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Arduino Uno based Maximum Power Point Tracking System by the Optimization of Solar Energy

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ABSTRACT

*The title of this work is **"Arduino Uno Based Maximum Power Point Tracking System by the optimization of solar energy"**. This paper's objective is to have a solar panel outputting its maximum possible power throughout; this occurs when the panel tracks the sun and rotates accordingly, to receive sunlight to the fullest extent always during the day time. This movement is achieved by installing a couple of servo motor switch the solar panel that changes its direction according to the positioning of the sun. There are basically three major parts of this project, sensor, Arduino Uno and two servo motors. Arduino Uno consists of ATmega328 microcontrollers. ATmega328 microcontroller receives sensor output signal and controls servo motors according to the assigned program. One servo motor is used horizontally to move the panel upward and downward. The other is used vertically from left to right direction. As the solar panel is connected in servo motor so the position of solar panel is same to the servo motor. Since the maximum solar ray is fallen down on the solar panel module so it can achieve maximum power output.*

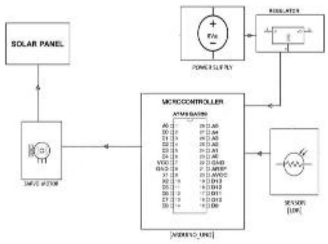
Key words: Solar Panel, Sensor, Arduino Uno, Servo motor, solar photovoltaic cell.

1. INTRODUCTION

An autonomous solar system is a photovoltaic solar power plant which is not connected to the grid. The extraction of the maximum power from solar panels called 'MPPT technique' (Maximum Power Point Tracking) provides an effective method to solve the optimization problem .A multi-junction solar cells are different from silicon PV cells as they are capable of converting solar irradiation into energy at high efficiency [1]. PV array represents the essential power conversion unit of a photovoltaic system. The output characteristics of PV array depend on the irradiation, the temperature and output voltage of PV array [2]. Among the MPPT strategies which are the most used: the method of incremental conductance (I.C.), the Perturbation and observation (P&O), and fuzzy logic [3, 4]. The performance of a standalone photovoltaic system depends mainly on the technical regulation and control adopted. In fact, there are many methods for estimating charging status 'State Of Charge: SOC'. The simplest method is the use of coulomb metric measurement [5].The main objective of this work is to track the sun and rotate the solar panel accordingly, to receive sunlight to the fullest extent always during the day time, optimization of solar energy using MPPT with an Arduino, designing a DC-DC converter solution to connect the solar panel to the load, measuring the viability and technical feasibility of MPPT, looking in to the background of solar power globally and giving details on the different methods of MPPT, using an Arduino in this system.

2. BLOCK DIAGRAM

Figure 1. Block Diagram of solar tracker using MPPT system with an Arduino

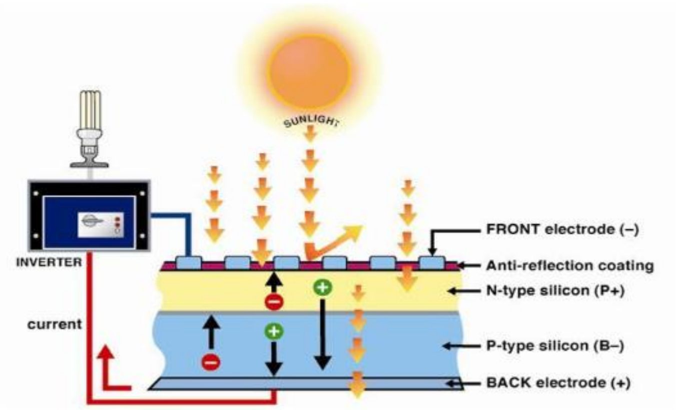


The above Figure 1 shows the Block diagram of solar tracker using MPPT system with an Arduino uno. In this when the sun light falls on the LDR. Then the sensor or LDR is active and the output LDR signal is follows in the Arduino analog input p in Ao. Then the programmable logic function of Arduinois active. According to our program which is burn/loaded before in Arduino, The digital output in D9 gives 0 as a result the horizontal servo motor isa ctive and rotate 180^{0}left to right. AccordingtoourprogramdigitalpinD10gives0and1andtheverticalservomotor rotate180^{0}leftt or right and right to left.

3. SOLAR PHOTOVOLTAIC (SPV) CELL

A solar photovoltaic or solar cell is a device that converts light into electric current using the photoelectric effect. The figure 2 shows the diagram of SPV. SPVs are used in many applications such as railway signals, domestic lighting, street lighting and powering of remote telecommunication systems. The various types of materials applied for photo-voltaic solar cells includes mainly in the form of silicon (single crystal, multi-crystalline, amorphous silicon) [6]-[8], cadmium-telluride [6] [7], copper-indium-gallium-selenite [6] [7] [9], and copper-indium-gallium-sul- fide [10][11]. It has a p-type of silicon layer placed in contact with an n-type silicon layer and the diffusion of electrons occurs from the n-type material to the p-type material. In the p-type material, there are holes for accepting the electrons. The n-type material is rich in electrons, so by the influence of the solar energy, the electrons move from the n- type material and in the p-n junction, they combine with holes. This creates a charge on either side of the p-n junction to create an electric field. As a result of this, a diode like system develops which promotes charge flow. This is the drift current that balances the diffusion of electrons and holes. The area in which drift current occurs is the depletion zone or space charge region that lacks the mobile charge carriers. So in dark, the solar cell behaves like a reverse biased diode. When light falls on it, like diode the solar cell forward biases and current flows in one direction from anode to cathode like a diode. Usually the open circuit (without connecting the battery) voltage of a solar panel is higher than its rated voltage. For example a 12 volt panel gives around 20 volts in bright sun light. But when the battery is connected to it, the voltage drops to 14-15 volts. Solar photovoltaic (SPV) cells are made of extraordinary materials called semiconductors for example silicon, which is presently the most generally used. Essentially, when light strikes the cell, a certain bit of it is absorbed within the semiconductor material. This means that the energy of the absorbed light is transferred to the semiconductor.

Figure 2.Solar Photovoltaic Cell



SolarPVcellsalsohaveoneormoreelectricfieldsthatacttoforceelectronsfreedby lightabsorptiontoflowinacertaindirection.Thisflowofelectronsisacurrentandby placing metalcontactsonthetopandbottom ofthe SPVcell,wecandrawthatcurrentoffto utilize remotely.Thecellsvoltage definesthe power thatthe solar cellcanproduce.The process ofconvertinglight into electricityis called the solarphotovoltaic(SPV) effect. An array ofsolarpanelsconvertssolarenergy intoDCelectricity.TheDCelectricity then entersaninverter.TheinverterturnsDCelectricity into120-voltACelectricity needed by home appliances.

4. SOLARPANEL

Collectionofsolarcells is called a solar panel.Thesolarpanelconvertsthesolarenergy into electricalenergy.ThesolarpanelusesOhmicmaterialfor interconnectionsaswellasthe external terminals. So the electronscreated in the n-typematerial passes through the electrode tothewire connectedtothebattery.Throughthebattery,theelectronsreachthep-type material.Here the electronscombine withthe holes.Sowhenthe solar panelisconnected to thebattery,itbehaveslikeanotherbattery,andboththe systemsare inseriesjustliketwo batteries connected serially.

4.1 WorkingPrincipleofSolarPanel

The figure 3 shows the circuit diagram of the solar panel. The solar panel output power is measured in Watts or Kilo watts. We can measure different output ratings like 5 watts, 10 watts, 20 watts, 100 watts and above in Solarpanel. We can find out the power requiring for the load before selecting the solar panel, it is necessary. If we calculating the power requirement in solar panel we used watt hours or Kilowatt hours.Asa generalrule,average powerisequalto20%ofpeakpower.Therefore eachpeakkilowattof solararray givesanoutputpowerthatcorrespondstotheenergy productionof4.8kWh/day. That is 24 hours x1 kWx20%. The solarpanel performance dependsona number offactorslikeclimate,conditionsof the sky,orientationofthepanel,intensity anddurationofsunlightanditswiringconnections.If sunlightisnormal,a12volt15wattspanelgivesaround1ampere current.Ifproperly maintained,asolarpanelwilllastaround25years.Itisnecessarytodesignthearrangement ofsolarpanelontherooftop.Usually itisarrangedfacingtheeastatanangleof45degree. Solar trackingarrangementisalsoused thatrotatesthe panelasthe sunmovesfromeastto west.Wiringconnectionisalsoimportant.Goodquality wirewithsufficientgaugetohandle thecurrentwillensurepropercharging ofthebattery.Ifthewireistoolengthy,thecharging currentmayreduce.Soasarule,thesolarpanelisarranged10-20feetheightfromthe groundlevel. Propercleaningof thesolar panel oncein month is recommended. This includes cleaningofthesurfaceto removedust andmoistureand cleaningand re connection ofthe terminals. Thesolarpanelhastotallyoffourprocessstepsoverload,undercharge,lowbattery anddeep dischargecondition, let'sallthem. Fromthebelowcircuit,we useda solar panel beinga currentsourceisused tocharge the battery B1viaD10.Whilebattery getsfully chargedQ1conductsfromoutputofcomparator. ThisresultsQ2to conductanddivertthesolarpowerthroughD11andQ2suchthatbatteryis notovercharged.Whilethebattery isfully chargedthevoltageatcathodepointofD10goes up.The currentfromsolar panelis bypassed via D11 andthe MOSFETdrainandsource. WhiletheloadisusedbytheswitchoperationQ2usually providesapathtothenegative whilethepositive isconnectedtothedcviathe switchintheeventover load.Thecorrect operation ofthe load in normal condition is indicated bywhile theMOSFET Q2 conducts.

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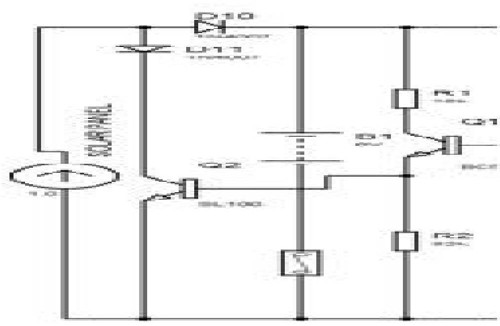
Figure 3.circuitdiagram

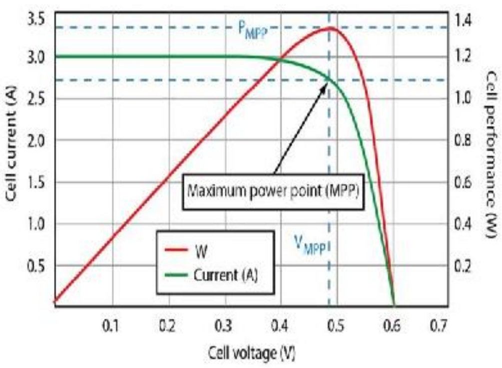


5. MAXIMUMPOWERPOINTTRACKING(MPPT)

Maximum Power point Tracking methodusedinSolarPV arraystoexpose uniformsolar irradianceandmaintaina maximumpoweroutputforaperiodoftime.Infigure 4themaximumpoweroutputcan clearly beseenatthe„knee‟ofthecurve.Thisisthepositionthatismostsoughtafterandis achievedwhenmaximumvoltageandmaximumcurrentareachievedatthesametime. MPPTis amethodto ensurethatmaximumvoltageandmaximum currentisreachedasmuch aspossibleandoveralltomake maximumutilizationof PVmodulesandminimizethepower failureduetoenvironmentalconditions[12].Thisisdoneby havingthesolararray trackthe pathofthesunandalsoby makingsurethatnoneofthesolararray becomespartially shaded atany stageduetocloud,branchesoftreesetc.,andifthisdoesoccurasystemisinplaceto adjustthe panelandgetitbacktooutputthe maximumcurrentandvoltage andhence the maximumoutputpower. The MPPT should include a self-tuning mechanism [13,14], which rules the power stage and drives the system to operate at the MPPT. Many MPPT algorithms have been proposed [15–18], some with faster positioning at the MPP and some others more precisely. A good dynamic behaviour is useful in situations with quickly changing irradiation conditions or load characteristics [16, 17]. DetailsofthetwomethodsusedtotracktheMPParegivenbelow;

themethodthatisbeingusedinthisworkisthe PerturbandObserve(P&O) method.If irradiance levelsdiffer throughoutthe solararray,thisresultsinmultiplelocalmaxima points beingproduced.ThisresultsinnonlinearityofthePVcharacteristiccurves,whichmeans thereismorethanone„knee‟intheP-Vcurve.Multiple localmaximaarenotgoodfor tracking asitreducestheeffectivenessofthetracking system,andtheseresultsinoverallloss in power output.

Figure 4. MPPT (P – V) Curve



5.1 HowMaximumPowerPointTrackingworks

Here iswhere theoptimizationormaximumpowerpointtracking comesin.Assumeyour batteryislow,at12volts.AMPPTtakesthat17.6voltsat7.4ampsandconvertsitdown,so thatwhatthebattery getsisnow10.8ampsat12volts.Nowyoustillhavealmost130watts, and everyoneis happy.Ideally,for 100% powerconversionyouwouldgetaround 11.3ampsat11.5volts,butyou havetofeedthebattery ahighervoltagetoforcetheampsin.Andthisisasimplified explanation-inactualfacttheoutputoftheMPPTchargecontrollermightvarycontinually to adjust forgettingthemaximum ampsinto thebattery.

Figure 5. MPPT Curve

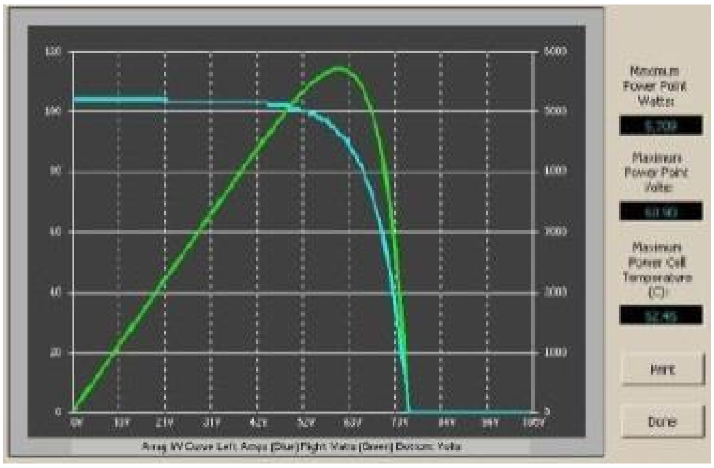


Figure 5 shows the MPPT Curve, Ifyou look at thegreenline,you willseethat it hasasharppeakattheupperright-thatrepresentsthemaximumpowerpoint.Whatan MPPTcontrollerdoesis"look"forthatexactpoint,and thendoesthevoltage/currentconversion tochangeittoexactlywhatthebattery needs.Inreallife,thatpeakmovesaround continuouslywith changes in light conditions andweather.AMPPTtracksthemaximumpowerpoint,whichisgoing tobedifferentfromthe STC (StandardTestConditions)ratingunderalmostallsituations.Underverycoldconditionsa120wattpanelisactually capableofputting over130+wattsbecausethepoweroutputgoes upaspaneltemperaturegoesdown-butifyou don'thavesomeway oftracking thatpower point,youaregoing toloseit.Ontheotherhandunderveryhotconditions,thepowerdrops- you lose power as thetemperaturegoes up. Thatis why youget lessgain in summer.

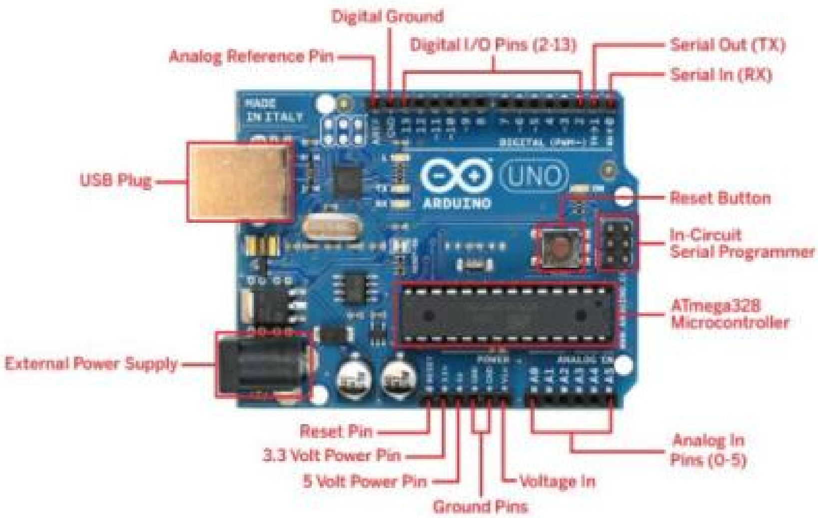
5.2 PerturbandObserve(P&O)methodofMPPT

ThisisanalgorithmwhichisusedasamethodofMPPT.TheP&Otrackingprocessis carriedoutby observingthearray outputpoweranddeterminingthenextaction,eitherto increaseordecreasethearray operating voltage.Inrecenttimesthismethodhas beenwidely usedto achievethemaximum amount of power from a solarpanel.Thepresenceofmultiple20localmaximumpowerpoints,theseoccurwhenanentire PV array donotreceiveuniformsolarirradiance,duetopartialshading,reducetheeffectiveness ofthismethodgreatly.IftheoperatingvoltageofaPVarray isperturbedinagiven directionandifthepowerdrawnfromthePVarray increases,thismeansthattheoperating pointhasmovedtowardstheMPPandtherefore,theoperating voltagemustbefurther perturbedinthesamedirection.Otherwise,ifthepowerdrawnfromthePVarray decreases, the operating point has moved awayfrom the MPP and therefore, the direction of the operatingvoltageperturbation must be reversed.

6. ARDUINOUNO

AnArduino Unoisactuallyamicrocontrollerbasedkit, it is basically used in communications and in controlling or operatingmanydevices.The figure 7 shows the Arduino Uno kit. A typical exampleof Arduinoboard is ArduinoUno.It consists of ATmega328- a28 pin microcontroller.

Figure 7.Arduino Uno



ArduinoUnoconsistsof 14digitalinput/outputpins(ofwhich6canbe usedas PWM outputs),6analog inputs,a16MHzcrystaloscillator,aUSBconnection,apowerjack,an ICSPheader, anda reset button.

PowerJack: Arduinocanbepowereitherfromthepcthroughа USBorthroughexternal sourcelikeadaptororabattery.Itcanoperateonaexternalsupplyof7to12V.Power canbe applied externallythrough the pin Vin or bygivingvoltagereferencethrough theIORef pin.

DigitalInputs: Itconsistsof14digitalinputs/outputpins,eachofwhichprovideortakeup40mA current. Some ofthem havespecial functions like pins 0 and 1, which act as Rxand Tx respectively,forserialcommunication,pins2and3-whichareexternalinterrupts,pins3,5,6,9,11 which provides PWMoutput and pin 13 where LED is connected.

Analog inputs: It has 6analoginput/output pins, each providingaresolutionof10 bits.

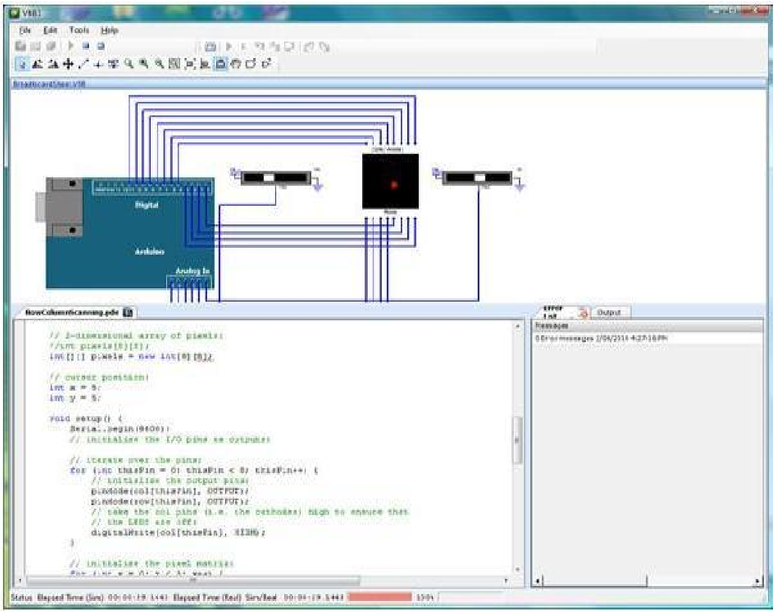
ARef: It provides referenceto theanaloginputs

Reset: It resets themicrocontroller when low.

6.1 HowtoprogramanArduino?

Themostimportantadvantagewith Arduinoistheprogramscanbedirectly loadedtothe device without requiring anyhardware programmer toburn the program. Thisisdone becauseofthepresenceofthe0.5KB ofBootloaderwhichallowstheprogramtobeburned into the circuit. All wehaveto do is to download the Arduino softwareandwritingthe code. The Arduinotoolwindow consistsof the toolbarwiththe buttonslike verify,upload, new, open,save,serialmonitor.Italsoconsistsof a texteditor towrite the code,a message area whichdisplaysthefeedbacklikeshowingtheerrors,thetextconsolewhichdisplaysthe outputand aseries ofmenus like the File, Edit,and Toolsmenu. The figure 8 shows an program window.

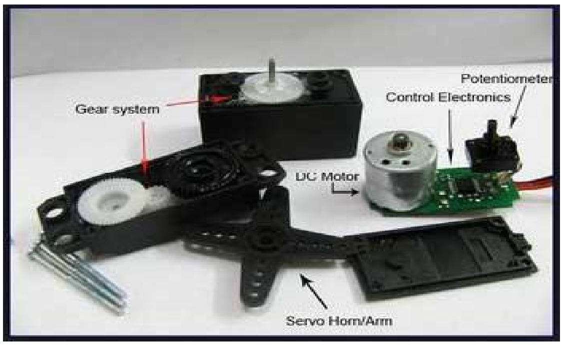
Figure 8.program anArduino



7. WORKING PRINCIPLE OF SERVO MOTOR

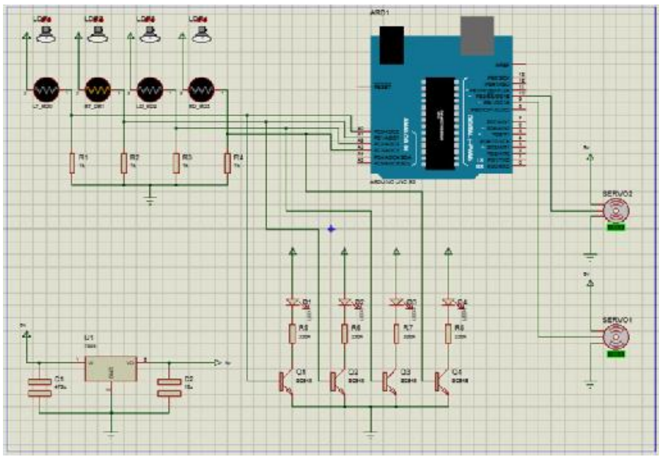
Basically theservomotorisaDCmotor (insomespecialcasesitisAC motor)along withsome otherspecialpurposecomponentsthatmakeaDCmoto.Inaservounit,youwill findasmallDCmotor,a potentiometer,geararrangementandanintelligentcircuitry.The intelligentcircuitry alongwiththepotentiometermakestheservotorotateaccordingtoour wishes.AsmallDCmotorwillrotatewithhighspeedbutthetorquegeneratedby its rotationwillnotbe enoughtomoveevena lightload.Thisiswhere thegearsysteminside a servomechanismcomesintothe figure 9.Thegearmechanismwilltake highinputspeedofthe motor (fast)andatthe outputwewillgeta outputspeedwhichisslowerthanoriginalinput speed but morepracticaland widelyapplicable.Say atinitialpositionofservomotorshaft,thepositionofthepotentiometerknobissuchthat there isnoelectricalsignalgeneratedattheoutputportof thepotentiometer.Thisoutputport of the potentiometer is connected with one of the input terminals of the error detector amplifier.Nowanelectricalsignalisgiventoanother inputterminaloftheerror detector amplifier.Now difference betweenthese twosignals,one comes frompotentiometerand anothercomesfromexternalsource,willbeamplifiedintheerrordetectoramplifierand feedstheDCmotor.Thisamplifiederrorsignalactsastheinputpowerofthedcmotorand the motor startsrotatingindesireddirection.Asthe motor shaftprogressesthepotentiometer knobalsorotatesasitiscoupled withmotorshaftwithhelpof gear arrangement.Asthe positionof thepotentiometerknobchangesthere willbeanelectricalsignalproducedatthe potentiometerport.Astheangularpositionofthepotentiometerknobprogressestheoutput or feedbacksignalincreases.After desiredangular positionof motor shaftthepotentiometer knobisreachesatsuchpositionthe electricalsignalgeneratedinthepotentiometerbecomes same asof externalelectricalsignalgiven toamplifier.Atthiscondition,therewillbe no outputsignalfromtheamplifiertothemotor inputasthereisnodifferencebetweenexternal appliedsignalandthesignalgeneratedatpotentiometer. Astheinputsignaltothemotoris nilatthatposition,the motorstopsrotating.Thisishowasimpleconceptualservomotor works.

Figure 9. Parts of Servo motor



8. CIRCUITDIAGRAM

Figure 10. CircuitDiagramofsolar tracker usingMPPT system with an Arduino



8.1WorkingprincipalofthisCircuit

Thiscircuitshowsin figure 10, thatthefixed5vvoltageregulatoroutputis connectedinArduinopower input.Because fixed5visneededto active anArduinoandalsoshowsthatthe voltage regulatoris connected inparallel with allotherparameters in this circuit.Whenthelightfallson thefirstsensororLDR.ThenthesensororLDRisactiveandthe outputLDRsignalisfollowsintheArduinoanalog inputpinAo.Thentheprogrammable logicfunctionofArduinoisactive.According toourprogramwhichisburn/loadedbeforein Arduino,ThedigitaloutputpinD9 gives0asaresultthehorizontalservo motorisactiveand rotate 180^0 left to right.Similarlywhen light falls on LDR2 thentheArduinoanalogpin A2 is activeand then accordingtoourprogramdigitaloutputpinD9gives1andthehorizontalservomotorrotate 180^0right to left.SimilarlywhenlightfallsonLDR3andLDR4 thentheanaloginputpinA3 andA4 isactive andaccordingtoourprogramdigitalpinD10gives0and1andtheverticalservomotor rotate180^0lefttorightandrighttoleft.Andalso showsthatwhenLDR1isactivethentheT1 isactive because T1base isconnectedintheLDR1outputandhenceLED1isON. Similarly when light is fallsLDR2, LDR3,LDR4thenLED2,LED3,LED4is ON.

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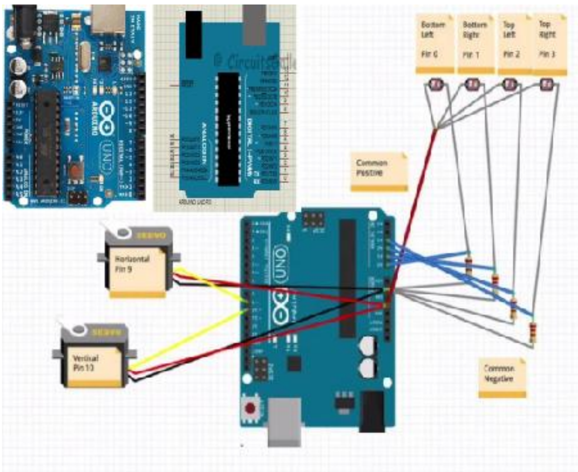
9. CONNECTIONDIAGRAM

Fig.11. Connection Diagram



SNAP SHOT

RESULT

WetestedandoptimizedtheDevelopmentboardandchecktheelectricalconnection betweenMicro-Controller andservo motor whichwasused tocontrolthe motors smoothly.AfterattachingtheSensor,wesuccessfully developedtheprogramtodetecttheinput signal to control the dcservo motors with Micro-Controller.

CONCLUSION

Insimpleterms this workistohaveasolarpaneloutputtingitsmaximum possible power allof the time,thisoccurswhentrackthe sunandrotate the solar panel accordingly, to receivesunlight to the fullest extent alwaysduringthe daytime.Inthisworkwelearnedaboutparametersinfluencingenergy conversionofPhotovoltaic (PV) arrays.Also learnedaboutthegeneralconceptofMaximumPower PointTracking (MPPT) and how to program burn anArduino.

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