


Fig 10 Half Bridge Sub-Module Output Waveform

Half Bridge Sub-Module Output Waveform Is Depicted In Fig 10. From This Waveform It Is Observed That, The Voltage Is Varied From0 $to\ 400V$ And The Variations Observed In This Waveform Will Be Less.

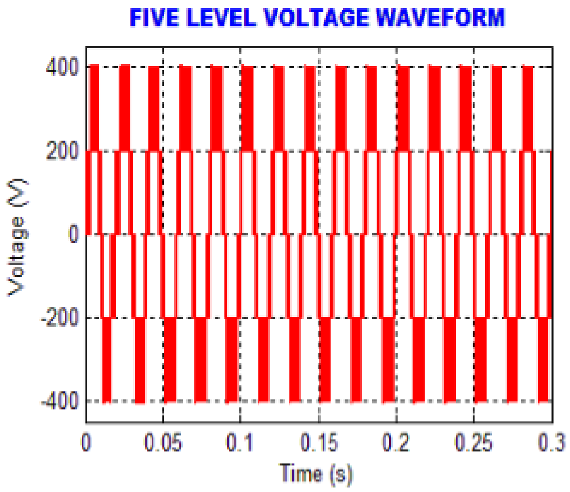


Fig 11 Voltage Representation Of Mmc

Voltage Waveform Of Proposed Mmc Is Depicted In Fig 11. Here Five-Level Converter Is Used And The Waveform Shows That, There Are Two Levels In The Positive Side, Two Levels In The Negative Side And One Zero Level That Results In Five Level.

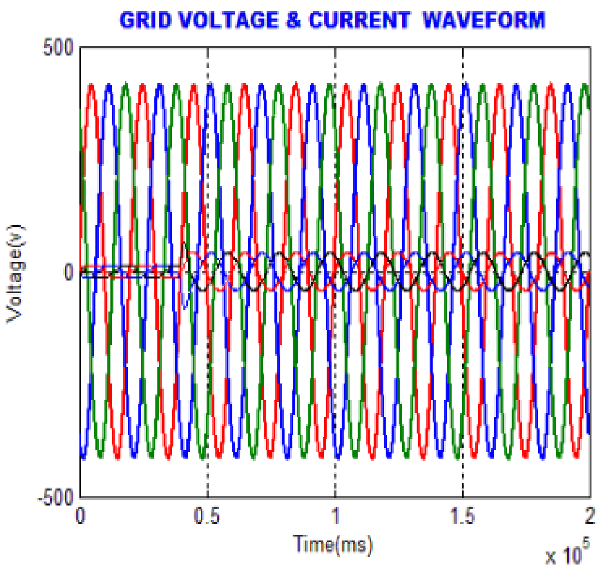
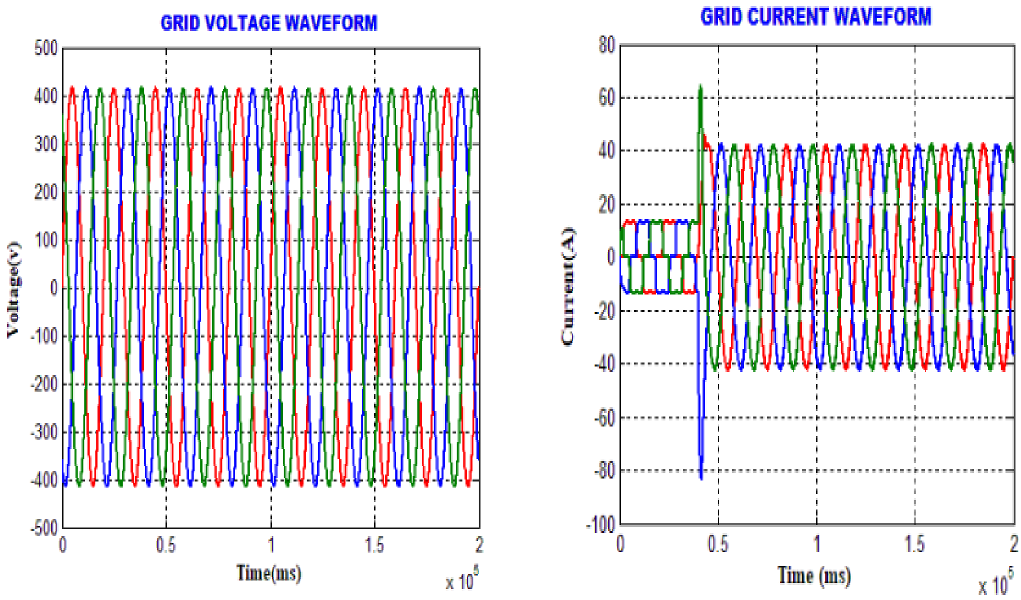


Fig 12 Grid Voltage And Current Waveform

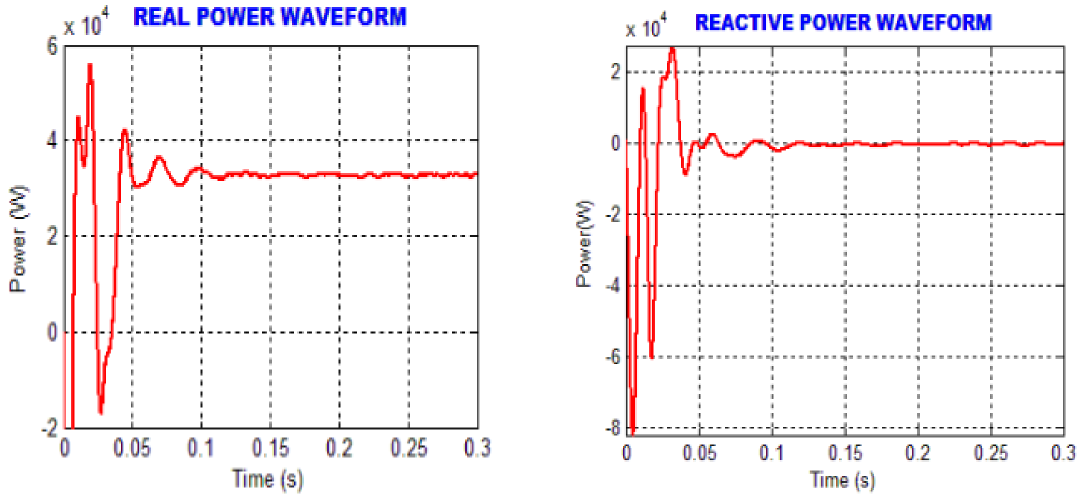
Grid Voltage And Current Waveform Is Depicted In Fig 12. From This Figure It Is Observed That, Before The Working Of Mmc There Will Be Harmonics Between The Times $0\ to\ 0.5s$ And After The Working Of Mmc The Harmonics Will Be Neglected And So The Waveform Will Be Sinusoidal In Nature. It Is Also Noted That The Voltage And Current Are In-Phase That Gives The Power Factor Is Unity.



(A) (B)

Fig 13 Waveforms For (A) Grid Voltage (B) Grid Current

Waveforms For (A) Grid Voltage, (B) Grid Current Is Depicted In Fig 13. From The Figure 13 (A) It Is Observed That, The Grid Voltage Is Set At $415V$ And The Waveform Will Be Sinusoidal In Nature. From The Figure 13 (B) It Is Observed That, Before The Working Of Mmc There Will Be Harmonics Between The Times $0\ to\ 0.5s$ And After The Working Of Mmc The Harmonics Will Be Neglected And So The Waveform Will Be Sinusoidal In Nature.



(A) (B)

Fig 14 Waveforms For (A) Real Power (B) Reactive Power

Waveforms For (A) Real Power, (B) Reactive Power Is Depicted In Fig 14. From This Waveform It Is Observed That, Initially There Will Be Oscillations In Both Real And Reactive Power Waveform, This Occurs Due To Harmonics And After A Certain Period The Reactive Power Waveform Will Be Goes To Zero.

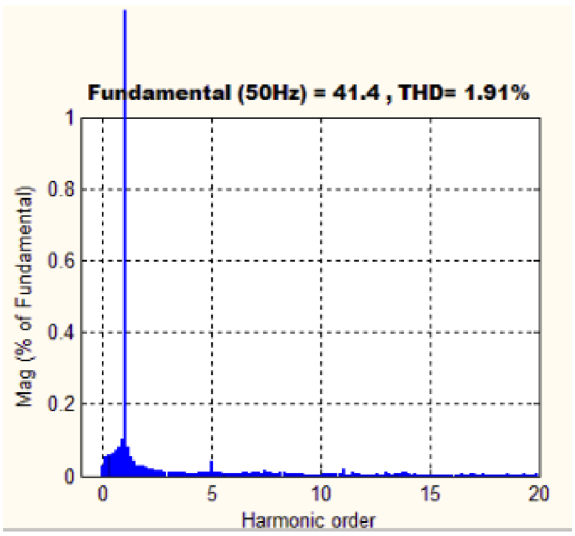


Fig 15 Grid Current Thd For Phase Disposition

Grid Current Thd For Phase Disposition Is Depicted In Fig 15. From This Waveform It Is Noted That, The Grid Current Thd For Phase Disposition Is 1.91%.

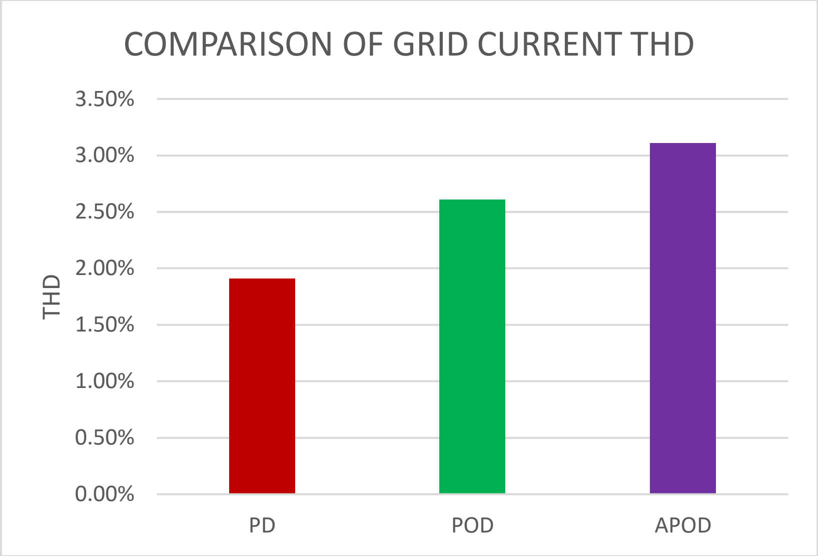


Fig 16 Comparison Of Grid Current Thd

The Comparison Of Grid Current Thd Is Depicted In Fig 16. From This Comparison, It Is Noted That The Grid Current Thd For Pd Attained Is 1.91 %. On Comparing The Thd With Pod And Apod, The Thd For Pd Gives Better Performance.

V. Conclusion

The Pv Integrated Grid System With Mmc Is Employed In This Proposed Work, Where A Modular Five-Level Inverter Is Utilized. Mmc Is Selected Because Of Its Easy Scalability And High Modularity. The Benefit Of Using This Proposed Converter Is It Allows High Voltage Conversion Ratio, Efficiency Is High And It Requires Decreased Component Stresses. In Five Level Mmc, The Pv Array Is Directly Linked To Half Bridge Sub-Module And It Does Not Require Additional Dc-Dc Converters For Mppt. Comparatively Mmc Based Half Bridge Sm Is Superior Than Full Bridge Sm Because The Power Loss And Cost Of Mmc Based Half Bridge Sm Is Lesser Than Full Bridge Sm. Various Multicarrier Modulation Techniques Such As Pd, Pod And Apod Are Used To Control Mmc Which Reduces Switching Losses And Thd Of Ac Side Voltages. . Artificial Neural Network (Ann) Is Used To Control The Grid Power And The Output Of Ann Is Fed To Multicarrier Pd, Pod And Apod That Compares Reference Signal With These Carrier Signals Achieves Grid Synchronization. Thus It Is Clear That Comparatively The Performance Of Pd Is Better Than Pod And Apod.

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