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CERTIFICATE

This is to certify that the thesis entitled "Hybrid Power Supply using DC bus" submitted by Aadesh Deshmukh (161030023), Prathamesh Kokate (161030024), Rishikesh Patil(161030058), Ankur Desai (161050013) and Tamal Golui (161050038) in the partial fulfillment of the requirements for the award of Bachelor of Technology degree in Electrical Engineering at Veermata Jijabai Technological Institute, Mumbai is an authentic work carried out by them under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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Hybrid Power Supply using DC bus for Residential systems

Abstract

The objective of this paper is to provide a sustainable alternative to traditional low voltage AC distribution system for consumer use using DC system. Around 50% of energy presently used in any house is consumed as DC as electronic devices comprise mostly of DC circuits and as power passes through a transient dc, resulting in significant loss when grid distributed ac is rectified. Also with the advent of alternative energy sources based locally near the site of consumption like solar panel arrays, biofuels which generally tend to generate electricity in DC, losses due to inversion and conversion are bypassed by directly using a DC system. Also using a DC system will reduce costs for electronics devices as there will be no need for energy conversion circuits in the designs of the devices.

Introduction

Direct current power distribution systems have become the topic of substantial research due to their potential to reduce power conversion loss, improve power quality, increase system reliability reduce system cost, etc.

When a source of dc generated electricity such as solar PV array is available, dedicated dc reduces the losses that occur from inversion and rectification. Results show site energy saving between 9% and 20% when solar PV array is used.

Since solar panel depends on the sun they won't be much good at night and will produce less energy depending on the season. So we need a backup supply to feel the void of solar energy. Ac grid connected is a very good option.

So using AC grid, solar supply along with batteries we can produce a highly reliable and energy efficient supply if DC bus is used.
Solar energy is a renewable source of energy that is gaining ground because of the benefits it offers. In India, sunlight is available in abundance and there is technology available to harness this energy and convert it into electric power. Solar power panels serve the purpose of absorbing solar energy and converting it to electric power through the photovoltaic (PV) effect. Most homes have a roof or a backyard which can be utilized to install solar panels and produce electricity

A home solar system must provide enough electric energy to fulfil all the power requirements of a home. It should also be capable of providing AC power as traditionally all homes use AC power to operate lighting systems, gadgets, appliances and equipment such as computers, refrigerators, mixers, fans, air conditioners, TVs and music systems.

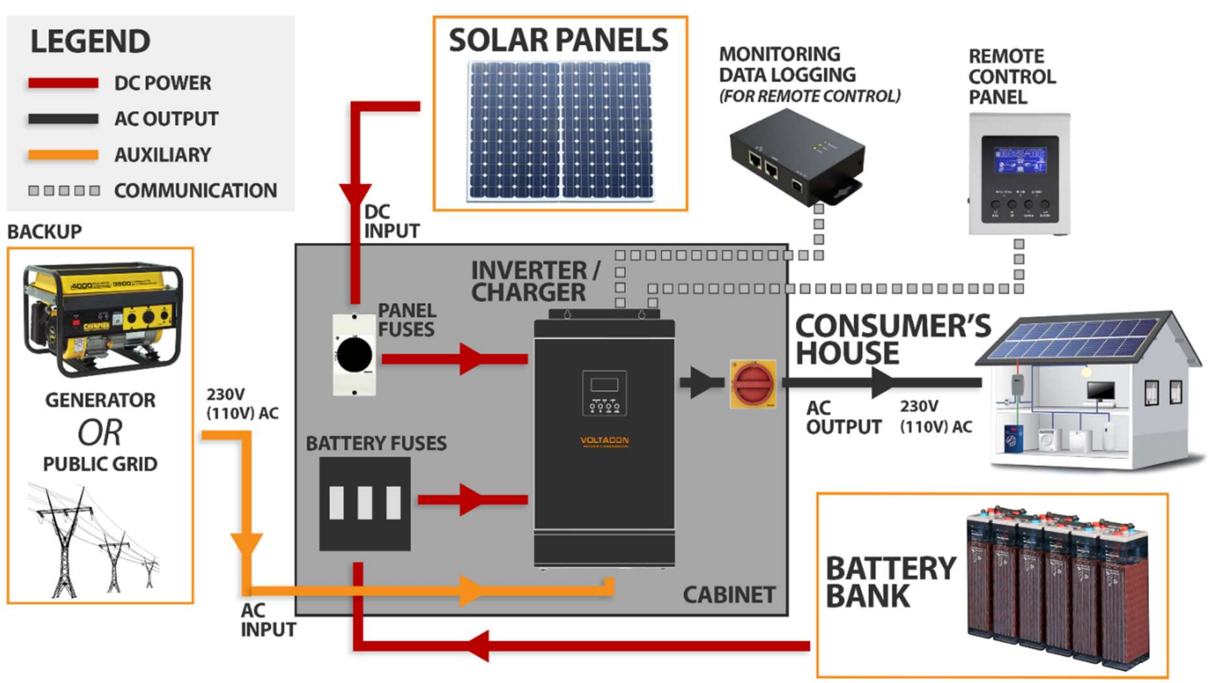
It requires the adequate number of solar panels to absorb as much solar energy as possible. When exposed to direct sunlight a typical home solar panel produces about 300 watts in one hour which means that in a normal day during summer, comprising 10 hours of sunlight, it can produce around 3000 watts or 3 kWh per day. This could vary depending on the number of hours of sunshine received during the day.

The system requires a battery which can be charged by the solar power generated and also can store electric power to be used in the night. Batteries are typically used in off-grid systems. The system needs an inverter to convert the DC power generated to AC power so that it can be used by AC specific appliances or energy storage devices in the home.

Components

SOLAR PANEL :-

Photovoltaic solar panels absorb sunlight as a source of energy to generate direct current electricity. A photovoltaic (PV) module is a packaged, connected assembly of photovoltaic solar cells available in different voltages and wattages. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. Most modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module can be either the top layer or the back layer. Cells must be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones based on thin-film cells are also available.



The cells are connected electrically in series, one to another to a desired voltage, and then in parallel to increase amperage. The wattage of the module is the mathematical product of the voltage and the amperage of the module

A PV junction box is attached to the back of the solar panel and functions as its output interface. External connections for most photovoltaic modules use MC4 connectors to facilitate easy weatherproof connections to the rest of the system. Also, a USB power interface can be used.

Module electrical connections are made in series to achieve a desired output voltage or in parallel to provide a desired current capability (amperes) of the solar panel or the PV system. The conducting wires that take the current off the modules are sized according to the ampacity and may contain silver, copper or other non-magnetic conductive transition metals. Bypass diodes may be incorporated or used externally, in case of partial module shading, to maximize the output of module sections still illuminated.

Some special solar PV modules include concentrators in which light is focused by lenses or mirrors onto smaller cells. This enables the use of cells with a high cost per unit area (such as gallium arsenide) in a cost-effective way.

BATTERY:-

The different types of batteries that may be used in solar electric and backup power systems.

Lead Acid

The common automobile batteries in which the electrodes are grids of metallic lead-containing lead oxides that change in composition during charging and discharging. The electrolyte is diluted sulfuric acid. The new AGM Battery technology has made a huge impact on lead-acid batteries, making it one of the best batteries to use in solar electric systems. Learn more about AGM batteries here. Industrial-type batteries can last as long as 20 years with moderate care, and even standard deep cycle batteries, such as the golf car type, should last 3-5 years. Intermediate batteries, such as the S460 and other batteries made by Surrette should last 7 to 12 years.

Lithium

Lithium batteries have many advantages over traditional battery types. They have an extremely long cycle life and high discharge and recharge rates. Learn more about Lithium batteries here.

NiCad (Nickel Cadmium)

Alkaline storage batteries in which the positive active material is nickel oxide and the negative contains cadmium.

Downsides:

1. Very expensive

2. Very expensive to dispose of - Cadmium is considered VERY hazardous.

3. Low efficiency (65-80%)

4. Non-standard voltage and charging curves may make it difficult to use some equipment, such as standard inverters and chargers.

Type	Energy Density (Wh/kg)	Energy Efficiency (%)	Power Density (W/Kg)	Cycle Life (Cycles)	Self Discharge (%/Month)
Lead-Acid	30 - 40	70 - 90	180	200 - 2000	3 - 4
Li-Ion	100 - 250	75 - 90	1800	500 - 2000	5 - 10
Li Polymer	130 - 200	70	3000	>1200	4 - 8
Ni-MH	30 - 80	70	250 - 1000	500 - 100	30
Ni-Cd	40 - 60	60 - 90	140 - 180	500 - 2000	10 - 15
NaS	150	80 - 90	120 - 150	2500	-
VRB	25 - 40	80	100 - 150	>16,000	<1
Zinc Bromide	70	70	-	1000	-

NiFe (Nickel Iron)

Energy storage density = 55 watts per kilogram

Alkaline-type electric cells using potassium hydroxide as the electrolyte and anodes of steel wool substrate with active iron material and cathodes of nickel plated steel wool substrate with active nickel material. This is the original "Edison Cell". Very long life

Downsides:

1. Low efficiency - may be as low as 50%, typically 60-65%. Very high rate of

2. Self-discharge

3. High gassing/water consumption

4. High internal resistance means you can get large voltage drops across series cells.

5. High specific weight/volume

6. Can reduce the overall efficiency of the solar system as much as 25%

This also means that the output voltage varies with load and charge much more than other batteries. If you are using an inverter, the inverter needs to be designed with these voltage swings in mind. You may not be able to use NiFe's if your system depends on a stable voltage, for example, if you are running certain common DC appliances such as a refrigerator directly off the batteries. Also when using NiFe's to power DC lighting, you will notice the light intensity fluctuates. One could always use a voltage regulator to feed those appliances that need it, but that would decrease the efficiency even more.

Currently, it appears that the only source for new NiFe batteries is from Hungary, and we have heard mixed reports on them. In short, we do not recommend them unless they are nearly free. The high losses in charging and discharging will add an extra 25-40% to the size of the solar panels you will need for the same energy usage.

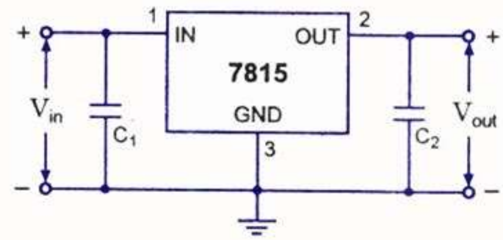
In short, despite some hype about long life and thousands of cycles, we feel that overall these batteries are a very poor choice for all solar applications.

VOLTAGE REGULATOR:-

A voltage regulator is a system designed to automatically maintain a constant voltage level. A voltage regulator may use a simple feed-forward design or may include negative feedback. It may use an electromechanical mechanism, or electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

DC Voltage regulator:-This circuit regulates a DC power output. It has a very wide application range. It can be used to control the speed of a motor, a pump, a toy train, the brightness of a LED or lamp, etc. Practically, it can be used in any application that uses a regulated DC power with pulse width modulation (PWM). It was originally used as a jumbo LED dimmer.

AC Voltage regulator:-AC voltage regulator (controller) is a device which is convert fixed Alternating voltage to variable Alternating voltage without changing frequency.



Connection of 7815 Voltage Regulator

DC BUS:-

The war of the currents was fairly decisively won by AC. After all, whether you’ve got 110 V or 230 V coming out of your wall sockets, 50 Hz or 60 Hz, the whole world agrees that the frequency of oscillation should be strictly greater than zero. Technically, AC won out because of three intertwined facts. It was more economical to have a few big power plants rather than hundreds of thousands of tiny ones. This meant that power had to be transmitted over relatively long distances, which calls for higher voltages. And at the time, the AC transformer was the only way viable to step up and down voltages. But that was then. We’re right now on the cusp of a power-generation revolution, at least if you believe the solar energy aficionados. And this means two things: local power that’s originally generated as DC. And that completely undoes two of the three factors in AC’s favor. (And efficient DC-DC converters kill the transformer.)

No, we don’t think that there’s going to be a switch overnight, but we wouldn’t be surprised if it became more and more common to have two home electrical systems — one remote high-voltage AC provided by the utilities, and one locally generated low-voltage DC. Because most devices these days use low-voltage DC, with the notable exception of some big appliances. Batteries store DC. If more and more homes have some local DC generation capability, it stops making sense to convert the local DC to AC just to plug in a wall wart and convert it back to DC again.

Safety:- Electricity starts getting dangerous to humans somewhere around 30-50 V. That’s where the current levels that push through the human body resistance start to become troublesome. But while everyone says “safety first!” it’s also worth noting that you’ve got 110 or 230 V AC in your walls right now. Clearly it’s “washing machine first” in the real world. Which is to say that although sub-30 V DC would be safer, we suspect that the safety will be designed into the connectors, or into circuit breakers.

Resistive Heating:-The problem with lower-voltage wiring is simple physics. For a given power demand, P=I*V, so a lower voltage means pushing more current. But substituting in Ohm’s Law, more current also means dramatically higher resistive losses P=I^2*R in the wires. Reducing the resistance of the wire by using more copper is one alternative, but you get more bang for the buck by focusing on the current-squared term. That’s the reason that, for instance, power over Ethernet (PoE) schemes use around 48 V

INVERTERS:-

Inverters change Direct Current (DC) to Alternating Current (AC). Stand-Alone inverters can be used to convert DC from a battery to AC to run electronic equipment, motors, appliances, etc. Synchronous Inverters (sometimes called utility-interactive) can be used to convert the DC output of a photovoltaic module, a wind generator or a fuel cell to AC power to be sold to the utility grid. Multifunction inverters perform both functions.

Synchronous Inverters (grid-tie)

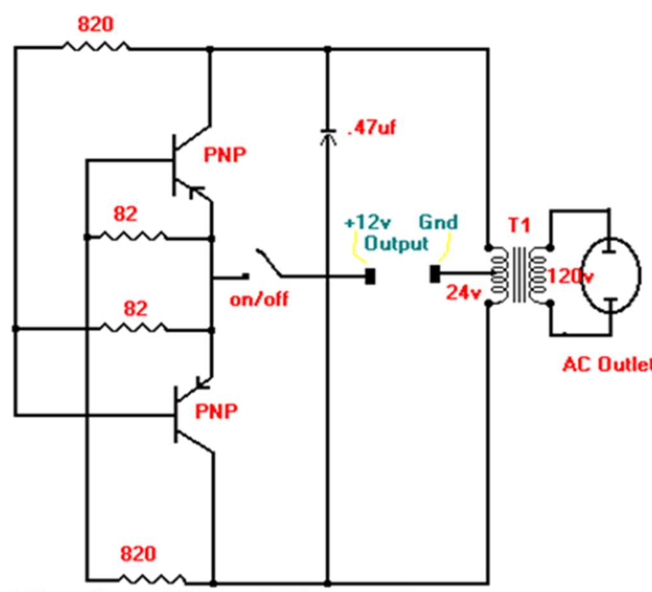
Synchronous inverters change DC power into AC power to be fed into the utility grid. A power system with this type of inverter uses the utility company as a storage battery. When the sun is shining, your electricity comes from the PV array, via the inverter. If the PV array is making more power than you are using, the excess is sold to the utility power company through a second electric meter. If you use more power than the PV array can supply, the utility makes up the difference. This type of system makes the most sense if you have utility power, because there are no batteries to maintain or replace, but it has a very long payback period and may not be cost-effective at today's electric rates. Using a multifunction inverter allows you to sell excess power to the utility, and also maintain a battery bank for standby power in the event of a utility power failure. Grid-tie inverters to directly connect wind turbines to the utility grid without batteries are under development.

Multifunction Inverters

Some true sine wave inverters can operate as Stand-Alone inverters and as Synchronous inverters at the same time! In a typical installation, this type inverter is connected to a battery bank, the utility power lines, a standby generator and the house load center. When batteries are in a charged condition, the inverter supplies AC power to the house from the batteries. If the batteries become discharged, the inverter supplies the house loads from the utility lines, while charging the batteries. If the batteries become fully charged by another power source, such as photovoltaic modules or a wind or hydroelectric generator, excess power may be sold back to the utility. If utility power fails, the inverter can still operate, supplying critical loads. If a standby generator is started, it can also supply power to loads. The inverter will synchronize to the generator and allow loads to be powered that are too large for either the generator or inverter to supply alone.

Stand-Alone Inverters

Stand-Alone inverters convert DC power stored in batteries to AC power that can be used as needed. Selecting an inverter for your power system based on the maximum load you will be powering, the maximum surge required, output voltage required, input battery voltage and optional features needed. High quality stand-alone inverters are available in sizes from 100 watts, for powering notebook computers and fax machines from your car, to 11,000 watts, for powering an entire house or small commercial operation. The size of an inverter is measured by its maximum continuous output in watts. This rating must be larger than the total wattage of all of the AC loads you plan to run at one time. The size of the inverter can be minimized if the number and size of the AC loads is kept under control. Wattage of most AC loads can be determined from a tag or label on the appliance, usually located near where the power cord enters, or from the owner's manual. If the inverter is expected to run induction motors, like the ones found in automatic washers, dryers, dishwashers and large power tools, it must be designed with surge capability to deliver power many times its rating for short periods of time while these motors start. Stand-alone inverters are available with three basic power output waveforms: square wave, modified square wave (sometimes called modified sine wave) and pure true sine wave. Synchronous Inverters and utility companies normally deliver a pure sine wave.

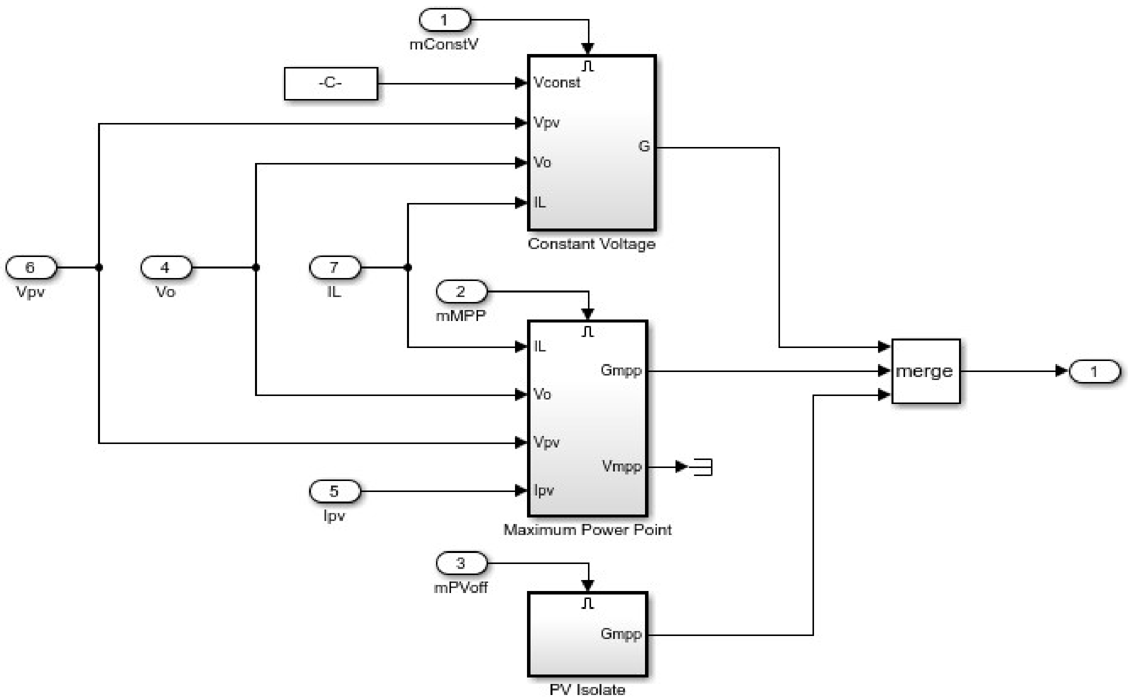


12 volt to 120 volt Power Inverter

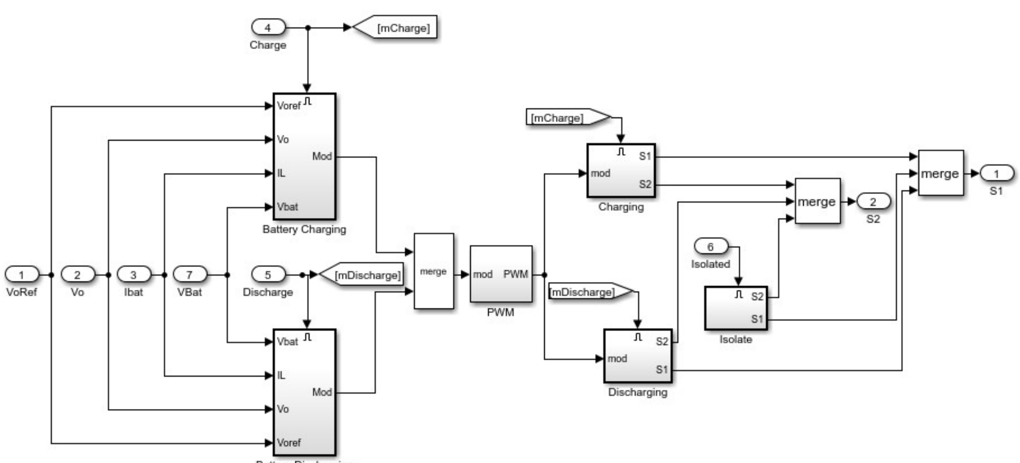
Design

Below are some circuit realisations for a DC bus based AC-DC hybrid system for residential use.

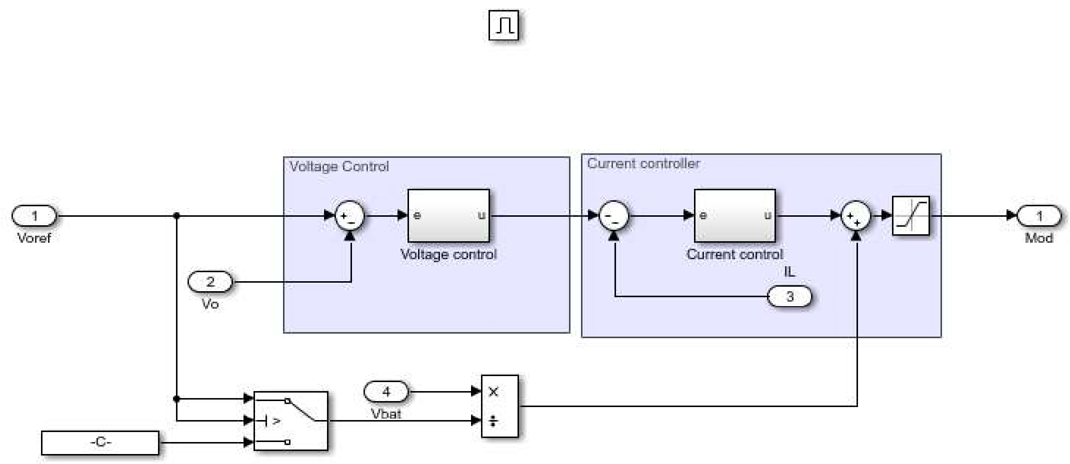
PV panel-



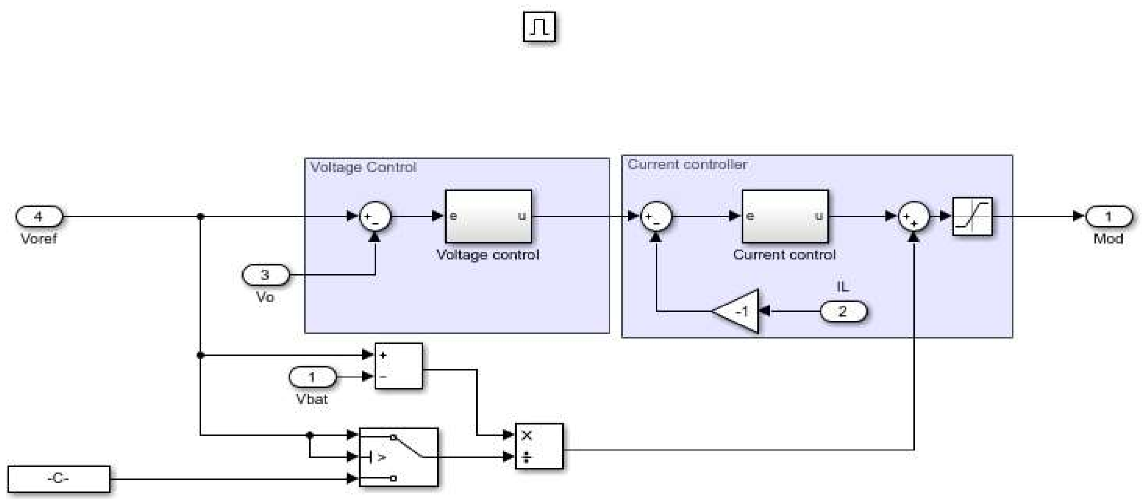
Battery manament system-



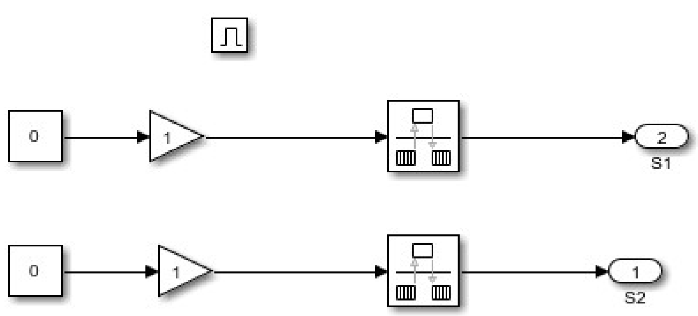
Battery Charging-



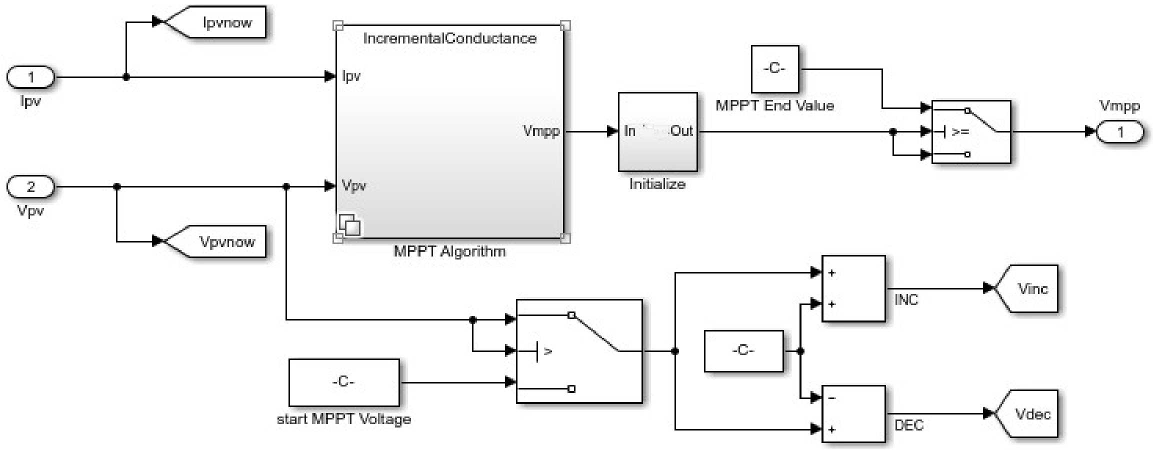
Battery Discharging-



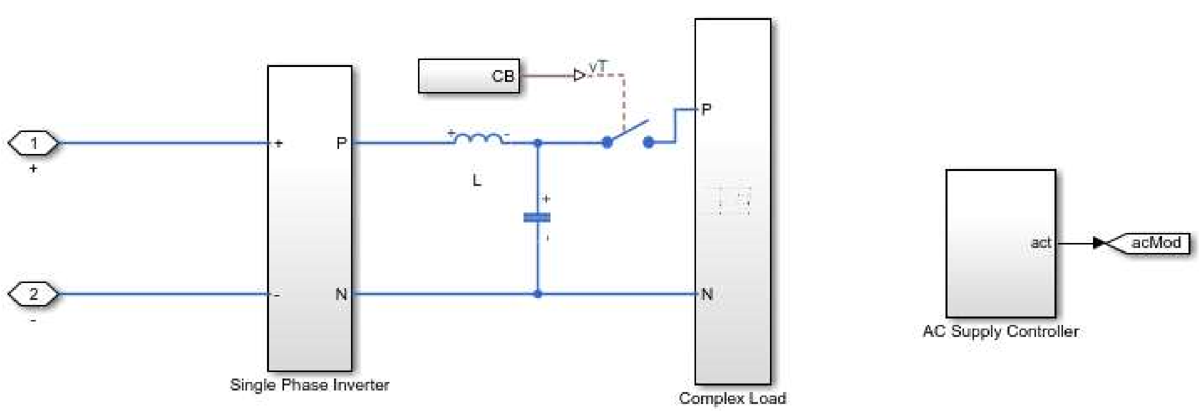
Battery Isolation-



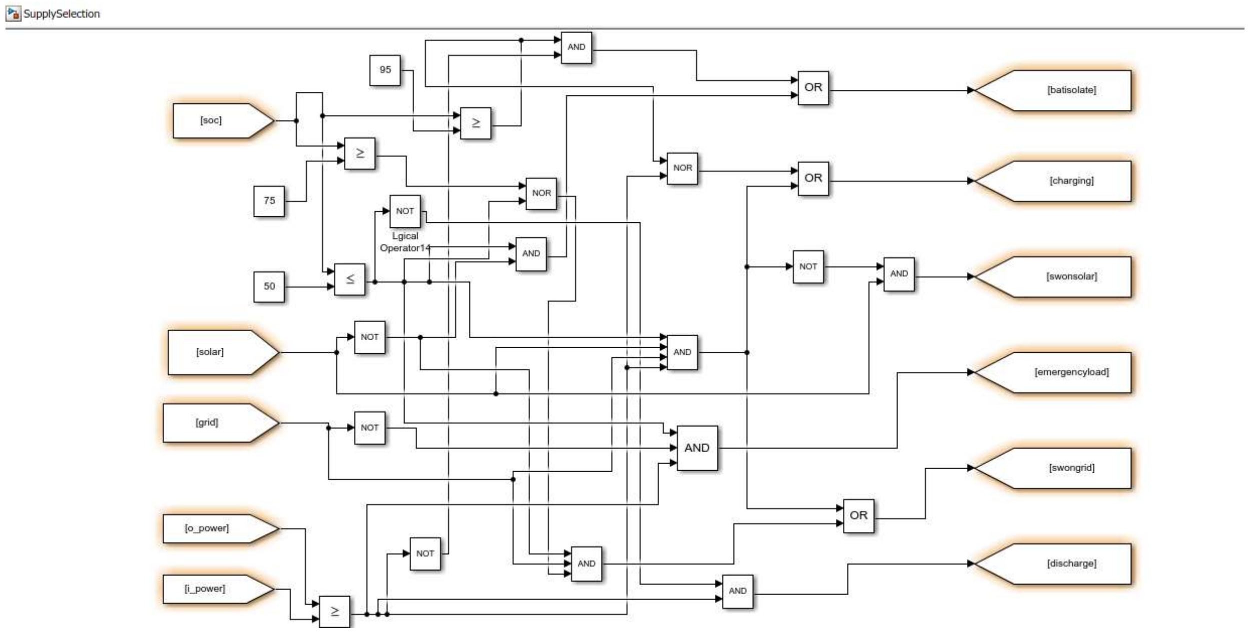
Maximum Power Point Tracking (MPPT)-



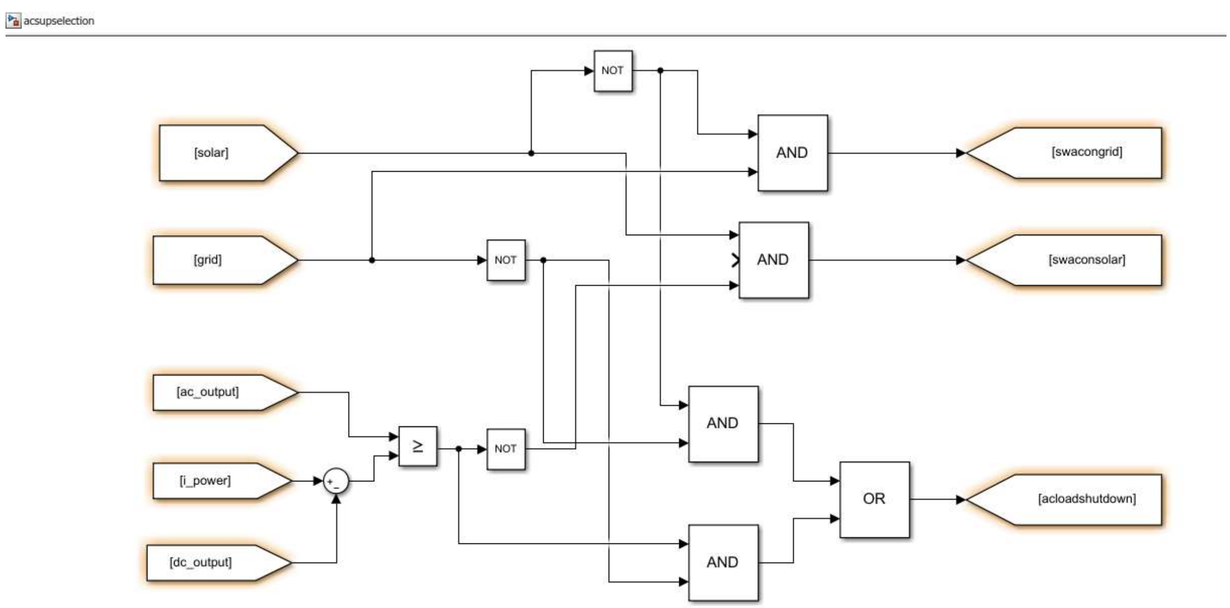
AC grid-



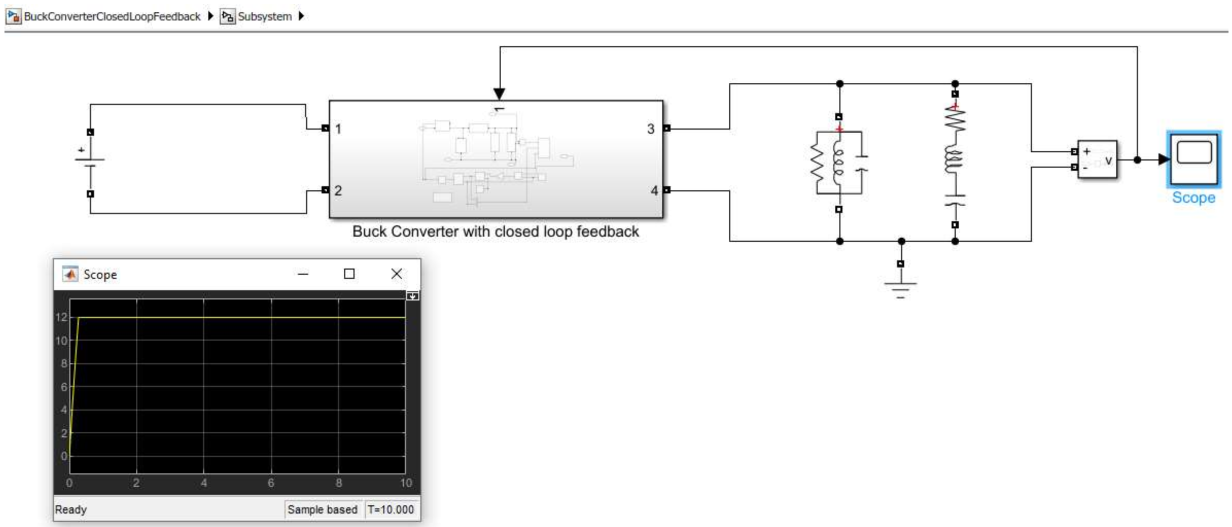
DC Supply Selection Cuircuit-



Ac Supply Selection-



Buck Converter for DC bus-



Here we see that multiple input sources are available. To keep optimum efficiency we prioritize these input sources which are then selected accordingly by the priority encoder. The order of priority is (1-highest, 4-lowest):-

1 - Solar AC/DC
2 - Battery Supply up to a certain percentage
3 - AC grid
4 - Battery supply

Design Specifications for the solar panel are as follows:

- Nominal max power (P_{max}) : 330W
- Optimum operating voltage (V_{mp}) : 37.2W
- Optimum operating current (I_{mp}) : 8.88A
- Open circuit voltage (V_{oc}) : 45.6V
- Short Circuit current (I_{sc}) : 9.45A
- Maximum series fuse rating : 15A
- Maximum system voltage : IEC 1000V & UL 1000V

The various appliances that will be used on this system are given in the table below:-

Appliances	**Min Rating (W)**	**Max rating (W)**	**Quantity**	**Daily use (hrs)**	**Average power consumption (Whr)**
LED TV	17	120	1	6	280
Fridge	150	400	1	24	6000
Ceiling fan	60	70	5	12	3900
Mobile Charger	10	50	4	2	80
Iron	1000	1500	1	0.25	300
Laptop/PC	50	100	2	3	450
Set Top Box	27	35	1	6	180
Tube Lights	22	30	5	8	880
Washing Machine	450	1300	1	1	600
Water Filter	70	100	1	0.5	45
LED lights	15	30	5	12	900
Oven	1000	5000	1	0.25	500

Working

Three inputs are provided to the source selection circuit:

1. Solar output
2. AC mains supply
3. Battery

Two outputs are taken from it

1. DC output through DC bus
2. AC supply

During normal conditions all the power consumed by the loads will supplied by solar. DC bus will have two voltage levels 5V and 12 V as required by the load. In day time with enough solar power all the load power will be supplied by solar. For ac load the solar power will be converted to ac by using inverters and filters. The battery will be charged simultaneously from solar panel.

Battery charge will never be allowed to exceed 95% and fall below 50% to extend battery life.

The DC bus will be maintained by multiple Buck convertors that are shown above in the multisim simulations. The Buck convertors will be responsible for voltage regulation of the DC bus voltage to maintain voltage within the specific limits that can be tolerated by various devices. Most electronics devices require 12V DC voltages while some can function between the range of 24V to 12V DC. Some high-power appliances like Air Conditioners, Refrigerator etc. can require up to 48V DC. Here we will have to provide for Multiple buck convertors that will have to adjusted to give the required voltage levels for these devices. Also due to difficulties in maintaining voltage regulation with many loads connected to output of a single Buck Convertor we will have to give Output outlets for supply with Buck converters rather than a single Bus regulated by a complex function to maintain a voltage. This will also allow us to supply various devices that require various DC voltage levels without having to maintain independent DC buses for these voltages.

The selection of sources will depend on the priorities given to them depending on the availability of solar energy, battery level and load type. The overall source priority is given by:

1. Solar power
2. Battery supply if charging level is high up to certain drainage level
3. Ac mains supply
4. Battery supply

The priority is decided taking into consideration the fact that to increase efficiency we must use solar power as much as possible and provide uninterrupted supply to the consumer.

The cases of priority are explained below:

CASE 1: Battery Isolate

1. Solar energy available and Battery charged above 95%

OR

2. Battery charged at 50%, solar power absent

Here Battery will be isolated from the System.

CASE 2: Charging

1. Solar energy available and Battery charged below 95% (I_power>O_power)

OR

2. Battery charge below 50%, solar power weak (O_power>input_power)

Here, Battery will be isolated from the supply system and the AC grid will handle the load and solar power will be used to charge the battery.

CASE 3: Switch on Solar

1. Solar energy available and Battery charged below 95% (I_power>O_power)

Here as solar power is available to power entire bus hence load will shift on solar

CASE 4: Emergency

1. Battery charge below 50%, solar power weak (O_power>input_power)
2. AC grid is not available.

Here battery is used to supply power to dc bus even when we have constrained ourselves to prevent battery from falling below 50%, but as we have no other option (solar weak/absent, AC grid unavailable).

CASE 5: Load on Grid

1. Battery charge below 50%, solar power weak (O_power>input_power)

OR

2. Battery is charged between 75% and 50%, Solar power unavailable

Here all load is connected to ac and battery is charged by ac grid. Until the battery is not charged up to 75 % the use of dc bus is not recommended to avoid conversion losses but the dc bus is still active the supply is given by rectifying ac mains supply.

CASE 6: Discharging

1. Solar energy is not available (at night or due to rainy season)
2. Battery is charged above 50%
3. Ac is not available.

Here battery is used to supply all load. In this case battery is used as a normal inverter. Here it is recommended to use minimum load until Solar power or ac supply is restored.

Conditions for AC loads are given as follows-

CASE 1: Ac load on solar

When solar power is in excess all AC loads will be switched to solar interfaced via inverter

CASE 2: Ac load on grid

When solar power is limited, we will switch AC load to grid

CASE 3: Ac load shutdown

Unavailability of both solar and grid, will lead to shutting down of solar load. As we are maximizing use of DC load, battery will supply DC load only.

Conclusion

We are using solar energy as a means to provide the required electric power consumption in a house. But major problem with solar is its reliability. However, if it is used judicially its reliability can be increased and also the efficiency is improved by using battery. The output of solar is dc however we use ac for our household appliances which leads to conversion losses and reduces the efficiency of solar. Thus, to avoid these losses we are using dc bus with different voltage levels which will supply power to the devices which can run on dc e.g. chargers, LCD TV, BLDC fan, LED light etc. Thus, using a power selection device which will take power from appropriate source depending on voltage level of battery, availability of solar energy and the type of load to be fed we can improve the reliability and efficiency so that the dependence on AC grid decreases and the solar source is reliable. Here we are taking care of all the uncertainties like power cut, rainy season, etc. Also, provisions are made to supply power back to ac grid in case the solar power is at peak and battery is fully charged. Thus using this circuit, we are improving the reliability and efficiency of solar power supply by decreasing its dependence for reliability on ac source.

Appendix

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