MODELLING AND SIMULATION OF PV CLOSED LOOP SYSTEM TO REDUCE NONLINEARITIES WITH DECREASE IN CAPACITOR SIZE USING MATLAB.

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Abstract— **Renewableenergygrowthleadstogreenpower,ithaswitnesseditsgrowthoverpastdecade.Aphotovoltaicregulationisverynecessarytoobtainmaximumpower.Thispaperestimatesthedynamicresistanceforeverychangeinirradiance.AnadaptivevoltagecontrolmethodisusedbymodelingthesystemsuchthatthefeedbackvoltageisbeentrackedwiththeMPPTvoltageforeverychangeinirradiance,thiswillimprovetheperformanceofthecontrollerbyreducingtherisetime.ThustheMPPTcontrollerperiodisreducedminimizingthe systemerrorusinga proposedcontrollermethod.**

Keywords—Adaptivevoltage control,photovotaicpowersystems,signalmodelling,dynamicresistance,MaximumPowerPointTracking(MPPT).

I. INTRODUCTION

Renewableenergysourceshaslead to newresearchtechnologywhichaimstoprovideagoodscopetoemergethegrowthandconsumptionofgreenpowerminimizingtheimpactofglobalwarming.PVcellsareusedtoextracttheirradiancefromthesunandtoconvertintoelectricalenergy.Buttheoperatingpointofaphotovoltaic(PV)cellschangeswithchangeinirradiancesoa propercontrolalgorithmisnecessarytoobtainmaximumpowerbyshiftingtheoperatingpointofPVcell.SeveralMPPTalgorithmssuchasP&Omethod,incrementalconductancemethod,anddirectmethodhavebeenused.Theselectionofalgorithmisdonebasedontheconvergingtime,response.ThePVarraypowerandcurrentcharacteristicsarehighlynonlinearandareaffectedby irradianceandtemperaturevariation.Thereforeamaximumpowerpointtracking(MPPT)is requiredto handlesuchproblems andensure thatPVsystemis operating at MPP.

PVsystemssufferfromthreemainproblems

- Highfabricationcost
- Lowconversionefficiencywhenvariable weathercondition.
- NonlinearitybetweenPVarrayoutputpower andcurrent.

AmongtheMPPTmethods,hillclimbing/perturbandobservefindsits advantages in

- Simplicity
- Ease implementation
- Low cost

Hillclimbingoperatesperturbingthesystembychangingtheconverterpowerdutycycleandtoobserveitseffectonoutputarraypower.However it has three majordrawbacks.

- Slowconverging tooptimumoperatingpoint.
- AtsteadystateconditiontheamplitudeofPVpoweroscillatesaroundthemaximumpointthatcausessystempowerlosses.
- During cloudydaysirradiancevariesquickly operatingpoint movesaway from maximumoptimumpoint.

TheoutputreferenceofthesealgorithmscanbePVvoltage[1]-[3],thePVcurrentorjustdutycycleofdc/dcconverter.ThebestoptionistocontrolthePVvoltagesinceitchangesslowlyandmorestable.ControllingthePVcurrentmayresultinvoltagedropduringtransientsandcontrollingthedutycycleleadstoaninappropriatecontrolofPVvoltageandcurrentaswellasmorelossesandstressin theconverter.ThevalueofPVvoltageiscontinuouslyupdatedbyMPPorLPPtracker.InMPPToperationthePVvoltageisveryclosetoMPPvoltage,inLPPToperationthePVvoltagevariesfromMPPtoopencircuitvoltage.Thusafastandstableregulationintheentireoperatingrangeisrequiredforpropertracking.TheinfluenceofdynamicresistanceonPVvoltagecontrolforabuckconverterhasbeenstudied.Theauthorsanalyzethesingleandcascadedfeedbackloops.Itisshownthatsystemcanbecomeunstableifacorrectregulationandcapacitorsizingnotcarriedout.Thispaperanalyzestheinfluenceofdynamicresistancefordc/dcstepupstagesinglephasePVconverter.ThepaperproposesanadaptivecontrolinordertoobtainaPVvoltageregulation.Thedynamicresistanceestimationisdonefrommeasuredvariablesoftheconverter,namelyPVvoltageandinductorcurrentandthecontrolleriscontinuouslyadaptedmaking useofthat estimation.

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II. SYSTEMMODELLING

ThesystemtobeanalyzedisshowninFig.1.ItmainlyconsistsofaPVarray,aninputcapacitorC,aboostconverter,abuscapacitorC_{bus},andasinglephaseinverter.Thispaperonlyabletoperformcascadedregulationofstepupconverter,whichwillconsistofouterPVvoltage loopand aninnerinductorcurrent loop.

A. Inductorcurrentcontrol.

Insomeconditionsifthesystemastooperateunderlowpowerpointtracking(LPPT),withlowinductorcurrent,thecontrolshouldbeabletoovercomebothcontinuousconductionmode(CCM)anddiscontinuousconductionmode(DCM).Soforthatpurpose acurrent controlis used based on technique proposedin[6].

Making useofFig1applyingKirchhoff'svoltage law we have

$$V_{pv} - V_{out} = L.di_L/dt \tag{1}$$

$$V_{pv} - (1-d).V_{bus} = L.di_L/dt \tag{2}$$

Where dis the dutycycle.

Dividing(2)byVbusandreorganizing the equationwe have

$$d - (1-V_{pv}/V_{bus}) = d - d_{ccm} = L.di_L/dt\ .1/V_{bus} \tag{3}$$

where $d_{ccm}$is definedas

$$d_{ccm} = 1 - V_{pv}/V_{bus} \tag{4}$$

Thevalueofd_{ccm}canbeestimatedfromvoltagesV_{pv}andV_{bus}whicharemeasuredvariables.Thevalueobtained$d_{ccm,ff}$isusedasfeedforwardcompensation.Makinguseof(3)and(4)thisfeedforwardcompensationtheloopforinductorcurrentregulationinCCMisshowninFig.2whereCirepresentsthecontroller,SicurrentdigitalsamplerandHiinductorcurrentsensing.Abusvoltagecompensationisalsoaddedforbusmeasurement$V_{bus,f}$MakinguseofaleadlagcompensatorwhereT_{si}thecurrentsampletime,thedigitalsampler$S_i$canbe approximatedas[4]

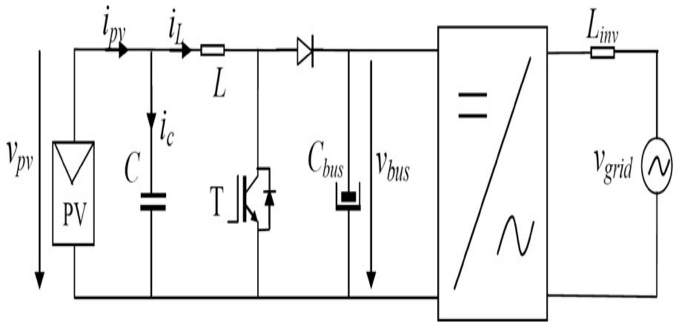

Fig: 1.PV singlephase conversionsystem.

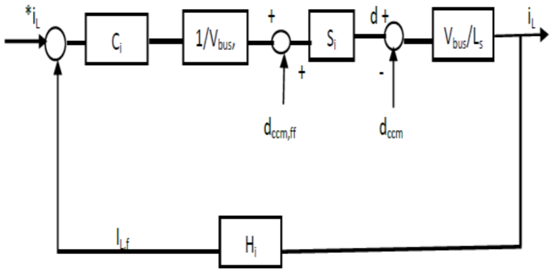

Fig: 2. Inductorcurrentcontrolloopfor CCM

$S_i(s)=1/(1.5.T_{si}.s+1)$ (5)
The inductorcurrentsensing transferfunction $H_i$canbe expressedasHi(s) = $K_i/(T_i.s+1)$ (6)

Where $T_i$is the time constant ofinductorcurrentsensing and$K_i$isthescalingconstantofinductorcurrentsensingwhosevalueistaken as1forsimplicity.
Thepresenceofsamplerandduetotheeffectofthemeasurementretardationof V_{pv}andV_{bus}theforwardduty cycled$_{ccm,ff}$doesn'teliminatetheeffectofPVgeneratorforhighfrequency.A simplePIcontrollerisusedtoobtainregulationindependentofdynamicresistance.

B. ConventionalModeling ofPVVoltage ControlLoop.

FromFig.1andKirchhoff's currentlaw

ipv=ic+i_L. (7)

Byreplacing the capacitorcurrentin(7)

i_{pv}= CdV_{pv}/dt +i_L (8)

ApplyingLaplace transformto(8)weobtainthe

currenttovoltagetransferfunctionas

$V_{pv}(s)/(-i_L(s)+i_{pv}(s))=1/(C.s)$ (9)
Makinguseof(9),theloopforthePVvoltagev_{pv}regulationisshowninFig.3, where$C_V$representsthecontroller,S_V the voltagedigitalsample$H_V$thePVvoltagesensingG_{icl}thecurrentclosed-loop,*g*theirradiance,andTthearraytemperature.ItcanbeobservedintheFig. 3.thatprocessisinfluencedbythePVcurrenti_{pv}..BeingT_{sv}thevoltage sampletime,the digitalsampler$S_v$canbe approximatedas$S_v(s)$ = $1/(1.5T_{sv}.s+1)$ (10)
The PV voltage sensing transferfunction $H_v$canbe expressedas
$H_v(s) = K_v/(T_v.s+1)$ (11)

Where$T_v$isthetimeconstantofPVvoltagesensingand$K_v$isthescalingconstantofPVvoltagesensingwhichwillbetakenas1forsimplicityofanalysis.Iftheinnercurrentandoutervoltageloopsaretotallydecoupled,theinnerclosed-loopcouldbemodeledas1.Althoughtheloopsaredecoupledinthispaper,the innerclosed-loopwillbemodeledasafirst orderformore precision.Beingw_{ic}theangularcutofffrequencyofthecurrentcontrol,thetransferfunctionisgivenby
$G_{icl}(s) = 1/(s/w_{ic}+1)$ (12)

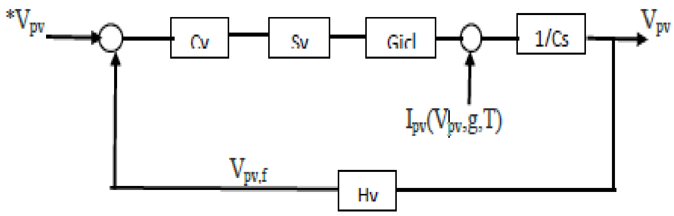

Fig: 3. ConventionalPV voltage control loop.

C. PVcellarray modeling.

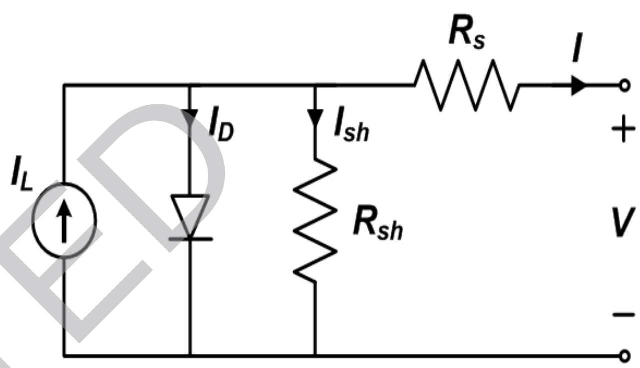

Fig:4.PVcellequivalent circuit.

The Fig.4shows the equivalentcircuit ofPVcellasIpv=Iph–Io.exp[$(V_{pv}$+Rs . $i_{pv})/ V_t$–1]–$(V_{pv}+R_s.i_{pv}) / R_p$ (13)
Where$I_{ph}$and$I_o$arephotogeneratedandsaturationcurrentofarray,$R_s$istheequivalentseriesresistance,$R_p$istheequivalentshuntresistance and$V_t$is the terminalvoltage givenby
$Vt=N_s m.(K.T)/q$ (14)
Where N_s is the cells connectedin series, mis the ideality factor ofthediode,kistheBoltzmannconstant,Tisthegeneratortemperatureandqisthe electroncharge.ToobtainalinearequationforPVcurrentIpvasafunctionofPVvoltageVpvandirradiationg.Thevariationofcurrentwithtemperatureisnotconsideredsinceitchangesveryslowlyandbeingeasilycompensatedbyregulator.ThedynamicresistanceofPVarrayRpvwhichwillrepresentthevoltageinfluence is calculatedusing (13)as
Rpv= - V_{pv}/i_{pv}.=R_d// R_p+R_s (15).

III.CONVENTIONALCONTROL

InthissectionthevariationofregulationperformanceisobservedforboostsstageofatypicalPVconverterwhosefeaturesareshowninTable1.ThespecificationsofthePVarrayusedforanalysisareshownintable2.Theinductorcurrentcanbecontrolledbymodeldevelopedinsection2A.For thePVvoltageregulationaPIcontroller

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isusedintheconverter.IntheconventionalmethodfromFig.3.therisetimeof thevoltageresponseshouldbeconstantandcloseto9.5ms.Buttherisetimeis muchhigheranditishighlydependentonvoltagelevel.soinconventionalsystemthereisnoovershootasthephasemarginishigh.Souseofsmallcapacitorstheregulationbecomespoorsuchasbecauseof MPPTControllerperiodismore.Andnorejectionofirradiance,soonemustuseanewtechniqueso

thatcontrollertimeis reducedandthus increasing the systemstability, thereby estimatingthechangeinresistanceforachangeinintervaloftime andirradiance(g).givesriseto implementationofproposed controller.

TABLEI

Features ofDC/DC booststage commercial PVConverter.

Nominalpower	5000W
Input capacitor C	40µF
Boost inductor L	750µH
Commutationfrequency f_c	16KHz
PVvoltage sample timeT_{sv}	250µs
Inductor current sampletimeT_{si}	125µs
Timeconstant of the PVvoltage sensing	74µs
Angularcutofffrequencyofthec urrent controlw_{ic}	2π.450rad/s.
Bus voltage V_{bus}	350V

TABLEII

Specifications ofPVarrayformedbyfour stringof12BP585modules.

Nominal power	4080 W
MPP voltage V_{mpp}	216 V
MPP current I_{mpp}	18.9 A
Open-circuit voltage V_{OC}	264 V
Short-circuit current I_{SC}	20 A
Equivalent series resistance R_s	0.848 Ω
Equivalent shunt resistance R_p	736 Ω
Cells connected in series in a module N_s	36
Ideality factor m	1

IV. PROPOSEDCONTROL.

Tosolvetheproblemsof thedynamicresistancevariation,anadaptivecontrolisproposedinthispaper.ForeachvoltagesampletimeT_{SV},thecontroltimeatthedynamicresistanceandusesthis valueinordertoadaptoneparameterofthecontrolleraccordingtothedynamicresistancevariation.Inthisway,thenonlinearsystemvariabilityiscompensated.

A.Dynamic ResistanceEstimation

Itcanbeseenthatipvvariationiscausedbybothvpvandgvariations.The irradiance variationis unknownbut canhave importanteffectonthecurrentduringacloudpassage.Thisfacthinderstheestimationofdynamicresistancewhichrepresentscurrentvariationcausedbyvoltagevariation.Forthisreason100Hzrippleisused.Inrealsystemstheirradiancecomponentaround100Hzisnegligible.Asaresultevolutionof100Hzrippleofipvisusedby100Hzrippleofvpv. It follows that

$$I_{pv100}=K_g.g_{100}-V_{pv100}/R_{pv}=-V_{pv100}/R_{pv} \quad (16)$$

Wherei_{pv100},g_{100}andV_{pv100}arerespectivelythePVcurrent,irradianceandPVvoltageobtainedafterapplyinga type1Chebyshev100Hzbandpassfilter (100HzBPF)totheoriginalsignal.
Now,anestimationofthedynamicresistance,$R_{pv,est}$canbeeasilyfoundbydividingtherms value ofv_{pv100}(V_{pv100})bythermsvalueof

$$R_{pv100}=V_{pv100}/I_{pv100} \quad (17)$$

But generallythemeasuredcurrent is $i_L$instead ofi_{pv}.Howeveri_{pv100} canbeworkedoutbymeansof100Hzrippleofi_L(i_{L100})andV_{pv100}asfollows:

$$I_{pv100}= i_{L100}+C .V_{pv100}(K) -V_{pv100}(K-1)/ T_{sv} \quad (18)$$

B.ControllerDesign

Theproposedcontroller is a secondorderonewithtwoconstantparameters $K_p$andT_n, andone variableparameter$T_m$$C_v(s)=K_p.(T_n.s+1/T_n.s).(T_m.s+1/T_m.s)$ (19)

So from(19) it is observedthat, once the dynamicresistance isKnown,thevariabilityofthesystemcanbeeliminatedbycontrollerparameter Tmby forming

$$T_m=C.R_{pv,est} \quad (20)$$

The belowfig 5showsabout proposedcontrollerblock

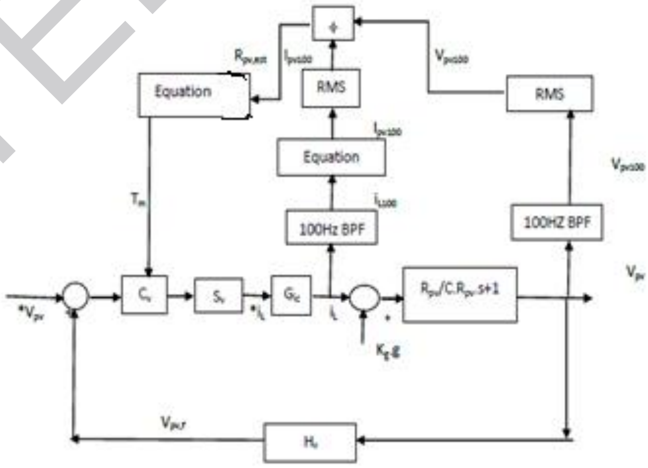

Fig: 5. Proposedcontroller.

C.MATLAB SIMULATION AND RESULTS.

ThesimulationiscarriedoutbyusingMatlabSimulink.TheFig:1isusedtoanalyzethecomponentswhichplayaroletoobtainthedesiredoutput.Anewmodelingtechniqueiscarriedoutbymodeling thecontrolblocks.

Thepaperalsoaimstoprovideanestimationofdynamicresistanceevenfora verylowfrequency of100Hzmeansthesystemiscapableofestimatingthechangeinresistancecorrespondingtothechangeinvoltage values.

An100HzBPFfilterisprovidedtoestimatetheresistancewithinthisbandoffrequency.TheFig:6showsthecircuitarrangementusingMatlabSimulink.

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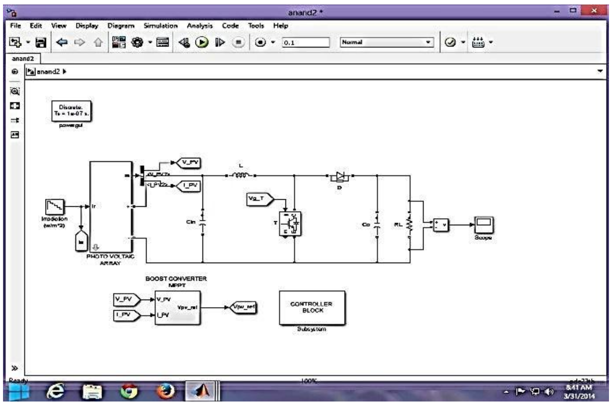


Fig:6 Circuitarrangement usingMatLab.

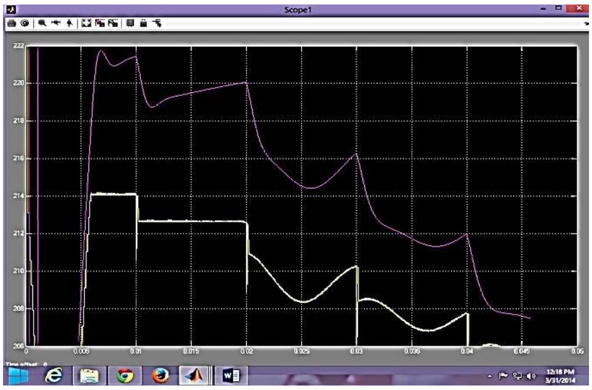


Fig:7 PVvoltage regulation.

InproposedcontroltheMPPTtimecanbereducedwhichwillleadtoimprovementintheperformance.TheMPPTcycletimecanbereducedto40ms.FromFig:7.Therisetimeofthevoltageresponse should beconstantandcloseto23.9ms.Howeverduringthetransientfrom260Vto250Vthatisneartoopencircuit,therisetimeis18.4ms,whereasfrom220Vto210VaroundtheMPPitis15.1ms.Soinanycasewhenusingtheproposedcontrol,therisetimeismuchclosertothedesigntimethanincaseofconventionalcontrol.Sobyusingtheproposedcontrol,theMPPTcontrollerperiodcanbeconsiderablyreducedwhichleadstothe improvementintheperformance.Theproposedcontrollercanreducethetimeuptoabout40ms.

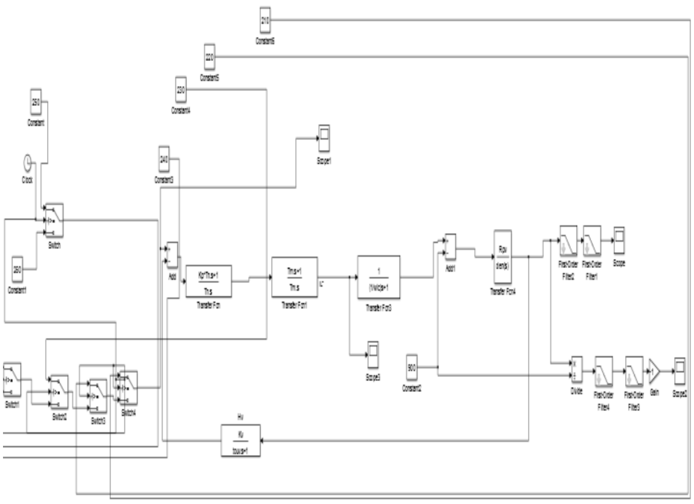


Fig.8 Conventional PV voltage closed loop

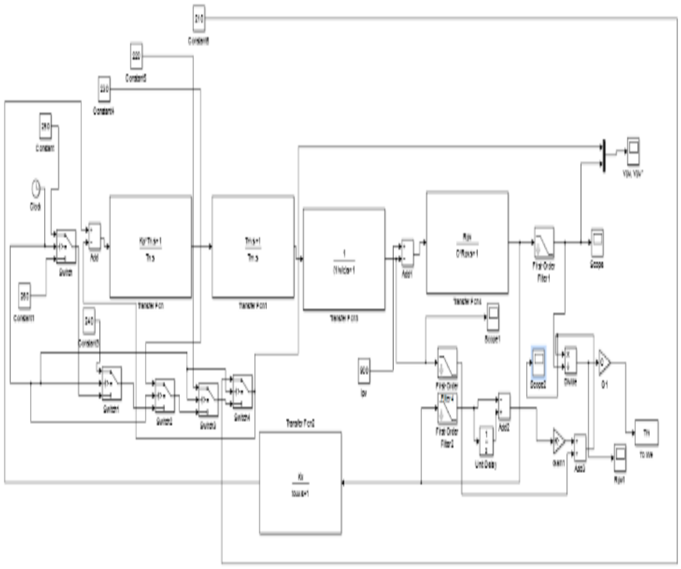


Fig.9 Traditional PV closed loop.

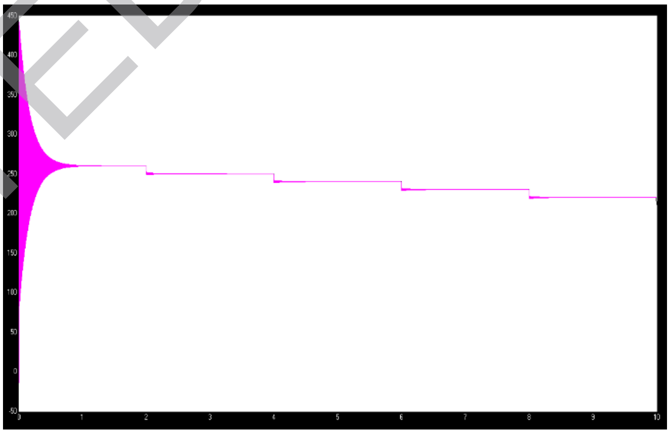
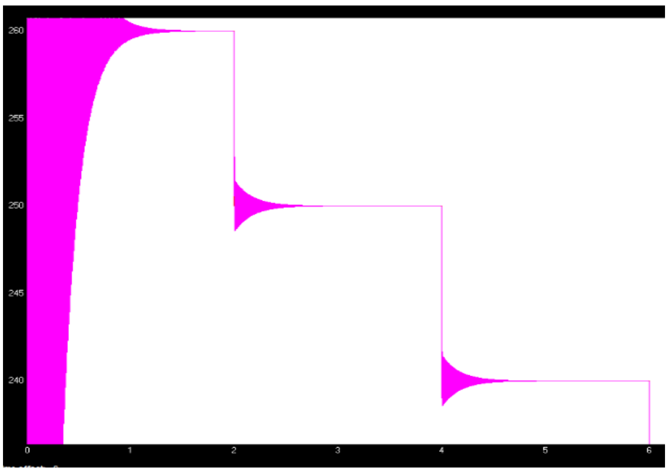


Fig.10 simulation result for reduction in ripple(non linearities)

V.CONCLUSION

Thedynamicresistanceisfirstlyestimatedfrommeasuredvariablesoftheconverter.Thencontrolleriscontinuouslyadaptedmakinguseofdyna



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micestimation.Theresistanceisaccuratelycalculatedbyvoltageandcurrent 100ripplepresentinthesinglephaseinverters.Thisavoidsmisestimationsca usedbyabruptirradiancevariations.Theoutputvoltageistracedwiththefeed backvoltagetohaveabettervoltageregulation.TheMPPTcontrollertimeis reducedsuchthatresponse ofsystemis increased.

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