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# An Interleaved High-Power FlybackInverter for Photovoltaic Application

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***Abstract*—Thispaper presents analysis,design, and implementation ofan isolated grid-connected inverterfor photovoltaic(PV)applications basedon interleavedflybackconverter topologyoperatingin discontinuouscurrentmode (DCM).The primary objectiveofthisstudyistodesigntheflybackconverterathigh power anddemonstrateitspracticality with goodperformanceas acentraltypePV inverter.Forthispurpose,aninvertersystem rated at2kWisdevelopedbyinterleavingofonlythreeflybackcells with addedbenefitof reducedsizeofpassivefiltering elements. The efficiency of this system is better as compared to the earlier system. This paper also give an optimum strategy for the interleaved flyback inverter to improve the efficiency over wide operating range .**

***KeyWords*—- Flybackconverter,harmonics,interleaved converters,photovoltaic inverters**

## I.Introduction

Solar energy is considered as one of the most renewableandfreelyavailablesourceofenergyandthe candidatetoplayagreaterroleintheenergymarketofthe world in the near future. Therefore,theprimary objectiveofthestudypresentedinthis paperistocontributetotheresearchanddevelopmentinthe photovoltaic inverter technology with the help ogflyback inverter athighpower .Theflyback converterisisthelowestcostconverteramongthe isolatedtopologies sinceitusestheleastnumberof components.In othertype of isolated topologies, the energystorageinductorandthetransformer areseparate elements.But the combinationof thesetwocomponents inaflybacktopology makes cost effective and reduction in the size of wholw circuit.Forthis reason,aswetrytoachievethehigh-power implementation oftheflybackconverterwithgood performance,whichisourprimary researchcontribution, we willalsotrytopreservethecostadvantage during thefinal implementationstage.

Practicalimplementationofatransformer with relatively largeenergystoragecapability isalwaysachallenge.Theair gapiswheretheenergyisstored,soahigh-power flyback converterdesign needsarelativelylargeairgap which is imporatant part of the scheme design.A flybackconverter builtwith a transformer that has large leakagefluxandpoorcoupling willhavepoorenergy transfer efficiency. Mainlyforthisreason,theflyback convertersare generallynotdesignedforhigh power.Asaresult, theflyback topologyfindsalimitedroleinphotovoltaic applicationsonly atverylowpowerasamicroinverter.

## II.PROPOSED SYSTEM

Fig.1 showsthe blockdiagram oftheproposedinverter system.Theresultsof anearlierwork based onthesametopologywhere theprimary objective wasto provetheconceptwithadesignat1kWwere presentedin.Since thetime ofthatwork, therehavebeen majordesignchangesandupgrades inordertoprocesstwice morepowerandatthesametoachieve betteroverall performance.

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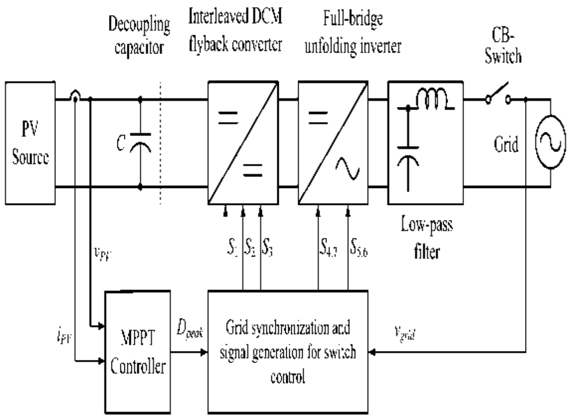


**Figure1**Blockdiagramoftheproposedgrid-connectedPVinvertersystem based oninterleavedDCMflybackconverter topology.

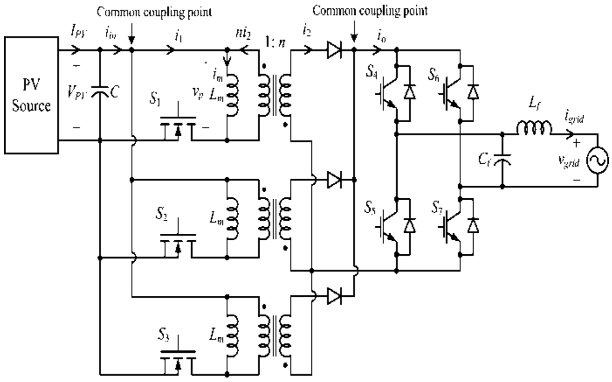


**Figure2** CircuitschematicoftheproposedPV inverter system basedonthree-cellinterleavedflybackconverter topology

Asmentioned before,thechoiceofoperationmodeforthe converterisDCM.Thefundamentalmotivations forselecting DCMoperationare summarizedbelow.

1) It provides dynamic response and stability for all the operating condition under consideration.

2) No reverse recovery problem.The diodes exhibits reverse recovery problem in CCM operation which causes noise. So this operation eliminates all complications.

3)Noturnonlosses.

4)Smallsizeofthetransformer.

5)Easy control.No needfor a feedback loop for the control of thegrid current.Onlyanopenloopcontrol is enough to synthesizea sinusoidalcurrent with good THD. This makes the implementationof the controlsystem less complex for DSP andallows faster executiontime

Contrary totheaforementioned greatbenefitsoftheDCM operation,ithasseveraldisadvantagesaswell. Inthismodeof operation, thecurrent waveforms have higher form factor (highRMStomeanratio)comparedtocontinuous current mode(CCM).Thisnormallyleadstomorepowerlosses.So, asasolution, everycurrentcarrying pathincluding the switching devicesshouldhavelowresistivity.Another drawback ofDCMoperation isthecurrentpulseswithlarge peaksandhighamountofdiscontinuityinthe waveforms. Deviceparalleling isawaytohandlethehighpeak currents. Nevertheless,thesedisadvantagescanbeconsiderablyreduced byinterleavingofseveralcells.Asafirstbenefit,thecurrent ineachcellwillhavemuch less peak butthesameamount of discontinuity. However,thediscontinuity willbesignificantly reducedassoonasthecells connectatthecommon point.All thisbenefitscomefrom theability ofphase-shifted several cellsspreadingthepowerflowevenlyovertheswitchingcycle withminimum discontinuity atthesourceandgridside.In brief,theeffective interleaving hasthepotentialtosolveor greatly reducetheadverse effectsoftheDCMoperation [21]. Consequently,the circuitdiagramofthe proposedinverter systembasedonthree-cellinterleavedDCMflybackconverter topology is shown below

## III.CONVERTERDESCRIPTION

As showninFig.2,thePVsource isapplied toathree-cell interleavedflybackconverterthroughadecoupling capacitor. Eachflyback converter usesametal–oxide–semiconductor field-effect transistor(MOSFET)forswitching attheprimary side,aflybacktransformer, andadiodeatthesecondaryside. Thetopology alsohastoemployafull-bridge inverter anda low-passfilterforproperinterface tothegrid.When the flybackswitches( s1,s2,s3)areturnedon,acurrentflows from thecommon point(thePVsource)intothemagnetizing inductanceoftheflybacktransformers,andenergyisstoredin theformofmagnetic field.Duringthe ontimeoftheswitches, no currentflows to the outputdue to the positionof the secondaryside diodes;therefore,energytothegrid issupplied bythecapacitor andtheinductor .Whentheflybackswitches areturnedoff,theenergy storedinthemagnetizing inductances istransferredintothegridintheformofcurrent. So,theflybackinverteractslikeavoltage-controlled current source. The converteris operated in DCM for easy and stable generation ofACcurrentsatthegridinterface. TheDCM operation ofconverterunderopen-loopcontrolproduces triangularcurrentpulsesatevery switching period. If sinusoidal PWMmethodisusedforcontrol,theinverterwill regulate thesecurrentpulsesintoasinusoidal current inphase withthegridvoltage.

Thefull-bridgeinverterisonlyresponsibleforunfolding thesinusoidallymodulatedDCcurrentpacksintoACatthe rightmoment ofthegridvoltage.Sincetheswitchesofthe inverter areoperated at the grid frequency, the switching losses areinsignificant.Onlyconductionlosses areconcerned.

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Forthisreason,thebridgecanusethyristororeventransistor switchesforlowercost.However,foreasycontrol alsothe availability inthelaboratoryforfastprototyping,weprefer using IGBTswitchesforthisdesign. But,thefinalprototype will not use IGBTs.

## IV. CONVERTERANALYSIS

Theanalysisoftheconverter isperformed basedonthe circuitschematicgiveninFig.2andonlyconsiders thefirst flybackcell. And it is done over one particularswitching periodwhenboththegridvoltageandthedutyratioareat their peak values. Later, the analysis results will be generalized toincludeallthecellsandextendedforthe operation oftheconverteroverafullgridperiod. Consequently, Fig.3showsthecontrolsignalfortheflybackswitch,flybacktransformer primaryvoltage(V p ),and magnetizationcurrent( Im) withitscomponents andover theselectedswitchingperiodwherethedutyratio isatits peak value.

Thecontrolsystemusedinthisdesigndoesnotemploy a feedback loopfortheregulation oftheoutputcurrent. Thereforethewaveform qualityofthegridcurrentisgreatly dependent onthequalityoftheDCvoltageattheflyback converter input,whichisalsothevoltageatthePVterminals. Forthatreason,arelativelyconstantDCvoltageisrequired forsynthesizingasinusoidal currentwithlowdistortionunder open-loopcontrol.Otherwise,somelowfrequency harmonics appearsatthe gridcurrentcausingincreasedTHD.Inaddition, therippleatthePVvoltage cancreateslightutilization losses atthePVpower asreportedin.So,low rippleisalso preferredforperfectutilizationofthe solarpower.Themain reasonthatcausesthevoltage ripple insingle- phasegrid-connectedPVinvertersisthedemandoftheload by the PV source to deliver fluctuating power with a magnitude twicethatoftheaveragepowerandafrequency twicethatofthegridfrequency

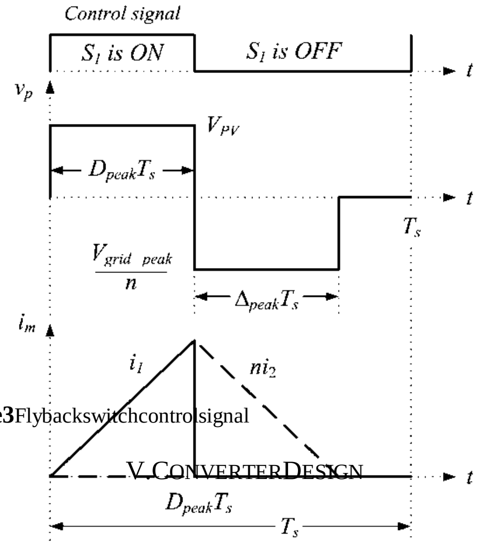


**Figure3**Flybackswitchcontrolsignal

## V.CONVERTERDESIGN

Since thedesignisintendedmainlyforsmallelectricpower systemsincluding residentialapplications, thepowerratingis selectedas2kW.TableIgivesthespecificationstobeused forthedesign oftheproposedinvertersystem.Theswitching frequency( )isselectedas40kHzinordertoachievehigh efficiency alongwithsmallersizedmagnetics. InDCM operation,theturnonswitchinglossesareeliminatedsincethe currentstartsfromzeroateveryswitching cycle,whichisan important advantage, butinreturn theswitchitselfwillface large peak current stress and associated high turn-off switching losses.So,thechoiceofswitching deviceshould havefastcurrentfalltimetoreducetheturn-offlosses. Forthisreason,weuseMOSFETastheflybackswitch.Duetoth efactthattheMOSFETs withlowvoltageratingshave muchloweron-stateresistance andmoreefficient as faras the conductionlossesareconcerned,wepreferlow voltagedesign. Ass,themaximum converter inputvoltage is108.5Vfortheselected PVmodule arrangement. Inaddition,theflyback switchesmayfacewith highvoltagestress during turn offduetotheleakage inductance oftheflybacktransformer. So,aclampand/ora snubbershouldbeemployedtokeeptheswitching transients withinthe safeoperatingarea (SOA)ofthe selecteddevices.

## VI. CONTROL SYSTEM DESIGN

Thecontrolsystemisdesignedtoperform twoimportant controljobssimultaneously withoutusingafeedbackloop. Whileitisharvesting themaximum poweravailableinthe solarcells,itmustpump thatpowerintotheutility gridwith high power quality. For thefirst job, it should regulate a proper DC current andvoltage atthe PV interface for maximum energyharvesting. Forthesecondjob,itmust providecontrol toconvert theDCcurrent,which comesfrom thepanelsandcontinuously regulatedfortheMPPTpurpose, intoACcurrentatthegridinterfaceforpower injection. In addition,thisACcurrentshould besynchronizedwith thegrid frequency, shouldhavelowharmonic distortion, andapower factorclosetounity. Thisgeneratesthepeakvalueoftheduty ratioinformationinorder toregulatethemagnitudeof thegridcurrent.Similartothevoltagemodulationratioused toregulatethemagnitude oftheoutputvoltageinavoltage sourceinverter;thesignalgeneratedbytheMPPTblockin thisapplicationregulatesthemagnitudeofthegridcurrent.Ifth iscontrolprocessisimplementedsuccessfully, the instantaneousaverageofthesecondarycurrentsisgoingtobe sinusoidal andinphasewiththegridvoltage.Anothercontrol signal (Control2) that is also synchronizedwith the PLL outputisusedtocontroltheH-bridge IGBTinverterfor unfolding purpose.Thewholecontrolsystem isimplemented inTMS320F28335 TexasInstrument's DSPController.The flowchartoftheDSPfirmware isillustratedinFig11.Inthe design ofDSPcontroller firmware, thePWMinterruptis utilizedandthecontrollerwaitsforthatinterrupt.

## VII.SIMULINK MODEL USING PLEC

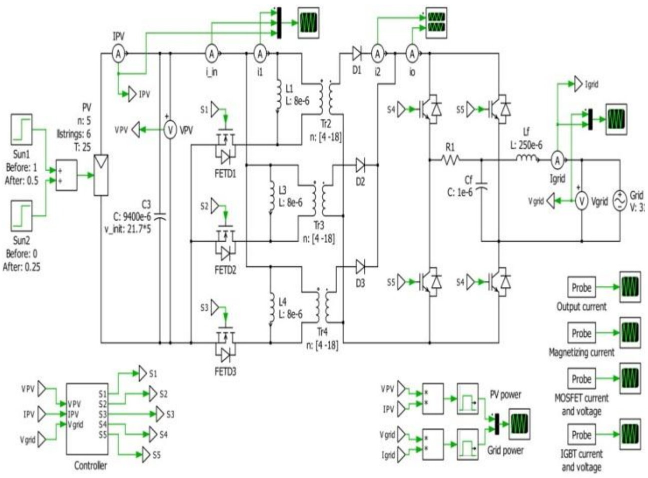


**Figure4** PLECS model of theproposed PV inverter system

## CONCLUSION

Theflyback topologyisselectedbecauseofitssimple structureandeasy powerflowcontrolwithhigh power quality outputsatthegridinterface.It should be noted that interleaved flyback topology is practical at high power as a central type pvInverter,which is the main contribution of this paper.Furthermore, theperformance oftheproposedsystemis comparabletothecommercialisolatedgrid-connected PV inverters inthemarket,butitmayhavesomecostadvantage duetoitstopologicalbenefit

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