A New Single Phase PV fed Five Level Inverter Topology connected to the Grid

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Presentation By

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Objectives of This Paper

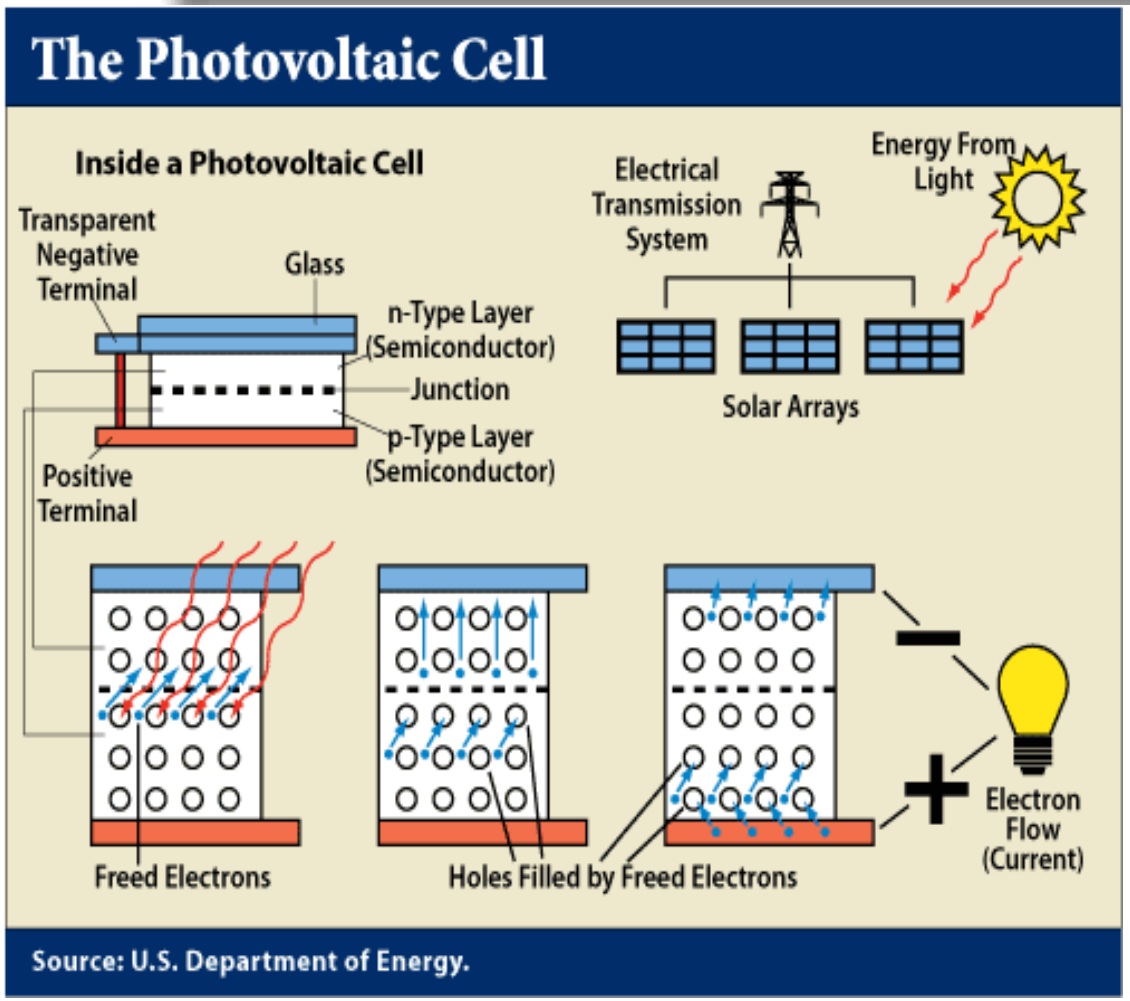
To design a new Multilevel Inverter Topology for Photovoltaic Applications with minimum number of Switches

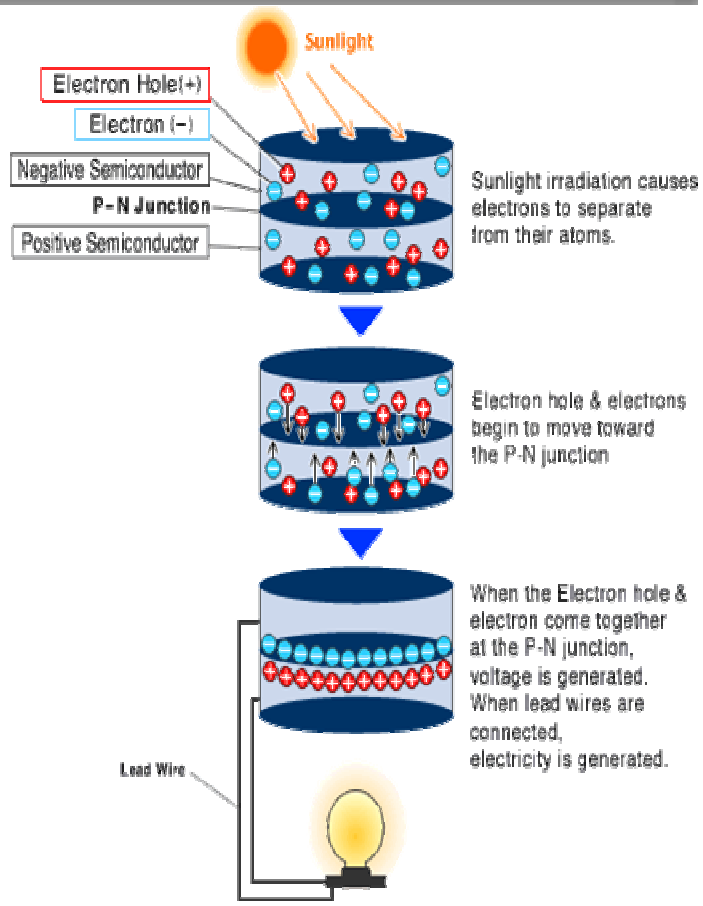
To Design a Control algorithm for New Topology with minimum carrier signals

To suggest a Novel Carrier for Multilevel inverters

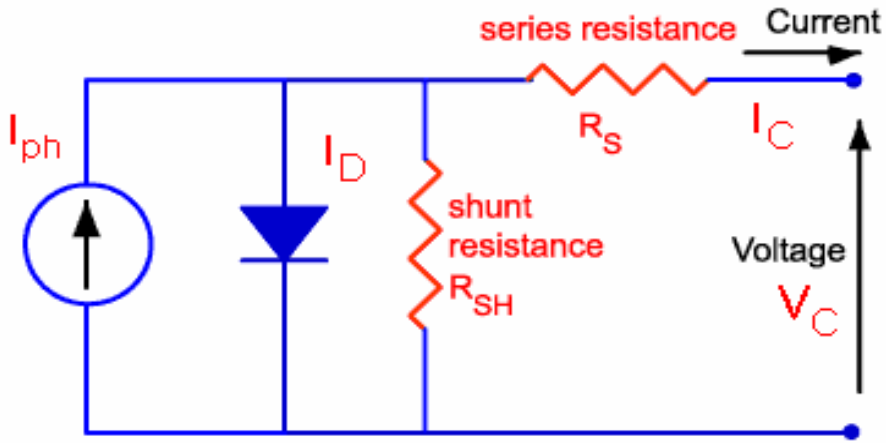
To compare the novel carrier with Conventional Triangular Carrier (Comparison based on Ma and Mf with THD)

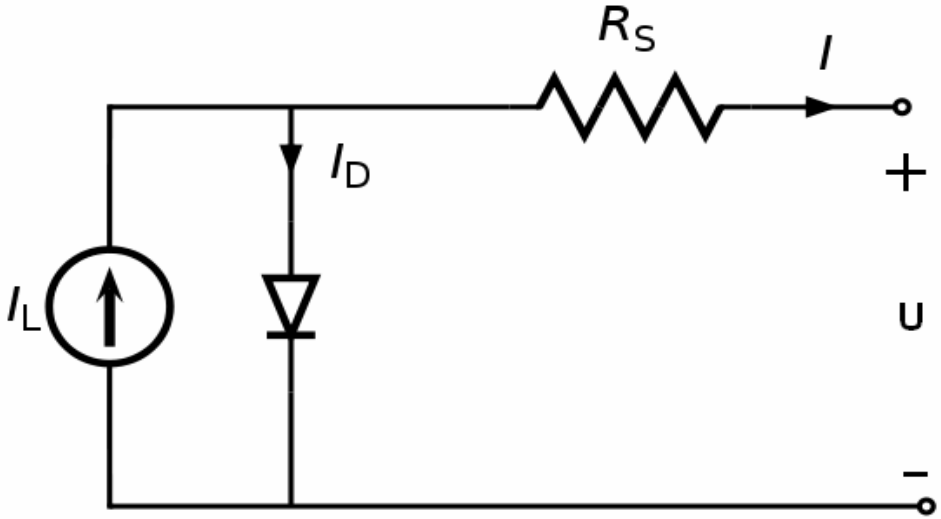
PHOTOVOLTAIC CELL WORKING PRINCIPLE





PHOTOVOLTAIC CELL MODELING





From the figure

$$I = I_L - I_D ----(1)$$

Where I=Output Current In Amps

I_l=light Current Or Photo Generated Current In Amps

I_D= Diode Current in amps

PHOTOVOLTAIC CELL MODELING Cont…

By Shockley equation, current diverted through diode is

$$I_D = I_o\left[\exp\left(\frac{U + IR_s}{nkT / q}\right) - 1\right]$$

Where I_o= Reverse Saturation Current
n= Diode Ideality Factor
K=Boltzmann's Constant
T= Absolute Temperature
q= Elementary Charge

For silicon of 25^0C nkT/q=0.0259 volts=α

$$I_D = I_o\left[\exp\left(\frac{U + IR_s}{\alpha}\right) - 1\right]$$

PHOTOVOLTAIC CELL MODELING Cont…

Substituting above equation in equation (1) we get

$$I = I_L - I_o\left[\exp\left(\frac{U + IR_s}{\alpha}\right) - 1\right] ----(2)$$

Where α=nkT/q is known as Thermal Voltage Timing Completion Factor

The four Parameters I_L,I_o,R_s and α need to be determined to Study the I-U characteristics of PV cells

PHOTOVOLTAIC CELL MODELING Cont…

LIGHT CURRENT I_L determination

$$I_L = \frac{\phi}{\phi_{ref}}\left[I_{L,ref} + \mu_{I,SC}\left(T_c - T_{c,ref}\right)\right]$$

$Where\ \phi$ = irradiance(W/m^2)

ϕ_{ref} = reference irradiance(1000 W/m^2 is used in this study)

$I_{L,ref}$ = Light current at reference condition (1000 W/m^2 and 25 ^0c)

T_c = PV cell temperature

$T_{c,ref}$ = Reference Temperature ($25^0 C$ is used here)

$\mu_{I,SC}$ = Temperature coefficient of the short circuit current ($A/^0C$)

Both $I_{L,ref}$ and $\mu_{I,SC}$ can be obtained from manufacturer data sheet

PHOTOVOLTAIC CELL MODELING Cont…

SATURATION CURRENT I_O determination

$$I_o = I_{o,ref}\left(\frac{T_{c,ref}+273}{T_c+273}\right)^3 \exp\left[\frac{e_{gap}N_s}{q\alpha_{ref}}\left(1-\frac{T_{c,ref}+273}{T_c+273}\right)\right]$$

Where $I_{o,ref}$ = Saturation current at the reference condition (A)

e_{gap} = Band gap of the material (1.17eV for Si materials)

N_s = Number of cells in series of the PV module

q = Charge of the electron ($1.60217733 \times 10^{-19}$ C)

α_{ref} = The value of α at the reference condition

$$I_{o,ref} = I_{L,ref}\exp\left(-\frac{U_{oc,ref}}{\alpha_{ref}}\right)$$

$U_{oc,ref}$ = The open circuit voltage of the PV module at the reference condition(V) (Will be provided by manufacturers)

PHOTOVOLTAIC CELL MODELING Cont…

Calculation of α

$$\alpha_{ref} = \frac{2U_{mp,ref} - U_{oc,ref}}{\frac{I_{sc,ref}}{I_{sc,ref} - I_{mp,ref}} + \ln\left(1 - \frac{I_{mp,ref}}{I_{sc,ref}}\right)}$$

Where

$U_{mp,ref}$ = Maximum power point voltage at the reference condition (V)

$I_{mp,ref}$ = Maximum power point current at the reference condition (A)

$I_{sc,ref}$ = Short circuit current at the reference condition (A)

α is a function of temperature, which is expressed as

$$\alpha = \frac{T_c + 273}{T_{c,ref} + 273}\alpha_{ref}$$

PHOTOVOLTAIC CELL MODELING Cont…

Calculation of Series Resistance R_s

Some manufactures provide value of R_s, if they do not provide
It can be calculated as follows

$$R_s = \frac{\alpha_{ref} \ln\left(1 - \frac{I_{mp,ref}}{I_{sc,ref}}\right) + U_{oc,ref} - U_{mp,ref}}{I_{mp,ref}}$$

R_s is taken as constant here

Thermal Model of Photovoltaic cell

$$C_{pv}\frac{dT_c}{dt} = k_{in,pv}\phi - \frac{U \text{ x } I}{A} - K_{loss}(T_c - T_a)$$

C_{pv} = The oveall heat capacity per unit area of the PV cell/Modul e $[J/(^0c.m^2)]$

$K_{in,pv}$ = Transmitta nce absorbtion product of PV cells

k_{loss} = Overall heat loss coefficien t$[W/(^0c.m^2)]$

T_a = Ambient te mperature(^0c)

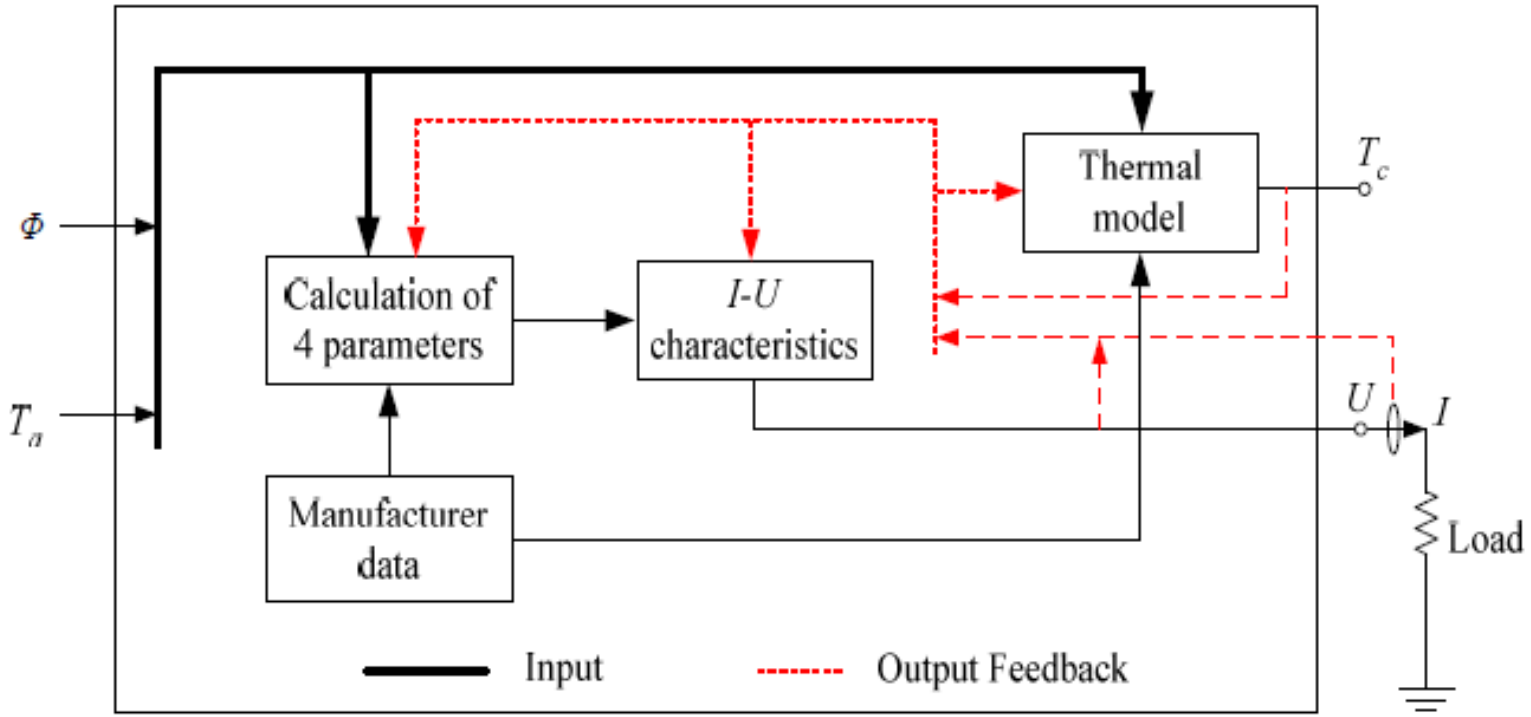
A = Effective area of the PVcell/ Module(m^2)

PHOTOVOLTAIC CELL MODEL PARAMETERS

$I_{L,ref}(I_{SC,ref})$	2.664 A
α_{ref}	5.472 V
R_s	1.324 Ω
$U_{oc,ref}$	87.72 V
$U_{mp,ref}$	70.731 V
$I_{mp,ref}$	2.448 A
Φ_{ref}	1000 W/m^2
$T_{c,ref}$	25^{0}c

C_{PV}	5 X 10^4 J/ (^{0}c.m^2)
A	1.5m^2
$K_{in,pv}$	0.9
K_{loss}	30 W/ (^{0}c.m^2)

PHOTOVOLTAIC CELL MODEL IN MATLAB/SIMULINK



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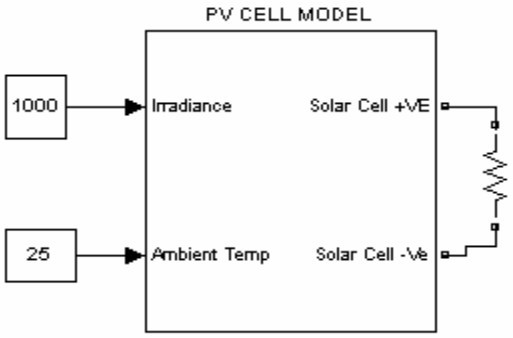
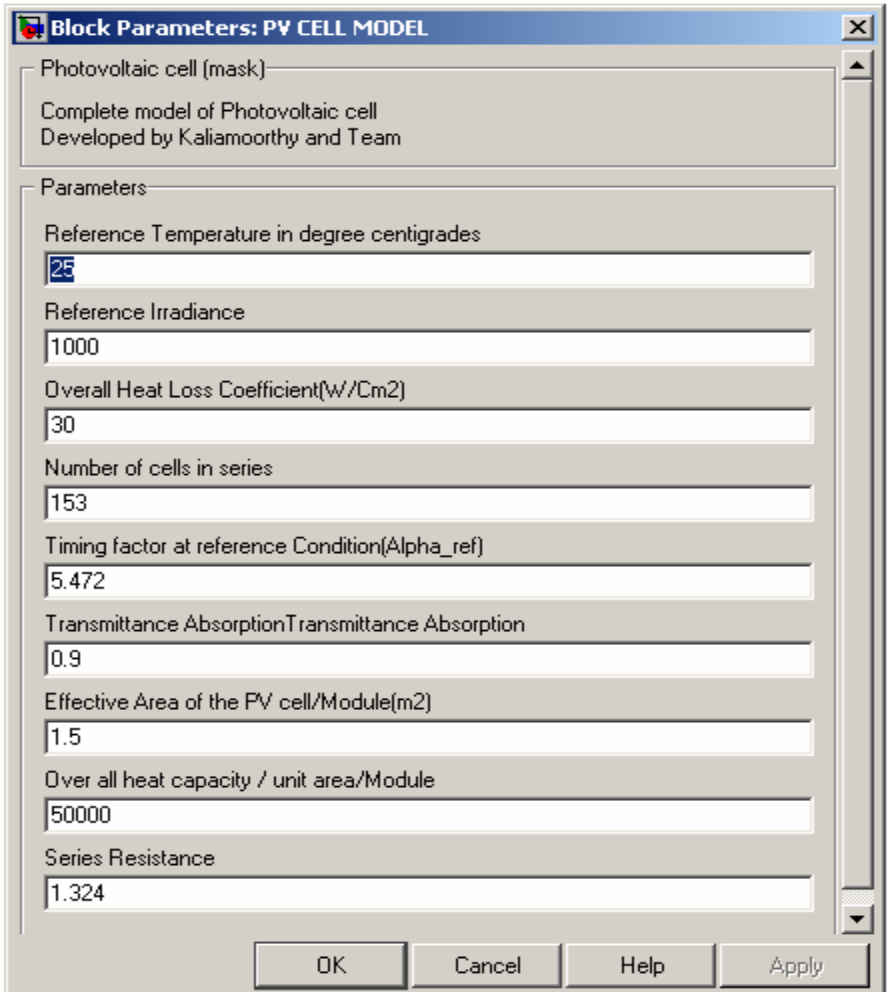
PHOTOVOLTAIC CELL MODEL IN MATLAB/SIMULINK





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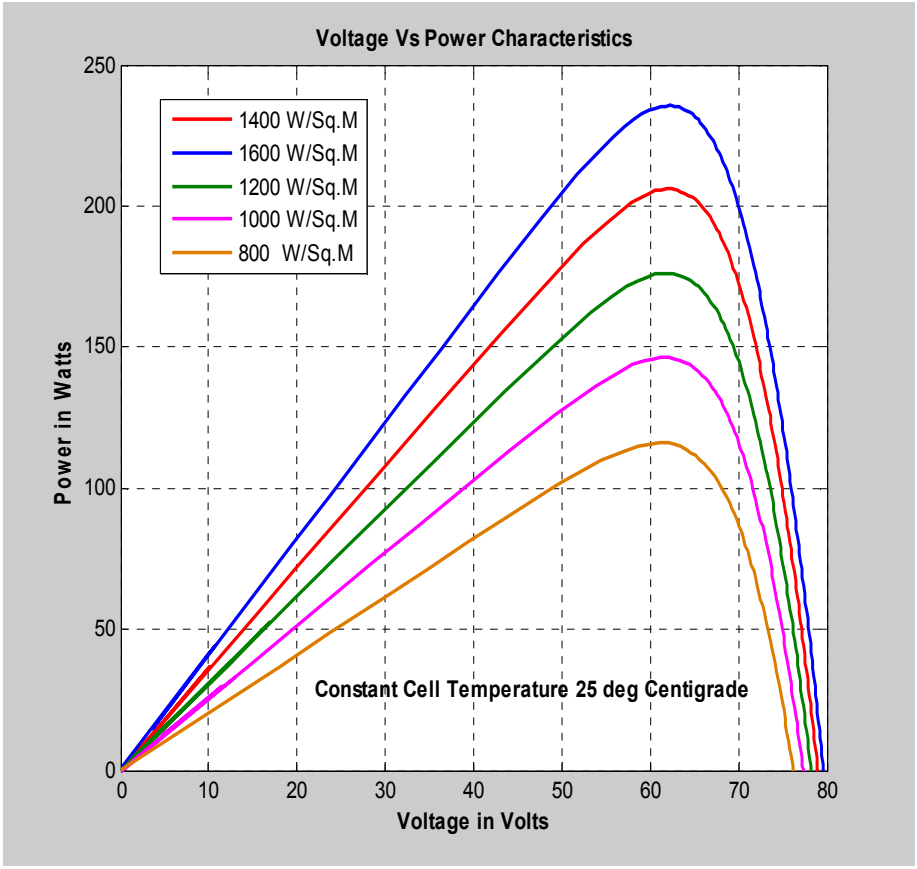
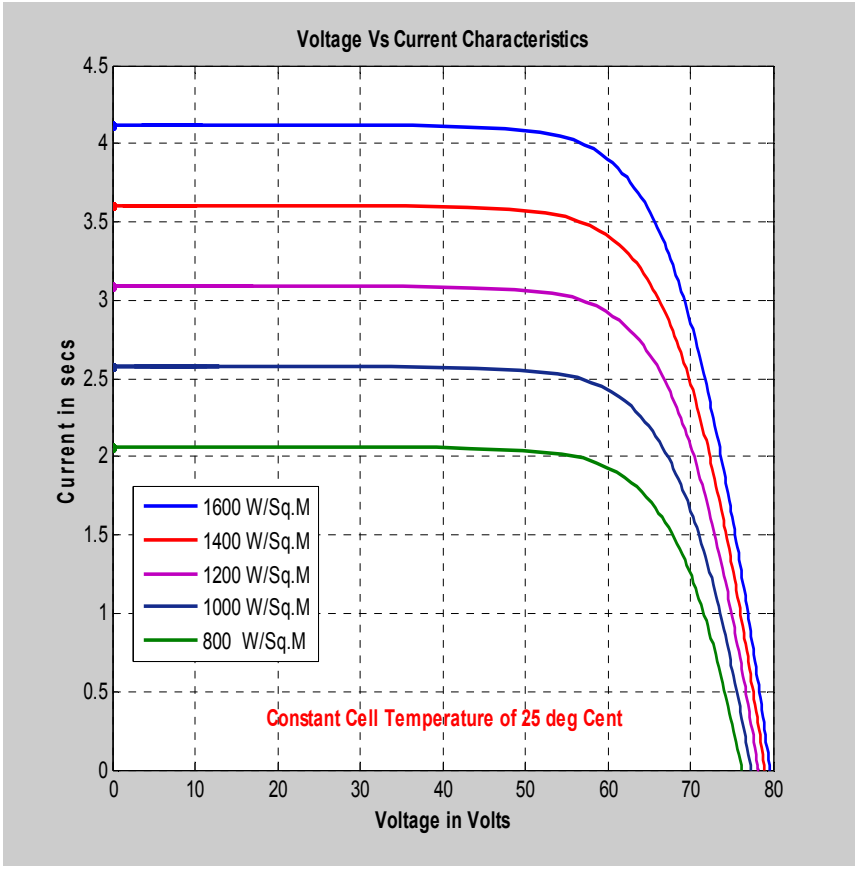
CHARACTERISTICS OF PV CELL AT CONSTANT CELL TEMPERATURE





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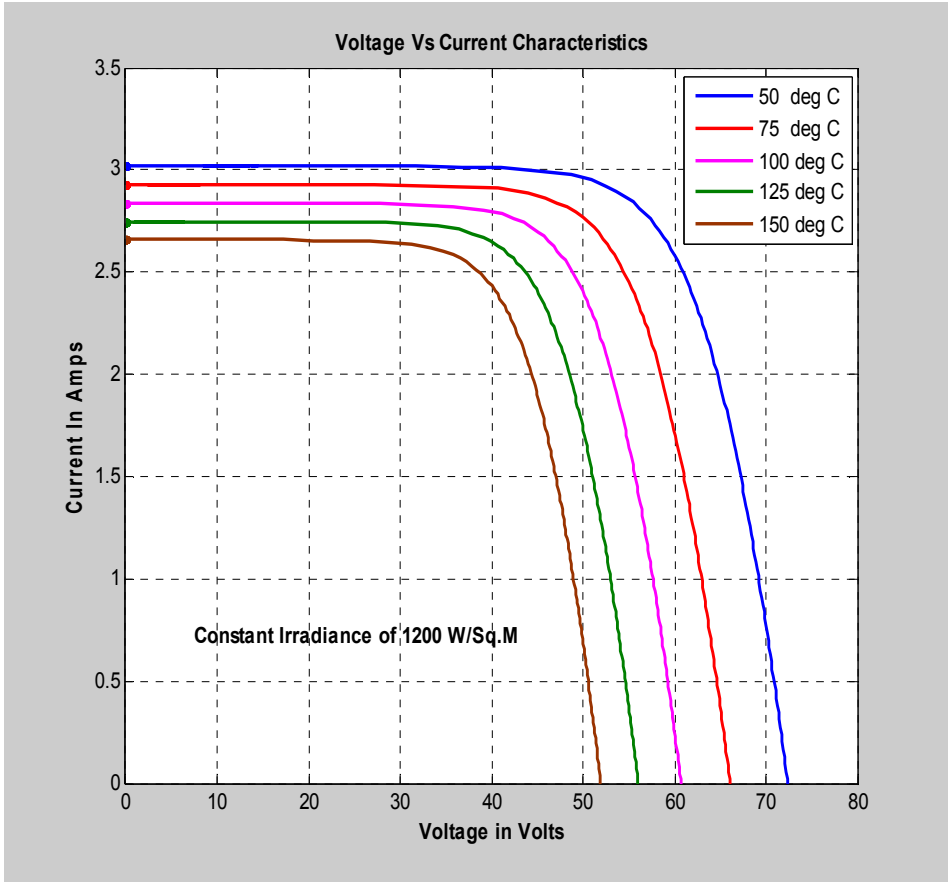
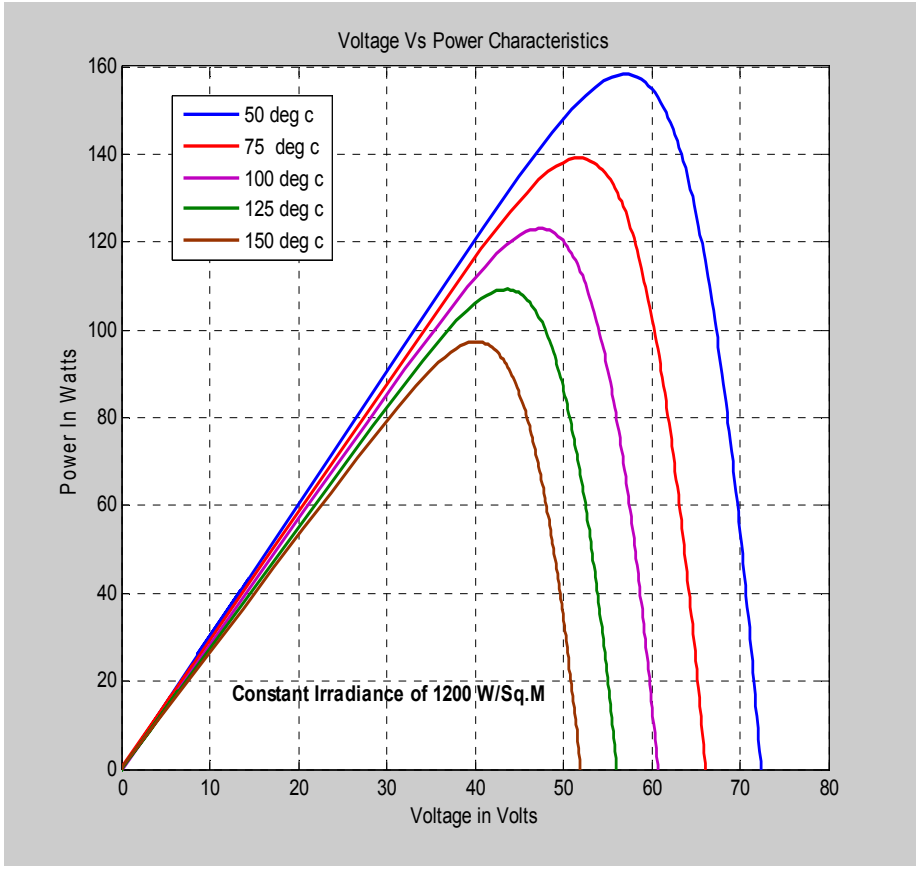
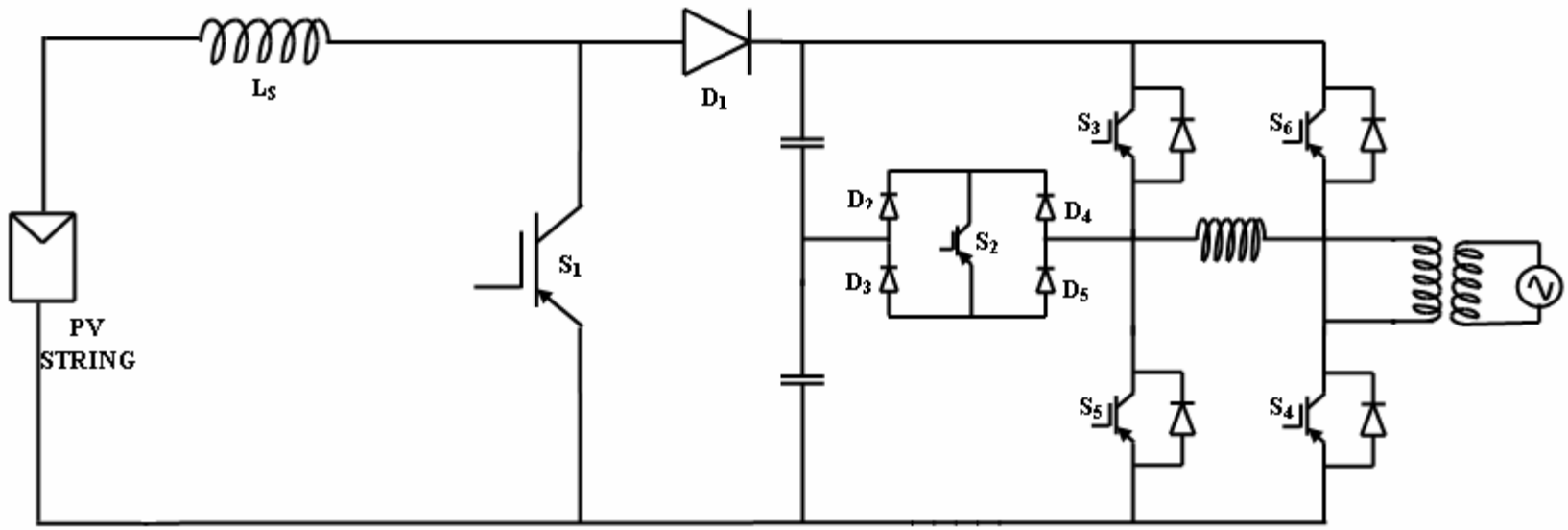
CHARACTERISTICS OF PV CELL AT CONSTANT IRRADIANCE

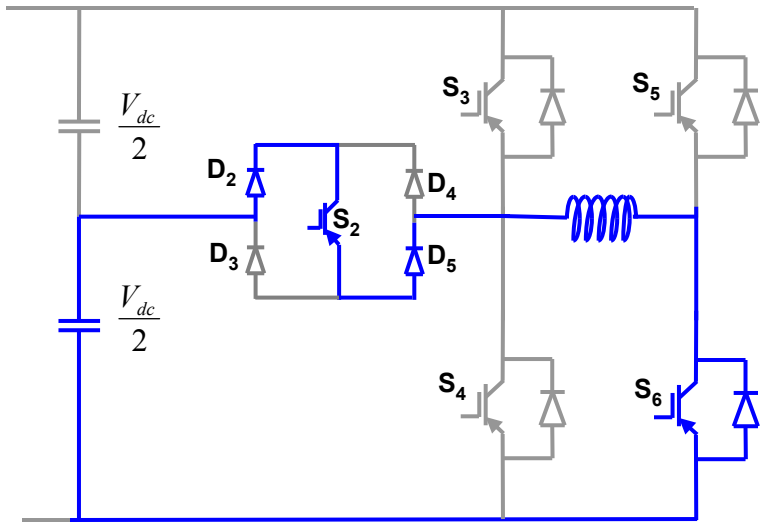


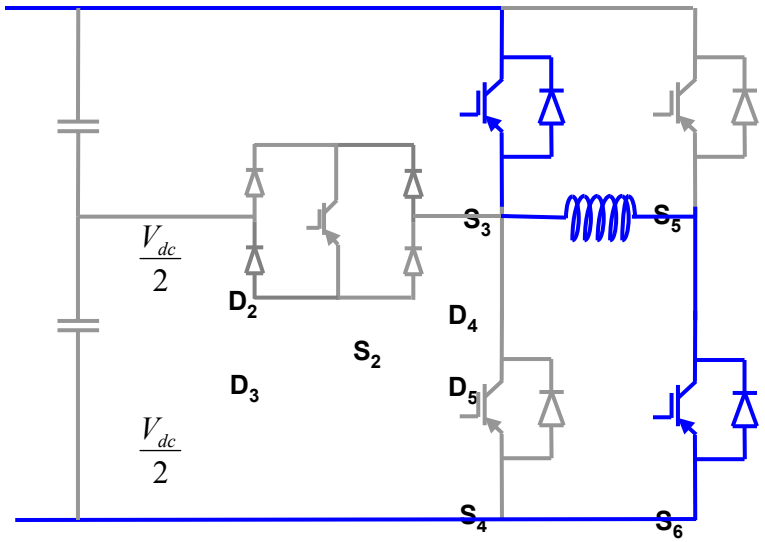


New PV fed Multilevel Inverter



Operation of Five Level Inverter with Auxiliary Switch





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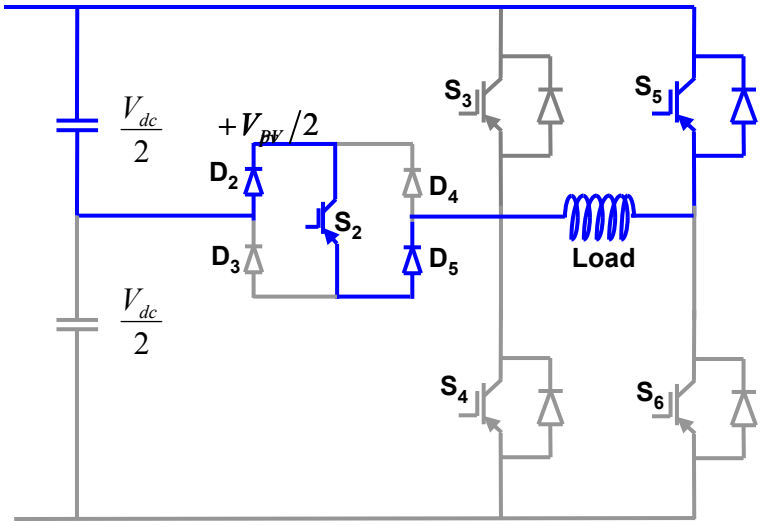
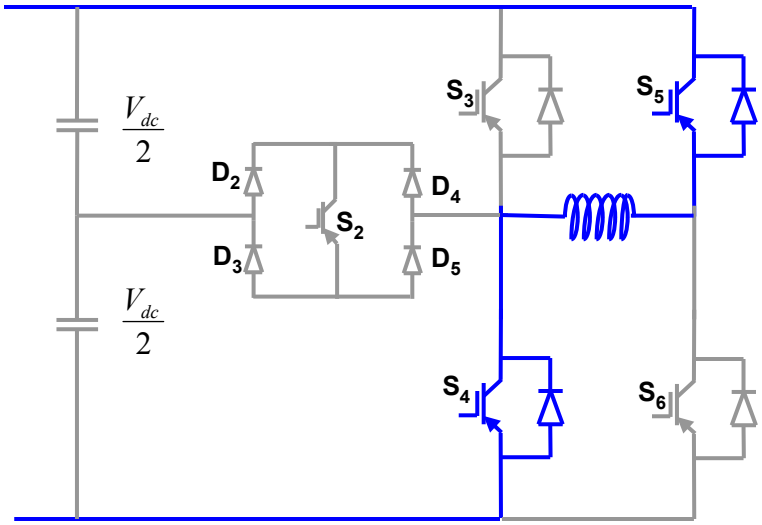
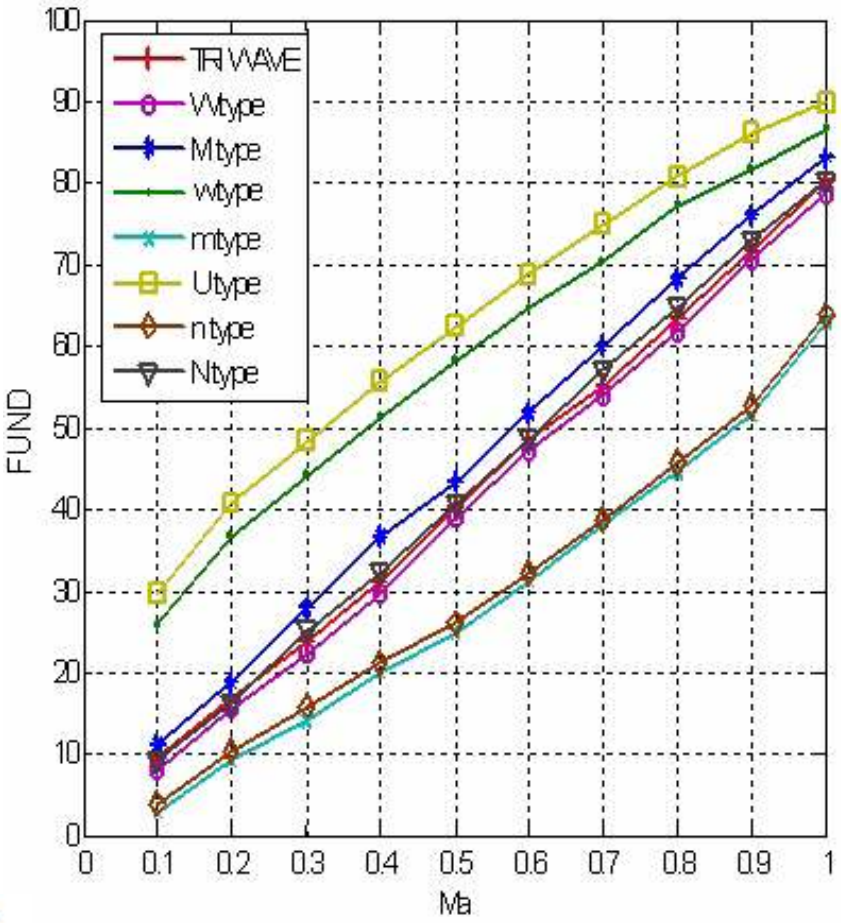
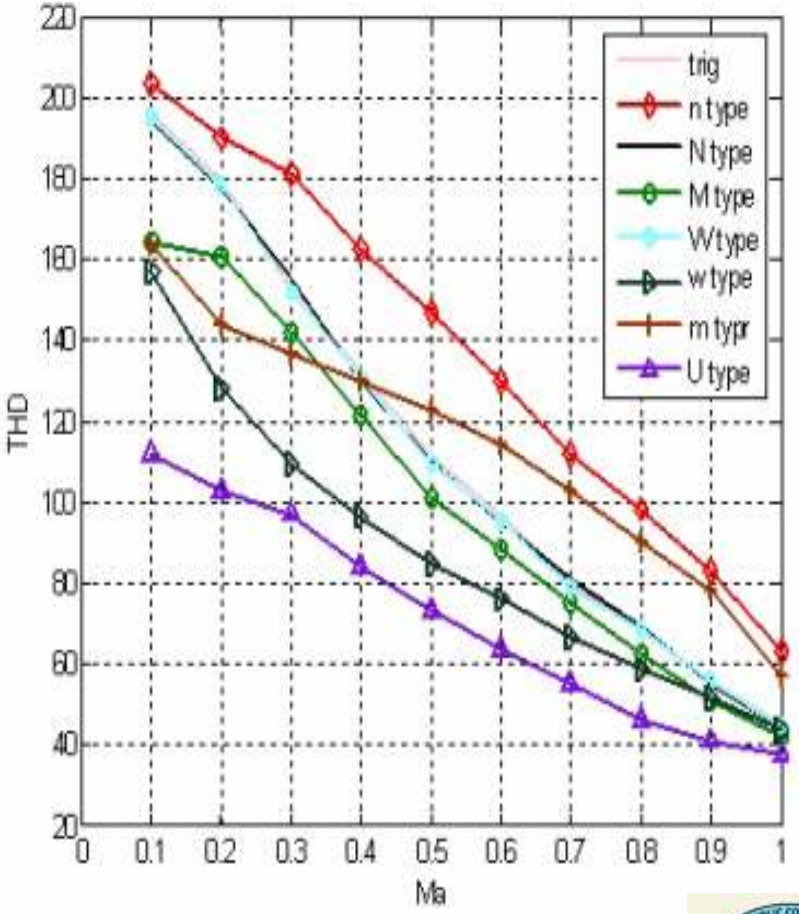




S_2	S_3	S_4	S_5	S_6	V_{inv}
ON	OFF	OFF	OFF	ON	$+V_{pv}/2$
OFF	ON	OFF	OFF	ON	$+V_{pv}$
OFF	OFF or (ON)	OFF or (ON)	ON or (OFF)	ON or (OFF)	0
ON	OFF	OFF	ON	OFF	$-V_{pv}/2$
OFF	OFF	ON	ON	OFF	$-V_{pv}$

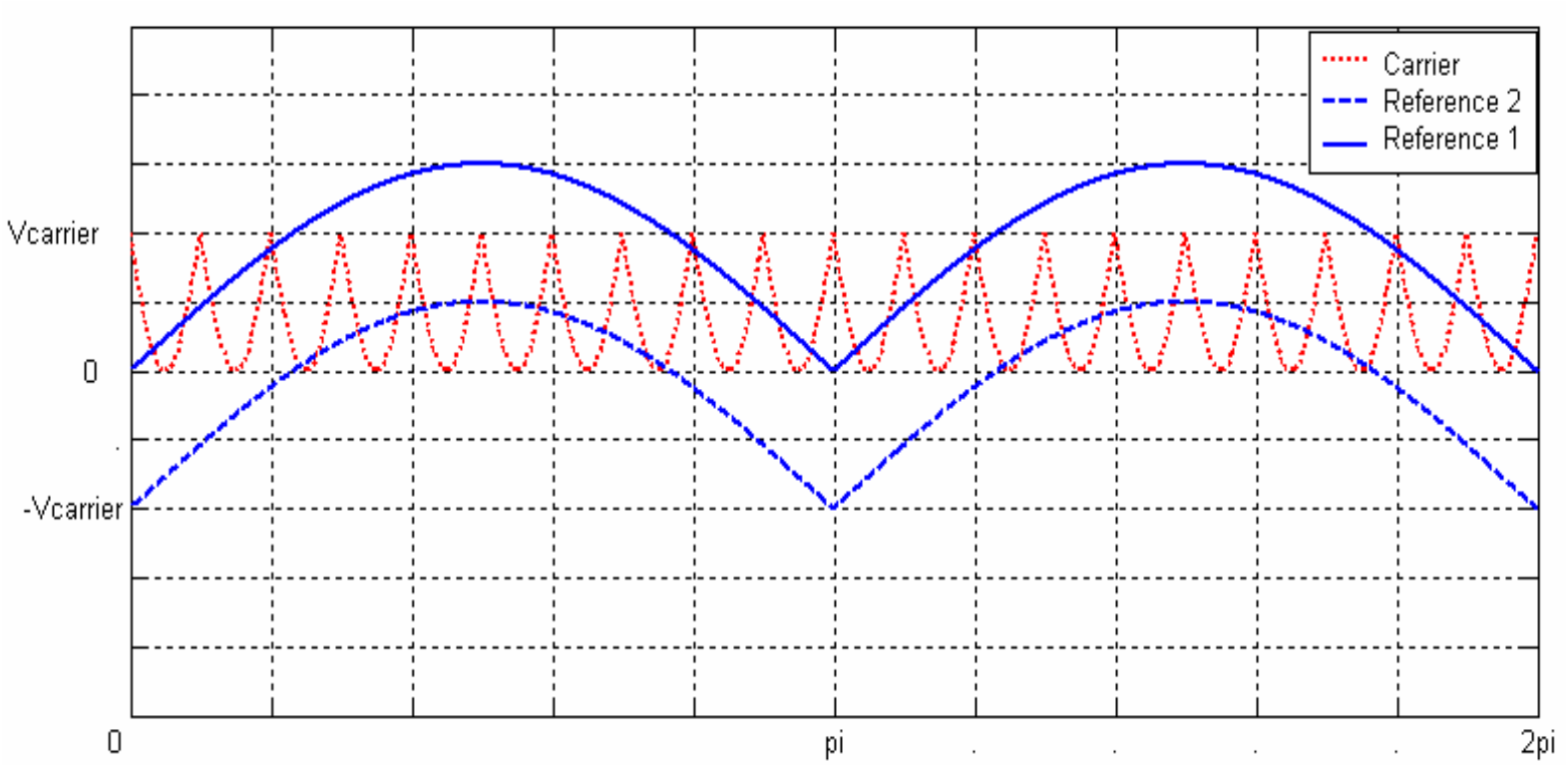
Comparison of Different Carrier Waves





One can never consent to creep when one feels an impulse to soar – Electromagnetism –Maxwell-1865

New Five Level Inverter with Auxiliary Switch- A dual Reference Modulation Technique



PWM Strategy and Operating Principle

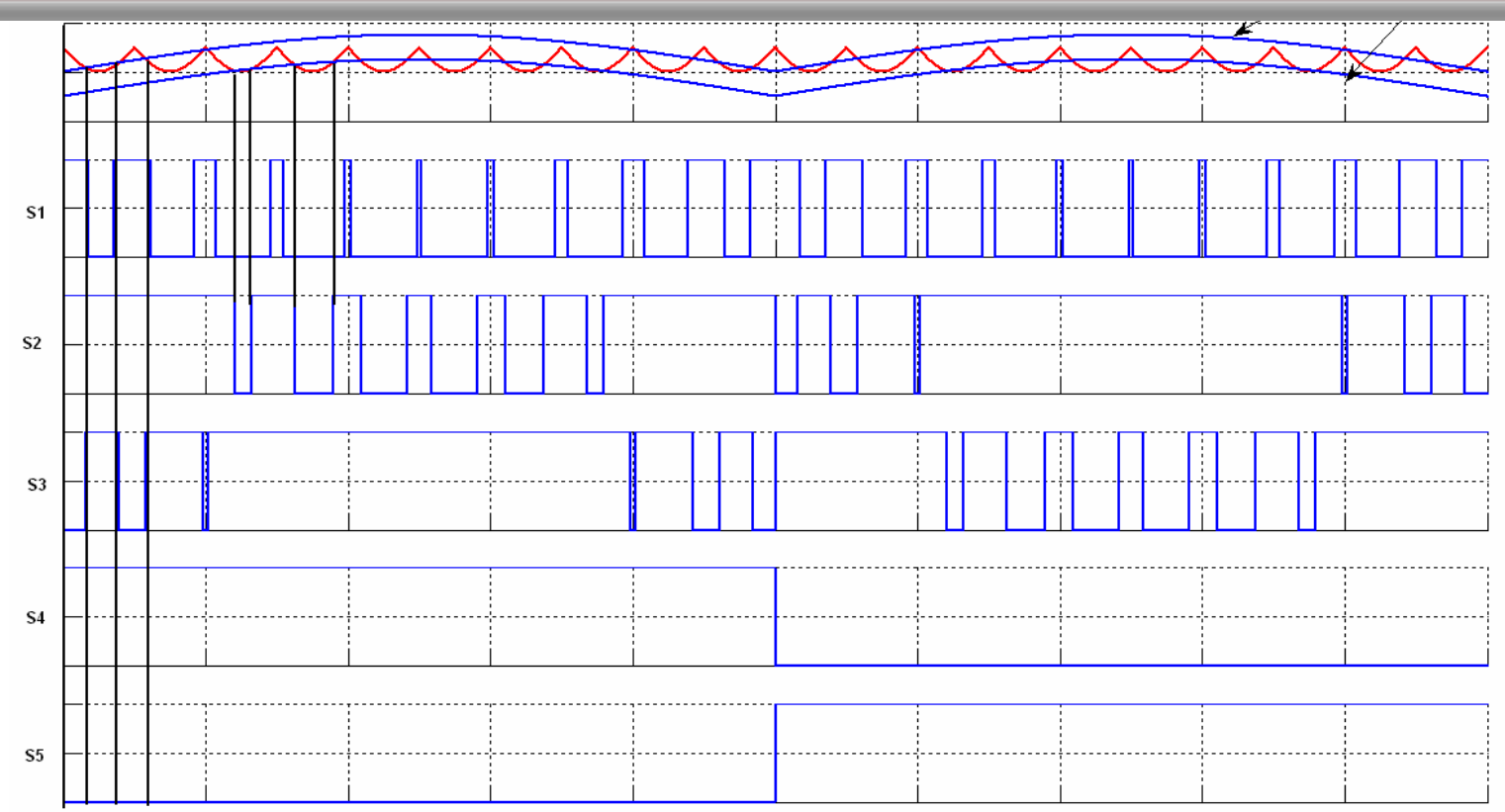
Modulation index Ma for five-level PWM inverter is given as

$$M_a = \frac{A_m}{2A_c}$$

Where Ac is the peak-to-peak value of carrier and Am is the peak value of voltage reference V_{ref}. Since in this work two reference signals identical to each other are used, above equation can be expressed in terms of amplitude of carrier signal V_c by replacing A_c with V_c and $A_m=V_{ref1}=V_{ref2}=V_{ref}$

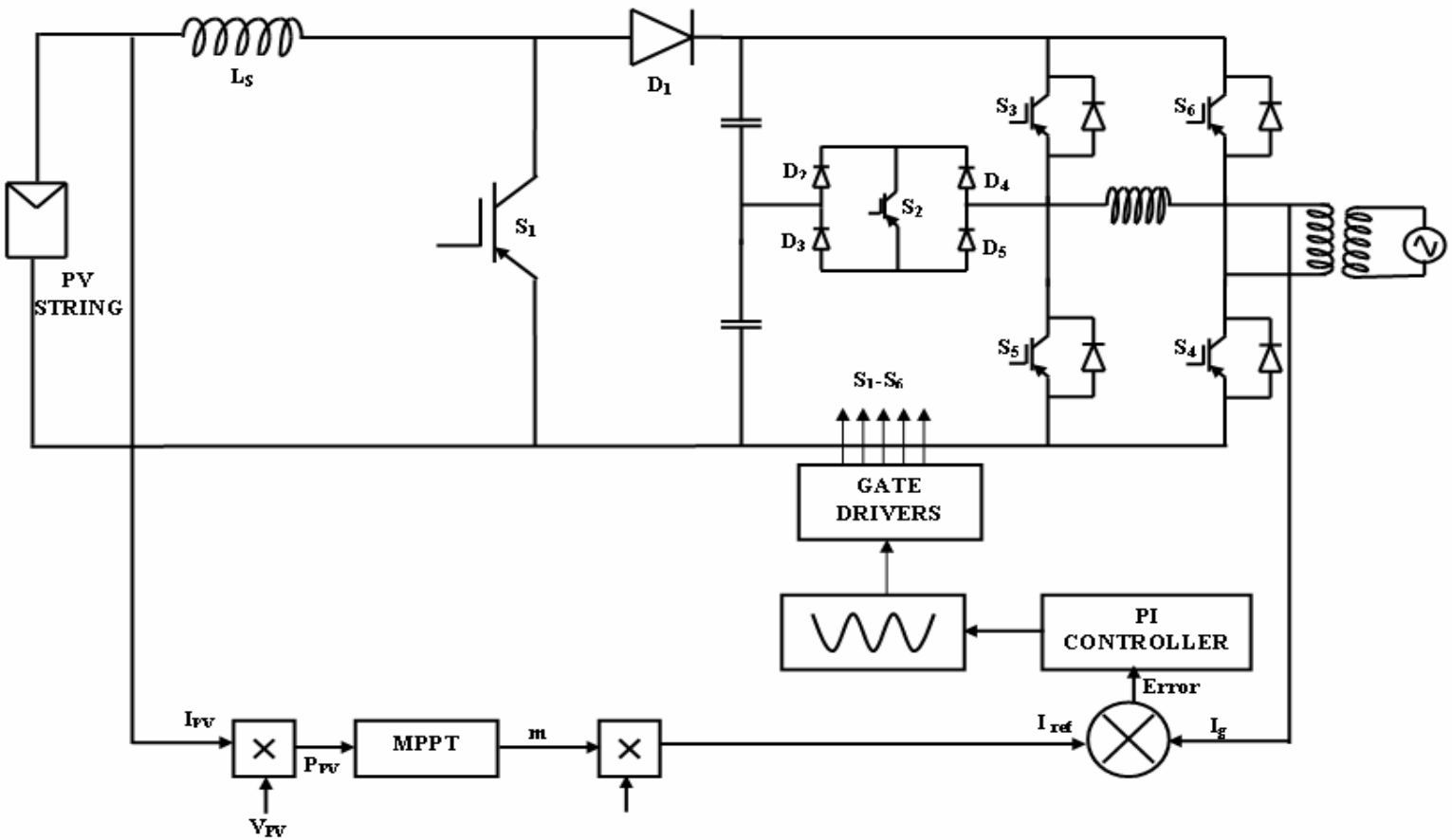
$$M = \frac{V_{ref}}{2V_c}$$

PWM Strategy and Operating Principle

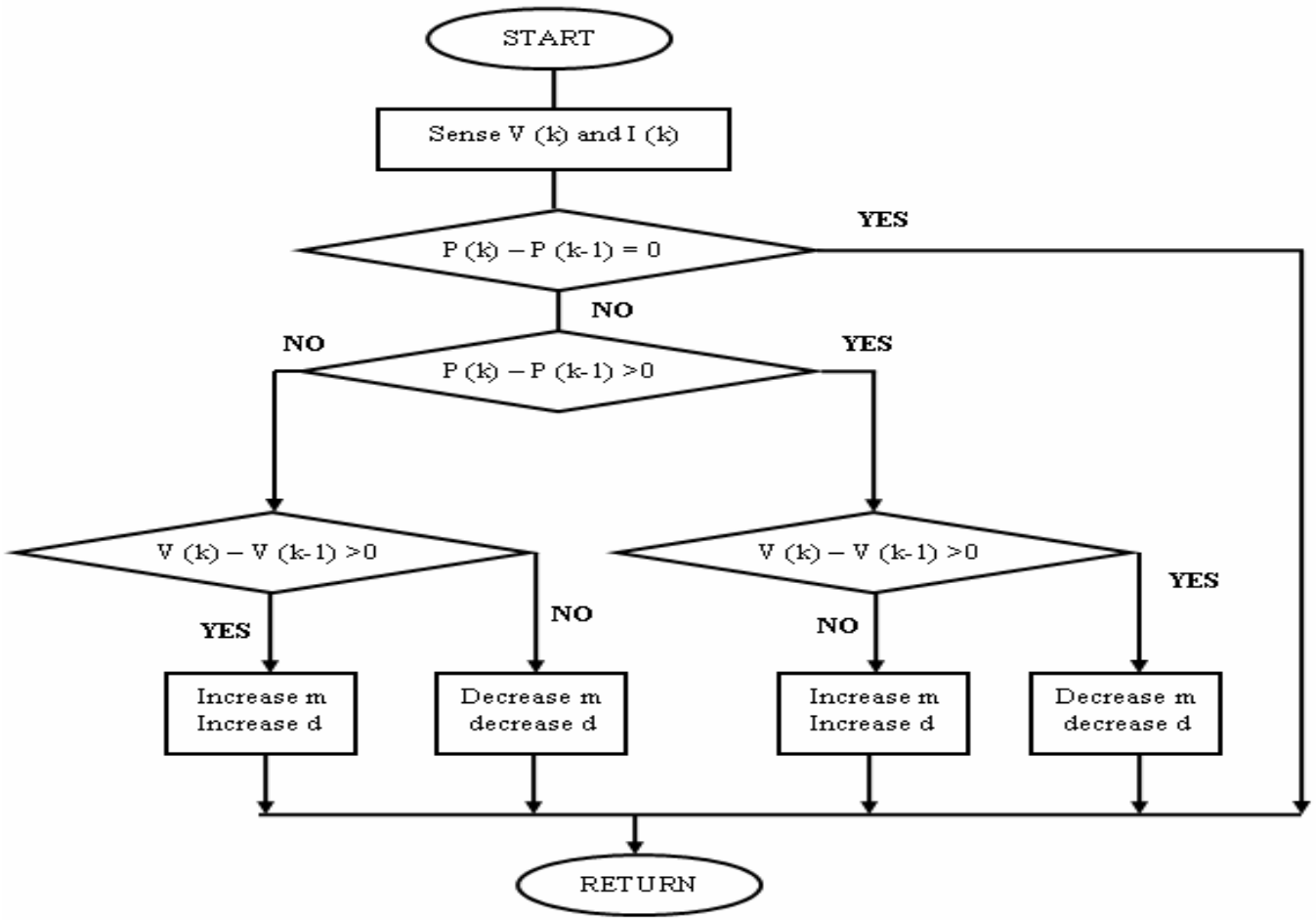


Switches S2–S4 will be switching at the rate of the carrier signal frequency, while S5 and S6 will operate at a frequency equivalent to the fundamental frequency.

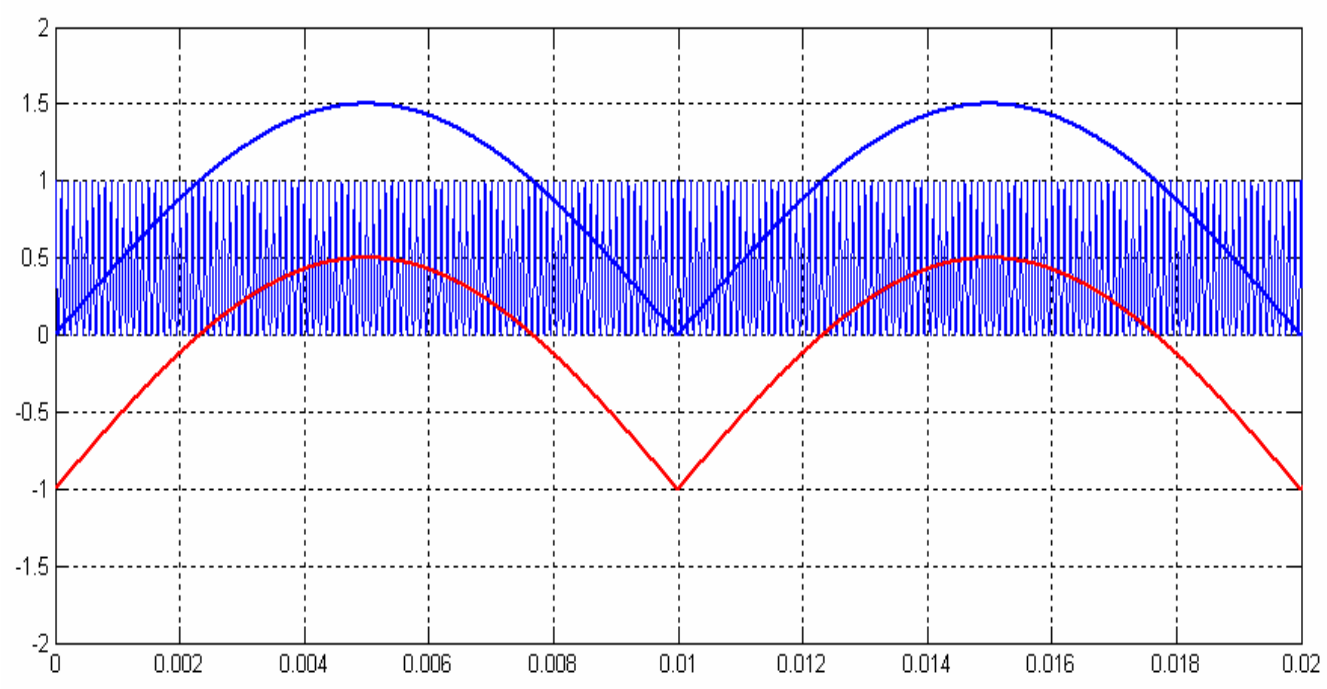
CLOSED LOOP CONTROL SYSTEM



Maximum Power Point Algorithm

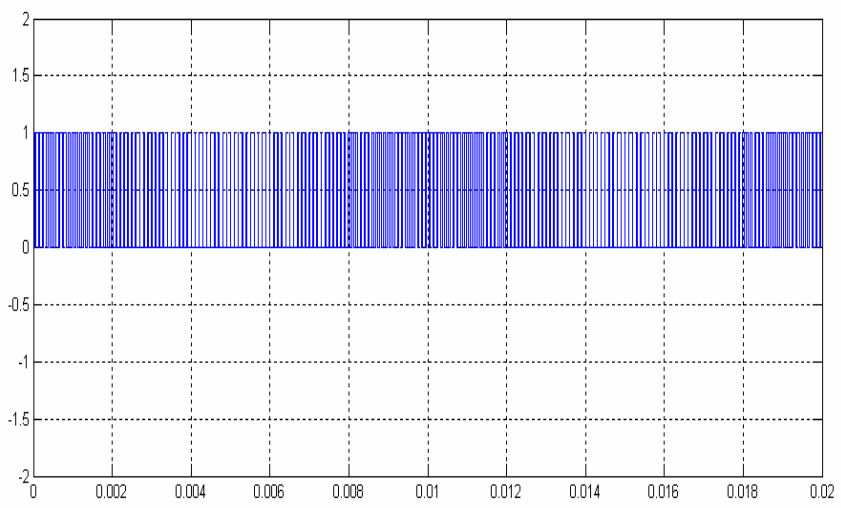


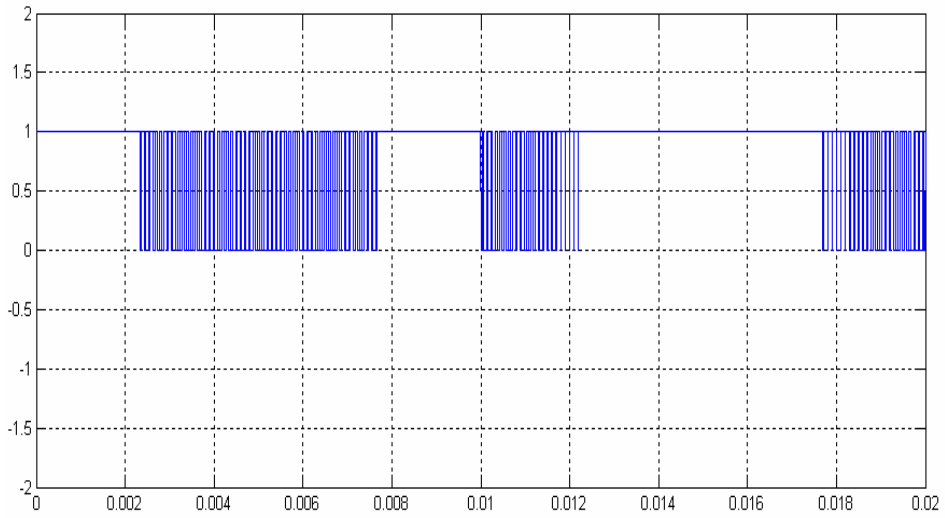
SIMULATION RESULTS



Dual Reference and Carrier Comparison

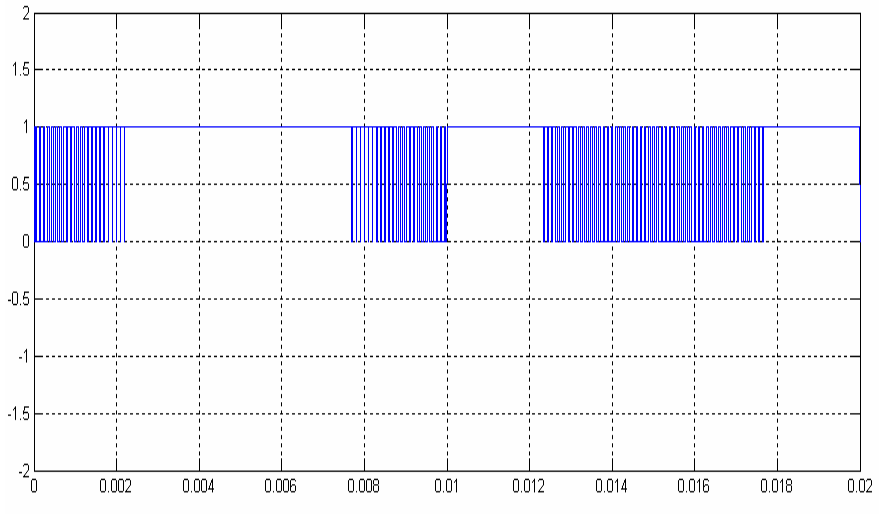
SIMULATION RESULTS

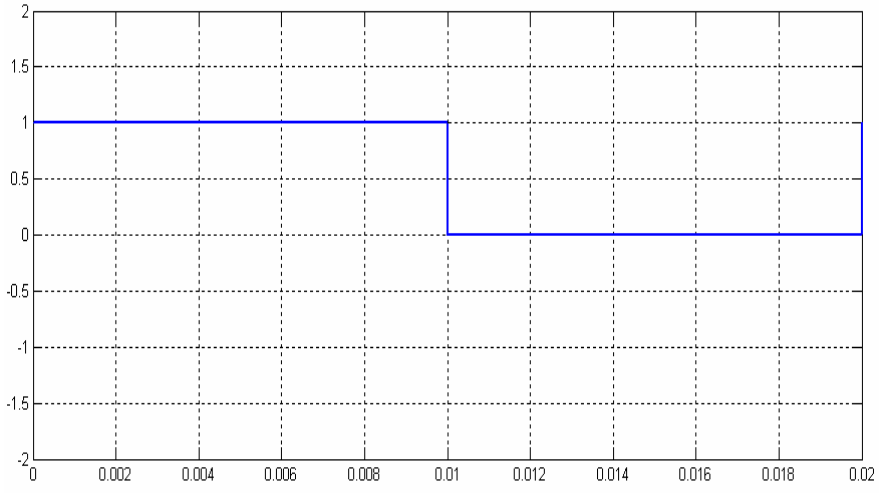




Switching Signals to S2 and S3

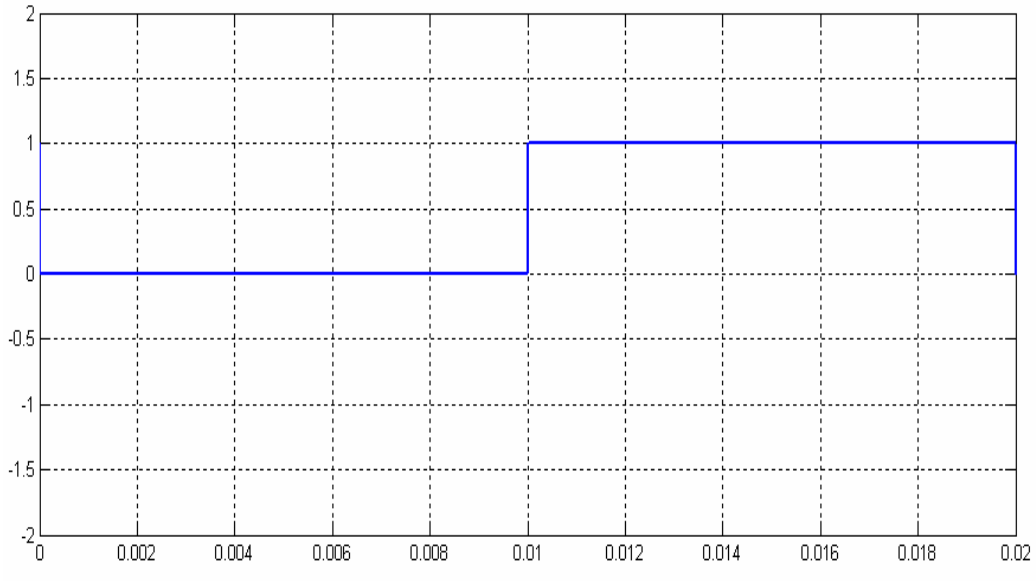
SIMULATION RESULTS





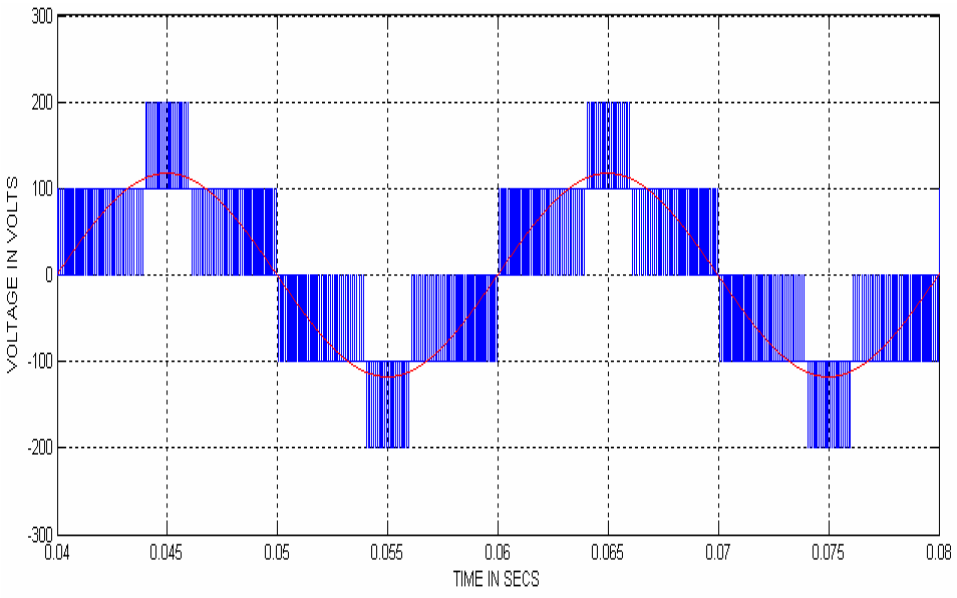
Switching Signals to S4 and S5

SIMULATION RESULTS

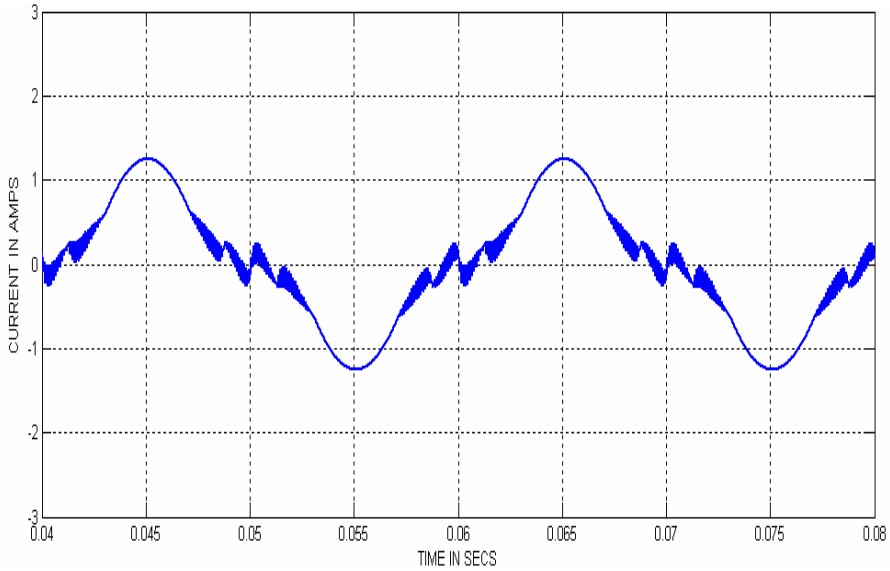


Switching Signals to S6

SIMULATION RESULTS

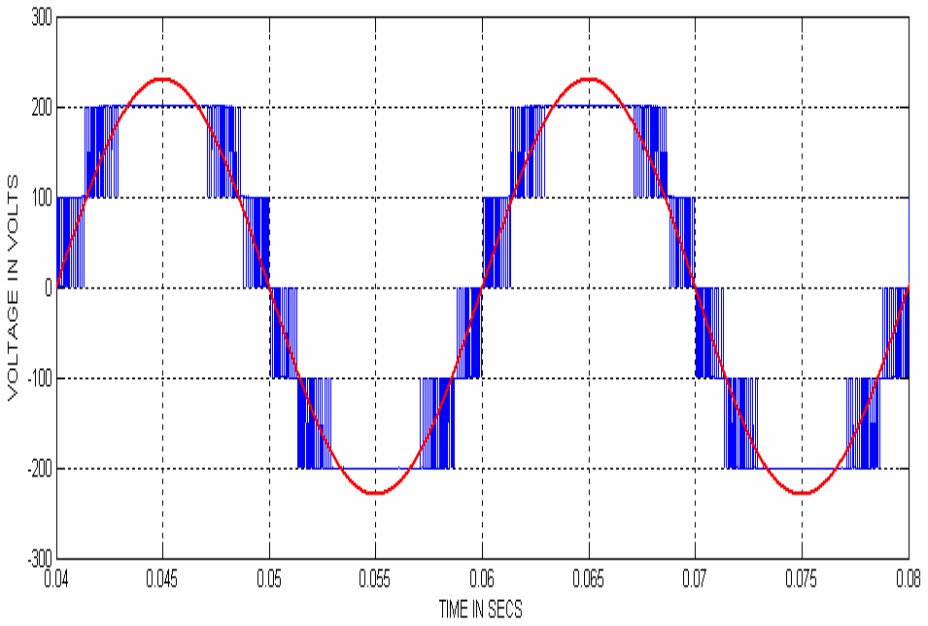


OUTPUT VOLTAGE WITH M ,D < 0.5

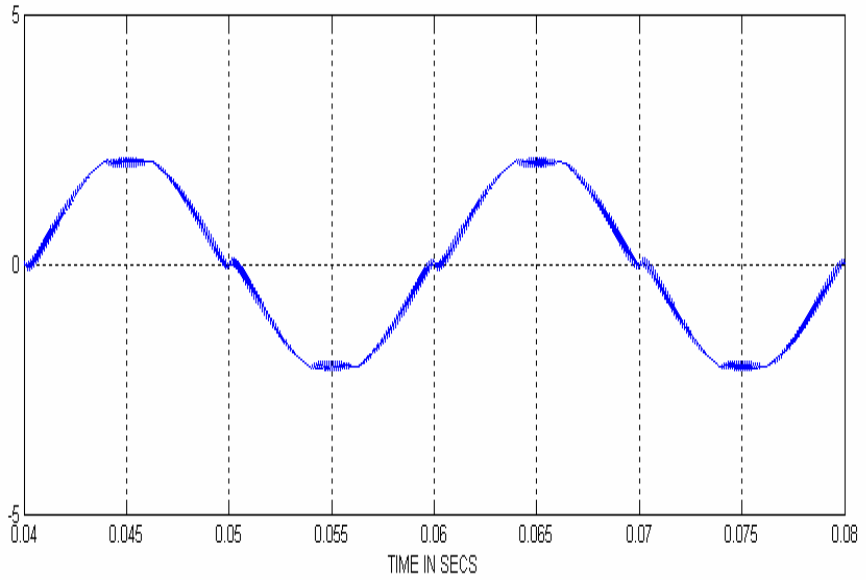


INVETER CURRENT WITH M ,D < 0.5

SIMULATION RESULTS

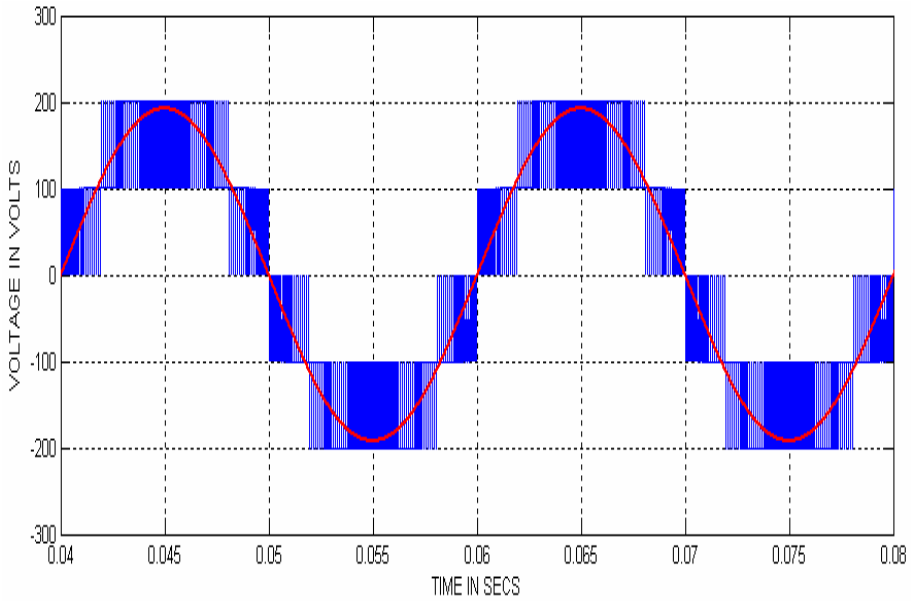


OUTPUT VOLTAGE AND ITS FUNDAMENTAL WITH M ,D > 1.0

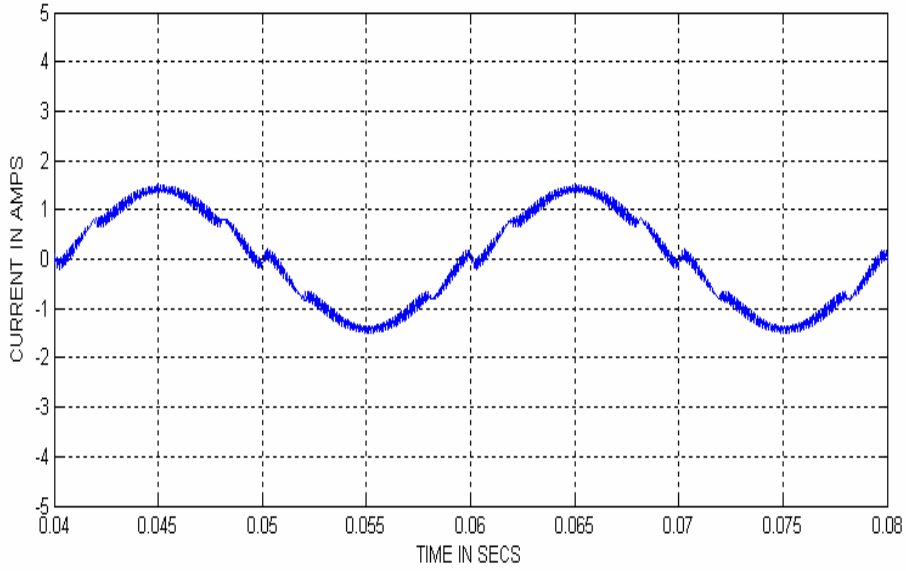


INVETER CURRENT WITH M ,D > 1.0

SIMULATION RESULTS

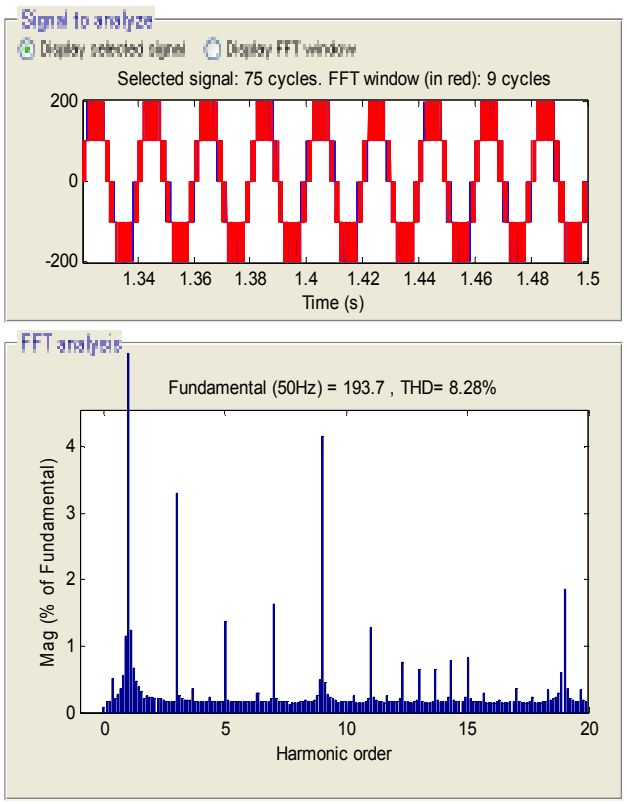


OUTPUT VOLTAGE AND ITS FUNDAMENTAL WITH 0.5 <M ,D > 1.0

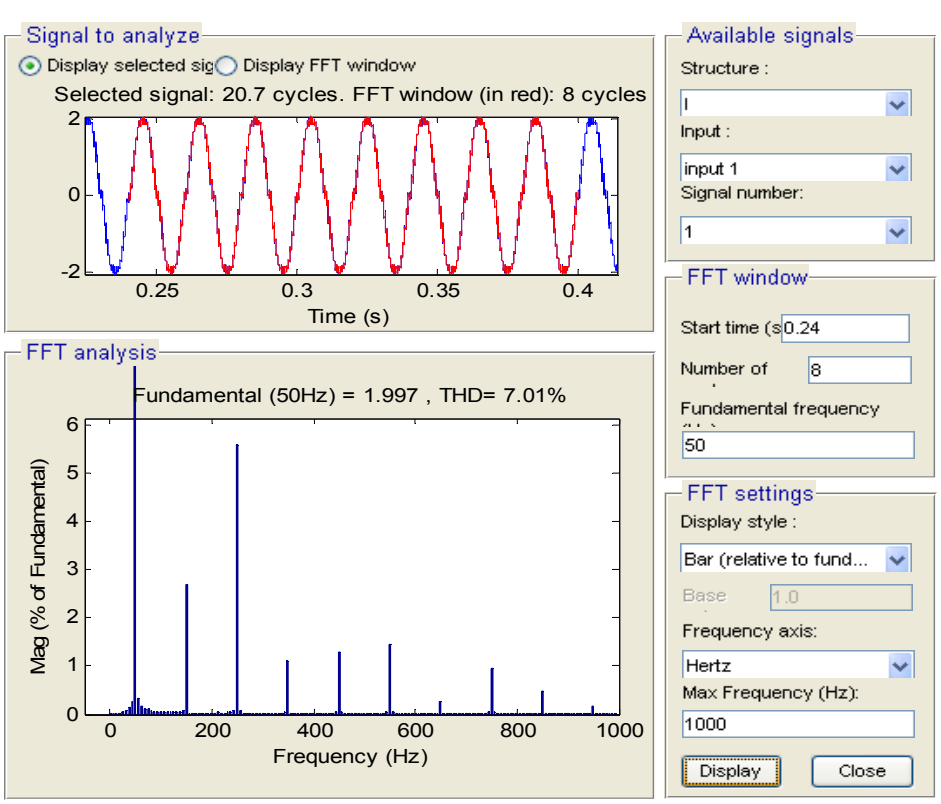


INVETER CURRENT WITH M ,D > 1.0

SIMULATION RESULTS



Harmonic Spectrum of Voltage With 0.5 <M ,D > 1.0 With out filters



Harmonic Spectrum of Current With 0.5 <M ,D > 1.0 Without filters

No one can make you feel inferior without your consent –Regenerative Circuit-Edwin Armstrong-1914

CONCLUSION

This paper presented a single-phase five-level inverter with a dual reference modulation technique for PV application. The dual reference modulation technique involves comparing two reference signals identical to each other except for an offset equivalent to its carrier signal, with a rectified inverted sine carrier signal to generate PWM switching signals for the switches. The circuit topology, control algorithm and operational principle of the proposed inverter were analyzed in detail. The results show that the THD of the five-level inverter is much less than that of the conventional three-level inverter. Furthermore, both the grid voltage and the grid current are in phase at near unity power factor.

Thank You