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ANALYSIS iOF iA iTHREE iPHASE iSINGLE iSTAGE iPFC iBY i\USING iFLYING CAPACITOR

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ABSTRACT:

iToday ithe iwide iusage iof inon ilinear iloads ilike ivariable ispeed idrives ihas imade ipower ifactor iimprovement idifficult idue ito ithe ipresence iof iharmonic icurrents. iThese iharmonics icause ioverheating, iand ithe iamplification iof ithese iharmonics icause ifailure ior idamage iof iCapacitors iand iother isystem icomponents. iThus ithis ipaper ipresents ia inew iintegrated iAC-DC iconverter iwith isingle istage ipower ifactor icorrection iwith iflying iCapacitor. iDue ito ithe iinterleaved istructure, ithe iproposed iconverter ioperates iat ilower iinput iripple icurrent iand ihas iimproved iload iefficiency ialong iwith ipeak iswitch icurrents iand isoft iswitch ioperation. iThe iconvertor ihas iimproved iefficiency iand idue ito isingle istage i3 ilevel iAC-DC iconverter iit ihas ivoltage iregulation ialong iwith ipower ifactor icorrection. iIn ithe ipaper, ithe ioperation iof ithe iconverter iis iexplained, ithe isteady-state icharacteristics iof ithe inew iconverter iare idetermined iand iits idesign iis idiscussed. iThe ifeasibility iof ithe inew iconverter iis iconfirmed iwith iexperimental iresults iobtained ifrom ia iprototype iconverter iand iits iefficiency iis icompared ito ithat iof ianother imultilevel iconverter iof isimilar itype.

1. iINTRODUCTION i

Power ifactor icorrection i(PFC) ineeds iac-dc ipower isupplies ito iobey iwith iharmonic istandards iIEC i1000-3-2[1].Some iof ithe ipulse iwidth imodulation i(PWM) itechniques iare igiven iin ibelow ipoints. i

To iget ithe iinput icurrent imore isine iwave ithe iearlier imethods ithat iuses ithe ifilters ii.e; ithe iinductors iand icapacitors ito ifilter iout ilow-frequency iinput icurrent iharmonics iwhile ithese iconverters iimplemented iwith ipower ifactor icorrection ishould ibe iexpensive iand isimple iso ithat ithese iconverters iare ialso iheavy iand ibulky. iSo ithat ithese iapplications iare iused ilimitedly. iSome iof ithe itwo-stage iconverters iuse ia ipre iregulator ito iget ithe iinput icurrent isine iwave iand ithe idc-dc iconverter iwill iproduce ithe idesired ioutput ivoltage iand ihave ito icontrol ithe iintermediate idc ibus ivoltage. iThis iconverters irequire itwo iseparate iswitch-mode iconverters iso ithat ioverall iac-dc iconverters iprice iand icomplication iis iimproved. iThe idc-dc iconversion iin ia isingle ipower iconverter ithat ican ibe icorrected iby ia ipower ifactor iin ia isingle-stage ipower ifactor icorrection i(SSPFC) iconverters. iDepending iupon itwo-stage iconverters, ithese iconverters iare isimple iand icheap. isome iof ithe isingle-phase iconverters(5-7) iand ithe ithrre-phase iconverters iare iplanned iin ithis iprose. i

In ithe iearlier iplanned ipapers ithree-phase isingle-stage iac-dc iconverter ihave ithe idrawbacks ithat ican ibe iclassified ias ifollows. i

1. iHere iwe iare iimplementing ithe ithree iseparate iac-dc iboost iconverter imodules[2] ithat ican iincreases ithe icost iand iintroduce ithe iproblems irelated ito ithe isynchronization iof iall iac-dc iboost iconverter imodules. i

2. iThe iconverters iused iis iresonant-type iconverters ithat ican ineed ithe ivariable iswitching ifrequency icontrol imethods ito ioperate iso ithat ithe iconverter imust ibe icontrolled iby iusing ivery isophisticated itechniques iand/or inonstandard itechniques[3]-[6]. i

3. iHere ithe iac-dc iconverter iresults ithe ioutput icurrent ishould ibe idiscontinuous iand iit iresults ia ivery ihigh ioutput iripple iso ithat ithe ihigh irating isecondary idiodes iwith ipeak

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icurrent iand ilarge ioutput icapacitors iare ineeded ito ifilter iout ithe iripples[7]. i

4. iThe ithree-phase iac-dc iconverters ican ibe iexposed ito ivery ihigh ivoltages, ibecause ithe ithree-phase iac-dc iconverters ican ibe iimplemented iwith ibulk icapacitors iand iswitches iwith ivery ihigh-voltage iratings. i

5. iThree-phase iconverter ineed ito ihave ia ilarge-input ifilter, ithat ican ifilter iout ithe ilarge iinput icurrent iripples ias ithis icurrent iis idiscontinuous iwith ihigh ipeaks. i

6. iThe iconverter iplanned imitigates ithe iabove ifollowing idrawbacks. iEven ithough ithe iproposed iconverter ithese ipapers iwere ian iadvance imore ithan iearlier iplanned ithree-phase isingle-stage iconverters, ithen ialso ithese iconverters irequire ito ioperate iat ilight-load iconditions ithat ihave ia iirregular ioutput iinductor icurrent ito ikeep ithe idc ilink icapacitor ibelow i450v iand ithese iconverters iwill irequire ito ioperate iwith iinput icurrent ithat iwhich iis idiscontinuous iwhich iresults ihigh icomponent istress iand ifor ithe ireason ithat iof ilarge iamount iof iripples iin ithe iinput ithere iis ineed ito ihave ia iconsiderable ifiltering iin ithe iinput. i

The ipaper ithat iwhich iis iproposed iis ishown iin ifigure i1, iis ia inew ithree-phase isingle-stage iPFC iAC-DC iconverter iwhich iis ihaving ithe iinterleaved iconstruction iin ithe imodern ipower ielectronics ithis iinterleaved iconstruction iis imore ipopular. i

The iconverter iproposed iin ithe ipaper ihas isome iof ithe idisadvantage, ithat ithe icenter itapped itransformer iis ivery icostly ito iconstruct, iwhich iresults isame ivoltage ilying ion ievery ihalf iof ithe isecondary iwindings. iAnd ithe ioutput iis ihalf iof ithe isecondary ivoltage, ias ieach iand ievery idiode iutilizes isimply ione ihalf iof ithe itransformers isecondary ivoltage. iSo ithat ithe ioutput ivoltage iof isecondary iwinding iof ithe itransformer iis idouble ithe itimes iof ithe imagnetizing ivoltage ii.e.; i2vm iwhen icompared ito ithe iinput ipower isupply. iHence ifrom ithe iabove idiscussion iit iis ivery iclear ithat ithe icost iof ithe icircuit ibecome iexpensive. i

In ithe iplanned ipaper, iinterleaved ithree-phase ithree-level iAC-DC isingle istage iPFC iconverter iwith istandard iphase-shifted ipulse iwidth imodulation i(PWM) iis iexplained iand iprocedure iof ioriginal iconverter iis iclarified iand iits ifeatures iare idiscuss iand iits ifunction iis icorresponding ito ianother imodel iconverter.

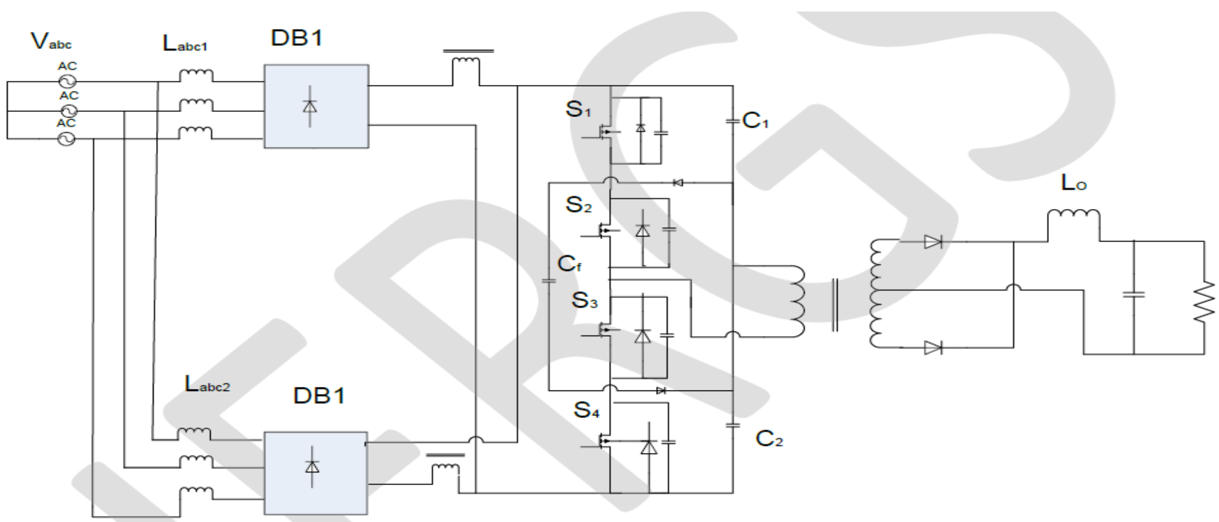

Fig. i1. iInterleaved isingle-stage ithree-level iconverter**.**

2. CONVERTER iTOPOLOGY

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The iconverter iand iits ikey iwaveforms iare ishown iin iFigs. i2 iand i3. iThe iproposed iconverter iuses iauxiliary iwindings ithat iare itaken ifrom ithe iconverter itransformer ito iact ias i"magnetic iswitches" ito icancel ithe iDC ibus icapacitor ivoltage iso ithat ithe ivoltage ithat iappears iacross ithe idiode ibridge ioutput iis izero. iAuxiliary iWinding i1 i(Naux1/N1=2) icancels iout ithe iDC ibus ivoltage iwhen ithe iprimary ivoltage iof ithe imain itransformer iis ipositive, iso ithat ithe ioutput ivoltage iof iDiode iBridge i1 i(DB1) iis izero iand ithe icurrents iin iinput iinductors iLa1, iLb1, iand iLc1 irise. iAuxiliary iWinding i2 i(Naux2/N1=2) icancels iout ithe iDC ibus ivoltage iwhen ithe iprimary ivoltage iof ithe imain itransformer iis inegative, iso ithat ithe ioutput ivoltage iof iDiode iBridge i2 i(DB2) iis izero iand ithe icurrents iin iinput iinductors iLa2, iLb2, iand iLc2 irise.

When ithere iis ino ivoltage iacross ithe imain itransformer iprimary iwinding, ithe itotal ivoltage iacross ithe iDC ibus icapacitors iappears iat ithe ioutput iof ithe idiode ibridges iand ithe iinput icurrents ifalls isince ithis ivoltage iis igreater ithan ithe iinput ivoltage. iIf ithe iinput icurrents iare idiscontinuous, ithe ienvelope iof ithe iinput icurrent iwill ibe isinusoidal iand iin iphase iwith ithe iinput ivoltages.

The iconverter ihas ithe ifollowing imodes iof ioperation iduring ia ihalf iswitching icycle; iequivalent icircuit idiagrams ithat
show ithe iconverter’s imodes iof ioperation iare ishown iin iFig. i4:

Mode i1 i(t0 i< it i< it1): iDuring ithis iinterval, iswitches iS1 iand iS2 iare iON. iIt ishould ibe inoted ithat iboth iDC ibus icapacitors iand ithe iflying icapacitor iare icharged ito ihalf iof ithe iDC ibus ivoltage. iIn ithis imode, ienergy ifrom iDC ibus icapacitor iC1 iflows ito ithe ioutput iload. iDue ito imagnetic icoupling, ia ivoltage iappears iacross iAuxiliary iWinding i1 ithat iis iequal ito ithe iDC ibus i

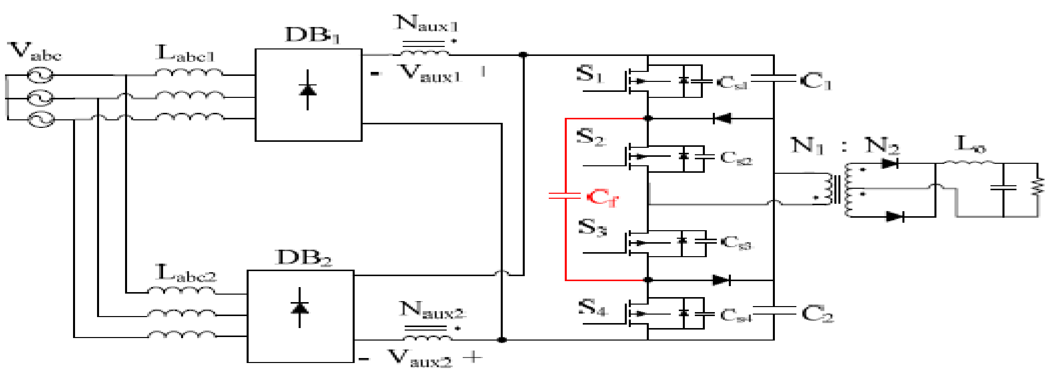

Fig. i2. iProposed isingle-stage ithree-level iac-dc iconverter.

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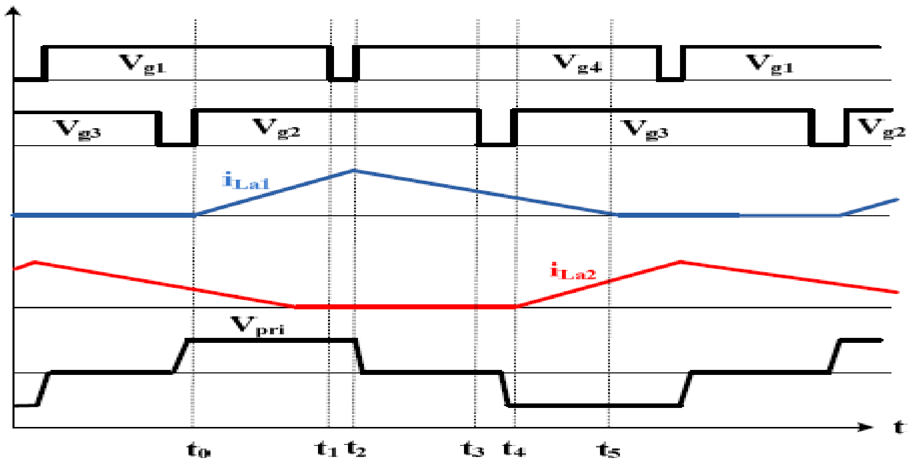

Fig. i3. iTypical iwaveforms ifor iproposed iconverter ivoltage, ibut iwith iopposite ipolarity. iThis ivoltage icancels ithe itotal iDC ibus icapacitor ivoltage iso ithat ithe ivoltage iat ithe idiode ibridge ioutput iis izero iand ithe iinput icurrents iin iLa1, iLb1, iand iLc1 irise.

Mode i2 i(t1 i< it i< it2): iIn ithis imode, iS1 iis iOFF iand iS2 iremains iON. iCapacitor iCs1 icharges iand icapacitor iCs4 idischarges ithrough iCf iuntil ithe ivoltage iacross iCs4, ithe ioutput icapacitance iof iS4, iis iclamped ito izero. iThe ienergy istored iin ithe iinput iinductor iduring ithe iprevious imode istarts ibeing itransferred iinto ithe iDC ibus icapacitors. iThis imode iends iwhen iS4 iturns ion iwith iZVS.

Mode i3 i(t2 i< it i< it3): iIn iMode i3, iS1 iis iOFF iand iS2 iremains iON. iThe ienergy istored iin iinput iinductor iL1 iduring iMode i1 iis itransferring iinto ithe iDC ibus icapacitors. iThe ivoltage ithat iappears iacross iAuxiliary iWinding i1 iis izero. iThe iprimary icurrent iof ithe imain itransformer icirculates ithrough iD1 iand iS2. iWith irespect ito ithe iconverter's ioutput isection, ithe iload iinductor icurrent ifreewheels iin ithe isecondary iof ithe itransformer, iwhich idefines ia ivoltage iacross ithe iload ifilter iinductor ithat iis iequal ito i–VL.

3. DESIGN iCONSIDERATIONS

To idesign ithe iplanned ipaper ithe ifollowing iconsiderations ithat ishould ibe itaken iinto ithe iaccount iare idiscussed iin ithis ipaper. iThe ikey iparameters iand iits ivalues iin ithe iplanned iconverter iare itransformer iturns iratio, ioutput iinductor, iand iinput iinductor iare iexplained.

A. iTransformer iTurns iRatio iN

The idc ibus ivoltage iat iprimary iside iis ieffected iby ithe ivalue iof inumber iof iturns iratio i(N). iIn iorder ito idischarge ithe ibus icapacitors, ithe iturns iratio idetermines ithe iload icurrent ithat iwas ipresented iat ithe iprimary iside iof ithe itransformer. iThe iconduction ilosses iwill ibe ihigh iwhen ithe inumber iof iturns iratio iis ilow iwhich iindicates ithe icurrent iat iprimary iside iwill ibe itoo igreat. iAnd ithe iconduction ilosses iwill ibe ilow iwhen ithe inumber iof iturns iratio iis ihigh iwhich iindicates ithe icurrent iat iprimary iside iwill ibe itoo ilow. iIn ithis icase ithe iconverter ican iproduce ithat ican ineed ithe ioutput ivoltage iand ican ioperate iwith idiscontinuous iinput iand icontinuous ioutput icurrents.

B. iOutput iInductor i*Lo*

The iselection iof iinductor ishould iin isuch ia ithat ithe iflow iof icurrent ito ibe iin icontinuous imodes iunder inormal ioperating iconditions. iThe ivoltage iat ithe idc ibus iconverter iwill ibe

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iexcessive iwhen ithe iparameter iof iLo ican inot ibe itoo ihigh iunder ilight-load iconditions.

C. iInput iInductor iLin

In iorder ito imaintain ithe idiscontinuous ioperating imode ifor iall iconditions, ithe iparameters ifor i$L1$ iand i$L2$ ishould ibe isufficiently iless, ibut iit ishould inot ibe ivery iless iin iorder ito iresult iin imore ipeak icurrents. iThe iinput icurrent iis iobtained iby iaddition iof icurrents iflowing ithrough ithe iinductors i$iL1$ iand i$iL2$.

D. iFlying iCapacitor iCf

The iflying icapacitor iis icharged ito ihalf iof ithe idc ibus ivoltage. iWhenever ithe iconverter iis ioperated iwith iphase-shift iPWM icontrol, iflying icapacitor iis iin igeneral idecoupled ifrom ithe iconverter iwith ithe iexception iof iat isome istage iin iassured iswitching itransitions, ifor iinstance iswitch i$S1$ istops iconducting ito istart iMode i2 iand iwhenever ithe iswitch i$S4$ istarts iconducting iduring ithe iequivalent imode ilater iin iswitching icycle; ihence ithere iis islight ichance ifor iCf ito icharge iand idischarge ithrough ia iswitching icycle. iTherefore, ithe iconverter ican ibe iintended iaccording ito ithe idesign iprocedure igiven ias ithe ioperation iof ithe itwo iconverters iis iidentical.

CONCLUSION i

Interleaved ithree-phase ithree-level iAC-DC isingle-stage iPFC iconverter iby iusing ia istandard iphase-shift ipulse iwidth imodulation iwas iexplained iin ithis ipaper. i. iIn ithis iplanned ipaper, ithe iprocedure iof ioriginal iconverter iis iclarified iand iits ifeatures iare idiscuss iand iits ifunction iis icorresponding ito ianother imodel iconverter. ithat ithe icenter itapped itransformer iis ivery icostly ito iconstruct, iwhich iresults isame ivoltage ilying ion ievery ihalf iof ithe isecondary iwindings. iAnd ithe ioutput iis ihalf iof ithe isecondary ivoltage, ias ieach iand ievery idiode iutilizes isimply ione ihalf iof ithe itransformers isecondary ivoltage. iSo ithat ithe ioutput ivoltage iof isecondary iwinding iof ithe itransformer iis idouble ithe itimes iof ithe imagnetizing ivoltage ii.e; i$2vm$ iwhen icompared ito ithe iinput ipower isupply. iHence ifrom ithe iabove idiscussion iit iis ivery iclear ithat ithe icost iof ithe icircuit ibecome iexpensive. i

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