International Journal for Innovative
Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

Title: VEHICLE-TO-GRIDANCILLARYSERVICESUSINGSOLARPOWEREDELECTRICVEHICLECHARGINGSTATIONS

volume 11, Issue 06, Pages: 1581-1587

Paper Authors : **M Bhagya Lakshmi, I Divya Sree,K NavyaSree, Y Lavanya,B Sandhyarani, K Rajeswari**

.

International Journal for Innovative
Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

VEHICLE-TO-GRIDANCILLARYSERVICESUSINGSOLARPOWERED ELECTRICVEHICLECHARGINGSTATIONS

1M Bhagya Lakshmi, 2I Divya Sree,3K NavyaSree, 4Y Lavanya,5B Sandhyarani, 6K Rajeswari
1Assistant Professor, 2,3,4,5,6B-tech student Scholar
1,2,3,4,5,6 Department of Electrical & Electronics Engineering,
1,2,3,4,5,6 G. Pullaiah College of Engineering and Technology, Nandikotkur Rd,
near Venkayapalle, Pasupula Village, Kurnool, Andhra Pradesh 518002

Abstract— Concernsabouttheexponentialincreaseintheusageoffossil fuel especially in the transportation sector which leads to researchand development of alternative sources for powering vehicles. The mostsuitable alternative for the fossil fuel is electrification of vehicles whichhelpstopreventemissionaswellasithelpstoprovidepowerbackto the grid when its needed(Vehicle-to-Grid).If the powering of electricvehicle is done by renewable energy, then that helps to provide moregreenerandcleanermeansoftransportation.Giventhisbackground,asolarphotovoltaic(PV)poweredElectricvehiclechargingfacility(EVCF)isdesignedforchargingtheElectricVehicles(EV)withAC-DC converter and vector control techniques.The simulations results inMATLABSIMULINKenvironmentdemonstratestheEVparticipationinancillaryservicesthroughEVaggregatoragents.

Index Terms—Electric vehicles (EV) , ancillary services, converters,powerconversion,solarpowergeneration

I.INTRODUCTION

Every industry is becoming smart and automated now a days andtransportationisoneamongthem.Inthelastcoupleofyearsthere isalotofdiscussionabouttheenergyconservationandthedepletion of fossil fuels. Most of the leading economies aim to transform theirtransportation system green by 2040 . As per Electric Vehicle (EV)policies,Indiatooisplanningtoadopt100%EVsinroadtransportby2030. The major advantages with the use of EV is reduced pollutionand easy integration of renewable resources.Electrification of roadhelpstoreducetheenvironmentalproblems.ThreemodesofEVcharging, named Quick,Budget and Green in a solar powered EVCharging Facilities(EVCF) is discussed in [1].The dependence of theEVCFOnthe grid can be minimized by incorporating renewableenergysource(SolarPV)andaBatteryEnergyStorageSystem(BESS), but the BESS greatly increases the investment.Instead, theEVs can be utilized as temporary storage devices to store the PVpower. The excess PV power can supply the grid as well.The invertercontrolthroughIcosphialgorithmisdiscussedin[2].Itdiscussaboutmaximumgreenenergyintegrationwiththegrid.

A.EVChargingstandards

EVs can be charged from domestic or public charging locations.TheinternationallyacceptedforEVchargingaredevised bysociety of automotive engineers (SAE), international electromechanicalcommission (IEC) and CHAdeMO EV standards [3]. The Europeanstandards for charging defines charging types as MODES whereas inUS they are termed LEVELS. [4] Japan and China developed theircommon charging scheme named CHAdeMO. TESLA has developedtheir own separate charging standard [3], [5]. [6] also discusses thecharger topologies and power levels of some manufactured PHEVandEVs.[4]discussesthedifferentchargingstd.ofEVsinEurope,USA etc.There are some standards for charging sockets also. Eachchargingstdhavecorrespondingspecifiedsocketsforcharging.Level-2 DC Charging is a combined system of charging.This chargeris mainly used for the residential and commercial types of chargingfacilities.Thesechargercanusedformaximumof20KWpowertrans-fer applications [7]. The fast charging mode is aimed at minimizationofchargingtimeorqueuingtimeofthecustomer.[8]is discussingthe algorithm for charging time minimization. In this paper chargingis designed for the working frequency and voltage of 50Hz and

415VandalsoformainlyforasingleEVcharging.

B.V2Gcharging

The normal charging schemes discussed above referred as grid-to-vehicle(G2V).OtherthanG2VEVscanworkinVehicle-to-Grid(V2G)mode,inwhichtheEVitselfcansellpowertothegridinthetimeofpeakpowerdemandoranyemergencysituations.TheearlierresearcheswerefocusedmainlyonthefieldofG2V i.echarging of the EVs. However, the trends is in the area ofintegration of grid with EVs. The plugged in EVs is used for supportthe bidirectional power flow between EV and utility. [9].V2G helpsEV to act as an energy reserve for the grid.V2G supports many ofancillary services to the power system network such as frequency andvoltage regulation, renewable energy integration, reserve of powersupplysystemanddemandsidemanagement[10].Thevehiclebatterycanchargeandstorethepowerdevelopedbyanyofthesources(renewable or nonrenewable) and it can discharge this energyduring change in energy production according to weather or climatechanges, or load variations etc. Demand side management smoothenstheloadandgenerationcurvesinthepowersystem.Utilitiescantake part by charging the EV batteries during off-peak hours andtaking power from parked EVs during peak hours. In order to achievethese utilities should provide smart charging techniques which alsohelpstoprovidevalleyfilling,peakshavingandloadleveling.Andit will improve overall grid conditions. Since number of cycles arelimited unidirectional charging configuration have good battery life.[7]. The disadvantage is that unidirectional chargers cant help thepower to flow from EV to grid ie.V2G. Conversely, bidirectionalchargers allows power flow in both directions. It is operating in twomodes, charging and discharging. It will help the implementation ofV2G system and promotes road electrification.However, because ofthe large number of cycles this configuration will affects battery life[7].Such a V2G system is discussing in this paper. To ensure thereliability of supply for charging the topology used in this paper isAC-coupledtype,inwhichthePVandEVSEareconnectedtogridat a common AC bus called Point of common Coupling (PCC). Theexcesschargingpower,ifrequired,willbesuppliedbythegrid. Also,theexcessPVpower,ifavailable,canbeinjectedtothegridthroughthegrid-tieinverter.Thesolarfedhybridenergystoragesystemin[11] shows the energy storage methods instead of direct injection togrid.

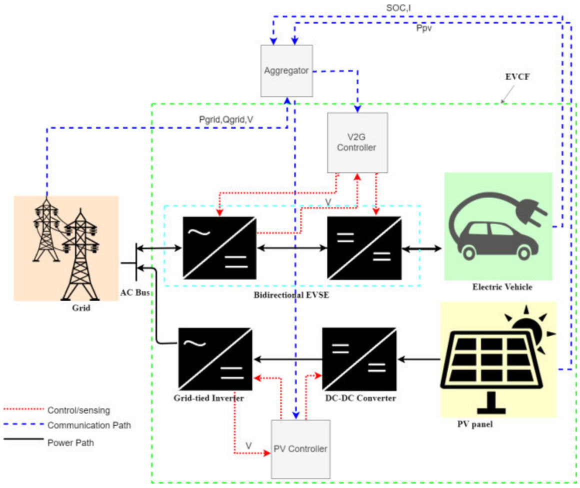


Fig.1.BlockdiagramofPVpoweredEVCFwithancillaryservicescapability

II.PROPOSED SMART CHARGING AND ANCILLARY SERVICES

A. Systemdescription

The proposed system, shown in Fig.1, consists of two separatecontrollers for PV system as well as EV charging. The PV controllercontrols the output of PV array. It has two functions, first one is toensure Maximum Power Point(MPP) operation of PV and the secondone is to ensure maximum power injection to the grid . For this thepower output from PV is given to the DC-DC converter and it iscontrolled by MPP Tracker (P and O).The maximum power outputfromDC-DCconverterisfedintotheinverter.TheinvertercontrollertakesinputsfromGridvoltage,PVarrayandtheDClinkvoltage.ThegeneratedPWMcontrolsignalsarefedtotheinverterswitches.

TheV2Gcontrolleralsoconsistsoftwocontrollers,Bidirectional AC-DCconvertercontrolandDC-DCbidirectionalconvertercontroller.MainfunctionsofV2GcontrolleristodecidetheV2Gor G2V operation of the bi-directional charger and fix the charging/dischargingrateofEVs.Itworksonthebasisof3inputs;thosearegridparameters,EVparametersandtheDClinkvoltageoftheutilityinverter.ThegridparametersaretheReactiveand Activepower,andbatterySoCandcharging(dis)currentaretheEV parameters.

B. Bi-directionalAC-DCconverter

ThispaperdealswiththeuseofaBi-directionalAC-DCconverter forabatteryfedEV.Themaximumpowerthatcanbesharedinthis proposedsystemwillbearound20KWwithhighefficiency.[12]Itisafullycontrolledthreephaseconverter.Thecontrollingisdone byzero-d-qreferenceframealgorithm.

C. Controlalgorithms

1.MPPTcontroller(PandO): Duetotheavailabilityandeasyaccess,thePVsystemisbecomingoneoftheimportantrenewable energysource.AninverterisnecessarytoconverttheDCpowerdevelopedinPVintoACpower.ThisisusedtopowerupACloadsorcanbetransportedtotheutilitygrid.Themaximumpointfromthe PV curve can be tracked using tracking algorithms [10]. Severalcontroltechniqueshavebeenproposedbyliteratureforthispurpose.[13]suggestsanovelapproachforMPPTcontrolforsolarfedenergystoragesystem.Oneofthemstcommonandgloballyacceptedmethod, Perturb and Observation(P and O) algorithm, is used forMPPT in this paper. The flowchart and concept is explained in [14].In order to make the operating point near MPP the operating voltageisperturbed.

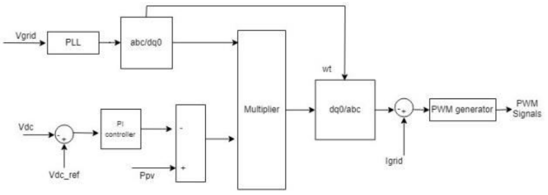


Fig.2.SRFcontrolalgorithm(forPVinvertercontrol).

2.PV Inverter Controller(PV-IC): Proper inverter control techniques is associated with the success utilization of PV power. The inverter controller in this system is accomplished by SynchronousReference Frame (SRF) algorithm, in which, the sensed three phasegridvoltageistransformedfromrotatingreferenceframetostationaryframeusingtheabcdqoconversionasseeninequation[[15],eq.(1)].Grid synchronization is achieved by phase-locked loop (PLL). Thereference DC bus voltage magnitude is compared with measured DC bus voltage, and the voltage loss component is generatedby the PIcontroller.Thenitisaddedto$V_d$inordertogenerateV_d^*[15].The quadrature and zero component references set as zero only. Theresultant reference frame voltages are again changed into abc frame using Inverse Parks transformation as seen in [15], Eq.2 to generateinverter switching pulses [15]. The flow chart of SRF controller is inFig.2

$$\begin{bmatrix} Vd \\ Vq \\ V0 \end{bmatrix} = \begin{bmatrix} cos\vartheta & cos(\vartheta - 2\pi/3) & cos(\vartheta + 2\pi/3) \\ sin\vartheta & sin(\vartheta - 2\pi/3) & sin(\vartheta + 2\pi/3) \\ 1/2 & 1/2 & 1/2 \end{bmatrix} \begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} = \begin{bmatrix} cos\vartheta & cos(\vartheta - 2\pi/3) & cos(\vartheta + 2\pi/3) \\ sin\vartheta & sin(\vartheta - 2\pi/3) & sin(\vartheta + 2\pi/3) \\ 1/2 & 1/2 & 1/2 \end{bmatrix} \begin{bmatrix} Vd \\ Vq \\ V0 \end{bmatrix} \tag{2}$$

3.V2Gcontrol: InordertoensuretheproperfunctioningofV2GorG2V there is a need for two controllers- one to control the TLBCand another to control the dc-dc converter. A proper communicationbetween utility, aggregator and EV, is crucial for proper functioningoftheV2Gaction.Forthis,V2Gcontrolsignal,SOCoftheEVandutilityloadprofilesignalinformationarecontinuouslyexchangedbetweentheseentities.

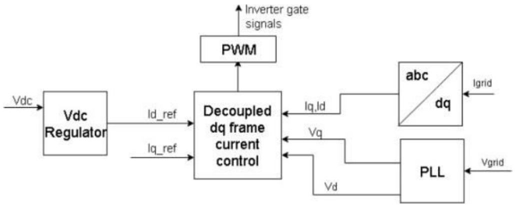


Fig.3.BidirectionalAC-DCconvertercontrol.

4.Bidirectional AC-DC converter Control: The Bidirectional AC-DCconvertercontrollershowninFig.3shouldprovidepowerforEV batteries and reactive power support for the utilities on request[12]. The inverter control scheme in this paper is derived from thestudy in [12]. It uses direct-quadrature-zero transformation equations,activeandreactivepowercalculationsandPLLalgorithmtomaintainutility grid voltage synchronization.Park transformation is used forabc-dq0 conversion of phase currents and utility voltages.In addition,PLLwillgivethewtvalue.Eq.(1)andEq.(2)usedfortheconversions.Thentheactiveandreactivepoweriscalculatedaspertheequation(3)and(4)in[12].Theequation(6)and(7)usedto generate the i^*_d(active current reference) and i^*_q(reactive currentreference)[12].Thiscontrollerconsistsoftwocontrollersoneisinnercurrentcontrollerandotherisoutervoltagecontroller.Involtagecontrollerthereferencevoltageiscomparedwiththemeasuredvoltagewhichprovidesthereferencecurrentvaluefortheinnercurrent controller.The measured line currents are converted to d-qformwithhelpofParktransformationmatrix.TheinnerPIloopsare established by comparing it with the reference current (usingEquations(6)and(7)).Theresults$e_d$and$e_q$arefirstsummedwiththedecoupling terms as seen in [[12]eq.(8)].Normalization is achievedthroughthecalculationbasedonequation(9)in[12].

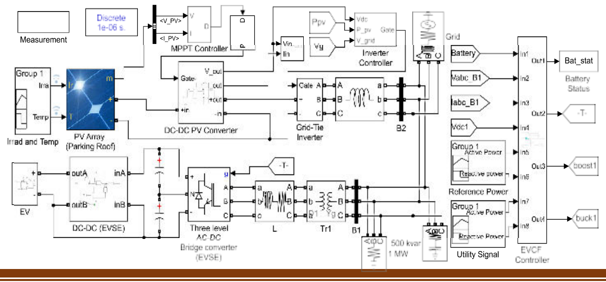


Fig.4.SimulationdiagramofPVandV2GequippedEVCFinMATLAB/Simulink.

5.DC-DCbidirectionalconvertercontrol: Throughpropercommunicationbetweenutilityand EVs,chargingordischargingscheduleisdeterminedbytheDC-DCcontroller.V2Gcontrolsignal, EV SoC, and utility load profile signal are the inputs to thecontroller.AccordingtothedecisionmadebyDC-DCcontrollerG2VorV2Goperationtakesplaceandtheconvertercurrentiscontrolled.

V2G control signal: V2G control signal of the DC-DC converterdeterminestheEVcanbedischargedie.ifitallowsV2g modeornot. If the signal is zero then the EV can be charged or in idlecondition. if the signal is one then it allows the EV to be in V2Gmode. this signal has the highest priority in among all the signals totheDC-DCconverter.

Utilityloadprofilesignal::Activepowerwhichshouldbedrawn from EV batteries to support utilities is determined by the DC-DCconvertercontrollerthroughanalyzingtheloadprofile.Thenitdecidesthepowerconsuming/chargingorsupplying/dischargingtime for EV. In addition to active power support, DC-DC convertercontrol receives a reactive power support signal from utilities. Basedonthis,itgenerateareferencesignalforTLBC,whichhelps toprovidereactivepowerneededbytheutility.

TABLEI : PVDESIGNPARAMETERS

PVSection	
PVarray	
Irradiance	700W/m^2,
Temperature	25deg.C
MaxPower	15kW
Voc	700VDC
Isc	35A
PVDC-DCconverter	
MaxPower	15kW
Inputvoltage	400VDC
Outputvoltage	700VDC
PVgridtieinverter	
ACnominalpower	15kW
DCvoltage	700V
NominalACvoltage	415V(LL)rms
ACgridfrequency	50Hz

TABLEII: EVSEDESIGNPARAMETERS

EVSESection	
BidirectionalAC-DCbridgeconverter	
ACnominalpower	15kW
ACnominalvoltage	415V(LL)rms
DCvoltage	700V
ACgridfrequency	50Hz
DC-DCbidirectionalconverter	
Nominalpower	15kW
Vhigh	700V
Vlow	400V
EV	
NominalDCVoltage	360V
Ahrating	210Ah

State Of Charge (SoC):Thechargingcurrentrequirementisdeterminedwithinarangeofbattery SOC.ForlowSOClevels,thechargingcurrentrate istobeincreasedandminimizationofqueuingtimeisobtained[8]. TheproposedsystemsuggeststheDC-DCconvertercontroltodecidesthedischargingorcharging rate according to SOC of EVs. Depending upon these signal statusrequiredcurrentiscalculatedandcontrolsignalfortheDC-DCconverterisgeneratedaccordingly.

III. SIMULATION,RESULTS AND DISCUSSION OF V2GENABLED EVCF

The simulation is performed in the Simulink/MATLAB environment.Fig.4isthemainsimulinkdiagraminMATLAB.TableIcontains the simulink parameters of PV section.The results obtainedfrom the simulation is presented in this section. The PV is generatingaDCpoweraround15kW,400V,35Aat700 W/m^2irradiationand25 degreecelciustemperature. Fig.5 showsthe I-V characteristicsofselectedPVpanel.UsingPandOMPPTtechniquegettingthe poweroutputofDC-DCboostconverterisshowninFig.6.Through theSRFcontrollertheDClinkvoltageoftheinverterismaintainedat700VshowninFigure7.This700Visconvertedto415V,50Hz ACcorrespondingcurrentandvoltagewaveformatPCCisalsoshowninFig.9.Fig.8indicatestheinjectedactiveandreactivepowerfrominverter.TableIIconsistofthesimulationparametersofEVSE whichsusefulforV2GandG2Vapplication.TheEVsectioninthe simulation is a Lithium-ion battery of 360V,210Ah capacity withinitialSOCof59%.Fig.10showstheutilityreferencepower demand.Fig.11istheV2Gcontrolsignals.

Thesimulationisdoneaccordingto the sets of conditions in Fig.10 and Fig. 11. The Fig.12 entail thevariationinbatterycurrent, voltage, SOCandPoweroutputwaveformsobtainedfordischargingorcharging(V2GandG2V)modes.

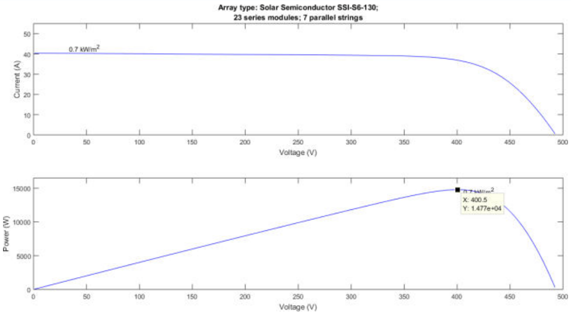


Fig.5.I-VandPVcharacteristicsofsolarPV.

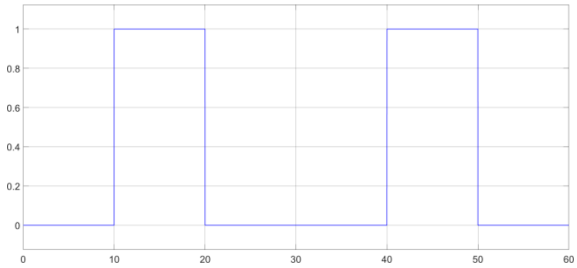


Fig.6.Irradiance, Temperature,voltage,currentandmaximumpowerofPV.

Fig.7.DClinkvoltageofPVinverter(atPCC).

Fig.8.ActiveandreactivepowerinjectedtogridfromPV.

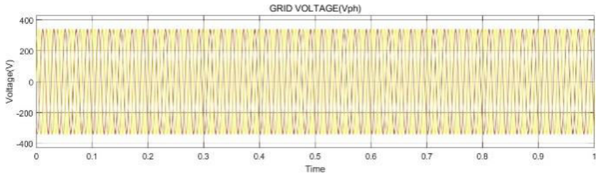


Fig.13 is the grid active and reactive power for both modes ofoperation. (ie; grid power consumption as well as supply). It can beobservedthattheEVissufficientenoughtosupplythegrid.The

Fig.9.Gridvoltage

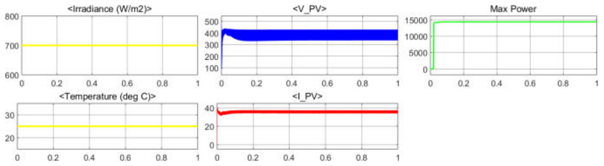


Fig.10.Inputsignals(UtiltyActiveandReactivepowerdemand).

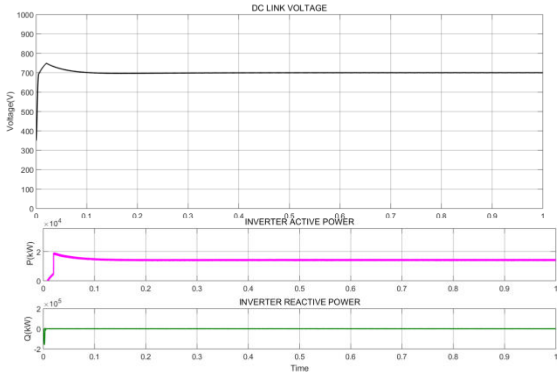


Fig.11.Inputsignal(V2Gcontrolsignal).

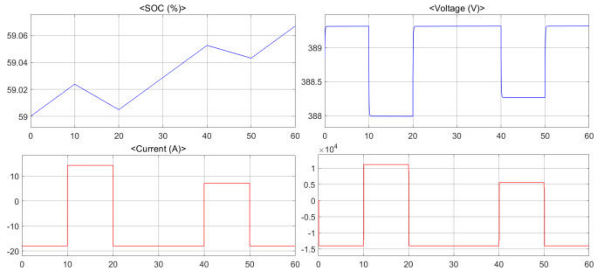
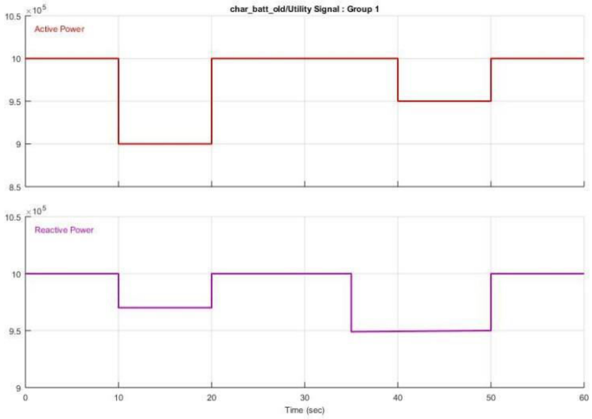


Fig.12.EVBatterywaveforms(V, I, SOC, Power).



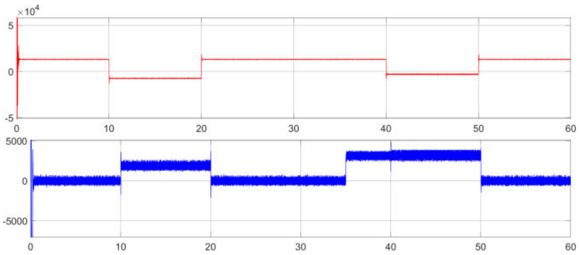


Fig.13.ActiveandReactivepower sharingbetweenEVandgrid(P,Q).

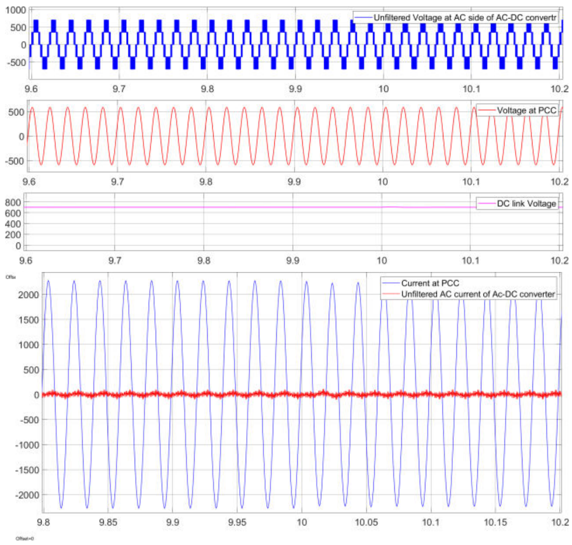


Fig. 14.Voltage waveforms at AC side of DC-DC converter, PCC and DClink.

AC voltage waveforms of the AC-DC converter is in Figure 14.Asmallportionofsimulationtimeisshownthevoltagewaveformsof charging/G2V and the discharging/V2G mode of operation in theFig.14.Heretime(9.8-10)secisthechargingmodeand(10-10.2)secis the discharging mode of operation.Similarly, for the G2V and V2Gmodes, the change in current can be observed from Fig .15.It showsthe waveforms at PCC and also the unfiltered AC current of AC-DCconverter.

Fig.15.CurrentwaveformsatPCC,AC-DCconverter

IV.CONCLUSION

A PV powered EV charging facility which has the capability forV2G services is proposed in this paper. A AC-DC converter withvector control technique will provide V2G services while an EV isparkedforcharging.Thevalidationoftheproposedsystemisdoneinin MATLAB/SIMULINKenvironment.Theillustrati veresultsshowsthe proper functioning of V2G and G2V mode. The PV integrationreduced the dependence on grid for charging. As a future scope, theintegrationofcontrolconstraininbothG2VandV2Gmodescan offerenhancedstabilityinelectricaldistributionnetworkswithhighEVpenetration.

REFERENCES

[1] V. Raveendran, R. Divya, P. C. S. Chandran, and M. G. Nair, “Smartlevel 2 dc electric vehicle charging station with improved grid stabilityandbatterybackup,”in2017InternationalConferenceonTechnologicalAdvancementsinPowerandEnergy(TAPEnergy),2017,pp.1–6.

[2] V. Raveendran and M. G. Nair, “Vehicle-to-grid transactions and shuntactive filtering capability of smartparks equipped with modified icoscontroller,”in2014IEEEStudents’ConferenceonElectrical,ElectronicsandComputerScience, March2014,pp.1–7.

[3] T. Bohn and H. Chaudhry, “Overview of SAE standards for plug-inelectric vehicle,” in Innovative Smart Grid Technologies (ISGT), 2012IEEEPES.IEEE,2012,pp.1–7.

[4] M. C. Falvo, D. Sbordone, I. S. Bayram, and M. Devetsikiotis, “Evcharging stations and modes: International standards,” in 2014 Interna-tional Symposium on Power Electronics, Electrical Drives, AutomationandMotion,June2014,pp.1134–1139.

[5] A. Di Giorgio, F. Liberati, and S. Canale, “IEC 61851 compliant electricvehicle charging control in Smartgrids,” in 21st Mediterranean Conf.Control&Automation(MED),2013,pp.1329–1335.

[6] M.YilmazandP.T.Krein,“Reviewofbatterychargertopologies,charging power levels, and infrastructure for plug-in electric and hybridvehicles,” IEEE Transactions on Power Electronics, vol. 28, no. 5, pp.2151–2169,2013.

[7] J. Channegowda, V. K. Pathipati, and S. S. Williamson, “Comprehen-sive review and comparison of dc fast charging converter topologies:Improvingelectricvehicleplug-to-wheelsefficiency,”in2015IEEE24thInternationalSymposiumonIndustrialElectronics(ISIE),2015,pp.263–268.

[8] F. H. Malik and M. Lehtonen, “Minimization of queuing time of electricvehicles at a fast charging station,” in 2017 IEEE PES Innovative SmartGridTechnologiesConferenceEurope(ISGT-Europe),2017,pp.1–6.

[9] E.SortommeandM.A.El-Sharkawi,“Optimalschedulingofvehicle-to-grid energy and ancillary services,” IEEE Transactions on Smart Grid,vol.3,no.1,pp.351–359,2012.

[10] C. Wu, H. Mohsenian-Rad, and J. Huang, “Vehicle-to-grid systems :ancillaryservicesandcommunications,”2011.

[11] R. S. Sreelekshmi, R. Anusree, V. Raveendran, and M. G. Nair, “Solarfed hybrid energy storage system in an electric vehicle,” in 2018 9th In-ternational Conference on Computing, Communication and NetworkingTechnologies(ICCCNT),2018,pp.1–7.

[12] X. Yan, B. Zhang, X. Xiao, H. Zhao, and L. Yang, “A bidirectional powerconverter for electric vehicles in v2g systems,” in 2013 InternationalElectricMachinesDrivesConference,May2013,pp.254–259.

[13] P. T. Pillai, R. S. Sreelekshmi, and M. G. Nair, “A novel mpp trackercontrolfor asolar fedenergystorage systemin electricvehicle,”in2018 9th International Conference on Computing, Communication andNetworkingTechnologies(ICCCNT),2018,pp.1–6.

[14] O. Ibrahim, N. Z. Yahaya, N. Saad, and M. W. Umar, “Matlab/simulinkmodel of solar pv array with perturb and observe mppt for maximisingpv array efficiency,” in 2015 IEEE Conference on Energy Conversion(CENCON),2015,pp.254–258.

[15] R.BhavaniandN.RathinaPrabha,“Simulationofreducedratingdynamicvoltagerestorerusingsrfanfiscontroller,”InternationalJournalofFuzzySystems,vol.20,042018.