Synchronization Between Solar Panel & AC Grid Supply For Different Loads

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Abstract: Today, with rising fuel costs, increasing concerns for global climate change, and a growing worldwide demand for electricity, utilizing renewable sources such as solar power becomes necessity rather than a luxury. The main focus is on providing energy at reasonable price but soon the day will come when the utilities will be focusing on encompassing sustainable use and environmental improvement into their agendas. Unlike conventional generation, the sunrays are available at no cost and generate electricity pollution-free. In today's scenario solar power is provided to the load which remains in isolation with the grid. This paper aims at developing a real-time, robust and intelligent grid connected solar panel in order to provide power to the loads from solar panel at day time and switch the power to the constant DC sources as soon as the solar power falls below a pre-defined limit. This switching of power from solar panel to constant source is controlled through LabVIEW using Data Acquisition Card and power relay. The system can be deployed for a guaranteed access to power at home or industry, even if the solar energy fails or is insufficient.

Index Terms: Renewable sources, intelligent grid connected solar panel, LabVIEW, Data Acquisition Card

1. Introduction

Energy plays a pivotal role in our daily activities. The degree of development and civilization of a country is measured by the amount of utilization of energy by human beings. Energy demand is increasing day by day due to increase in population, urbanization and industrialization. The world's fossil fuel supply viz. Coal, petroleum and natural gas will thus be depleted in a few hundred years. The rate of energy consumption is increasing; supply is depleting resulting in inflation and energy shortage. This is called energy crisis. Hence alternative or renewable sources of energy have to be developed to meet future energy requirement. Now the point is what renewable and non-renewable energy are.

Non-Renewable Energy

These are the energy sources that we are using and cannot create in a short period of time. However, we get most of our energy from non-renewable energy sources, which include the fossil fuels – oil, natural gas, and coal. They're called fossil fuels because they were formed over millions and millions of years by the action of heat from the Earth's core and pressure from rock and soil in the remains of dead plants and animals.

Renewable Energy

These are the energy sources that we can use over and over again. Renewable energy sources include solar energy, which comes from the sun and can be turned into electricity and heat. Wind, geothermal energy from inside the earth, biomass from plants, and hydropower and ocean energy from water are also renewable energy sources.

Solar power as the best renewable source of energy in India

Due to its proximity to the equator, India receives abundant sunlight throughout the year. Solar PV solution has the

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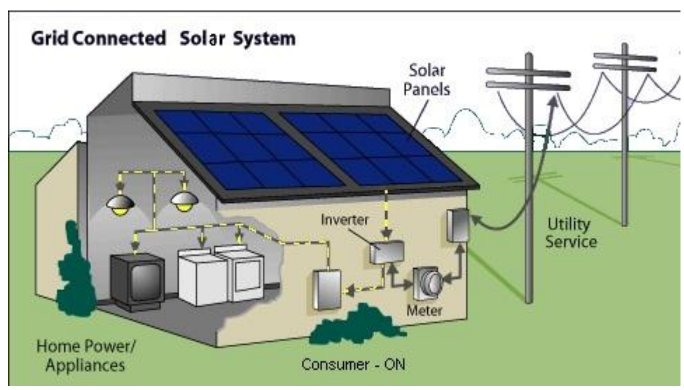
- Available throughout the year.
- Decentralized / off-grid applications – addressing rural electrification issues.
- Modularity and scalability.
- It causes no pollution to the environment.

The PV approach is particularly suited for the geographical and socio-economic features of this country having highly skewed energy distribution between urban and rural areas.

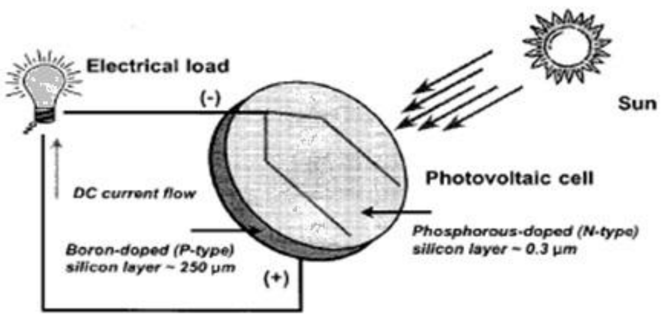


2. Solar energy: An Introduction

2.1 Photovoltaic: The Basics

Photovoltaic (PV), or solar cells as they are often referred to, are semiconductor devices that convert sunlight into direct-current (DC) electricity. A typical silicon PV cell is a thin wafer consisting of a very thin layer of phosphorous doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact (the P-N junction.) When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the cell is connected to an electrical load. The amount of current generated by a PV cell depends on its efficiency, its size (surface area) and the intensity of sunlight striking the surface. For example, under peak sunlight conditions a typical commercial PV cell with a surface area of about 25 square inches will produce about 2 watts peak power. If the sunlight intensity were 40% of peak, this cell would produce about 0.8

watts of power. Photovoltaic cells are connected electrically in series and or parallel circuits to produce higher voltages and/or currents. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of the complete PV generating unit. Photovoltaic panels include more than one PV module assembled as a pre-wired, field installable unit. A Photovoltaic array is the complete power-generating unit, consisting of a number of PV panels.



Solar power has so far played an almost non-existent role in the Indian energy mix. The grid-connected capacity in the country now stands at 481.48 MW, while the total solar energy potential has been estimated at 50,000 MW. On the upside, the market is set to grow significantly in the next ten years, driven mainly by rising power demand, escalating fossil fuel prices,. India has great potential to generate electricity from solar energy and is on course to emerge as a solar energy hub. The techno-commercial potential of photovoltaic (PV) in India is enormous. With GDP growing in excess of 8 percent, the energy gap between supply and demand will only widen. Solar PV is a renewable energy resource capable of bridging this gap. Most parts of India have 300 – 330 sunny days in a year, which is equivalent to over 5000 trillion kWh per year. This is more than India's total energy consumption per year Average solar incidence stands at a robust 4 – 7 kWh/sq mtr/day About 66 MW of aggregate capacity is installed for various applications comprising one million industrial PV systems – 80 percent of which is solar lanterns, home/street lighting systems and solar water pumps, among others The estimated potential envisaged by the ministry for the solar PV programme, i.e. solar street/home lighting systems, solar lanterns is 20 MW/sq km The potential of the solar thermal sector in India also remains untapped. The ministry has proposed an additional 500 MW during the Phase-I of the Jawaharlal Nehru National Solar Mission (JNNSM).

3 Software and Equipments Used

3.1 Solar Panels

A solar panel (also solar module, photovoltaic module or photovoltaic panel) is a packaged, connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each panel is rated by its DC output power under standard test conditions, and typically ranges from 100 to 320 watts. Solar panels use light energy (photons) from the sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells based on cadmium telluride or silicon. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture. Most solar panels are rigid, but semi-flexible ones are available, based on thin-film cells. Here, we are using two panels each of different rating. PV panel 1 is at 36V and has power rating of 252W. PV panel 2 is also at 36V but having power rating of 147W. Figure shows the PV panel used during this entire project.

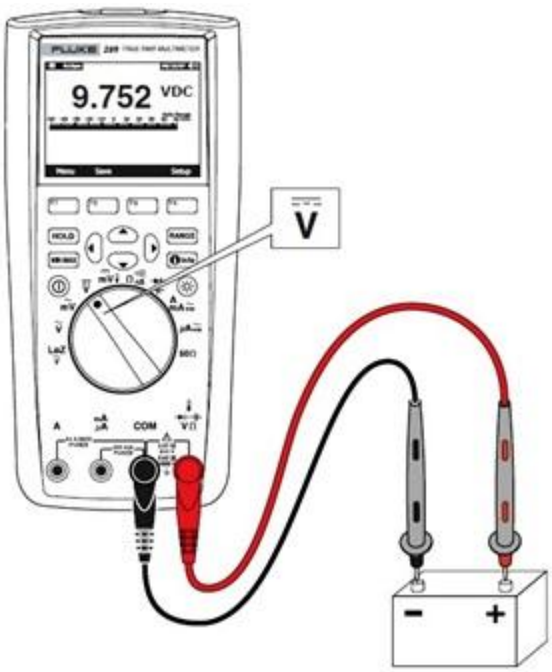
solar panel 1 solar panel 2

3.2 Labview 9.0

Labview is a highly productive development environment for creating custom applications that interact with real-world data or signals in fields such as science and engineering. Here, we are using 9.0 version of Labview. Labview itself is a software development environment that contains numerous components, several of which are required for any type of test, measurement, or control application. Each component is designed in some way to save you time or otherwise make you more productive by eliminating unnecessary details or making difficult operations easier. Labview programs are called virtual instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters. In Labview, we build a user interface, or front panel, with controls and indicators. Controls are knobs, push buttons, dials, and other input mechanisms. Indicators are graphs, LEDs, and other output displays. After you build the user interface, you add code using VIs and structures to control the front panel objects. The block diagram contains this code. Labview is designed to help us solve technical challenges that we face daily. Regardless of what industry we are in, Labview has built in functions for common tasks such as data acquisition and analysis, to more specialized functions for applications such as control design, simulation, or RF design. Regardless of our programming experience Labview has thousands of built-in analysis functions, and a wide array of toolkits and modules that offer specific functionality in areas such as real-time control, RF design, SCADA application development, motion control and machine vision, to name just a few. We can use Labview to quickly configure and use almost any measurement device, from stand-alone instruments to USB data acquisition devices, motion controllers, image acquisition systems, and programmable logic controllers (PLCs). Larger applications are made by adding lower level VIs to a main VI. VIs that are part of another application are referred to as "sub VIs. For example, we might create several VIs that perform different signal analysis and then use them as function blocks in your overall application.

3.3 PCB EXPRESS
There are two parts to Express PCB, CAD software and board manufacturing service. CAD software includes Express SCH for drawing schematics and Express PCB for designing circuit boards. Express PCB is very easy to use Windows application for laying out printed circuit boards.

FLUKE 287/289 DIGITAL MULTIMETER
The meter is used to measure various parameters like voltage, current, capacitance and testing diodes etc. The Meter has memory for storing individual measurements, measurements collected over a specified duration, and measurement events. All stored data can be viewed on the Meter or downloaded to a PC through the Meter's infrared (IR) communication link using Fluke View™ Forms.



3.4 TDS 2024B OSCILLOSCOPE
The TDS2000 Series digital storage oscilloscopes deliver an unbeatable combination of superior performance, unmatched ease-of-use, and affordability in an ultra-light weight. With up to 200 MHz bandwidth and 2 GS/s maximum sample rate, no other color digital storage oscilloscope offers as much bandwidth and sample rate. The TDS2000 Series oscilloscopes provide accurate real-time acquisition up to their full bandwidth, advanced triggers to isolate signals of interest, and 11 standard automatic measurements on all models.

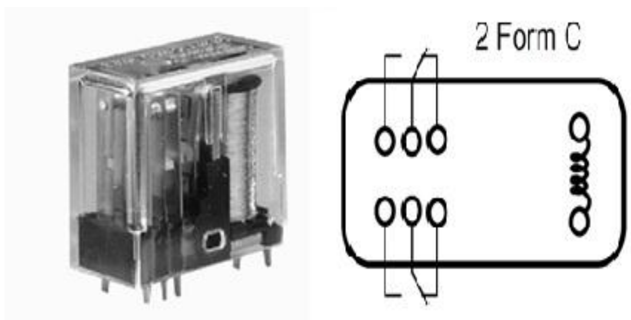
The main features of TDS 2024 oscilloscope are:

- 2.5k point Record Length on All 4 Channels
- Advanced Triggers including Pulse Width and Line-selectable Video
- 16 Automated Measurements, and FFT Analysis
- Built-in Waveform Limit Testing
- Automated, Extended Data Logging Feature
- Auto set and Signal Auto-ranging
- Built-in Context-sensitive Help, Multiple-language User Interface
- Probe Check Wizard
- 5.7 in. (144 mm) Active TFT Color Display
- Small Footprint and Lightweight – Only 4.9" Deep and 4.4 pounds
- USB 2.0 Connectivity, Host and Device Ports

3.5 DATA ACQUISITION CARD
Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems (abbreviated with the acronym DAS or DAQ) typically convert analog waveforms into digital values for processing. DAQ hardware is what usually interfaces between the signal and a PC. A DAQ card, or a data acquisitions card, is used to transfer data into a computer. This method allows for seamless transfer of input and output data through either digital or analog signals or channels. DAQ cards operate by utilizing both DAQ hardware and software.

RELAY
The relay used is OEN 57 and is of DPDT type having coil

rating of 24V and current rating up to 6A. It is a direct PCB type relay. It is dust protected and has high performance. The main purpose of the relay here is not the protection of system but to act as a contactor just for switching the circuit. The relay and circuit diagram is shown below:



3.6 Integrated Circuit and Optocouplers

The integrated circuit used here is LM324. The LM324 consist of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide voltage range. Operation from split power supplies is also possible so long as the difference between the two supplies is 3 volts to 32 volts. Application areas include transducer amplifier, DC gain blocks and all the conventional OP Amp circuits which now can be easily implemented in single power supply systems. A block diagram of LM324 is shown via fig a The 4N35 family is an industry standard single channel phototransistor coupler. It is made up of Gallium-Arsenide-diode infrared source optically coupled to a silicon NPN phototransistor. It has high direct-current transfer ratio and high-voltage electrical isolation up to 1.5-kV, 2.5-kV, or 3.55-kV Rating. The speed of switching is tr = 7 ms, tf = 7 ms. Its main application include remote terminal isolation, SCR and Triac Triggers. Figure b shows its schematic diagram.

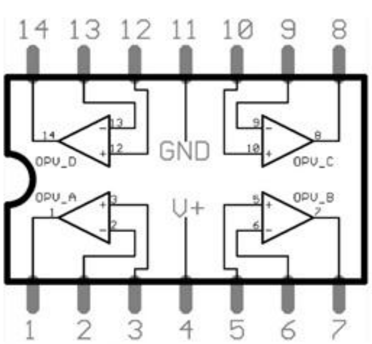


Fig a

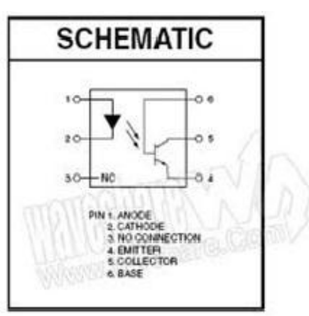


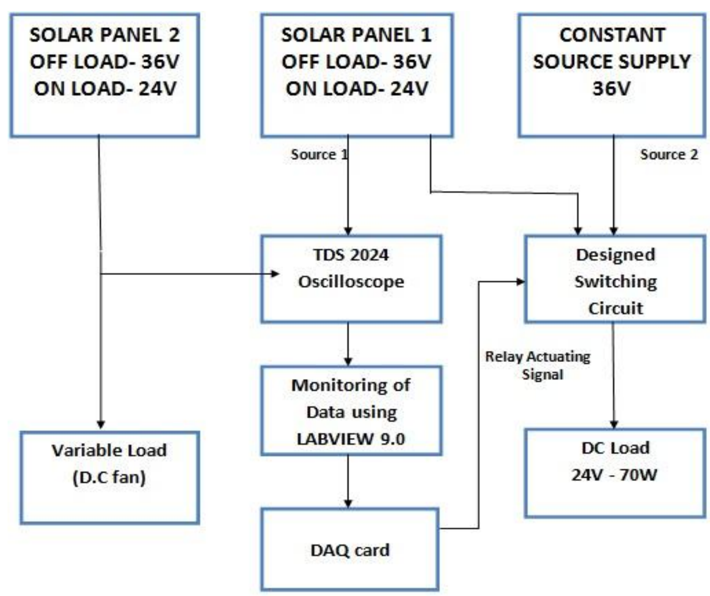
Fig b

4. METHOD PROPOSED

Real Time Monitoring of Data:

- The real time monitoring of Voltage, Current and Power of both panels on loaded and off loaded condition is done in LabView using TDS Tektronix 2024B Oscilloscope. The Oscilloscope had the facility of monitoring Voltages and Current through the 4 Channels, 2 for Voltage and 2 for Current, which helped us in monitoring both Voltage and current of both the panels simultaneously in LabView.
- The monitoring was done by making a VI (virtual instrument) in labview which acquires voltage and current through voltage and current probes of oscilloscope. The programming in LabView consists of various blocks which are then connected accordingly to get the desired output from the oscilloscope. In order to get the graphs of voltage, current and power we connected the blocks for the graphs. It was easy for us to make the adjustments and corrections (in case if any) in readings of voltage, current and Power in Real-Time using this oscilloscope.
- Also LabView and oscilloscope helps us in monitoring the total energy consumed by the load. It will tell us the amount of energy we saved by using solar panel instead of the constant supply. The energy consumed block is available as EPM (Energy Power Measurement) resource kit which develops a block of power usage in LabView.
- Monitoring of data is done mainly for analyzing the Voltage and current behavior during the daytime which helped us in developing the switching logic conditions.
- Apart for monitoring voltage and current using oscilloscope we used another device named as Fluke 287/289 True RMS multimeter. It was used in order to record any event i.e. change in voltage or current during a daytime. It had a disadvantage that it could only monitor 1 panel and only 1 thing i.e. either voltage or current at a time.

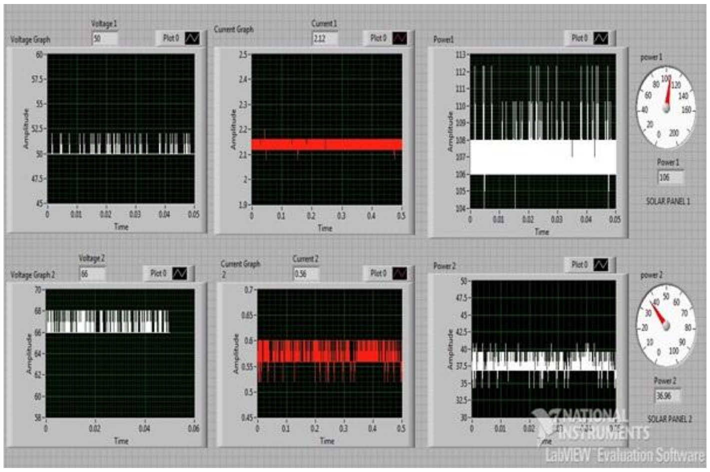
The following figure shows the block diagram of proposed method



Program in LabView for voltage and current reading acquired through oscilloscope

Monitoring of both the panels (voltage, current & power) can be done through this program. This program also saves the acquired data in a text file for future purpose.

Waveforms of Voltage, Current and Power of both Panels



SWITCHING:

- The smart switching has been done between solar panel and constant DC Source using double pole double throw solid state relay.
- In this process we have used Data Acquisition Card which will take digital input from the program designed in LabView and give digital output to actuate the switching circuitry.
- The switching circuitry consists of Op-Amp IC LM324, Optocoupler IC 4N35 and OEN58 Relay mounted on a PCB. The purpose of using of Op-Amp IC is to amplify the signal coming from DAQ card and going to Optocoupler IC. Optocoupler is used to isolate the relay and DAQ card, so that no damage occurs to the DAQ card as it is designed to carry current of few micro amperes whereas our load is carrying current of 2-3 ampere.
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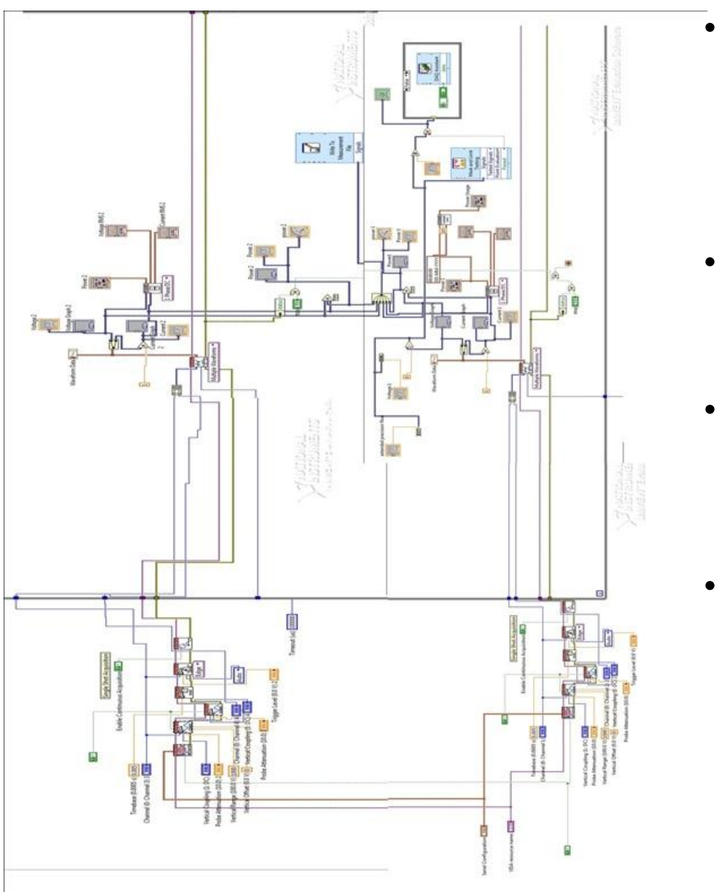

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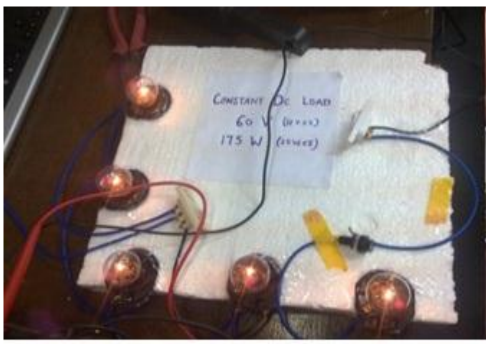
- The relay used here is a double pole double throw solid state relay which has a 24V coil rating. This coil rating means that for making the relay trip we need to keep the coil activated by supplying it to 24V supply. We have used a series of batteries in order to do so.
- The 24V supply is connected to the output of the Optocouplers IC. The output of Optocoupler IC consists of Base, collector and emitter. Until the input side of the Optocouplers doesn't get the supply the output side doesn't get short-circuited and the circuit is not completed leading to no tripping of the relay. Also we need a minimum 9V supply to activate the Op-Amp IC which we have again provided it by using a 9V battery.
- The monitoring of the solar panel, done by oscilloscope, will now be sent to the logic developed in LabView. The Logic we used is simple and is developed by only using the voltage of the panel.
- The panel had 2 voltages, one off-load and one On-load. The off-load voltage is found to be of the order 36V and the On-load Voltage is between 22- 28V depending upon the intensity of sunlight during the daytime. The voltage from the oscilloscope is taken and connected to one port of a greater than or equal to comparator (≥) while the same signal of the Voltage is connected to Mark and Limit testing Block in LabView.
- The other port of the comparator has a variable constant which can be varied accordingly depending upon the Off-load Voltage of the panel in various weather conditions in a year. The purpose of mark and testing block is to limit the On-load voltage between 22 and 28. The outputs of mark and testing block and output of the comparator Block is sent to the OR Gate Block. The OR gate simply works on the OR Gate logic.
- Here we defined 0 coming from the comparator for the value of off-load voltage panel is not greater than the defined value by the user and 1 is defined for the off-load value being greater than the value defined by the user in control variable. Whereas we defined 0 coming from the mark and testing block for the value of voltage is not between range defined by the user on the block and 1 for the value lying in the range.
- The output of the OR Gate is fed to the DAQ Assistant block present in the LabView. The DAQ assistant block is kept within the switch-case block present in LabView. The Switch-case block shows the execution of the program by displaying TRUE/FALSE on its assistant Block.
- If the Switch-case block shows TRUE then the DAQ card will consider it opposite and sends the trip command to relay so that the load is connected to Solar panel. And if the Switch-case block displays FALSE then the DAQ card consider it as True and send the relay the trip command to trip it to the Constant D.C source.
- Different resource conditions and load capacities needs tested to validate the control methods.

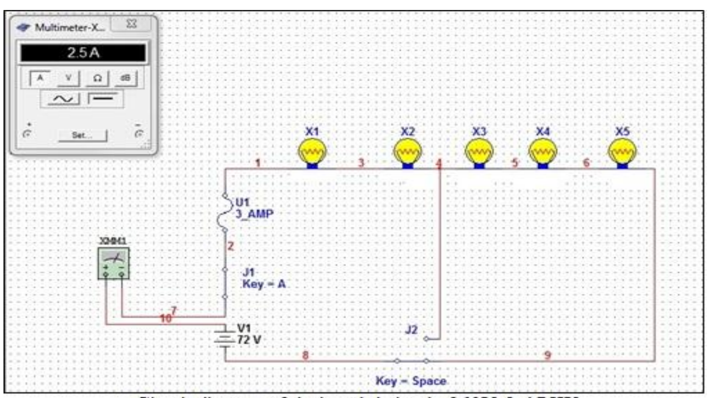
Output of comparator	Output of Mark and testing Block	Output of Gate	Supply
0	0	0	Constant D.C source
0	1	1	Solar panel
1	0	1	Solar panel
1	1	1	Solar panel

5. Designed Load for Given Solar Power

The Load has been designed in accordance with the solar power available. For PV panel 1 a constant load of 60V and 175W has been designed to which the panel can supply the power during daytime for about 7 hours. Constant load is a series combination of five 12V DC bulbs. The figure below shows the designed load and its current reading. A circuit diagram has also been shown.

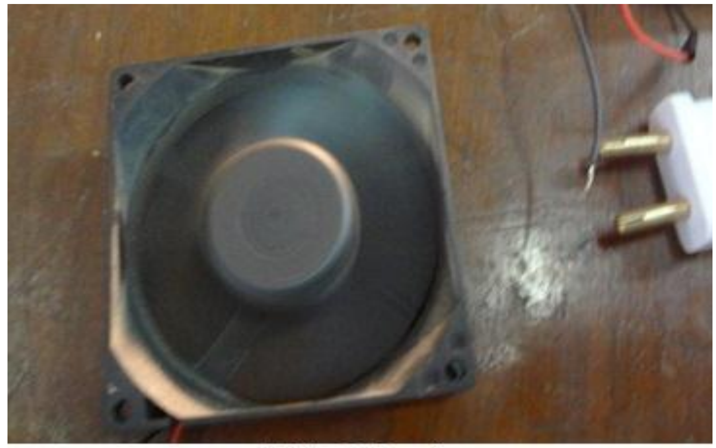


Designed Load Current Reading



Circuit diagram of designed dc load of 60V & 175W

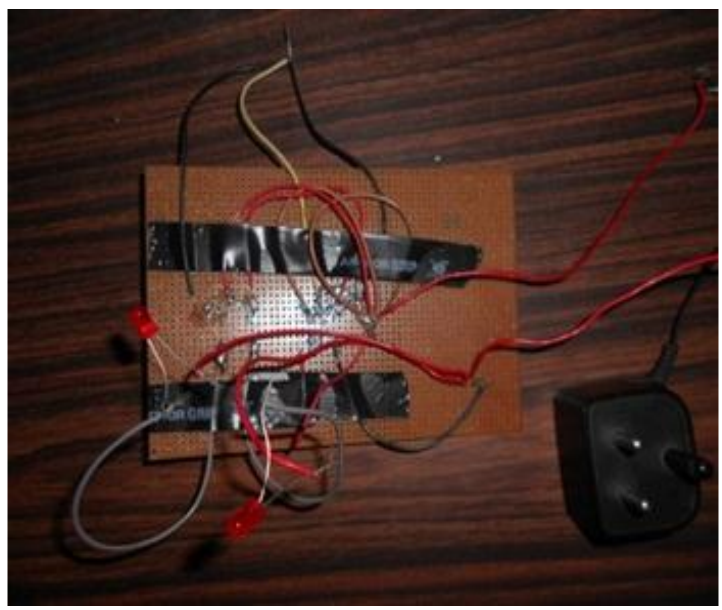
The power from the PV panel 2 is being fed to a constant load (bulb) of 110V and also to a variable load (which is a dc fan) of 18V. In this case also the power can be consumed from the panel for about 7 hours during daytime. Figure below shows the designed load.



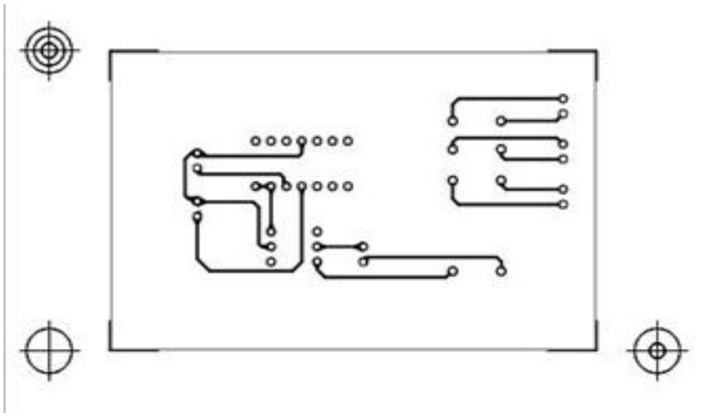
Variable Load

6. Switching Circuitry

The main purpose of this project is the smart switching between the solar power and constant d.c source irrespective of the condition that who is feeding the load. A person wants to save the electricity by using solar power during daytime but at the same time doesn't want that in case of solar power failure person has to switch to the constant power manually. For making this system smart, a switching circuit has been designed. At the initial level, a switching circuit was designed using L293D IC, a relay, a constant 9V supply and two led's for testing purpose. The figure below shows the circuit.

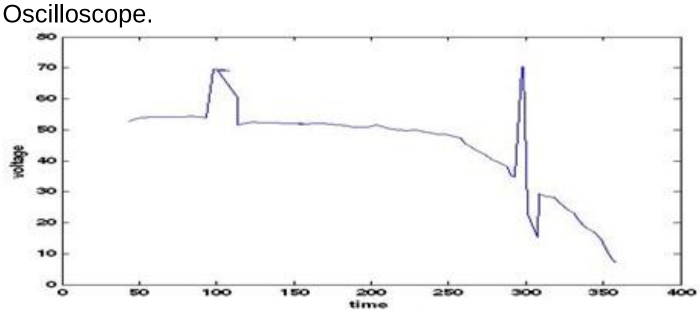


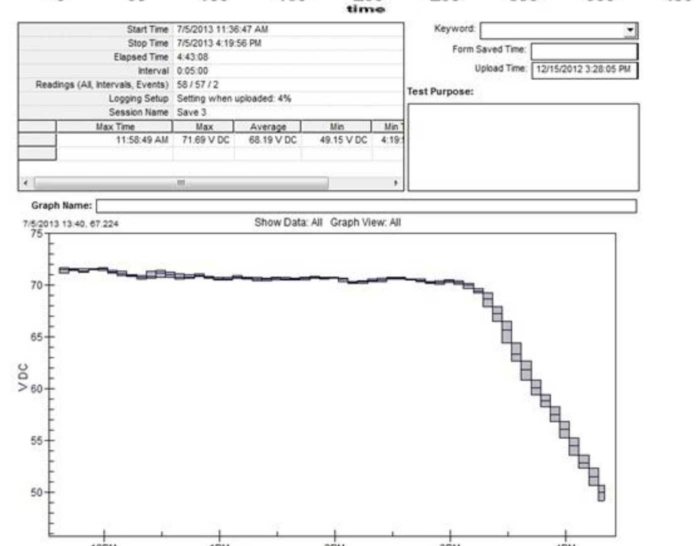
The experiment was successfully performed and the main switching circuit is designed using LM324 IC, 4N35 Optocoupler, OEN 57 relay and a constant 24 volt d.c supply for relay coil. The circuit diagram is shown:



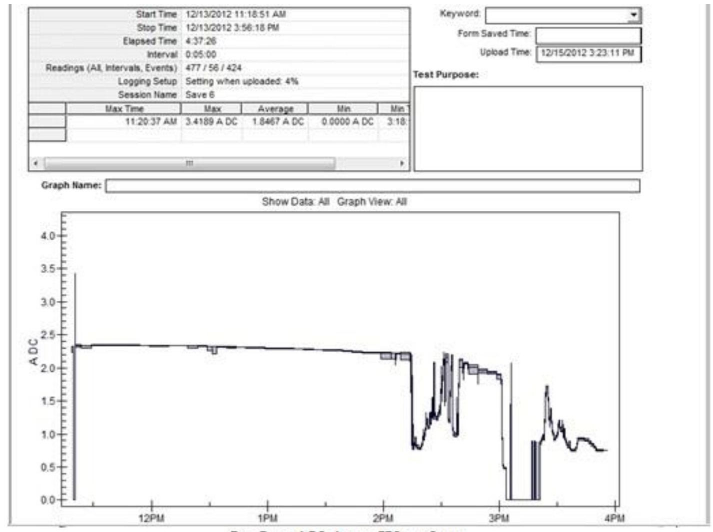
7. RECORDED DATA

The recorded data of the solar panels have been obtained for the last 5 months during daytime. Various graphs were obtained for voltage and current of both the panels using Fluke 287/289 True RMS multimeter and TDS Tektronix 2024B Oscilloscope.



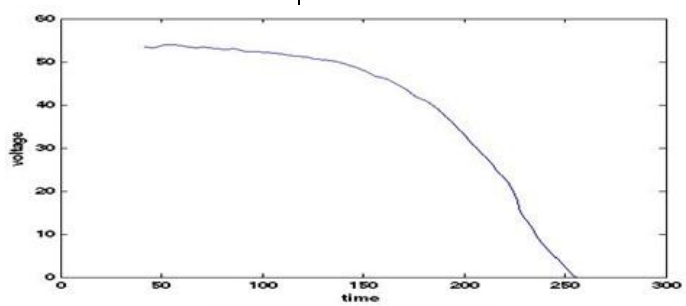


Off-Load Voltage Waveform

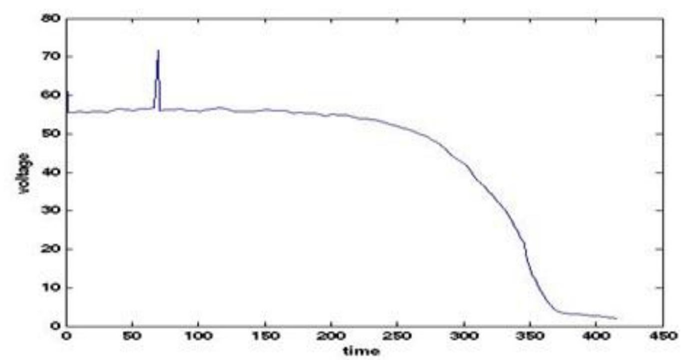


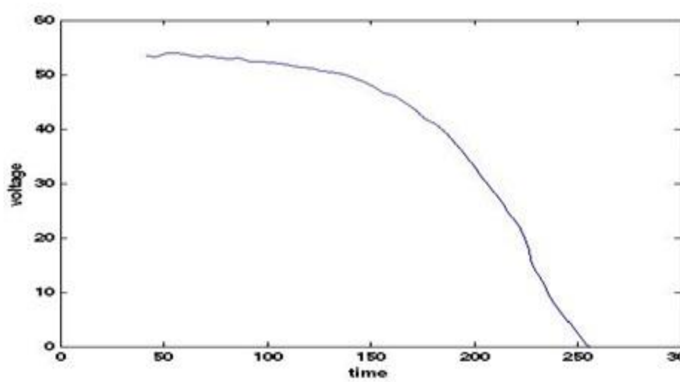
On-Load Voltage Waveform

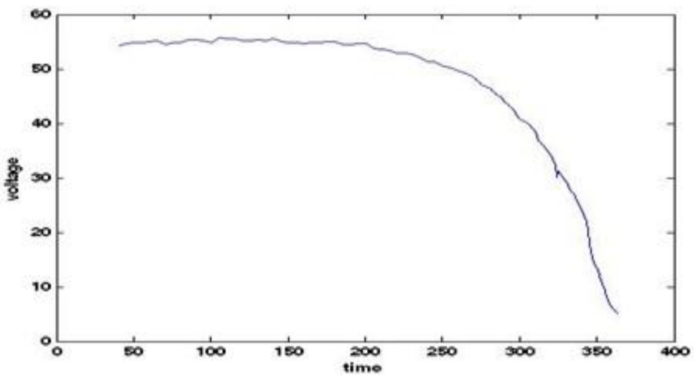
Various graphs of solar panel 1 are shown below. The 1st 3 Graphs Shown below is plotted with the help of Fluke 287/289 RMS Multimeter whereas all the other graphs were plotted from the project data obtained from the oscilloscope with the help of MATLAB.

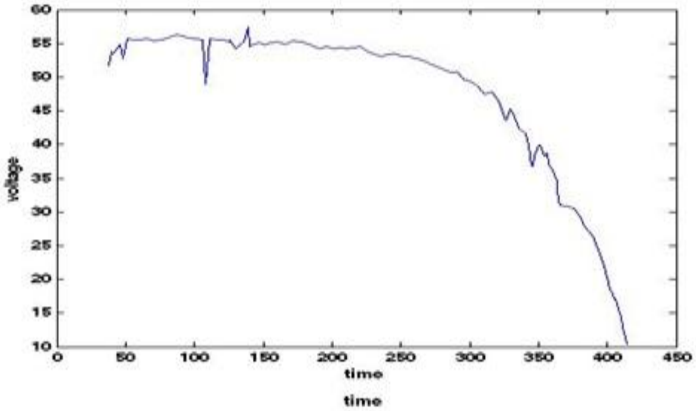


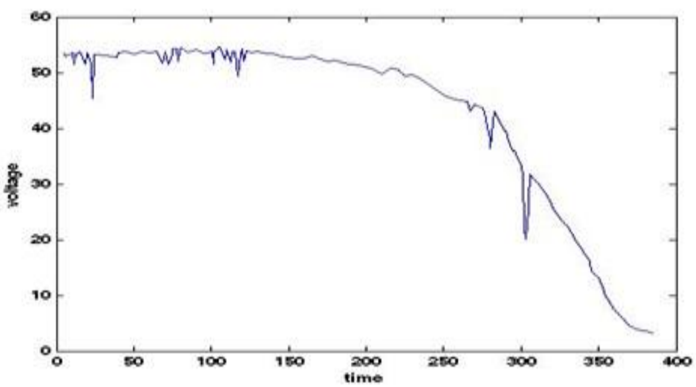
On-Load Current Waveform

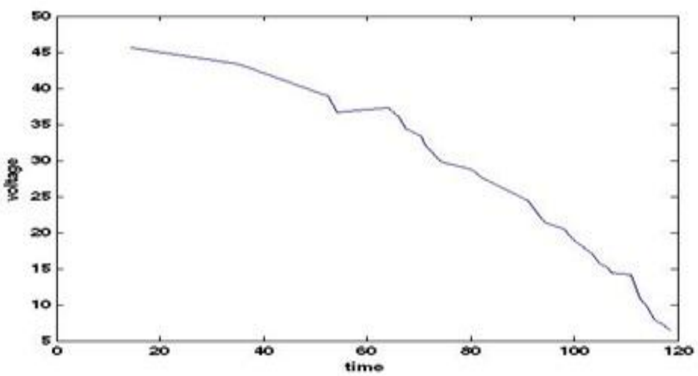


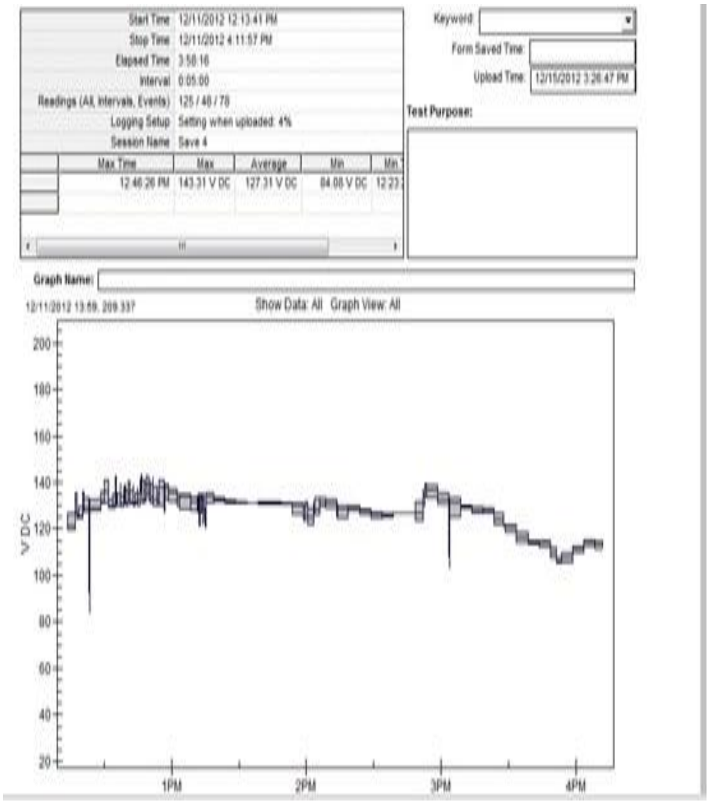


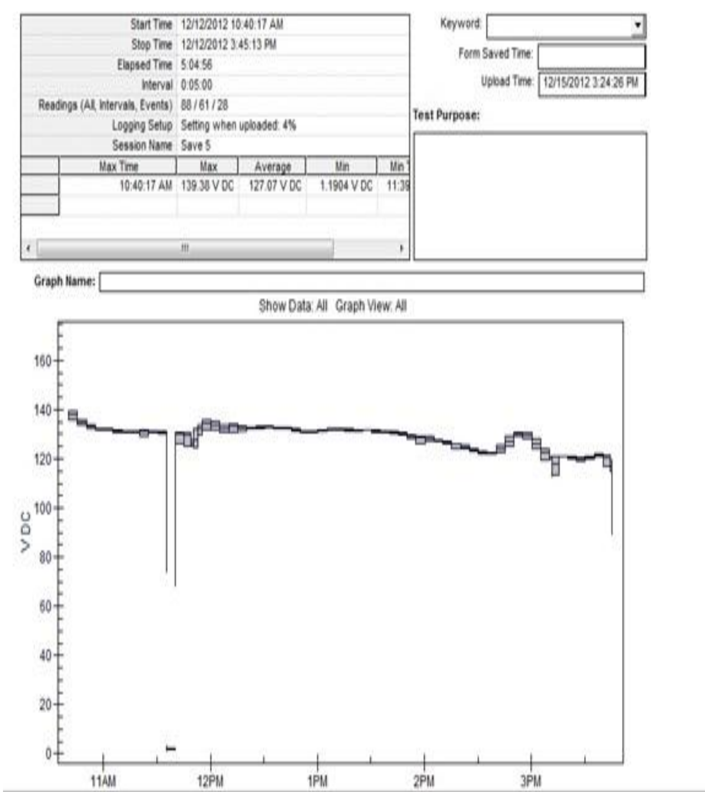




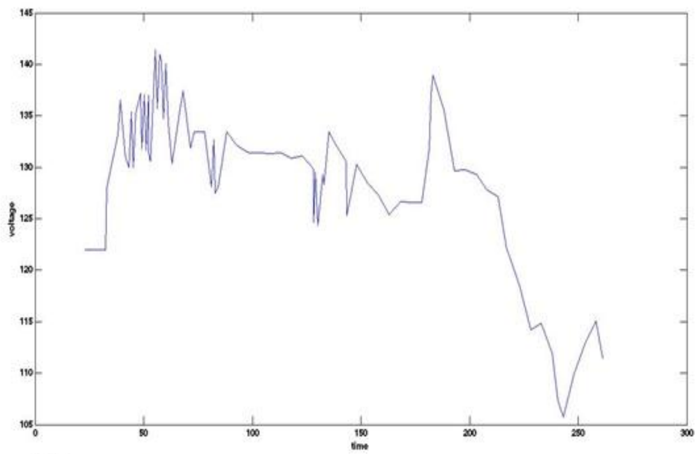


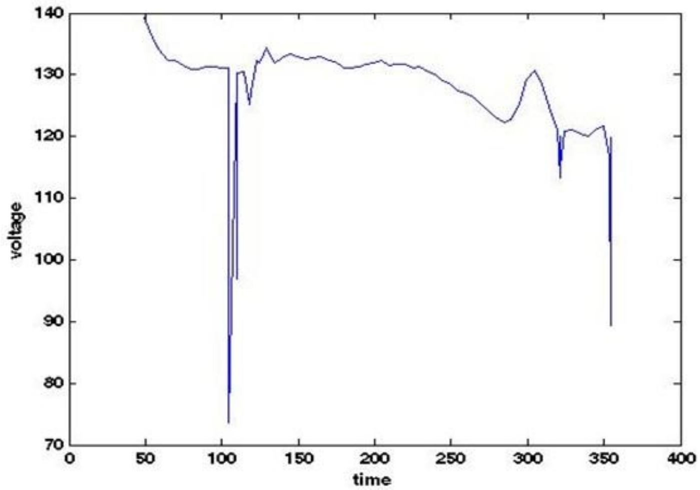






VARIOUS GRAPH OF SOLAR PANEL 2 (OFF LOAD-140V & ON LOAD 110V) ARE SHOWN BELOW





8. RESULTS

REAL TIME MONITORING OF SOLAR PANEL:

From the real time monitoring of solar panels in on load and off load position, we found that most of the voltage drops from off load to on load position which is due to poor voltage regulation of solar panels. Voltage regulation is about 30%. Also solar panels start producing power from 9:30 am to 4:30 pm. The peak power time is from 10:30 am to 3:00 pm with some fluctuations depending upon the weather conditions. 3-4V voltage drop is there in off load condition when sunlight drops down in day time, which is our one of the switching logic condition. For our 36V Solar Panel, on load working voltage is 20-26V during peak time, which is our one of the switching logic condition and the voltage drops down to 0V as sunlight goes away from solar panel. The on load current is 2.1-2.4 amp for the 24V constant DC load. The short circuit current for our 36V solar panel is 3.86 amps. We have also obtained different graphs of voltage, current and power for 2 solar panels simultaneously with the help of 4 channels Oscilloscope.

SWITCHING:

Switching was successfully done between solar panel-load and constant source-load with the help real time monitoring of solar panel and the designed switching circuit. The load switches from solar panel to constant source when specified logic conditions are met and vice versa. Switching takes place instantaneously with a small time lag which is due to software execution and other operating time of components used in circuit. When solar voltage fluctuates from its specified value then the Oscilloscope senses its and the fluctuation is seen in the system. The system checks the condition that we applied in the program and generates the tripping command from the program and sends it to the DAQ card. Then with the help of DAQ card the designed switching circuitry trips the relay to the constant D.C. source. At the end of the day the load successfully shifts from solar panel to constant D.C source. And the next day when the system monitors that the off-load voltage of the solar panel has reached a specified value then the load is again switched to solar panel successfully.
The DAQ card output is only 5V and 1mA and the relay coil voltage is 24V, therefore we have applied a circuit consists of op-amp and Optocoupler IC for successful operation.

9. ADVANTAGES

- Photovoltaic power production is gaining more significance as a renewable energy source due to its many advantages including everlasting pollution free energy production scheme, ease of maintenance, and direct sunbeam to electricity conversion.
- This give the user the option to use the system in two possible operating modes; the stand alone mode which is used to satisfy his needs, and power saving mode which is used to save electricity to utility when in excess through battery storage.
- Though the use of instruments and equipments we can monitor it all in real time like we can switch the power if we are lack of power from solar panel.
- Also we can have all these real time data stored in instruments which can be useful for betterment of the project.

10. CONCLUSION AND FUTURE SCOPE

CONCLUSION:

The monitoring of solar panels gave the correct data of voltage, current and power with the help of which the switching between solar panel and constant source have been successfully done during bad weather conditions when sunlight was low, at evening time and at morning time automatically. The data obtained also helped us in plotting various graph between voltage-time, current-time and power-time. The graphs thus obtained showed the changes in voltage, current and power due to any possible reasons mentioned above will help in designing the switching logic circuit for any solar panel.

FUTURE SCOPE:

The switching can be done between any two sources like between two solar panel sources and a load or between two loads and one source. Also if we use a three way switch relay than it can be possible that the switching is possible in panel-panel-constant source i.e.in case of low voltage from one panel the relay switch will go from one low voltage panel to the other high voltage panel with required voltage and in the end if the other panel also fails to deliver required power to the load than the load will be finally be shifted to the constant source.
The best future scope will be that if we are able to switch between A.C. power from grid and solar panel instantaneously and also at the same time we are able to deliver the A.C grid the extra power generated from the panel. The major problem

that will be faced is the synchronization between A.C. grid and solar panel. Also the problem of frequency and phases will have to be worked out. The TDS oscilloscope and the switching circuit can be eliminated from the system if we have a DAQ card of high input and high output rating. The DAQ card used here will monitor the data and at the same time will send the relay the switching command. Also the Optocoupler and op-amp used will be eliminated because now the signal coming from the DAQ card will be strong enough that it would not require amplification of the signal.

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