# A POWER CONTROL UNIT OF A SOLAR POWER GENERATION SYSTEM AND METHOD THEREOF

**ABSTRACT:**

The present invention relates to a PCU, a Micro Solar Power Generation unit. The PCU converts the variable direct current (DC) which is the output of a photovoltaic (PV) solar panels, into a utility frequency alternating current (AC) that can be fed directly to the Domestic Loads. The PCU also helps in storing the extra power generated into a battery and divert to Grid also. If there is a shortage in the power supply to the loads by the PCU, then the differential amount is recovered by the battery and the Grid.

**I CLAIM:**

1. A power control unit (A) of a solar power generation system, comprising segmented Micro controller unit (B), controllers and converters (C) EMI Filter (D) AVR (E) and Transformer (F) for preferential distribution of solar power to multiple ends; wherein, the multiple ends are battery, grid and load; and the Micro Controller unit (B) is segmented into solar micro controller unit and inverter microcontroller unit;
wherein, the power control unit distributes solar output power to the battery and to the grid when the output power is greater than the load; and
the power control unit draws the differential power from the grid when the solar output power is lesser than required the load.

2. The power control unit (A) as claimed in claim 1, wherein the Micro controller unit (B), controllers and converters (C) EMI Filter (D) AVR (E) are integrated on a single board or multiple boards.

3. The power control unit (A) as claimed in claim 1, wherein the Micro controller unit (B), controllers and converters (C) EMI filter and (D) AVR (E) are integrated on a single board.

4. The power control unit (A) as claimed in claim 1, wherein the controllers are Micro Controller Unit, maximum power point tracking (MPPT) controller, AVR controller, charge controller and DC to DC controller.

5. The power control unit (A) as claimed in claim 1, wherein the converters are DC to AC converter.

6. A method of solar power distribution by power control unit (A) of claim 1 to load, said method comprising direct feeding of the solar power to the load through maximum power point track charge controller, charge controller, inverter, isolation transformer and filter.

7. A method of solar power distribution by power control unit (A) of claim 1 to battery, said method comprising direct feeding of the solar power to the battery through maximum power point track charge controller.

8. A method of distribution of solar power and solar power stored in a battery by power control unit (A) of claim 1 to load, said method comprising feeding the power to the load through inverter, isolation transformer and filter.

9. A method of distribution of power from grid by power control unit (A) of claim 1 to load, said method comprising feeding the power through automatic voltage regulator, isolation transformer and filter.

10. A method of distribution of power from grid by power control unit (A) of claim 1 to load and battery, said method comprising feeding the power through automatic voltage regulator, isolation transformer, inverter and battery; and to the load by feeding the power through automatic voltage regulator, isolation transformer and filter sequentially.

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**Agent for the Applicant**
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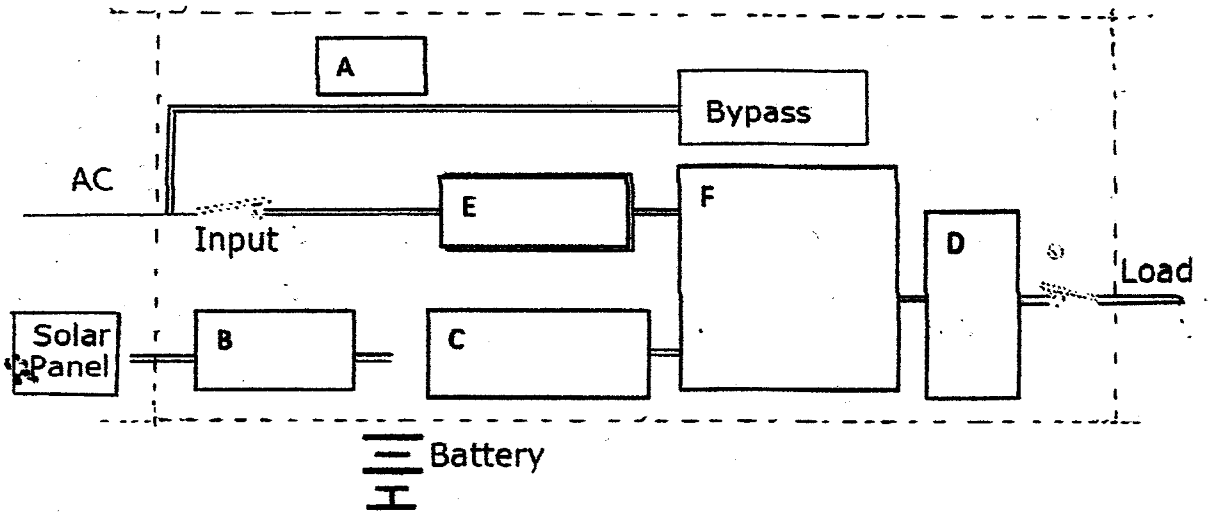


FIGURE-1

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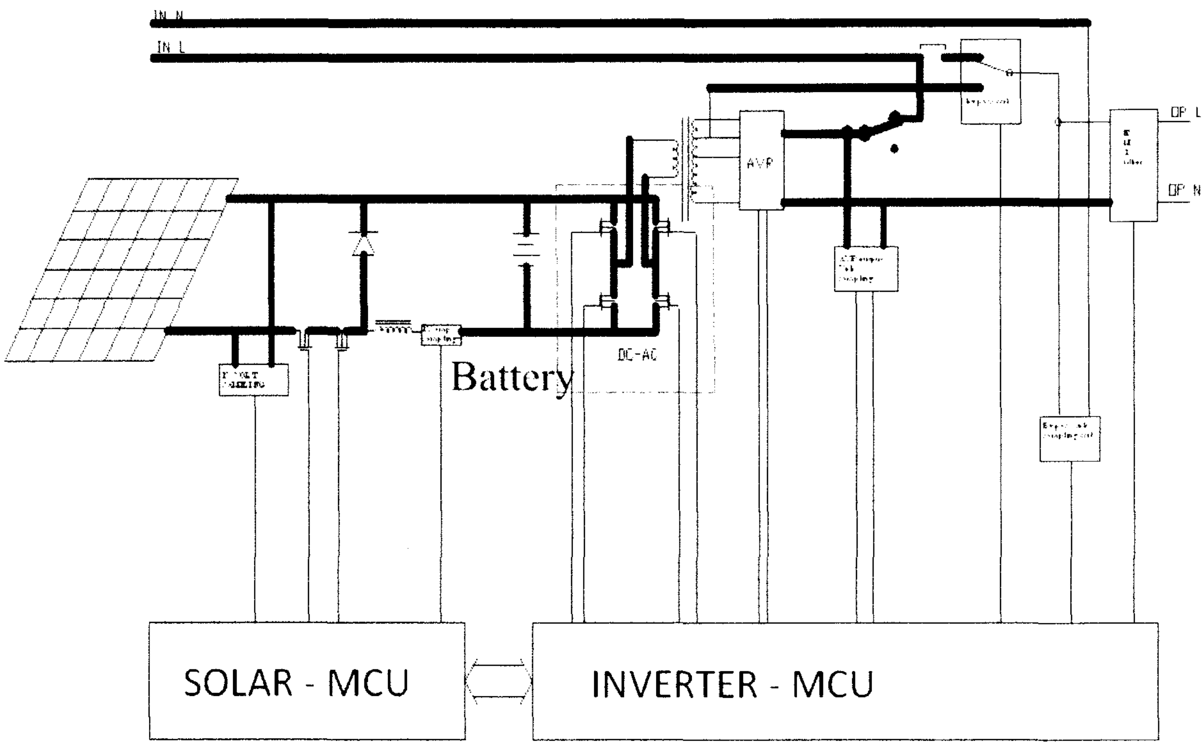


FIGURE-1A

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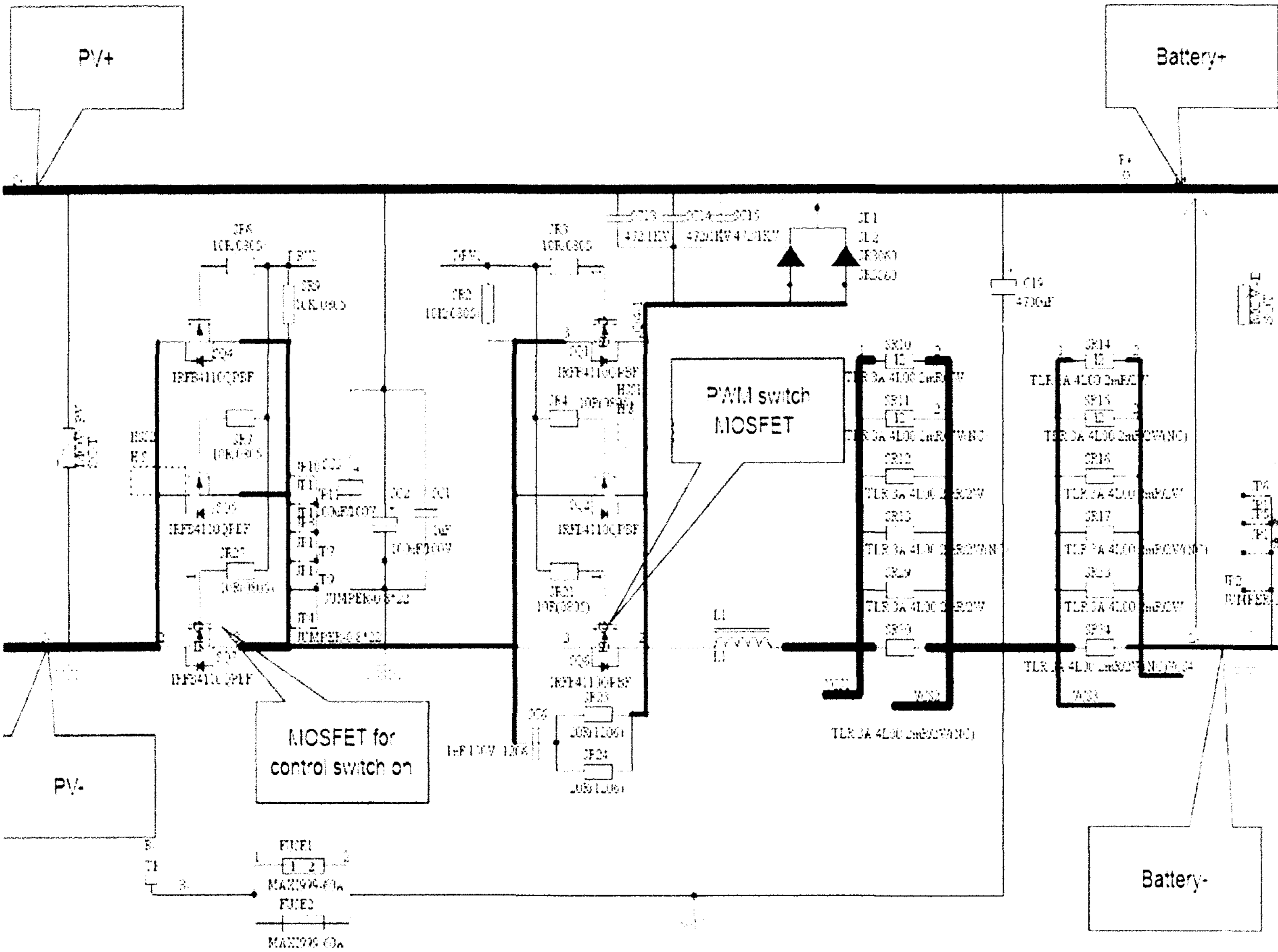


**FIGURE-2**

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(K. RAMA)
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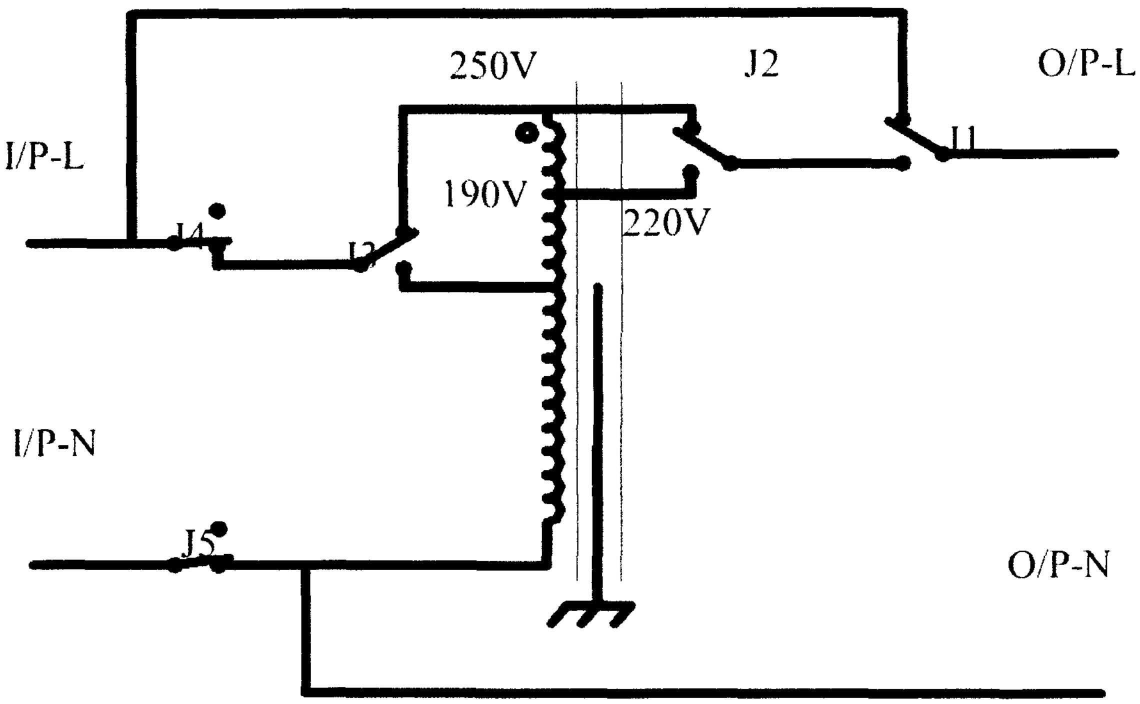


FIGURE-3

AGENT FOR THE APPLICANT
(K. RAMA)
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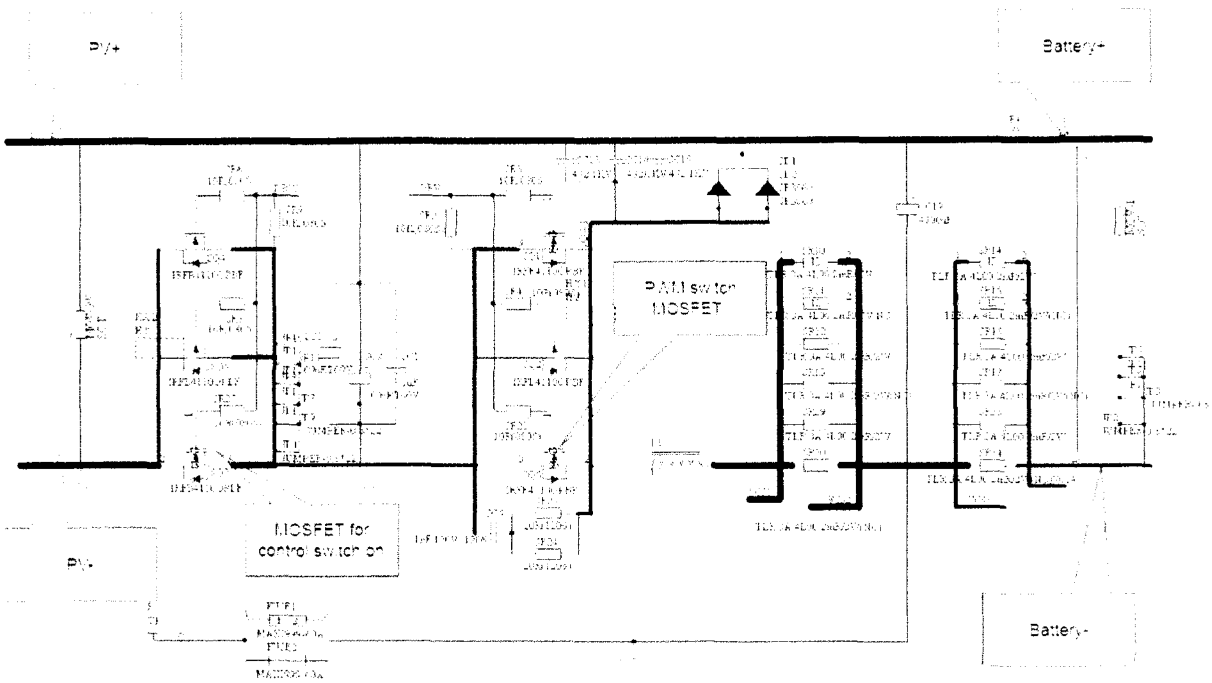


**FIGURE-4**

AGENT FOR THE APPLICANT
(K. RAMA)
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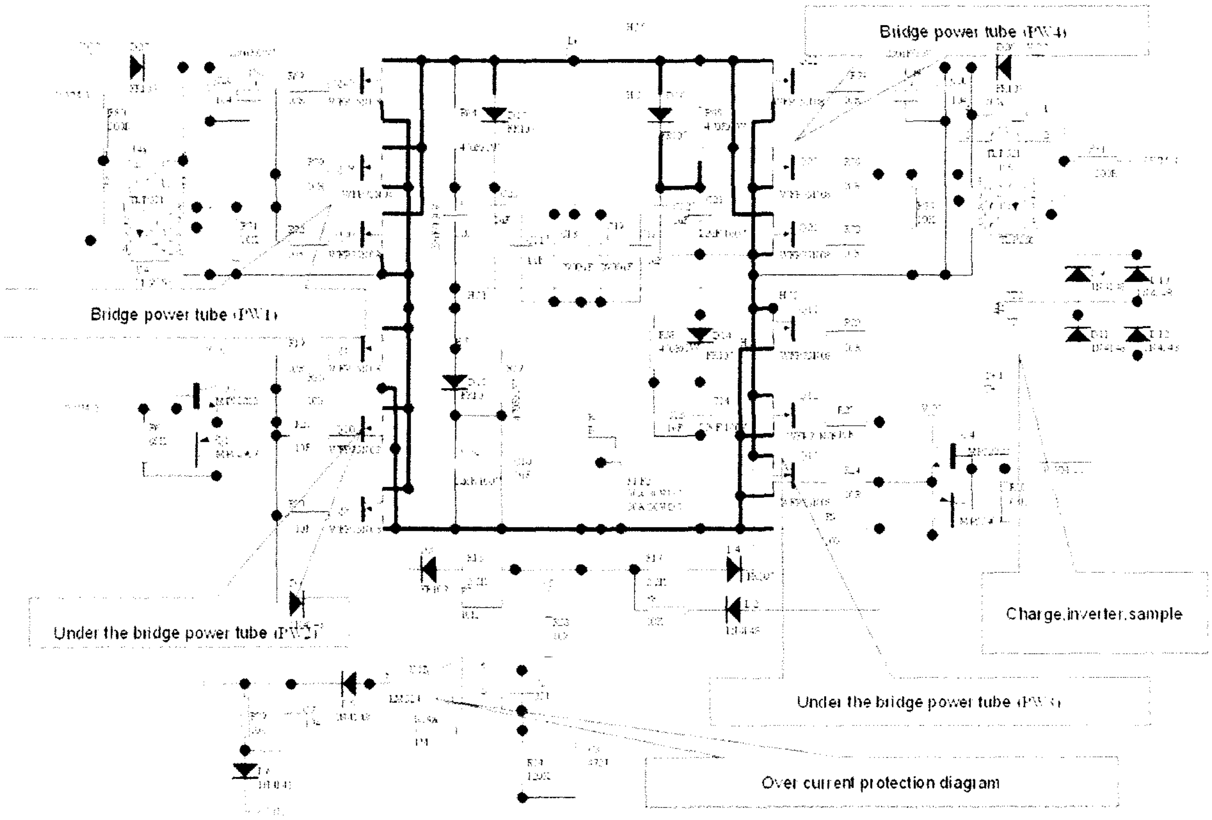


**FIGURE-5**

.AGENT FOR THE APPLICANT

(K. RAMA)
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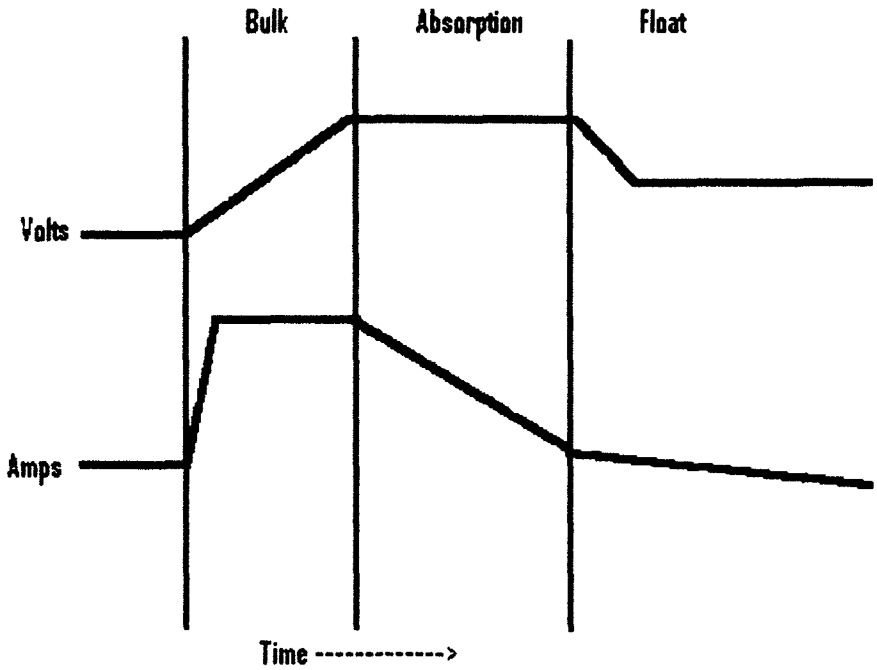


**FIGURE-6**

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(K. RAMA)
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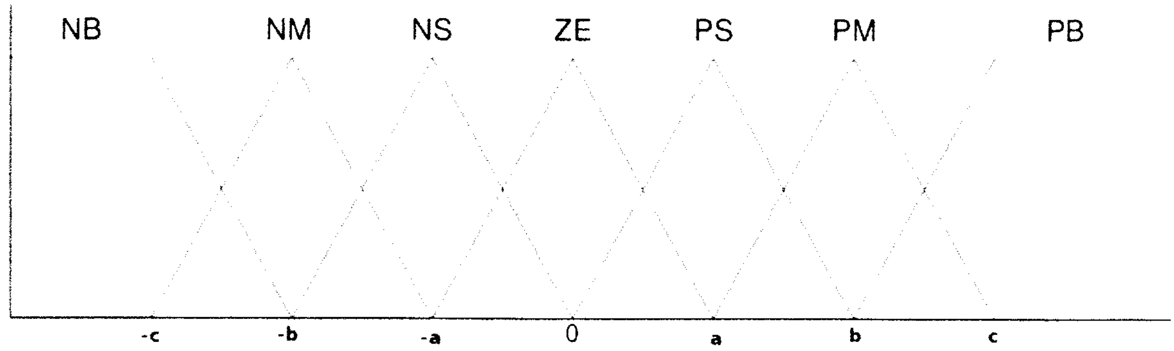


**FIGURE-7**

Rama
AGENT FOR THE APPLICANT
Rama
(K. RAMA)
IBHA IP SOLUTIONS

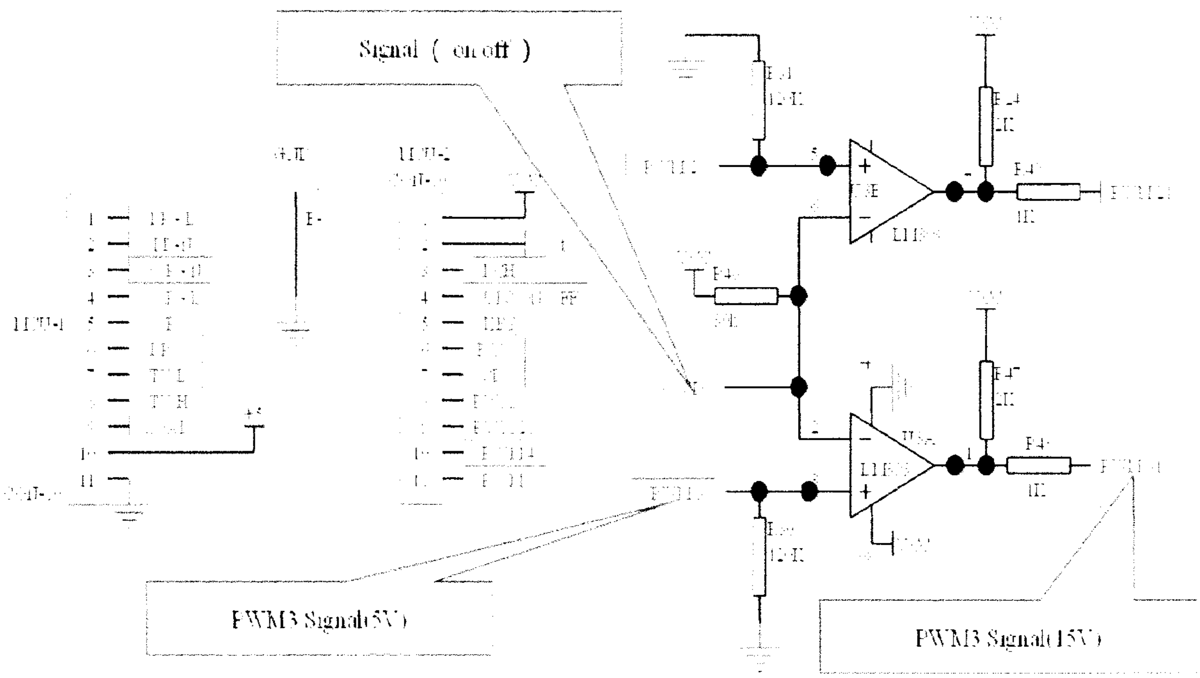


FIGURE-8

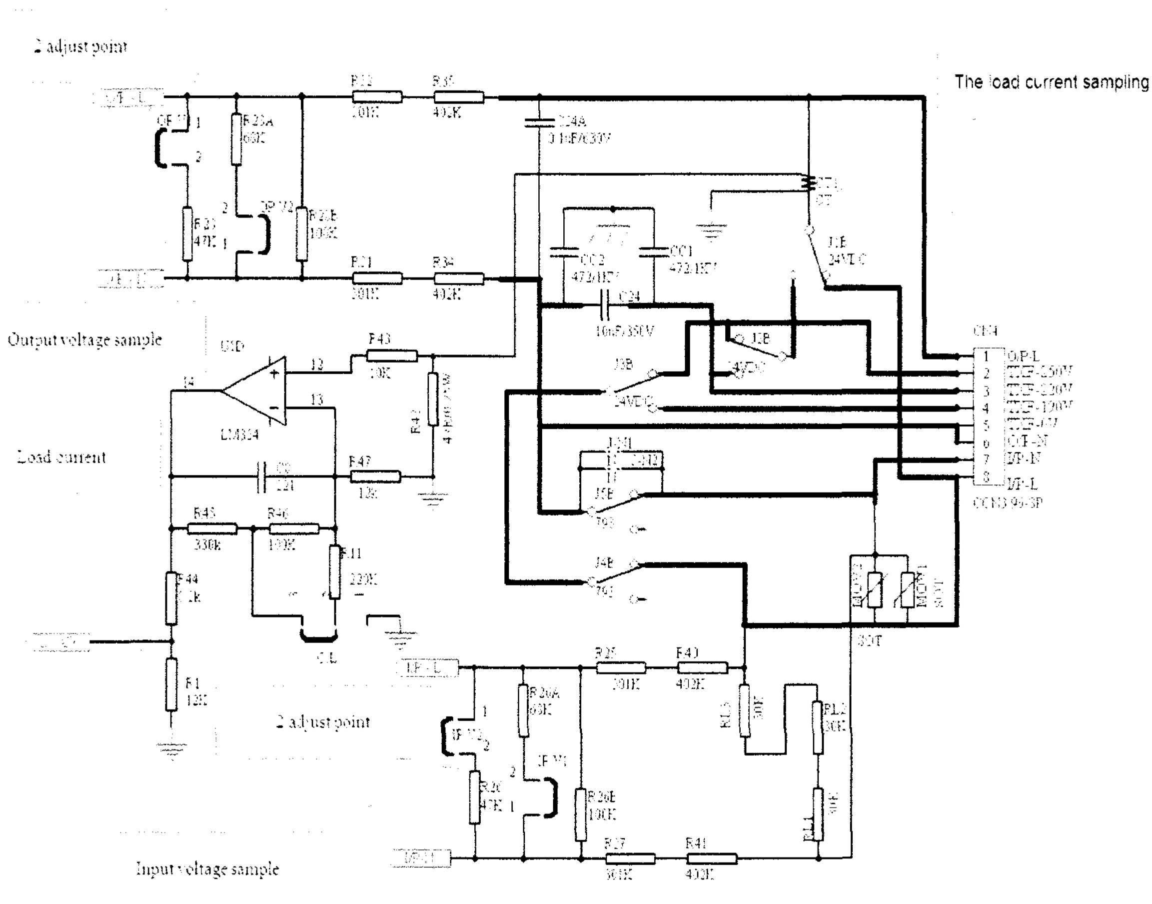


**FIGURE-9**

AGENT FOR THE APPLICANT

(K. RAMA)
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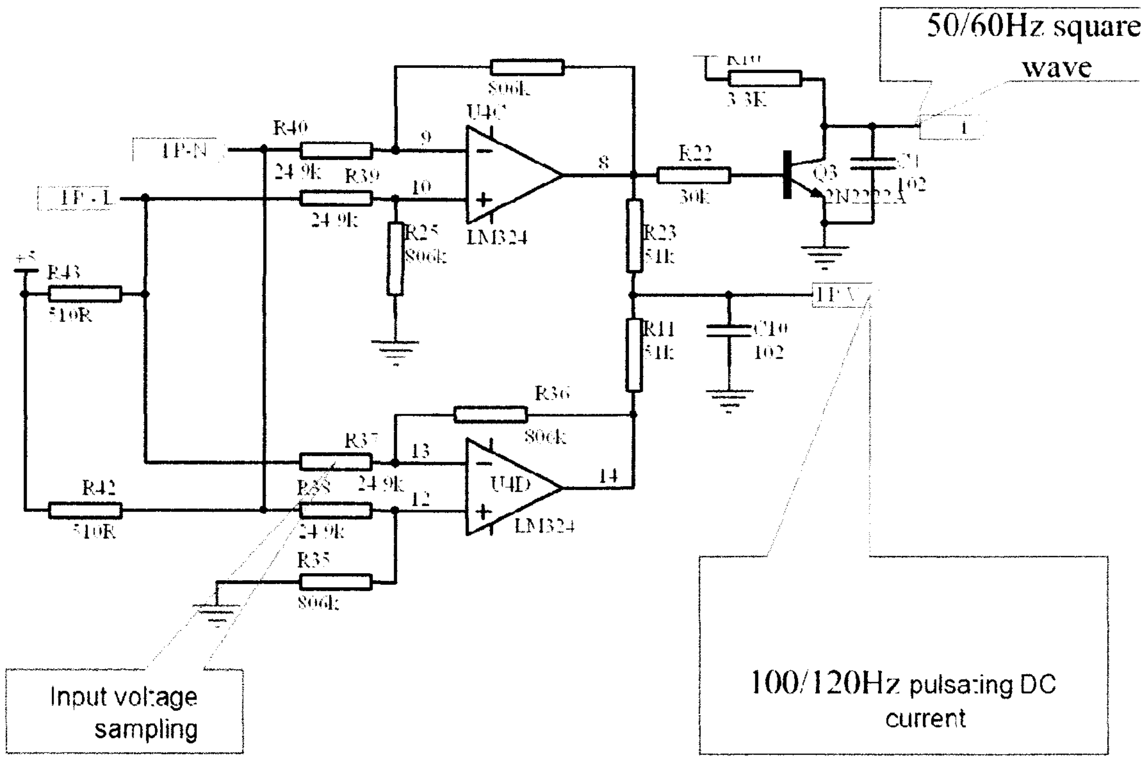


**FIGURE-10**

AGENT FOR THE APPLICANT

(K. RAMA)
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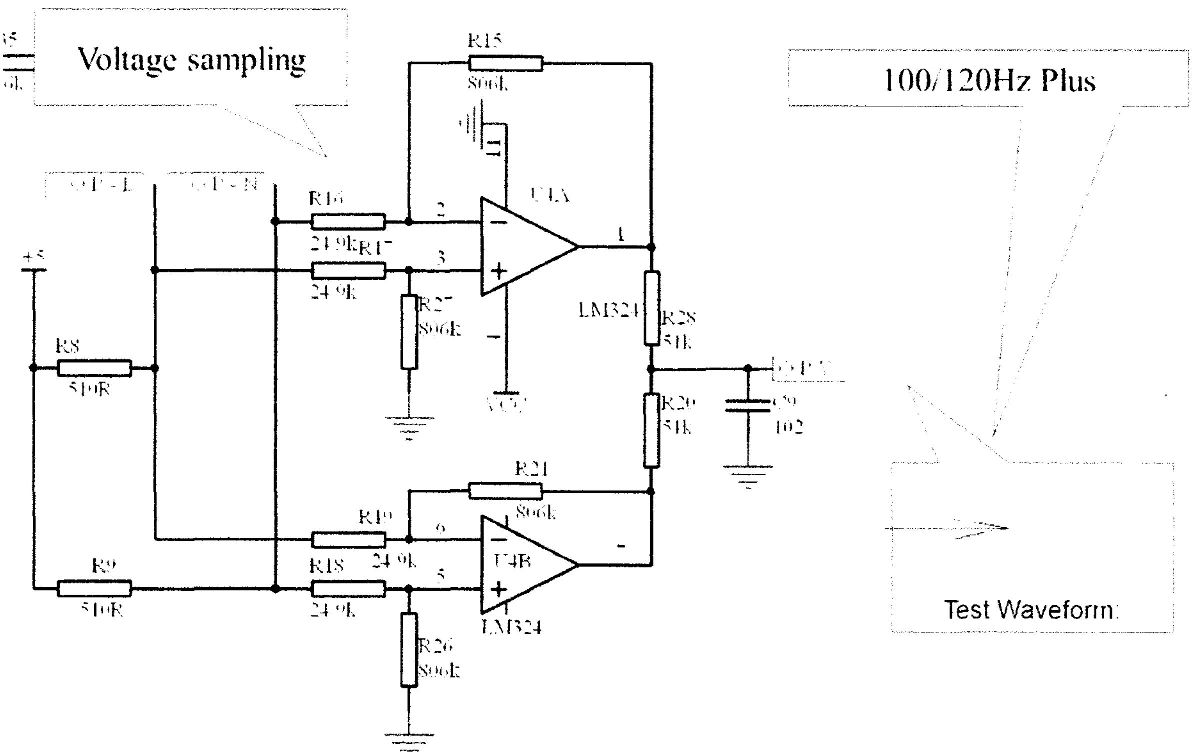


**FIGURE-11**

*Kamla*
AGENT FOR THE APPLICANT
*Ramy*
(K. RAMA)
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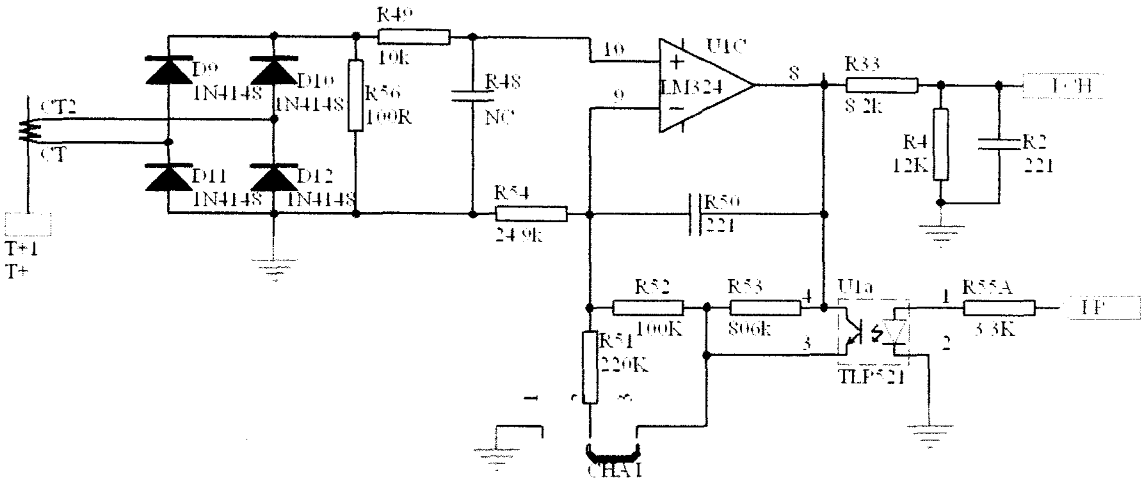
R49
10K
R48
NC
R56
100R
D9
1N4148
D10
1N4148
D11
1N4148
D12
1N4148
CT2
CT
T+1
T+
U1C
LM324
R33
8.2K
R4
12K
R2
221
R54
24.9K
R50
221
R52
100K
R53
806K
U1a
TLP521
R55A
3.3K
R51
220K
CHA1

**FIGURE-12**

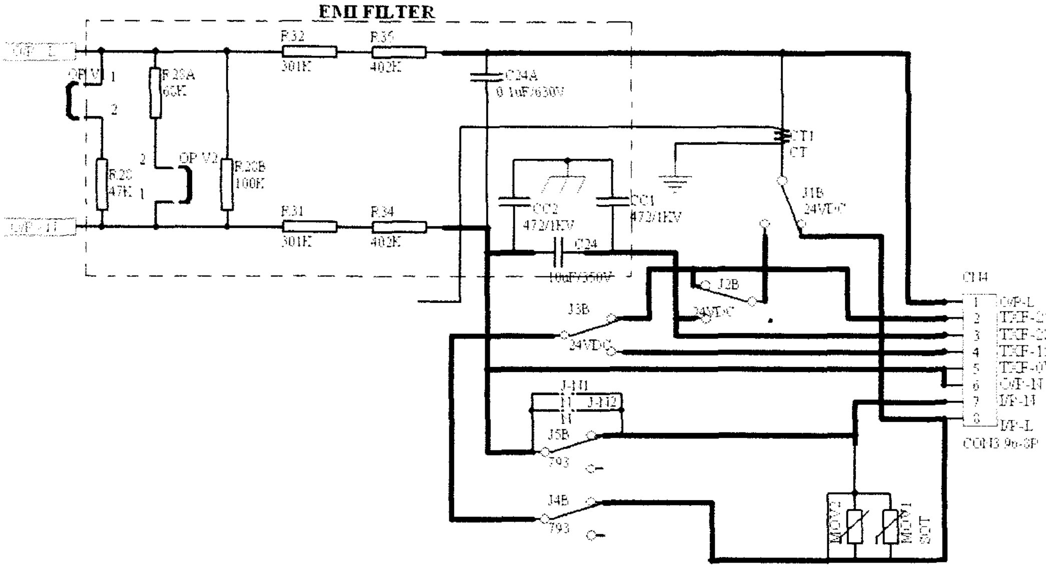


**FIGURE-13**

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2 adjust point

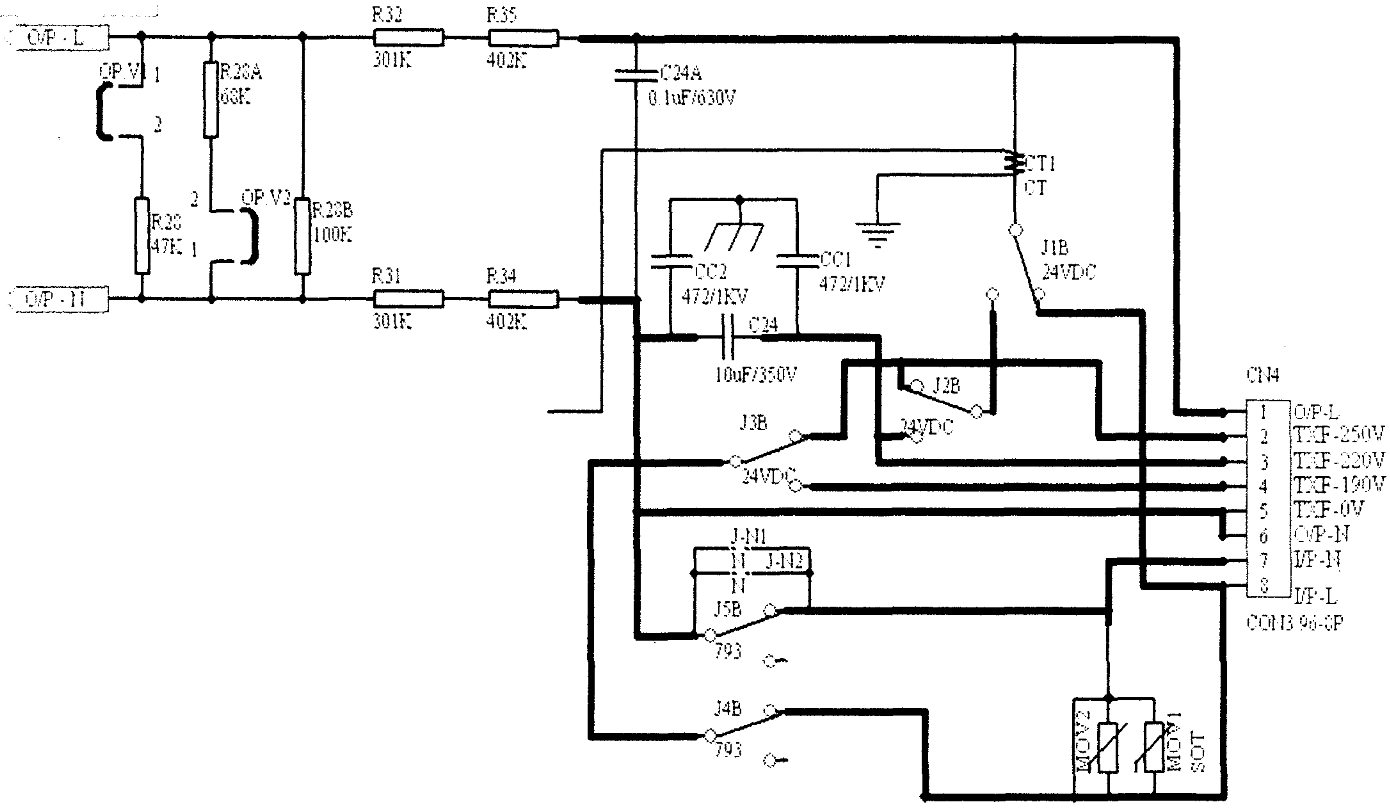


**FIGURE-14**

AGENT FOR THE APPLICANT
(K. RAMA)
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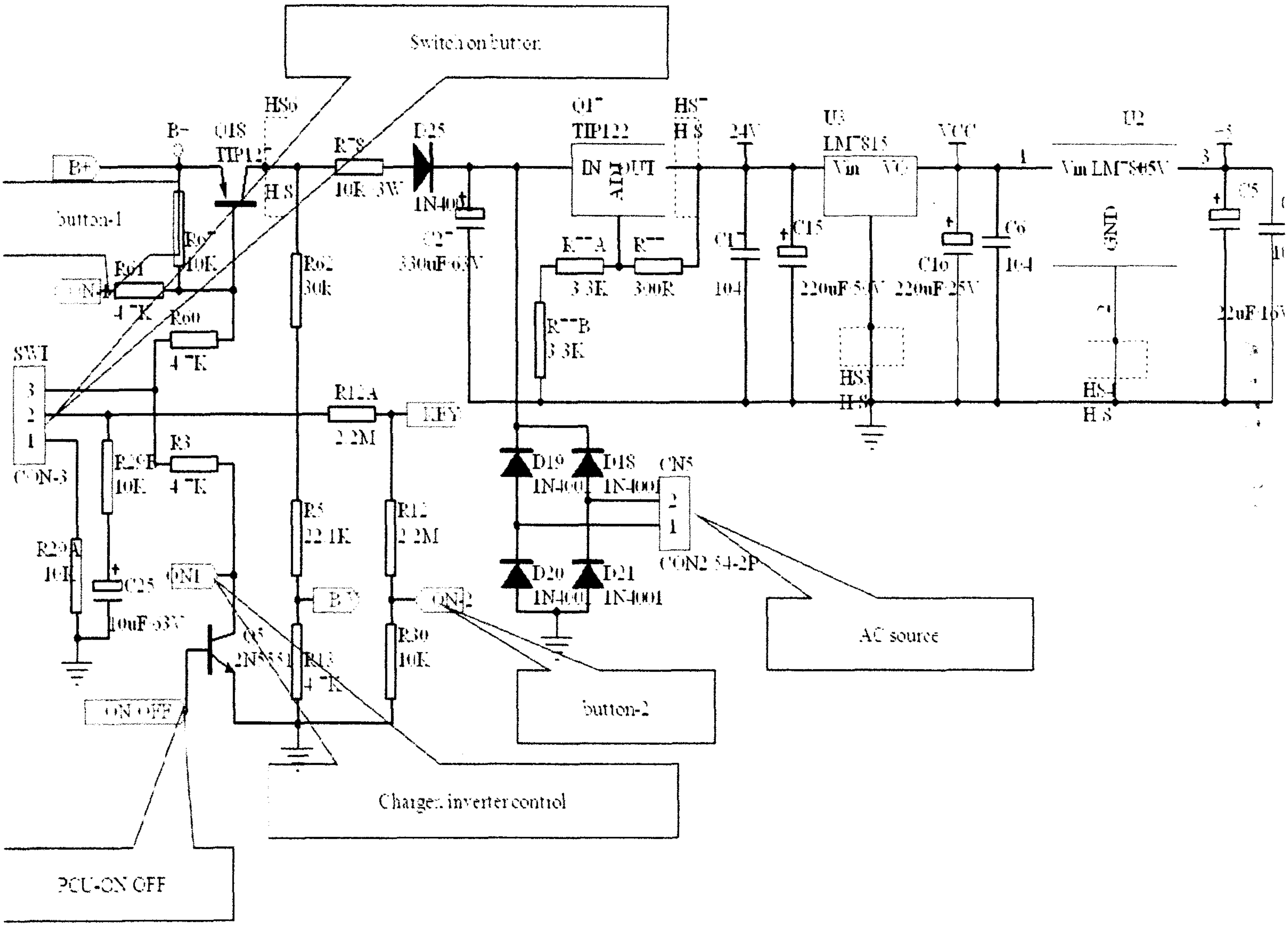


FIGURE-15

AGENT FOR THE APPLICANT
RAMA
IBHA IP SOLUTIONS

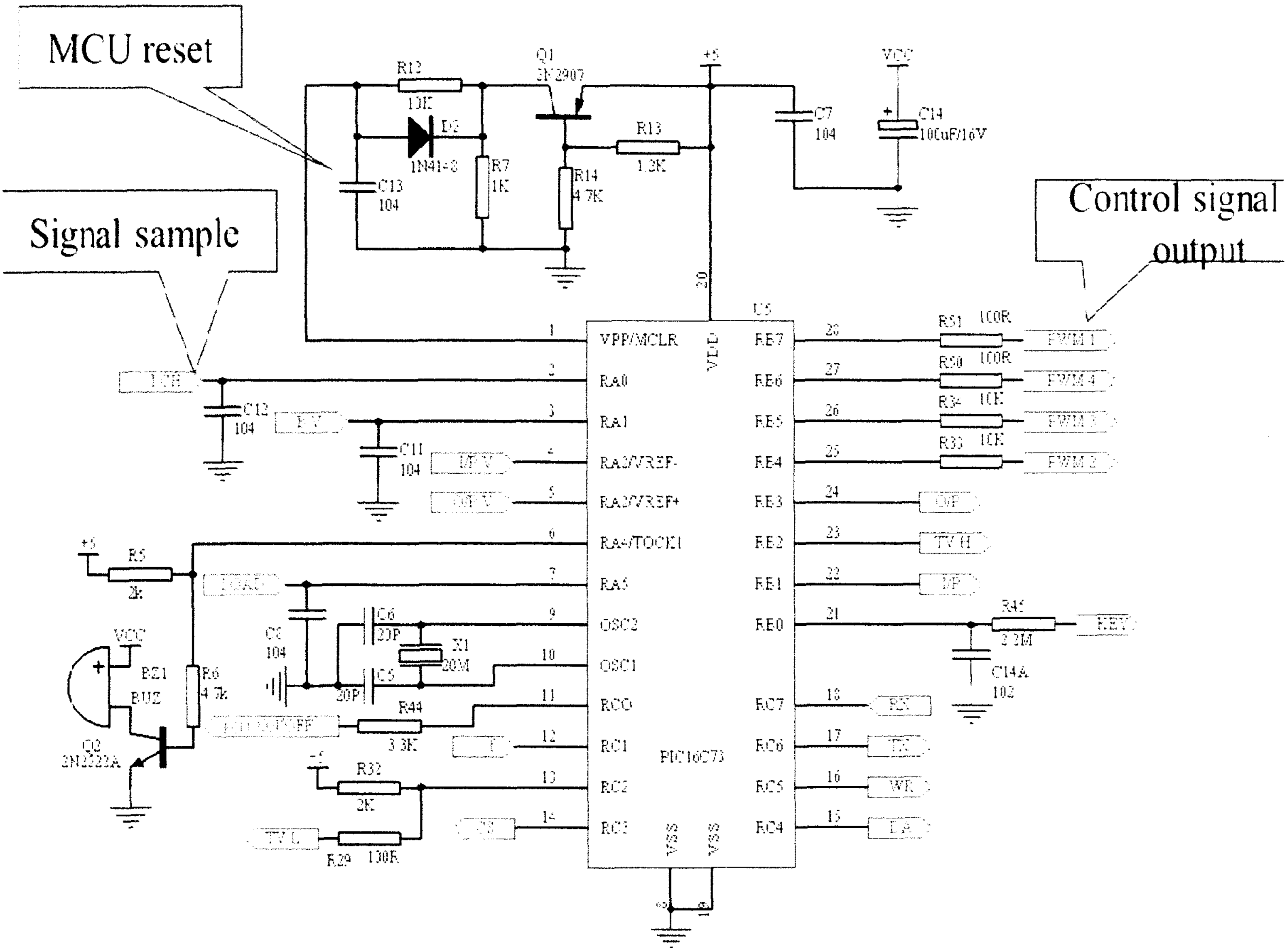
MCU reset
Signal sample
Control signal output
R12
10K
D2
1N4148
C13
104
R7
1K
Q1
2N2907
R13
1.2K
R14
4.7K
+5
VCC
C7
104
C14
100uF/16V
U5
VPP/MCLR
RA0
RA1
RA2/VREF-
RA3/VREF+
RA4/TOCK1
RA5
OSC2
OSC1
RC0
RC1
RC2
RC3
VDD
VSS
RE7
RE6
RE5
RE4
RE3
RE2
RE1
RE0
RC7
RC6
RC5
RC4
PIC16C73
R51
100R
R50
100R
R34
10K
R33
10K
PWM 1
PWM 4
PWM 3
PWM 2
R45
2.2M
KEY
C14A
102
C12
104
C11
104
R5
2k
R6
4.7k
BZ1
BUZ
Q2
2N2222A
C6
20P
C5
20P
X1
20M
C8
104
R44
3.3K
R32
2K
R29
100R
TV L
TV H

**FIGURE-16**

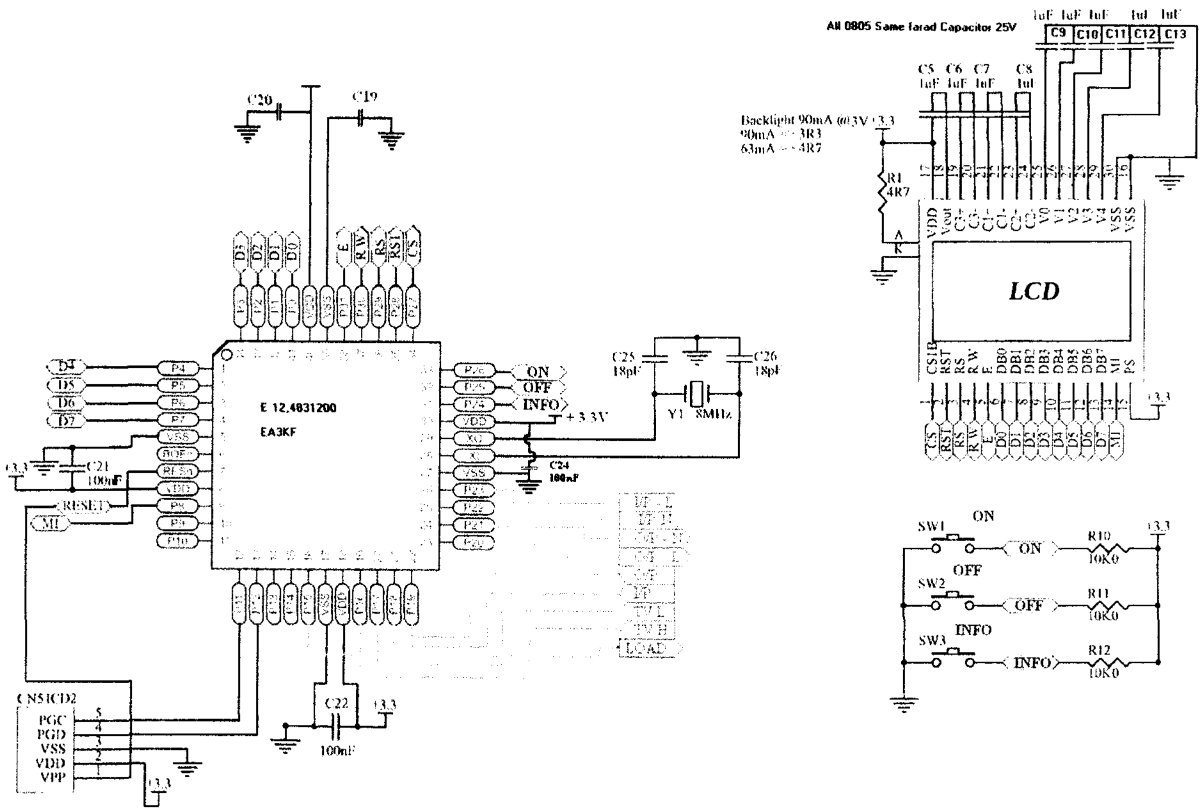


**FIGURE-17**

AGENT FOR THE APPLICANT
(K. RAMA)
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## TECHNICAL FIELD

The present invention is in relation to the field of energy, in particular to the field of solar energy. The present invention provides a power control unit (PCU) adoptable for the distribution of the solar power generated from the solar panels to the load, battery and grid; also the PCU can draw power from the battery and grid to supply to the load depending upon the requirement. The working of the PCU is controlled by the Microcontroller unit (MCU) split into two parts, *viz.,* solar microcontroller unit and inverter microcontroller unit.

## BACKGROUND

In the current industrial world, the importance of energy is ubiquitously known. Owing to the ever increasing demand for the power, the scientific world has been continuously looking for new avenues for generating the power and exploit the same without wastage. In the journey for the lookout of energy resources, solar energy or the energy generated from the sun has gained importance in view of certain advantages associated with it.

Solar energy can be continuously harnessed and is considered to be inexhaustible and eco-friendly. Considering the importance of the solar energy, technologies for its harnessing, storage and distribution are continuously being explored.

Most commonly electrical energy is produced on a small scale for the use of households and small/medium sized industrial units for heating, lighting purposes by the conversion of the solar energy to the electrical energy. The solar energy/power produced by the use of photovoltaics is obtained as direct current which is then converted into the required alternating current of desired voltage with the help of inverters.

The alternating current from the inverters has to be perfect sine wave output on par with the power supplied from the grid for better compatibility with the electrical devices. Earlier, inverters produced square wave alternating current which resulted in problems while operating with solid-state equipment and were not compatible with all electric devices.

Also, it is known that the solar power keeps fluctuating in terms of output because of variations in the environmental conditions. Hence for the optimum usage, the generated solar power has to be continuously fed to the load which may not be consistently required. In such situations the excess solar power has to be stored and utilized on requirement. Battery and Grid helps to absorb the excess solar power and recover when there is storage of it for proper utilization, thus judicious utility of the solar power can be maintained.

There is a need for a system which can provide solar power of required voltage of alternating current compatible with all the electrical devices, prudently store the excess solar power and recover stored power based on requirement.

Accordingly, the present invention provides a Power Control Unit (PCU) designed to provide electrical energy suitable to all the electrical appliances, absorb the excess solar power suitably without wasting and restore continuous supply of the electrical energy without interruption and method thereof.

**STATEMENT OF INVENTION**

Accordingly the present invention provides a power control unit (A) of a solar power generation system, comprising segmented Micro controller unit (B) controllers and converters (C) EMI Filter (D) AVR (E) Transformer for preferential distribution of solar power to multiple ends; wherein, the multiple ends are battery, grid and load, and the Micro Controller unit (B) is segmented into solar micro controller unit and inverter microcontroller unit; wherein, the power control unit distributes solar output power to the battery and to the grid when the output power is greater than the load; and the power control unit draws the differential power from the grid when the solar output power is lesser than required the load;
a method of solar power distribution by power control unit (A) of present invention to load, said method comprising direct feeding of the solar power to the load through MPPT charge controller, inverter, isolation transformer and filter; a method of solar power distribution by power control unit (A) of present invention to battery, said method comprising direct feeding of the solar power to the battery through MPPT charge controller; a method of distribution of solar power and solar power stored in a battery by power control unit (A) of present invention to load, said method comprising feeding the power to the load through inverter, isolation transformer and filter; a method of distribution of power from grid by power control unit (A) of present invention to load, said method comprising feeding the power

through automatic voltage regulator, isolation transformer and filter; a method of distribution of power from grid by power control unit (A) of present invention to load and battery, said method comprising feeding the power through automatic voltage regulator, isolation transformer, inverter and battery; and to the load by feeding the power through automatic voltage regulator, isolation transformer and filter sequentially.

**BRIEF DESCRIPTION OF FIGURES**

The present invention will be readily understood by the following detailed description in conjunction with the accompanying figures, wherein like reference numerals designate like structural elements, and in which:

Figure 1: provides the schematic diagram of the PCU.

Figure 1A: provides the system principle of the PCU with segmented MCU

Figure 2: provides the solar power main circuit where actually the power sharing or the generated power feed directly to the load happens.

Figure 3: provides the power supply voltage principle of the PCU.

Figure 4: DC to DC High Efficiency Controller

Figure 5: shows DC to AC controller circuit.

Figure 6: shows the current and the voltage during the 3 phases of the charge cycle.

Figure 7: Membership functions in fuzzification.

Figure 8: represents PWM signal control and processing which produce the AC output voltage from a DC input

Figure 9: shows circuit of load detection sampling and wiring

Figure 10: shows circuit with the input sampling and processing.

Figure 11: shows output voltage sampling and processing.

Figure 12: shows the current sampling circuit of inverter charging unit.

Figure 13: shows the comprising EMI filter.

Figure 14: shows the automatic voltage regulator.

Figure 15: shows the Switching Power Supply (SPS) of the PCU.

Figure 16: shows the chip diagram of PIC16C73.

Figure 17: shows the MPPT and Display Controller Section

## DETAILED DESCRIPTION OF INVENTION

The present invention will now be described more fully with reference to the accompanying figures. However, this invention should not be construed as limited to the embodiments set forth herein as many modifications and variations are possible in light of this disclosure for a person skilled in the art to which the invention belongs in view of the drawings, description and claims.

Like numbers refer to like elements throughout. It may further be noted that as used herein and in the appended claims, the singular forms "a", "an", and "the" include plural reference unless the context clearly dictates otherwise.

Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by person skilled in the art to which the invention belongs. Well-known functions or constructions will not necessarily be described in detail for brevity and/or clarity.

The present invention is in relation to a power control unit (A) of a solar power generation system, comprising segmented Micro controller unit (B), controllers and converters (C) EMI Filter (D) AVR (E) Transformer for preferential distribution of solar power to multiple ends; wherein, the multiple ends are battery, grid and load; and the Micro Controller unit (B) is segmented into solar micro controller unit and inverter microcontroller unit;

wherein, the power control unit distributes solar output power to the battery and to the grid when the output power is greater than the load; and

the power control unit draws the differential power from the grid when the solar output power is lesser than required the load.

In another embodiment of the present invention, the Micro controller unit (B), controllers and converters (C) EMI Filter (D) AVR are integrated on a single board or multiple boards.

In still another embodiment of the present invention, the Micro controller unit (B), controllers and converters (C) EMI filter and (D) AVR are integrated on a single board.

In still another embodiment of the present invention, the controllers are Micro Controller Unit, maximum power point tracking controller, AVR controller, charge controller, DC to DC controller.

In still another embodiment of the present invention, the converters are DC to AC converter.

The present invention is also in relation to a method of solar power distribution by power control unit (A) to load, said method comprising direct feeding of the solar power to the load through MPPT charge controller, inverter, isolation transformer and filter.

The present invention is also in relation to a method of solar power distribution by power control unit (A) of claim 1 to battery, said method comprising direct feeding of the solar power to the battery through MPPT charge controller.

The present invention is also in relation to a method of distribution of solar power and solar power stored in a battery by power control unit (A) to load, said method comprising feeding the power to the load through inverter, isolation transformer and filter.

The present invention is also in relation to a A method of distribution of power from grid by power control unit (A) to load, said method comprising feeding the power through automatic voltage regulator, isolation transformer and filter.

The present invention is also in relation to a method of distribution of power from grid by power control unit (A) to load and battery, said method comprising feeding the power through automatic voltage regulator, isolation transformer, inverter and battery; and to the load by feeding the power through automatic voltage regulator, isolation transformer and filter sequentially.

The current technology in various fields mandates continuous supply of power for efficient utility and reliability. Whereas the electrical energy obtained from certain sources are continuous, solar energy is an exception to it, however owing to the nature of the solar energy being renewable and clean source which does not pollute the surroundings it is much sought after as the source of generating power.

The fluctuations in the generation and storage of the solar power because of the inherent limitation associated with it has been tried to overcome by the use of power control unit (PCU). It is a device designed to improve the sustained quality of the power that is delivered to load. In some usages, power Controller refers to a voltage regulator with at least one other function to improve power quality (e.g. power factor correction, noise suppression, transient impulse protection, voltage stabilization.)

The Power Control unit (PCU) of the present invention is a leagued system consisting of a controllers, converters, battery and grid. It acts preferentially on the need basis to deliver a voltage of the proper level and characteristics to enable load to function in the required manner. The PCU of the present invention monitors the requirement of the power for the load and if the solar power output is in excess it stores the same in battery or grid. However, if the solar output power is less then it draws the power from the battery or the grid thus maintaining the power to the load in a sustained manner.

The PCU of the present invention apart from meeting the requirements of the load without any hindrance also provides the alternating current with pure sine wave output on par with the alternating current of the grid with low power loss. The PCU operates by photovoltaic priority mode in presence of grid power by alternating current mode or bypass operation mode in the PV as follows.

During the day, with ample sunlight, and mains is normal: solar panel will adjust to the largest state through solar power controller and give power to load through the PCU (Mains as a standby), and charge the battery at the same time.

During the evening (or rainy days, with no sun), and Mains is normal: the system will provide power through battery first, discharge until to the set value (reserved a certain power in case of emergency situation), and then automatically switch to the Mains and provide power to loads through the regulator.

The evening (or rainy days, with no sun), battery has been discharged to empty and Mains normal: System will switch to Mains and give power supply to loads through system regulator. At the same time, charger will start working and charge the battery.

PV Priority in the Absence of Grid Power:

Grid under abnormal AC input: the system will use battery power to provide power to loads through PCU system.

AC Priority:

When AC power supply is normal: AC input will provide power to equipment through regulator after removing the high frequency harmonic with filter. At this time, PV gives power to batteries only through MPPT control system;

When Mains overrun or cut off: The system will convert the energy of battery and PV systems to the power needed by equipment promptly, and give power supply to the user equipment to ensure power supply continuity.

When Mains overrun or cut off and without PV (no sun power): The system will convert the energy of battery to the power needed by equipment promptly, and give power supply to the user equipment to ensure power supply continuity.

By Pass:

This condition will be happen during over load or PCU failure.

The PCU converts the variable direct current (DC) which is the output of a photovoltaic (PV) solar panels, into a utility frequency alternating current (AC) that is fed directly to the Domestic Loads. In the PCU of the present invention, MCU, integration of Charger, Controller, Converter, Sensor and Interfacing Circuit, AVR, Filter, relays, Switching Power Supply are on a single printed circuit board and the PCU is controlled by the Microcontroller unit (MCU) which is sectioned logically into solar MCU and inverter MCU. Further, less board level troubleshooting will be required for our PCU, as all our ICs are controlled by the MCU (Micro Controller Unit). The overall PCU operation is controlled by the MCU (Micro Controller Unit). The sensor and interfacing circuit consists of precision amplifier, comparator and integrator Circuits which converts the electrical data into signal which can be read by the MCU for the operation of the PCU.

The Schematic diagram of the PCU is given in figure-1 and figure 1A provides the system principle of the PCU wherein the segmented MCU is shown.

The controller circuits which makes the operation of the PCU more advantageous are MCU, MPPT Charge Controller, AVR Controller, Battery Charge Controller, DC to DC high efficiency Controller, DC to AC Converter and Pulse Width Modulation. In addition to this Sensor and interfacing Circuit, EMI Filter, Automatic Voltage Regulator and Switching Power Supply circuit for their respective functions.

The Maximum Power Point Tracking Controller (MPPT) of the system provides higher efficiency up to 97% with lower power loss. The MPPT Charge Controller has the ability to down convert voltage while increasing the amps to give as much as 30% more power from a Solar array. The features of MPPT controller are high Tracking efficiency of 99%, several seconds tracking speed, 4-Stage Charge with Pulse Width Modulation (PWM) output, natural convectional cooling, full power output up to 45°C, temperature Compensation, automatically recognize day/night and diversified load control.

The pulse width modulation charger helps to remove buildup on the plates in a battery extending a battery's life.
MPPT control system adopts PWM adjustment technology which can bear the highest open circuit voltage of the PV battery. The product AC input equipped with high effective online synchronous voltage regulation technology, input from 165-275Vac operating with safety, greatly decrease the battery use frequency and extend the battery service life. The system equipped with auto-follow mains phase function make sure the PCU output voltage has same phase of the mains voltage, it greatly decrease the transfer time and the surge voltage occurred during transfer.

The DC to DC high efficiency conversion method is more power efficient (often 75% to 98%) than linear voltage regulation (which dissipates unwanted power as heat). This efficiency is beneficial to increasing the running time of battery operated devices. The efficiency has increased due to the use of power FETs, which are able to switch at high frequency more efficiently than power bipolar transistors, which incur more switching losses and require a more complicated drive circuit.

The PCU also provides protection functions for normal PCU Overload, abnormal PCU overload, overload in mains power, short circuit protection and the battery (or under the solar supply power state), the system will automatically detect the load is less than 5%, the PCU will determine the "no-load" and the system will automatically turn off.

The basic operation of the PCU will be as follows- when the solar output power is greater than the required load power then PCU will deliver the extra power to charge the battery and supply it to the grid and when the solar output power is lesser than the required load power the PCU will take the differential extra power from the grid. Thus sharing of power optimally is the important result of the invention.

The generated power from the solar panel due to the photovoltaic effect can be fed directly to the load and battery as per the following conditions which is happening by the Controller Circuit (MCU).

1. PV Priority (Solar Power → Load) : The generated power from the solar panel will be fed directly to the load through MPPT Charge controller, Inverter, Isolation Transformer and Filter.

2. PV Priority (Solar Power → Battery) : The generated power from the solar panel will be fed to the battery through MPPT Charge Controller.

3. PV Priority (Solar Power + Battery → Load) : The generated power from the MPPT Charge controller by Panel and Battery will be fed to the load through Inverter, Isolation transformer and Filter.

4. AC Priority (Grid → Load) : The power from the Grid will be fed to the load through Automatic Voltage Regulator, Isolation Transformer and Filter.

5. AC Priority (Grid → Load + Battery): The Power from the Grid will be fed to the battery through Automatic Voltage Regulator, Isolation Transformer, Inverter and Battery and to the load as in case 4.

Figure 2 shows the solar power main circuit where actually the power sharing or the generated power feed directly to the load happens.

***Power Supply Voltage Principle:***

An autotransformer has a single winding with two end terminals in which the primary and secondary coils have part and all of their turns in common. The primary voltage is applied across two of the terminals, and the secondary voltage taken from two terminals, almost always having one terminal in common with the primary voltage. The primary and secondary circuits therefore have a number of windings turns in common. Since the volts-per-turn is the same in both windings, each develops a voltage in proportion to its number of turns.

One end of the winding is usually connected in common to both the voltage source and the electrical load. The other end of the source and load are connected to taps along the winding. Different taps on the winding correspond to different voltages, measured from the common end. In a step-down transformer the source is connected across the entire winding while the load is connected by a tap across only a portion of the winding. In a step-up transformer, conversely, the load is attached across the full winding while the source is connected to a tap across a portion of the winding.

The figure 3 shows the power supply voltage principle of the PCU. J1, J2, J3, J4 and J5 are the switches which operate according to the voltage level has to be supplied to the load. Under Normal Voltage Condition if the voltage from Input supply Line is 220V, the switch J4 Normally Open in Condition and switch J2 Normally Closed Condition so, the output Voltage derived directly from Input Supply Voltage. Under Low Voltage Condition if the voltage from Input Supply Line is upto 190V then the switch J4 Normally Closed in Condition and J3 Normally Open in Condition. The Multi Functioned Transformer can Step up the voltage and then the switch J2 and switch J1 Normally Open in Condition and the output voltage is 220V. Under High Voltage Condition if the voltage from Input Supply Line is upto 250V then the switch J4 Normally Closed in Condition and J3 Normally Closed in Condition. The Multi Functioned Transformer can Step down the voltage and then the switch J2 and switch J1 Normally Open in Condition and the output voltage is 220V.The principle is also applied to set the voltage for online protection functions for the PCU. The single winding operate as a primary and Secondary winding of the transformer. The Step down and step up operation will be based on the input voltage of the PV & Grid and output voltage required for the charge controller & load.

***DC to DC High Efficiency Controller:***

DC to DC controller convert one DC voltage level to another, by storing the input energy temporarily and then releasing that energy to the output at a different voltage (Figure 4). The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors). This conversion method is more power efficient (often 75% to 98%) than linear voltage regulation (which dissipates unwanted power as heat). This efficiency is beneficial for increasing the running time of battery operated devices. The efficiency has increased due to the use of power FETs, which are able to switch at high frequency more efficiently than power bipolar transistors, which incur more switching losses and require a more complicated drive circuit. DC-DC controller is using the synchronous rectification replacing the flywheel diode with a power FET with low "on resistance", thereby reducing switching losses.

Electronic switch-mode DC to DC converters operate by storing the input energy temporarily and then releasing that energy to the output at a different voltage and current. Just like a transformer, they essentially just change the input energy into a different impedance level. So whatever the output voltage level, the output power all comes from the input; there's no energy manufactured inside the converter. In fact some energy is used by the converter circuitry and components while doing their job. It is this principle that makes a DC-DC Converter essential for MPPT.

The converter presents an electrical load to the solar panel that varies as the output voltage of the converter varies. This load variation in turn causes a change in the operating point (current and voltage characteristics) of the panel. Thus by intelligently controlling the operation of the DC-DC converter, the power output of the panel can be intelligently controlled and made to output the maximum possible.

***DC to AC Converter:***

The figure 5 represents the charger and DC to AC converter.
A power inverter, is an electrical power converter that changes direct current (DC) to alternating current (AC). The input voltage, output voltage, and frequency are dependent on design. Some applications for inverters include converting high-voltage direct current electric utility line power to AC, and deriving AC from DC power sources such as batteries.

The waveform in commercially available modified-sine-wave inverters is a square wave with a pause before the polarity transition, which only needs to cycle through a three-position switch that outputs forward, off, and reverse output at the pre-determined frequency. The peak voltage to RMS voltage do not maintain the same relationship as for a sine wave. The DC bus voltage may be actively regulated or the "on" and "off" times can be modified to maintain the same RMS value output up to the DC bus voltage to compensate for DC bus voltage variation.

The ratio of on to off time can be adjusted to vary the RMS voltage while maintaining a constant frequency with a technique called PWM. Harmonic spectrum in the output depends on this ratio. When operating induction motors, voltage harmonics is not a concern, however harmonic distortion in the current waveform causes problem by increasing copper loss and torque pulsation. Most AC motors will run on MSW inverters with an efficiency reduction of about 20% due to the harmonic content.

***Battery charge controller:***

Battery Charge controller limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may prevent against over voltage, which can reduce battery performance or lifespan, and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life. The terms "charge controller" may refer to either a stand-alone device, or to control circuitry integrated within a battery pack, battery-powered device, or battery recharger. Charge controller consist of several electrical components and encapsulated in a single microchip, an integrated circuit (IC) usually called a charge controller IC or charge control IC.

The Battery Charge Controller have 3 stage charge cycle:

1.Bulk : During the Bulk phase of the charge cycle, the voltage gradually rises to the Bulk level (usually 28.8 to 29.2 volts)* while the batteries draw maximum current. When Bulk level voltage is reached the absorption stage begins.

2.Absorption : During this phase the voltage is maintained at Bulk voltage level for a specified time (usually an hour)* while the current gradually tapers off as the batteries charge up.

3.Float : After the absorption time passes the voltage is lowered to float level (usually 26.8 to 27.4 volts, this value varies with ranges of PCU).)* and the batteries draw a small maintenance current until the next cycle.
The current and the voltage during the 3 phases of the charge cycle is shown in the figure 6.

### *MPPT Charge Controller:*

The MPP depends on irradiance conditions, the panel's temperature, and the load connected. Maximum power point tracking (MPPT) algorithms provide the theoretical means to achieve the MPP of solar panels. PV systems that lack MPPT *rarely* operate at the most efficient, MPP. This is why the rated power of the solar panel is almost never realized when connecting a load. The following components are logically connected for MPPT design: solar panel, current sensor, voltage sensor, DC-DC converter, digital controller, and the glue logic/ circuitry to connect everything together.

### *MPPT Algorithm:*

The ability of the MPPT algorithm is to detect multiple maximum and convergence speed. The irradiance levels at different points on a solar panel's surface tend to vary. This variation leads to multiple local maximum power points in one system. The efficiency and complexity of an algorithm determine if the true maximum power point or a local maximum power point is calculated. In the latter case, the maximum electrical power is not extracted from the solar panel.

For a high-performance MPPT system, the time taken to converge to the required operating voltage or current should be low. Depending on how fast this convergence needs to occur and tracking system requirements, the system requires an algorithm (and hardware) of suitable capability.

### *Fuzzy logic control:*

The fuzzy logic consists of three stages: fuzzification, inference system and defuzzification. Fuzzification comprises the process of transforming numerical crisp inputs into linguistic variables based on the degree of membership to certain sets. Membership functions, like the ones in the Figure 7, are used to associate a grade to each linguistic term. The number of membership functions used depends on the accuracy of the controller. In Figure-7 below seven fuzzy levels are used: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium) and PB (Positive Big). The values a, b, and c are based on the range values of the numerical variable.

The inputs of the fuzzy controller are usually an error, E, and the change in the error, ΔE. The error is chosen as ΔP/ΔV because it is zero at the MPP. Then E and ΔE are defined as follows:

$$E = \frac{P(k) - P(k-1)}{V(k) - V(k-1)} \qquad (1)$$

$$\Delta E = E(k) - E(k-1) \qquad (2)$$

The output of the fuzzy logic converter is usually a change in the duty ratio of the power converter, ΔD, or a change in the reference voltage of the DC-link, ΔV. The rule base, also known as rule base lookup table or fuzzy rule algorithm, associates the fuzzy output to the fuzzy inputs based on the power converter used and on the knowledge of the user. Table below shows the rules for a three phase inverter, where the inputs are E and ΔE, as defined in (1) and (2), and the output is a change in the DC-link voltage, ΔV. For example, if the operating point is far to the right of the MPP, E is NB, and ΔE is zero, then to reach the MPP the reference voltage should decrease, so ΔV should be NB (Negative) to move the operating point towards the MPP.

| E\dE | NB | NM | NS | ZE | PS | PM | PB |
|---|---|---|---|---|---|---|---|
| NB | NB | NB | NB | NB | NM | NS | ZE |
| NM | NB | NB | NB | NM | NS | ZE | PS |
| NS | NB | NB | NM | NS | ZE | PS | PM |
| ZE | NB | NM | NS | ZE | PS | PM | PB |
| PS | NM | NS | ZE | PS | PM | PB | PB |
| PM | NS | ZE | PS | PM | PB | PB | PB |
| PB | ZE | PS | PM | PB | PB | PB | PB |

**Table 1: Membership functions**

The last stage of the fuzzy logic control is the defuzzification. In this stage the output is converted from a linguistic variable to a numerical crisp one again using membership functions as those in the Figure 7. There are different methods to transform the linguistic variables into crisp values. It can be said that the most popular is the center of gravity method.

The advantages of these controllers, besides dealing with imprecise inputs, not needing an accurate mathematical model and handling non linearity, are fast convergence and minimal oscillations around the MPP. Furthermore, they have been shown to perform well under step changes in the irradiation.

***Pulse Width Modulation:***

The circuit as represented in figure 8 represents PWM signal control and processing which produce the AC output voltage from a DC input by using switching circuits to simulate a sine wave by producing one or more square pulses of voltage per half cycle. If the widths of the pulses are adjusted as a means of regulating the output voltage, the output is said to be pulse width modulated. With sinusoidal or sine weighted pulse width modulation, several pulses are produced per half cycle.

The pulses near the edges of the half cycle are always narrower than the pulses near the center of the half cycle such that the pulse widths are proportional to the corresponding amplitude of a sine wave at that portion of the cycle. To change the effective output voltage, the widths of all pulses are increased or decreased while maintaining the sinusoidal proportionality. With pulse width modulation, only the widths (on-time) of the pulses are modulated. It helps to remove buildup on the plates in a battery extending a battery's life.

Pulse = Stop and start like with your heart beat (Hammers the lead plates clean).
Width = Time the pulse is turned on and time is the pulse is turned off.
Modulation = Controls more or less volume of the charge.

All three of the above types of charging are used at the same time to charge faster and clean the plates. When the battery is low on charge, PWM will pulse longer with at a higher modulation. As the battery fills up it will pulse shorter with a lower out power level.

***Sensor and Interfacing Circuit:***

Comparator:

A comparator is special class of op-amp, where the device is used to compare voltages between its two inputs. Used in this manner the op-amp operates in open-loop; that is there is no negative feedback applied to the negative input as there is in the classical feedback circuits. Although in principle any op-amp can be used as a comparator using a compensated device such as a 741 for example will result in a response time in the tens of microseconds whereas a device optimized for comparator use such as the 311 will responding several hundred an no seconds. Comparator usually interfaces at their outputs with digital logic that is with a standard family such as TTL, CMOS etc. Therefore using standard op-amp outputs designed for linear=10-v swings will require some level shifting and or clamping in order to drive logic.

***Basic differential-input Comparator:***

A comparator circuit is one that provides an indication of the relative state of two input potentials. If one input is a reference potential and the other an unknown signal is above or below the reference potential.
It is generally designed that a comparator be capable of changing output states as rapidly as possible. Since comparator circuits normally operate without negative feedback, there is no necessity for frequency compensation. Since there is no closed loop to stabilize. Frequency compensation in a comparator is usually detrimental, because it slows down the open-loop speed of the amplifier.
Beyond the basic requirement of input-voltage ranges speed is the next criterion in selecting op-amps suitable for comparators, speed has two meanings for comparators, response times and slew rate. Response time is simply the total time required for an output transition to occur once an input. Slew rate indicates how rapidly the amplifier output can change during a transition. It can also be different for positive and negative going slopes.

***Potential Transformer:***

Potential Transformer are used to operate voltmeters, the potential coils of wattmeters & relays from high voltage lines. The primary winding of the transformer is connected across the line carrying the voltage to be measured & the voltage circuit is connected across the secondary winding. The potential transformer steps down the voltage. The design of a PT is quite similar to that of a primary transformer but the loading of PT is always small sometimes only a few Volt-ampere.

***Current Transformer:***

A CT is an instrument transformer in which the secondary current is substantially proportional to primary current and differs in phase from it by ideally zero degree. Current Transformer Basics can be stated that power flow and provide electrical inputs to power transformers and instruments.

Current transformers produce either an alternating current or alternating voltage that is proportional to the measured current. There are a variety of applications for current transformers. Some devices are used to measure current in electronics equipment or motors. Current transformers with small footprints mount on printed circuit boards (PCBs) and are used to sense current overloads, detect ground faults, and isolate current feedback signals.

Larger devices are used in many three-phase systems to measure current or voltage. Current Transformer has many performance specifications, including primary current, secondary current, insulation voltage, accuracy, and burden. Primary current, the load of the current transformer, is the measured current. Secondary current is the range of current outputs. Insulation voltage represents the maximum insulation that current transformers provide when connected to a power source. Accuracy is the degree of certainty with which the measured current agrees with the ideal value. Burden is the maximum load that devices can support while operating within their accuracy ratings. Typically, burden is expressed in volt-amperes (VA), the product of the voltage applied to a circuit and the current.

***Thermistors:***

Thermistor is a contraction of a term “thermal resistor“. Thermistors are generally composed of semi conductor materials. Although positive temp co-efficient of temp resistance.

The negative temp co-efficient of resistance can be as large as several percent per degree celcius. This follows the thermistor circuit to detect very small changes in temp which could not be observed with an RTD or a thermocouple. In some cases the resistance of thermistor at room temperature may decrease as much as 5% of each 1°C rise in temperature. This high sensitivity to temperature changes makes thermistors extremely useful for precision temperature measurements control and compensation.

Thermistors are widely used in applications which involve measurements in the range of -60°C to 15°C. The resistance of thermistors ranges from 0.5Ω to 0.75MΩ. Thermistors is highly sensitive device. The thermistor exhibits a highly non linear characteristics of resistance versus temperature.

***Optocoupler:***

An optocoupler is basically an interface between two circuits which operate at (usually) different voltage levels. The key advantage of an optocoupler is the electrical isolation between the input and output circuits. With an optocoupler, the only contact between the input and the output is a beam of light. Because of this it is possible to have an insulation resistance between the two circuits. Isolation like this is useful in high voltage applications where the potentials of two circuits may differ by several thousand volts.

The most common industrial use of the optocouplers (or optically-coupled isolators) is as a signal converter between high-voltage pitot devices and low voltage solid-state logic circuits. Optical isolators can be employed in any situation where a signal must be passed between two circuits which are isolated from each other. Complete electrical isolation between two circuits is often necessary to prevent noise generated in one circuit from being passed to the other circuit. This is especially necessary for the coupling between high-voltage information-gathering circuits and low-voltage digital logic circuits.

The optocouplers works well on either ac or dc high-voltage signals. For this reason, signal converters employing optical coupling are sometimes referred to the universal signal converters.

Simply the optocoupler is a device that contains an infra-red LED and a photodetector (such as a photodiode, phototransistor, Darlington pair, SCR or triac) combined in one package.

Examples of circuits has been mentioned here for the better understanding.

**Example 1: Load Detection Sampling and Wiring:**

The figure (9) shows circuit of load detection sampling and wiring. Two adjust point input voltage sample and input sample current from the AC and two adjust point output voltage sample and input current from Load and is comparing and matching by the comparator circuit and supplied to the load. The standard voltage and current reference will be from the AC input and variable voltage and current reference will be from the load.

**Example 2. Input Voltage Sampling and Processing:**

The figure (10) shows circuit clearly explains the input sampling and processing. Here the Input voltage sampling with 50/60Hz square wave pulse takes place and the 100/120Hz pulsating DC current given for the DCDC high efficiency controller circuit.

**3. Output Voltage Sampling and Processing :**

As explained earlier the output voltage sampling processing explained in terms of a circuit as in figure 11.

**4. Charge, inverter current Sampling :**

The circuit (as in figure 12) is the charge, inverter current sampling. It is a current sampling circuit of inverter charging unit. It will take a sample of current from the inverter and provide it to the MCU driver unit. MCU will provide the monitoring signals for charger circuit of inverter section.

According to the sampling current & load the output current of the charger will varies.

***EMI filter:***

Most electrical and electronic devices can generate and/or affected by EMI. Our PCU includes EMI filtering Circuits (Figure 13). Within switch-mode power supplies, a high dc voltage is chopped or switched at high frequency. This high speed switching process is intrinsic to switch-mode power supplies and provides its improved efficiency and reduced size when compared to linear power supplies. However, as a side effect, this switching generates unwanted EMI. In fact, most conducted EMI within switch-mode power supplies originates from the main switching MOSFETs , transistors, and output rectifiers.

In our PCU, it is the function of the EMI filter to keep any internally generated noise contained within the device and to prevent any external ac line noise from entering the device. EMI filters comprise a network of passive electronic components including capacitors and inductors that form L-C circuits.

Since unwanted EMI is at much higher frequencies than normal signals, the EMI filter works by selectively blocking or shunting unwanted higher frequencies. Basically the inductive part of the EMI filter is designed to act as a low frequency pass device for the ac line frequencies and a high frequency blocking device.

Other parts of the EMI filter use capacitors to bypass or shunt unwanted high frequency noise away from the sensitive circuits. The net result is that the EMI filter significantly reduces or attenuates any unwanted noise signals from entering or leaving the protected electronic device and fashioning PCU to give the standard output.

***Automatic Voltage Regulator :***

The automatic voltage regulator or AVR (figure 14), as the name implies, is a device intended to regulate voltage automatically, that is to take a varying voltage level and turn it into a constant voltage level. A voltage regulator may be a simple "feed-forward" design or may include negative feedback control loops. 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. AVRs range in size from small ones that can be mounted on printed circuit boards to those the size of a small house.

An AVR takes in a range of voltage levels and automatically outputs a voltage with a much narrower range of voltage levels. For example, a typical automatic voltage regulator for power quality application may have an input voltage range of +10% to -25% of the nominal input voltage and convert this to a regulated voltage range of +3% to -3% of the nominal output voltage. A voltage regulator may have a symmetrical input voltage range
(e.g. + 10% to -10% of nominal voltage) or an asymmetrical input voltage range. The choice of symmetrical versus asymmetrical input voltage range is dictated by purpose and design of the voltage regulator. The output voltage regulation range is almost universally symmetrical (e.g. +3% to -3% of nominal output voltage).

A voltage regulator may also perform a voltage step up or step down function whereby the nominal incoming voltage is transformed to a different output voltage level. For a voltage regulator with step up or step down capability, the input and output voltage ranges are usually applied to the input and output voltages.

***SPS:***

The circuit diagram (figure 15) represents the Switching Power Supply (SPS) of the PCU. From the Below mentioned SPS circuit we can understand the operation controls of our Switch control. Switch SW1 mentioned in the circuit is the main control of on, off & info scroll. Each control from the switches has different triggering & driver circuit to drive the PCU. Here for triggering the control of SW1 , Q18 & Q5 is used . SPS has the over control for PCU ON & OFF, Charger inverter control & overall Circuit Power Supply control. When the SW1 is On Condition the control of Q18 will switch control to the power Supply & similarly from Q5 PCU On Condition is maintained to provide charger , inverter control to active mode.

***Micro controller unit (MCU):***

Pin 1 and 20: pins closed the MCU reset circuit

Pin 2 : Sample signal from inverter charge current controller circuit

Pin 3 : Sample signal from Battery voltage monitoring circuit

Pin 4 and 5 : Reference voltage

Pin 6 : Signal for MCU TOCK

Pin 7 : Sample signal from load control circuit

Pin 9 and 10 : Connected with crystal oscillator circuit

Pin 8 and 19 : Ground

Pin 11 : UPS ON and OFF control

Pin 12 : Frequency Sample signal from input sampling circuit

Pin 13 : Threshold voltage low level trigger output from MCU

Pin 14 : Chip select signal from MCU

Pin 15 : Data acquisition signal from MCU to Interface circuit

Pin 16 : Write signal

Pin 17 : Transmitting signal

Pin 18 : Receiving signal

Pin 21 : Info Key

Pin 22 : Control Signal for input from MCU

Pin 23 : Threshold voltage high level trigger output from MCU

Pin 24 : Control Signal for output from MCU

Pin 25, 26, 27 and 28 : Control signals from MCU to PWM signal controller

**Chip Explanation:**

The Microcontroller used in the present invention is PIC16C73. The said Microcontroller is used to control the Inverter Section operation of our PCU. It interface with Solar MCU, which is used to observe the signals and data from Solar MCU and produce the corresponding signal for Charging and Discharging, Mode of Working, ON/OFF function Display Function, Buzzer alarm, Reset and other related functions. It also observe the status of Input/Output Voltage, Input/Output Current, Input/Output frequency, Load Level from the sampling signal from each sampling circuit. According to the signals it will generate the control and operation signal for PCU operation.

**Function Explanation using Pins:**

**Pin 1(VPP/MCLR):** Reset Input. A high on this pin for two mission cycle. While the oscillator is running to reset the device. This terminal was connected to the Output terminal of simple circuit with Diode D2, Capacitor C13 and Transistor Q1 for generating the Reset signal to MCU. It will be active when MCU needs to reset its Function.

**Pin 2(RA0):** This terminal was connected to the Output terminal of Input Current Sampling circuit (Fig No.16). The sampling signal from input current sampling circuit was transferred to RA0 which store and check the Status of Input Current range.

**Pin 3(RA1):** This terminal was connected to the Output terminal of Battery Voltage Sampling Circuit (Fig No.16). The sampling signal from Battery Voltage sampling circuit was transferred to RA1 which store and check the Status of Battery Voltage Range.

**Pin 4(RA2):** This terminal was connected to the Output terminal of Input Voltage Sampling Circuit (Fig No.16). This sampling signal is transferred to RA2, which is referred as a VREF-, used to trace the Input Voltage range.

**Pin 5(RA4):** This terminal was connected to the Output terminal of Output Voltage Sampling Circuit (Fig No.16). This sampling signal is transferred to RA4, which is referred as a VREF+, used to trace the Output Voltage range.

**Pin 6(RA/TOCK+):** This terminal was connected to the Output terminal of Buzzer Alarm through a simple circuit with Resistor R5, R6, and Transistor Q2. MCU send signal through this pin to Buzzer Alarm.

**Pin 7(RA5):** This terminal was connected to the Output terminal of Load Control Circuit( Fig No.16). It will detect and sense the load level and give the signal to for further operation *i.e.,* if the Load level is less than 5%, it will give the signal to RCO for control the output voltage value.

**Pin 8(VSS):** This pin is connected to Ground.

**Pin 9(OSC1) and Pin 10(OSC2):** This terminals are connected with Crystal Oscillator X1 circuit through Capacitors C5, C6, and C8. This circuit also connected Pin 7 for Load sensing Purpose.

**Pin 11(RCO):** It used to control the ON and OFF function of PCU. RCO will generate the corresponding signal and send the same to system through the resistor R44. (i.e) If the system was overloaded, the MCU send signal through RCO to shut down the PCU.

**Pin 12(RC1):** This terminal was connected to the Output terminal of frequency sampling circuit (Fig No.16), which used to detect the frequency level of system.

**Pin 13(RC2):** It used to identifying the Low threshold Voltage. It generate the sampling signal for detect the Low threshold Voltage level.

**Pin 14(RC3):** It will generate the Chip Select Signal for MCU Operation.

**Pin 15(RC4):** Pin read Input. A high on for two mission cycles from external source to read the data from the MCU.

**Pin 16(RC5):** Pin write Input. A low off for two mission cycles from external source to write the data in the MCU.

**Pin 17(Tx) and Pin 18(Rx) :** This Terminals are Universal Asynchronous and Synchronous Transmission and Reception Ports.

**Pin 19(VSS):** This terminal was connected to the ground.

**Pin 20(VDD):** It used to give the positive voltage supply to MCU and also connected to the MCU Reset Circuit.

**Pin 21(RB0):** It will give the control signal to Display Drive for show the scrolling data on LCD Display.

**Pin 22(RB1):** It will generate and give the control signal for input from Inverter MCU to Solar MCU.

**Pin 23(RB2):** It used to identifying the High threshold Voltage. It generate the sampling signal for detect the high threshold Voltage level.

**Pin 24(RB3):** It will generate and give the control signal for output from Inverter MCU to Solar MCU.

**Pin 25 to Pin28(RB4 to RB7):** This terminals are interface with Solar MCU. It also used to generate and send the PWM signal to the MOSFET of Up bridge and Down bridge circuits (Fig No.16) to control the charging and discharging operation.

***Description of Microcontroller:***

The Microcontroller sense the Input Voltage and Current Level from the Pins 2,3,4, 13 and 22 and sense the frequency level from Pin 12. According to the that Signals and load level which has been detected by Pin 7, the MCU generate the control signal send it to PWM Control circuit and also send the corresponding output signal to 24$^{th}$ Pin to operate the system. For example as per condition if the solar generated power is greater then the load then the solar MCU send that signal to Inverter MCU by interfacing circuit and the Inverter MCU generate the corresponding signal and deliver the signal to system through the output Pin.

If the Battery Voltage is low, then the Battery voltage sampling circuit send the signal to MCU through Pin 3, and the Inverter MCU generate the corresponding signal for charging the battery by checking the PV Voltage level from solar MCU and AC availability from Input Voltage Sampling circuit and deliver that signal to system through the output Pin. If the PV energy is sufficient for charging the battery, Inverter MCU generate signal that the battery is charged by PV through MPPT and send that signal to PWM charging discharging circuit. According to that signal the Up bridge and Down bridge circuits charge the Battery.

If Voltage from Solar below system voltage (24V/48V) is Low then the Solar MCU send the signal to Inverter MCU through the interfacing circuit and the Inverter MCU generate the corresponding signal that the battery is charged by AC and send that signal to charge and discharge control circuit. According to that signal the Up bridge and down bridge circuits charge the battery.

When the Off button of PCU is pressed, the system will send the Off signal to Inverter MCU, then it will check the status and give the corresponding signal to system for OFF the system. The same process will be followed for switch ON the PCU.

When the system is overloaded or PCU function failure due to some reasons, the Inverter MCU observe that status from Load Control terminal and Reset terminal then immediately it will generate the signal for Switch Off the PCU and automatically system transferred to Bypass condition.

**Pin Description:**

The solar MCU used in our PCU is 44Pin Microcontroller. It used to control the PWM operation, Switching function, Display function, MPPT operation. It also interface with Inverter MCU for system operation.

**Pin 1-4&Pin 41-44(P0-P7):** In this MCU, Terminals P0-P7 are connected to D0-D7 terminal of LCD Display for controlling the functionality of LCD by send the corresponding signal of system operation.

**Pin 5(Vss)&Pin 8(Vdd):** This terminals are connected to the +3.3V Power Supply through a 100nF capacitor.

**Pin 7(RESn):** Reset Input. A high on this pin for two mission cycle. While the oscillator is running to reset the device. This terminal was connected to the VPP output Pin of CN 5 Connector. It will be active when MCU needs to reset its Function.

**Pin 9(P8):** This terminal was connected to the MI of LCD Display for providing Master Interrupt signal to Display.

**Pin 12(P11):** This terminal was connected to the PGC terminal of CN 5 Connector.

**Pin 13(P12):** This terminal was connected to the PGD terminal of CN 5 Connector.

**Pin 17(Vss)&Pin 18(Vdd):** This terminals are connected to the +3.3V Power Supply through a 100nF capacitor.

**Pin 16(P15):** This terminal was connected to the Input terminal of Load Control Circuit (Fig No.17). It will send a signal to sampling circuit for detecting the Load level and send the output sampling signal to Inverter MCU.

**Pin 19(P16):** This terminal was connected to the Output terminal of TV.H from Inverter MCU. The Inverter MCU detect the high threshold voltage and send the output signal to Solar MCU for operation.

**Pin 20(P17):** This terminal was connected to the Output terminal of TV.L from Inverter MCU. The Inverter MCU detect the low threshold voltage and send the output signal to Solar MCU for operation.

**Pin 21(P18):** This terminal was connected to the Input Voltage Control signal from Inverter MCU.

**Pin 22(P19):** This terminal was connected to the Output Voltage Control signal from Inverter MCU.

**Pin 23(P20):** This terminal was connected to the Line terminal of Output AC Voltage.

**Pin 24(P21):** This terminal was connected to the Neutral terminal of Output AC Voltage.

**Pin 25(P22):** This terminal was connected to the Neutral terminal of Input AC Voltage.

**Pin 26(P23):** This terminal was connected to the Line terminal of Input AC Voltage.

**Pin 27(Vss)&Pin 30(Vdd):** This terminals are connected to the +3.3V Power Supply through a 100nF capacitor.

**Pin 28(X1)&Pin 29(X0):** This terminals are connected with Crystal Oscillator circuit through Capacitors C25, C26.

**Pin 31(P24):** It will give the control signal to Display Drive for show the scrolling data on LCD Display. It will generate the triggering signal and send it to triggering circuit with 10K resistor for control the INFO.

**Pin 32(P25):** It will generate the triggering signal and send it to the triggering circuit with resistor of 10K for Shut down the PCU

**Pin 33(P26):** It will generate the triggering signal and send it to the triggering circuit with resistor of 10K for Switch On the PCU.

**Pin 34(P27):** It will generate the Chip Select Signal for Display Operation.

**Pin 35(P28):** It will generate the Reset Signal for LCD Display.

**Pin 36(P29):** It will generate and send the signal of selecting the register for Command or data

**Pin 37(P30):** It will generate the Read/Write signal for LCD Display Operations.

**Pin 38(P31):** Ir will generate the Enable control signal for LCD Display Operations.

The description of the PIC16C73/73A/76 Pin out is given below.

| **Pin Name** | **DIP Pin#** | **SOIC Pin#** | **I/O/P Type** | **Buffer Type** | **Description** |
|---|---|---|---|---|---|
| OSC1/CLKIN | 9 | 9 | I | ST/CMOS(3) | Oscillator crystal input/external clock source input. |
| OSC2/CLKOUT | 10 | 10 | O | — | Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, the OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate. |
| MCLR/VPP | 1 | 1 | I/P | ST | Master clear (reset) input or programming voltage input. This pin is an active low reset to |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | the device. |
| | | | | | PORTA is a bi-directional I/O port. |
| RA0/AN0 | 2 | 2 | I/O | TTL | RA0 can also be analog input0 |
| RA1/AN1 | 3 | 3 | I/O | TTL | RA1 can also be analog input1 |
| RA2/AN2 | 4 | 4 | I/O | TTL | RA2 can also be analog input2 |
| RA3/AN3/VREF | 5 | 5 | I/O | TTL | RA3 can also be analog input3 or analog |
| RA4/T0CKI | 6 | 6 | I/O | ST | reference voltage |
| | | | | | RA4 can also be the clock input to the Timer0 |
| RA5/SS/AN4 | 7 | 7 | I/O | TTL | module. Output is open drain type. |
| | | | | | RA5 can also be analog input4 or the slave |
| | | | | | select for the synchronous serial port. |
| | | | | | PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs. |
| RB0/INT | 21 | 21 | I/O | TTL/ST(1) | RB0 can also be the external interrupt pin. |
| RB1 | 22 | 22 | I/O | TTL | |
| RB2 | 23 | 23 | I/O | TTL | |
| RB3 | 24 | 24 | I/O | TTL | |
| RB4 | 25 | 25 | I/O | TTL | Interrupt on change pin. |
| RB5 | 26 | 26 | I/O | TTL | Interrupt on change pin. |
| RB6 | 27 | 27 | I/O | TTL/ST(2) | Interrupt on change pin. Serial programming |
| RB7 | 28 | 28 | I/O | TTL/ST(2) | clock. |
| | | | | | Interrupt on change pin. Serial programming |
| | | | | | data. |
| | | | | | PORTC is a bi-directional I/O port. |
| RC0/T1OSO/T1 | 11 | 11 | I/O | ST | RC0 can also be the Timer1 oscillator output or |
| CKI | | | | | Timer1 clock input. |
| | 12 | 12 | I/O | ST | RC1 can also be the Timer1 oscillator input or |
| RC1/T1OSI/CCP | | | | | Capture2 input/Compare2 output/PWM2 output. |
| 2 | 13 | 13 | I/O | ST | RC2 can also be the Capture1 input/Compare1 |
| | | | | | output/ PWM1 output. |
| RC2/CCP1 | 14 | 14 | I/O | ST | RC3 can also be the synchronous serial clock |
| | | | | | input/output for both SPI and $I^2C$ modes. |
| RC3/SCK/SCL | 15 | 15 | I/O | ST | RC4 can also be the SPI Data In (SPI mode) or |
| | | | | | data I/O ($I^2C$ mode). |
| RC4/SDI/SDA | 16 | 16 | I/O | ST | RC5 can also be the SPI Data Out (SPI mode). |
| | 17 | 17 | I/O | ST | RC6 can also be the USART Asynchronous |
| RC5/SDO | | | | | Transmit or Synchronous Clock. |
| RC6/TX/CK | 18 | 18 | I/O | ST | RC7 can also be the USART Asynchronous |
| | | | | | Receive or Synchronous Data. |
| RC7/RX/DT | | | | | |
| VSS | 8, 19 | 8, 19 | P | — | Ground reference for logic and I/O pins. |
| VDD | 20 | 20 | P | — | Positive supply for logic and I/O pins. |

Legend : I = input O = output I/O = input/output P = power — = Not used
TTL = TTL input ST = Schmitt Trigger input

**Table 2- PIC16C73/73A/76 Pin out**

PIC16C7X Microcontroller Core Features:

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of Program Memory, up to 368 x 8 bytes of Data Memory (RAM)
- Interrupt capability
- Eight level deep hardware stack
- Direct, indirect, and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS EPROM technology
- Fully static design
- Wide operating voltage range: 2.5V to 6.0V
- High Sink/Source Current 25/25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
  - < 2 mA @ 5V, 4 MHz
  - 15 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

PIC16C7X Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Capture, Compare, PWM module(s)
- Capture is 16-bit, max. resolution is 12.5 ns, Compare is 16-bit, max. resolution is 200 ns, PWM max. resolution is 10-bit
- 8-bit multichannel analog-to-digital converter
- Universal Synchronous Asynchronous Receiver n Transmitter (USART/SCI)
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls
- Brown-out detection circuitry for Brown-out Reset (BOR)

| **PIC16C7X Features** | **72** | **73** | **73A** | **74** | **74A** | **76** | **77** |
|---|---|---|---|---|---|---|---|
| Program Memory (EPROM) x 14 | 2K | 4K | 4K | 4K | 4K | 8K | 8K |
| Data Memory (Bytes) x 8 | 128 | 192 | 192 | 192 | 192 | 368 | 368 |
| I/O Pins | 22 | 22 | 22 | 33 | 33 | 22 | 33 |
| Parallel Slave Port | — | — | — | Yes | Yes | — | Yes |
| Capture/Compare/PWM Modules | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| Timer Modules | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| A/D Channels | 5 | 5 | 5 | 8 | 8 | 5 | 8 |
| Serial Communication | SPI/$I^2C$ | SPI/$I^2C$ USART | SPI/$I^2C$ USART | SPI/$I^2C$ USART | SPI/$I^2C$ USART | SPI/$I^2C$ USART | SPI/$I^2C$ USART |
| In-Circuit Serial Programming | YES | YES | YES | YES | YES | YES | YES |
| Brown-out Reset | YES | — | YES | — | YES | YES | YES |
| Interrupt Sources | 8 | 11 | 11 | 12 | 12 | 11 | 12 |

**Table 3:** PIC16C7 Peripheral Features

***Description:***

The PIC16C7X is a family of high-performance, CMOS, fully-static, 8-bit microcontrollers with integrated analog-to-digital (A/D) converters, in the PIC16CXX mid-range family.

All PIC16/17 microcontrollers employ an advanced RISC architecture. The PIC16CXX microcontroller family has enhanced core features, eight-level deep stack, and multiple internal and external interrupt sources. The separate instruction and data buses of the Harvard architecture allow a 14-bit wide instruction word with the separate 8-bit wide data.

The two stage instruction pipeline allows all instructions to execute in a single cycle, except for program branches which require two cycles. A total of 35 instructions (reduced instruction set) are available. Additionally, a large register set gives some of the architectural innovations used to achieve a very high performance.

PIC16CXX microcontrollers typically achieve a 2:1 code compression and a 4:1 speed improvement over other 8-bit microcontrollers in their class.

The PIC16C72 has 128 bytes of RAM and 22 I/O pins. In addition several peripheral features are available including: three timer/counters, one Capture/Compare/ PWM module and one serial port. The Synchronous Serial Port can be configured as either a 3-wire Serial Peripheral Interface (SPI) or the two-wire Inter-Integrated Circuit ($I^2C$) bus. Also a 5-channel high-speed 8-bit A/D is provided. The 8-bit resolution is ideally suited for applications requiring low-cost analog inter- face, e.g. thermostat control, pressure sensing, and the like.

The PIC16C73/73A devices have 192 bytes of RAM, while the PIC16C76 has 368 byes of RAM. Each device has 22 I/O pins. In addition, several peripheral features are available including: three timer/counters, two Capture/Compare/PWM modules and two serial ports. The Synchronous Serial Port can be configured as either a 3-wire Serial Peripheral Interface (SPI) or the two-wire Inter-Integrated Circuit ($I^2C$) bus. The Universal Synchronous Asynchronous Receiver Transmitter (USART) is also known as the Serial Communications Interface or SCI. Also a 5-channel high-speed 8-bit A/ D is provided. The 8-bit resolution is ideally suited for applications requiring low-cost analog interface, e.g. thermostat control, pressure sensing, and the like.

The PIC16C74/74A devices have 192 bytes of RAM, while the PIC16C77 has 368 bytes of RAM. Each device has 33 I/O pins. In addition several peripheral features are available including: three timer/counters, two Capture/Compare/PWM modules and two serial ports. The Synchronous Serial Port can be configured as either a 3-wire Serial Peripheral Interface (SPI) or the two-wire Inter-Integrated Circuit ($I^2C$) bus. The Universal Synchronous Asynchronous Receiver Transmitter (USART) is also known as the Serial Communications Interface or SCI. An 8-bit Parallel Slave Port is provided. Also an 8-channel high speed 8-

bit A/D is provided. The 8-bit resolution is ideally suited for applications requiring low-cost analog interface, e.g. thermostat control, pressure sensing, and the like.

The PIC16C7X family has special features to reduce external components, thus reducing cost, enhancing system reliability and reducing power consumption. There are four oscillator options, of which the single pin RC oscillator provides a low-cost solution, the LP oscillator minimizes power consumption, XT is a standard crystal, and the HS is for High Speed crystals. The SLEEP (power down) feature provides a power saving mode. The user can wake up the chip from SLEEP through several external and internal interrupts and resets.

A highly reliable Watchdog Timer with its own on-chip RC oscillator provides protection against software lock up.

A UV erasable CERDIP packaged version is ideal for code development while the cost-effective One-Time-Programmable (OTP) version is suitable for production in any volume.

The PIC16C7X family fits perfectly in applications ranging from security and remote sensors to appliance control and automotive. The EPROM technology makes customization of application programs (transmitter codes, motor speeds, receiver frequencies, etc.) extremely fast and convenient.

The small footprint packages make this micro controller series perfect for all applications with space limitations. Low cost, low power, high performance, ease of use and I/O flexibility make the PIC16C7X very versatile even in areas where no micro controller use has been considered before (e.g. timer functions, serial communication, capture and compare, PWM functions and coprocessor applications).

*Family and Upward Compatibility:*

Users familiar with the PIC16C5X micro controller family will realize that this is an enhanced version of the PIC16C5X architecture.

*Development Support:*

PIC16C7XX devices are supported by the complete line of Microchip Development tools.

*PIC16C7XX Family of devices:*

| | | PIC16C73A | PIC16C74A | PIC16C76 | PIC16C77 |
|---|---|---|---|---|---|
| **Clock** | Maximum Frequency of Operation (MHz) | 20 | 20 | 20 | 20 |
| **Memory** | EPROM Program Memory | 4K | 4K | 8K | 8K |
| | Data Memory (bytes) | 192 | 192 | 368 | 368 |
| | Timer Module(s) | TMR0, TMR1, TMR2 | TMR0, TMR1, TMR2 | TMR0, TMR1, TMR2 | TMR0, TMR1, TMR2 |
| **Peripherals** | Capture/Compare/ PWM Module(s) | 2 | 2 | 2 | 2 |
| | Serial Port(s) (SPI/I²C, USART) | SPI/I²C, USART | SPI/I²C, USART | SPI/I²C, USART | SPI/I²C, USART |
| | Parallel Slave Port | - | Yes | - | Yes |
| | A/D Converter (8-bit) Channels | 5 | 8 | 5 | 8 |
| **Features** | Interrupt Sources | 11 | 12 | 11 | 12 |
| | I/O Pins | 22 | 33 | 22 | 33 |
| | Voltage Range (Volts) | 2.5-6.0 | 2.5-6.0 | 2.5-6.0 | 2.5-6.0 |
| | In-Circuit Serial Programming | Yes | Yes | Yes | Yes |
| | Brown-out Reset | Yes | Yes | Yes | Yes |
| | Packages | 28-pin SDIP, SOIC | 40-pin DIP; 44-pin PLCC MQFP, TQFP | 28-pin SDIP, SOIC | 40-pin DIP; 44-pin PLCC, MQFP, TQFP |

**Table 4: Family of devices Characteristics**

All PIC16/17 Family devices have Power-on Reset, selectable Watchdog Timer, selectable code protect and high I/O current capability. All PIC16C7XX Family devices use serial programming with clock pin RB6 and data pin RB7.

PIC16C7X Device Varieties :

A variety of frequency ranges and packaging options are available. Depending on application and production requirements, the proper device option can be selected using the information in the PIC16C7X Product Identification System section at the end of this data sheet. When placing orders, please use that page of the data sheet to specify the correct part number.

For the PIC16C7X family, there are two device "types" as indicated in the device number:

1. **C**, as in PIC16**C**74. These devices have EPROM type memory and operate over the standard voltage range.
2. **LC**, as in PIC16**LC**74. These devices have EPROM type memory and operate over an extended voltage range.

Architectural Overview:

The high performance of the PIC16CXX family can be attributed to a number of architectural features commonly found in RISC microprocessors. To begin with, the PIC16CXX uses a Harvard architecture, in which, program and data are accessed from separate memories using separate buses. This improves bandwidth over traditional von Neumann architecture in which program and data are fetched from the same memory using the same bus. Separating program and data buses further allows instructions to be sized differently than the 8-bit wide data word. Instruction opcodes are 14-bits wide making it possible to have all single word instructions. A 14-bit wide program memory access bus fetches a 14-bit instruction in a single cycle. A two- stage pipeline overlaps fetch and execution of instructions. Consequently, all instructions execute in a single cycle (200ns @ 20 MHz) except for program branches.

The table-3 below lists program memory (EPROM) and data memory (RAM) for each PIC16C7X device.

| Device | Program Memory | Data Memory |
|---|---|---|
| PIC16C72 | 2K x 14 | 128 x 8 |
| PIC16C73 | 4K x 14 | 192 x 8 |
| PIC16C73A | 4K x 14 | 192 x 8 |
| PIC16C74 | 4K x 14 | 192 x 8 |
| PIC16C74A | 4K x 14 | 192 x 8 |
| PIC16C76 | 8K x 14 | 368 x 8 |
| PIC16C77 | 8K x 14 | 386 x 8 |

**Table-5: Program memory (EPROM) and data memory (RAM) for each PIC16C7X device.**

The PIC16CXX can directly or indirectly address its register files or data memory. All special function registers, including the program counter, are mapped in the data memory. The PIC16CXX has an orthogonal (symmetrical) instruction set that makes it possible to carry out any operation on any register using any addressing mode. This symmetrical nature and lack of 'special optimal situations' make programming with the PIC16CXX simple yet efficient. In addition, the learning curve is reduced significantly.

PIC16CXX devices contain an 8-bit ALU and working register. The ALU is a general purpose arithmetic unit. It performs arithmetic and Boolean functions between the data in the working register and any register file.

The ALU is 8-bits wide and capable of addition, subtraction, shift and logical operations. Unless otherwise mentioned, arithmetic operations are two's complement in nature. In two operand instructions, typically one operand is the working register (W register). The other operand is a file register or an immediate constant. In single operand instructions, the operand is either the W register or a file register.

The W register is an 8-bit working register used for ALU operations. It is not an addressable register.

Depending on the instruction executed, the ALU may affect the values of the Carry (C), Digit Carry (DC), and Zero (Z) bits in the STATUS register. The C and DC bits operate as a borrow bit and a digit borrow out bit, respectively, in subtraction.

The characteristics and results obtained of a typical PCU is given in the below table -6

| | | |
|---|---|---|
| Broad workable Range | 500W/800W/1000W | 2500W |
| MPPT Voltage range | 24Vdc-45Vdc | 48Vdc-90Vdc |
| Battery Voltage range | 21Vdc-30Vdc | 48Vdc-60Vdc |
| MPPT MAX charge current | 10A/20A/30A/40A | |
| Input Ac Voltage Range | 230±25% | |
| Output AC Voltage | 230±10% | |

| | |
|---|---|
| Input Frequency Range | 45HZ-65Hz |
| Output Frequency Range | 50Hz±1% |
| Ambient Humidity | 10-90% |
| Ambient Temp | 0° to 45°C |
| panel Temp cycling range | -40° to 85°C |
| Conversion Efficiency | ≥98% |
| Efficiency mains mode | ≥96% |

**Table-6: Characteristics and results obtained of a typical PCU**

| PCU Rated power | Battery Voltage | PV input voltage | MPPT voltage Range | Medium irradiation | High irradiation | AC input voltage | AC output voltage | Conversion efficiency | loadtest efficiency | | | | | | | THD(% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 24V | 27V | 24V - 45V | | | | | | 5% | 20% | 50% | 70% | 85% | 100% | 130% | |
| 500W 800W 1000W | 24V | nil | nil | nil | nil | 230 | 230 | 98 | 99.24 | 98.60 | 98.40 | 98.18 | 97.65 | 96.80 | 95.68 | 11.86 |
| 500W 800W 1000W | 24V | nil | nil | nil | nil | 200 | 230 | 97 | 99.11 | 98.40 | 98.18 | 97.76 | 97.25 | 96.40 | 95.14 | 12.01 |
| 500W 800W 1000W | 24V | nil | nil | nil | nil | 190 | 229.9 | 96 | 98.60 | 97.32 | 97.01 | 96.64 | 96.20 | 95.30 | 93.00 | 15.00 |
| 500W 800W 1000W | 24 | nil | nil | nil | nil | nil | 230 | 98 | 98.18 | 97.65 | 96.47 | 95.99 | 95.58 | 94.67 | 91.93 | 12.86 |
| 500W 800W 1000W | 23.8 | nil | nil | nil | nil | nil | 230 | 97.2 | 97.76 | 97.25 | 95.78 | 95.22 | 94.86 | 93.92 | 90.59 | 15.60 |
| 500W 800W 1000W | 23.2 | nil | nil | nil | nil | nil | 230 | 96.8 | 96.64 | 96.20 | 95.08 | 94.45 | 94.13 | 93.17 | 89.25 | 18.34 |
| 500W 800W 1000W | 22.8 | nil | nil | nil | nil | nil | 229.8 | 95.4 | 95.99 | 95.58 | 94.39 | 93.68 | 93.41 | 92.42 | 87.91 | 21.08 |
| 500W 800W 1000W | 22.1 | nil | nil | nil | nil | nil | 229 | 94.5 | 95.22 | 94.86 | 93.69 | 92.91 | 92.68 | 91.67 | 86.57 | 23.82 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | 97.64 | | 230 | 230 | 98 | 95.22 | 94.86 | 93.69 | 92.91 | 92.68 | 91.67 | 86.57 | 23.82 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | 97.95 | | 230 | 230 | 98 | 95.99 | 95.58 | 94.39 | 93.68 | 93.41 | 92.42 | 87.91 | 21.08 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | 98.26 | | 230 | 230 | 98 | 98.60 | 97.32 | 97.01 | 96.64 | 96.20 | 95.30 | 93.00 | 15.00 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | | 98.57 | 230 | 230 | 98 | 99.11 | 98.40 | 98.18 | 97.76 | 97.25 | 96.40 | 95.14 | 12.01 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | | 98.88 | 230 | 230 | 98 | 99.24 | 98.60 | 98.40 | 98.18 | 97.65 | 96.80 | 95.68 | 11.86 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | | 99.19 | 230 | 230 | 98 | 98.18 | 97.65 | 96.47 | 95.99 | 95.58 | 94.67 | 91.93 | 12.86 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | 97.64 | | nil | 230 | 98 | 95.22 | 94.86 | 93.69 | 92.91 | 92.68 | 91.67 | 86.57 | 23.82 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | 97.95 | | nil | 230 | 98 | 95.99 | 95.58 | 94.39 | 93.68 | 93.41 | 92.42 | 87.91 | 21.08 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | 98.26 | | nil | 230 | 98 | 98.60 | 97.32 | 97.01 | 96.64 | 96.20 | 95.30 | 93.00 | 15.00 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | | 98.57 | nil | 230 | 98 | 99.11 | 98.40 | 98.18 | 97.76 | 97.25 | 96.40 | 95.14 | 12.01 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | | 98.88 | nil | 230 | 98 | 99.24 | 98.60 | 98.40 | 98.18 | 97.65 | 96.80 | 95.68 | 11.86 |
| 500W 800W 1000W | 24V | 27V | 24V - 45V | | 99.19 | nil | 230 | 98 | 98.18 | 97.65 | 96.47 | 95.99 | 95.58 | 94.67 | 91.93 | 12.86 |

**Table-7(Efficiency Chart on Three Stages)**

In the Table 7, every row explains the various operations of the PCU and the characteristics mentioned are Battery Voltage, PV Input Voltage, MPPT voltage range, Irradiation Level to the Panel, Grid Input and Output Voltage, Efficiency and Threshold level. For Example 9th row indicates, for the rated PCU 1000W, Battery fixed voltage is 24 V and at the medium irradiation the Solar Photovoltaic (SPV) Panel will produce the voltage of 27.7 V and Current 4.67A. The efficiency can be calculated as Efficiency = (Power Output/Power Input) and the Threshold can be calculated either by Voltage or Current.

$$THD_V = \frac{\sqrt{\sum_{k=2}^{\infty} V_{k\,rms}^2}}{V_{1rms}} \cdot 100\% = \frac{\sqrt{\sum_{k=2}^{\infty} V_k^2}}{V_1} \cdot 100\% .$$

$$THD_I = \frac{\sqrt{\sum_{k=2}^{\infty} I_{k\,rms}^2}}{I_{1rms}} \cdot 100\% = \frac{\sqrt{\sum_{k=2}^{\infty} I_k^2}}{I_1} \cdot 100\% .$$

| PCU Rated power | Battery Voltage | PV input voltage | MPPT voltage Range | Medium irradiation | High irradiation | AC input voltage | AC output voltage | Conversion efficiency | load test efficiency | | | | | | | THD % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 48V | 54V | 48V - 60V | | | | | | 5% | 20% | 50% | 70% | 85% | 100% | 130% | |
| 2500W | 48V | nil | nil | nil | nil | 230 | 230 | 98 | 98.24 | 98.65 | 98.45 | 98.18 | 97.65 | 96.50 | 95.68 | 11.66 |
| 2500W | 48V | nil | nil | nil | nil | 230 | 230 | 97 | 98.11 | 98.45 | 98.18 | 97.76 | 97.35 | 96.45 | 95.14 | 10.01 |
| 2500W | 48V | nil | nil | nil | nil | 190 | 229.9 | 98 | 98.50 | 97.30 | 97.01 | 96.54 | 96.00 | 95.30 | 93.00 | 15.00 |
| 2500W | 48 | nil | nil | nil | nil | nil | 230 | 98 | 98.18 | 97.65 | 96.47 | 95.99 | 95.50 | 94.67 | 91.93 | 10.66 |
| 2500W | 47 | nil | nil | nil | nil | nil | 230 | 97.2 | 97.76 | 97.35 | 95.70 | 95.22 | 94.96 | 93.80 | 91.59 | 15.60 |
| 2500W | 45.5 | nil | nil | nil | nil | nil | 230 | 96.8 | 96.54 | 96.00 | 95.09 | 94.45 | 94.13 | 93.17 | 89.25 | 18.34 |
| 2500W | 44.5 | nil | nil | nil | nil | nil | 229.6 | 95.4 | 95.99 | 95.59 | 94.39 | 93.50 | 93.41 | 92.42 | 87.91 | 21.09 |
| 2500W | 43 | nil | nil | nil | nil | nil | 229 | 94.5 | 95.22 | 94.55 | 93.69 | 92.91 | 92.58 | 91.67 | 86.57 | 23.02 |
| 2500W | 48v | 54V | 48V - 60V | 97.64 | | 230 | 230 | 98 | 95.22 | 94.55 | 93.69 | 92.91 | 92.58 | 91.67 | 86.57 | 23.02 |
| 2500W | 48v | 54V | 48V - 60V | 97.95 | | 230 | 230 | 98 | 95.99 | 95.59 | 94.39 | 93.50 | 93.41 | 92.42 | 87.91 | 21.09 |
| 2500W | 48v | 54V | 48V - 60V | 99.25 | | 230 | 230 | 98 | 98.50 | 97.30 | 97.01 | 96.54 | 96.00 | 95.30 | 93.00 | 15.00 |
| 2500W | 48v | 54V | 48V - 60V | | 99.57 | 230 | 230 | 98 | 98.11 | 98.45 | 98.18 | 97.76 | 97.35 | 96.45 | 95.14 | 10.01 |
| 2500W | 48v | 54V | 48V - 60V | | 99.88 | 230 | 230 | 98 | 98.24 | 98.65 | 98.45 | 98.18 | 97.65 | 96.50 | 95.68 | 11.66 |
| 2500W | 48v | 54V | 48V - 60V | | 99.19 | 230 | 230 | 98 | 98.18 | 97.65 | 96.47 | 95.99 | 95.50 | 94.67 | 91.93 | 10.66 |
| 2500W | 48v | 54V | 48V - 60V | 97.64 | | nil | 230 | 98 | 95.22 | 94.55 | 93.69 | 92.91 | 92.58 | 91.67 | 86.57 | 23.02 |
| 2500W | 48v | 54V | 48V - 60V | 97.95 | | nil | 230 | 98 | 95.99 | 95.59 | 94.39 | 93.50 | 93.41 | 92.42 | 87.91 | 21.09 |
| 2500W | 48v | 54V | 48V - 60V | 99.25 | | nil | 230 | 98 | 98.50 | 97.30 | 97.01 | 96.54 | 96.00 | 95.30 | 93.00 | 15.00 |
| 2500W | 48v | 54V | 48V - 60V | | 99.57 | nil | 230 | 98 | 98.11 | 98.45 | 98.18 | 97.76 | 97.35 | 96.45 | 95.14 | 10.01 |
| 2500W | 48v | 54V | 48V - 60V | | 99.88 | nil | 230 | 98 | 98.24 | 98.65 | 98.45 | 98.18 | 97.65 | 96.50 | 95.68 | 11.66 |
| 2500W | 48v | 54V | 48V - 60V | | 99.19 | nil | 230 | 98 | 98.18 | 97.65 | 96.47 | 95.99 | 95.50 | 94.67 | 91.93 | 10.66 |

**Table-8 : Efficiency Chart on 2500W Stage**

In the Table 8, every row explains the various operations of the PCU and the characteristics mentioned are Battery Voltage, PV Input Voltage, MPPT voltage range, Irradiation Level to the Panel, Grid Input and Output Voltage, Efficiency and Threshold level. For Example 9th row indicates, for the rated PCU 2500W, Battery fixed voltage is 48 V and at the medium irradiation the Solar Photovoltaic (SPV) Panel will produce the voltage of 54 V and Current 10.2A. The efficiency can be calculated as Efficiency = (Power Output/Power Input) and the Threshold can be calculated either by Voltage or Current.

$$THD_V = \frac{\sqrt{\sum_{k=2}^{\infty} V_{k\,rms}^2}}{V_{1rms}} \cdot 100\% = \frac{\sqrt{\sum_{k=2}^{\infty} V_k^2}}{V_1} \cdot 100\% .$$

$$THD_I = \frac{\sqrt{\sum_{k=2}^{\infty} I_{k\,rms}^2}}{I_{1rms}} \cdot 100\% = \frac{\sqrt{\sum_{k=2}^{\infty} I_k^2}}{I_1} \cdot 100\% .$$

From the details given herein it is evident that the present invention provides a high efficiency and highly reliable PCU. The PCU utilizes the solar power effectively to feed the load on par with the Grid power which is the need of the day as many of the electrical appliances do not perform at their optimum level if the power supply is sufficient and reliable. Considering the other advantage of diversion of the extra power to the battery or the grid saves power without wastage.

It is to be noted that the present invention is not restricted to the description herein but also would encompass that can be envisaged by a person skilled in the art based on the description, figures and claims herein.

Owing to the advantages of the PCU of the present invention it is evident that it can cater to the insistent demand to fill the lacuna with respect to the solar power generation, storage and recovery of the power. There can be continuous power supply in an eco-friendly manner according to the need of the day. The PCU can find huge application in both rural and urban areas to meet the demands suitably.