

DESIGN AND DEVELOPMENT OF DYNAMIC POWER DISTRIBUTION AND MANAGEMENT SYSTEM USING ARDUINO FOR SOLAR POWERABLE INVERTER SYSTEM

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ABSTRACT

Limited power sources like the solar inverter systems require optimum management making it imperative to implement power shedding and sharing for efficiency in power control and management. Increase in power demands by users on constant basis as a result of increase in population, necessitates the need to efficiently utilize the limited available power resources. The high costs often associated with the acquisition and installation of solar-inverter power system also encourage sharing and shedding of the limited energy resources among users. Although the entire solar inverter system is typically equipped with overload protection mechanism, this paper developed a standalone power control system to provide independent smaller power system units within the inverter system in which each unit is having an overload protection system with the aim of achieving scalability, efficiency, resilience, affordability and reliability. This approach will ensure that, each sub power system is developed and consequently functions independently of other units. The approach integrated ACS712 as current sensors, ZMPT101B type voltage sensor, Arduino UNO and relay modules each part playing significant roles in ensuring an efficient power sharing and shedding system. Each power user is connected to a current sensor which measures the amount of current passing through each segment. This information is coordinated by the Arduino UNO to effect appropriate actions by controlling the relay module to either switch on or off the load in accordance with the programmed over-current safe limit range for each unit. The voltage sensor works with the current sensors to determine the power to each user. An alarm is incorporated to provide alertness in the case any unit violates the principle of governing power sharing. The system was tested and functioned as appropriate, providing quick system response to facilitate efficiency and reliability in the use of shared solar energy resources.

Keyword: power sharing, power shedding, Arduino uno, overload protection and current sensor

INTRODUCTION

Solar inverter power system relies on the vast availability of solar energy using solar cells for the conversion of solar energy into electrical energy capable of powering loads to meet human daily needs. The stages involved in solar energy from production, installation, usage and maintenance ensure that clean energy is made available for a safer environment [1][2].

A typical solar based system consists of the arrangement of solar panels, cables, solar charge controller, circuit breaker, power inverter and battery bank. The solar panels consist of solar cells arranged in a way to provide an amount of electric power for a given space. The panels provide, DC power in terms of current and voltage. The DC power is transported from the solar panels through conductors usually stranded cables into the charge controller. The charge controller accepts the DC power and regulates the right amount of power to be delivered to charge the battery optimally. Every battery requires a certain amount of current and voltage for its charging. The charge controller ensures that the battery is protected against overcharging which consequently prolongs the life span of the battery. The power inverter uses the DC power supplied by the battery and converts to alternating power supply, AC. The AC output of the power inverter helps power loads that require ac inputs for both household and industrial usage [3][4].

The cost associated with solar inverter systems is still very high especially in the developing countries like Nigeria. As a result of the associated high cost, in many cases, solar based system is shared among users with each user may be having varying power needs [5].

In this paper, for a given solar installation, independent solar modules can be available within the solar installation. Each unit of power supply can be controlled and isolated from the rest of the main power supply. Any sub unit within the solar installation can be independently monitored appropriately with predefined mechanism to ensure true unit independence. This paper provides a mechanism that rides on the arduino UNO technology, current sensor, voltage sensor, relay module and liquid crystal display integrated for proper operations.

The arduino UNO is the sole coordinator of the shared power supply. It is a microcontroller board whose operation centers on the vast capabilities of ATmega328P chip. The ATmega328P is a replaceable chip on the board making reuse possible in case of any damage [6].

The current sensor makes reading of the current through each load possible. The project used ACS712 current sensor whose principle of operation hinged on Hall effects. The sensor is capable of measuring both direct current and alternating current. The Hall Effect is such that whenever a current is made to pass through a conductor, magnetic field is generated whose strength is directly proportional to the quantity of current passing through. This creates a voltage output that is directly proportional to the current flowing through the conductor. This behavior enables the sensor make accurate measurement of the current passing through the conductor. ACS712 current sensor comes in three versions; 5A, 20A and 30A with each version having specific sensitivities. ACS712 finds wide applications in power monitoring, power control, over current protection among others [7].

The voltage sensor of the ZMPT101B type sensor, is a voltage transformer applicable to only single-phase AC voltage supply. It is capable of giving analog output which makes it useful in power monitoring systems, smart homes, energy calculations and monitoring among others [8].

The relay module works to function as a magnetically controlled switch for each connected load. It enables a low power scheme to control a much larger power loads with electrical isolation between the low power side and the large power side. Thus, features of the relay ensure the safety of personnel. The control of the relay is limited to only two states; on or off depending on the command received from the microcontroller. The relay module can be powered by 5V or 12V with the 5V version readily adaptable to the output of most microcontrollers thereby making its operation seamless. A typical one channel relay module has three input pins and three output pins. The input pins are V_{IN} , VCC and GND. The V_{IN} pin is connected to the digital pin of the microcontroller while the VCC and GND pins are connected to the VCC and GND pins of the microcontroller respectively. The output terminals of the relay module are the COMMON, NORMALLY OPEN (NO), NORMALLY CLOSE (NC). The connection of the load to the output terminal of the relay module depends largely on what is required for operation [9].

METHODOLOGY

The diagram in figure 1. showed each block of component that made up the dynamic load sharing and control system with their various interconnections.

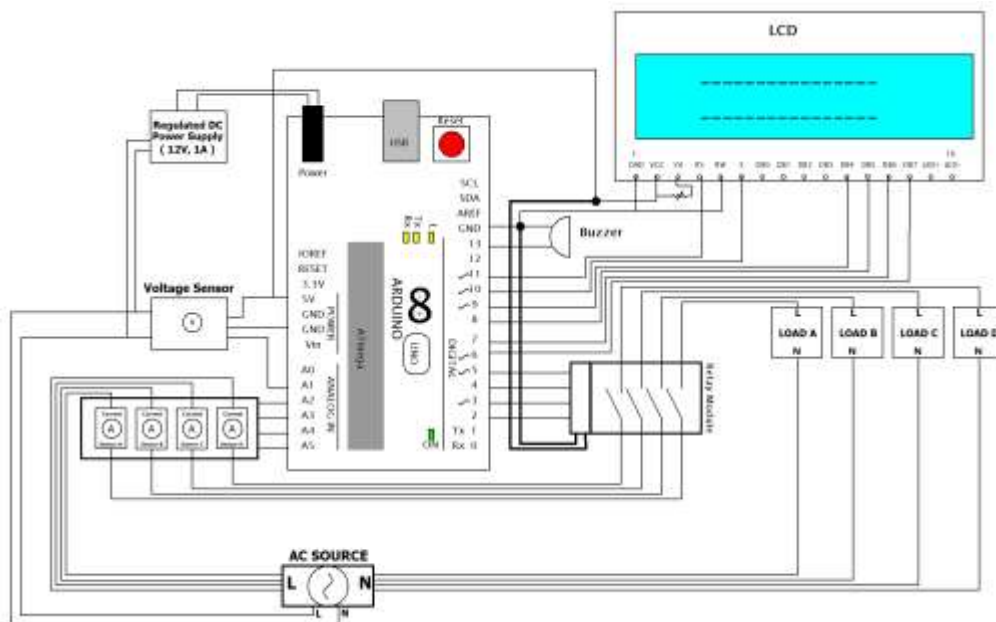


Figure 1. Hardware architecture of the load sharing and shedding power system

The Arduino UNO microcontroller is powered from a 12V, 1A DC power supply. The DC power supply is supplied from the mains where rectification, capacitor-based filtration and voltage stabilization take place. The rectification employed four IN4007 p-n diode connected as a bridge to convert the AC signal from the output of a step-down transformer to a DC signal. The rectified DC signal containing substantial ripples is fed into the capacitor to filter out voltage fluctuation. The filtered signal is fed into the voltage regulator, LM7812. The output of the voltage regulator delivered a constant 12V dc supply for the microcontroller.



28 Figure 2. System physical architecture of the automatic load shedding and sharing power system

Figure 2. showed the physical representation of the designed power distribution system. The connections between the current sensors, relay module and the load are done in such a way that the live cables from the mains is connected in series with the current sensor, ACS712 for current measurement of each load correspondingly. The arduino controller reads the current flow and takes actions whenever the power consumed by any of the load exceeds the preset power level. The relay works in NORMALLY OPEN in the default state and NORMALLY CLOSE when the load on any load unit falls within the allowable power level. As soon as overload occurs in any unit, overload fault warning is displayed on the liquid crystal display and the corresponding circuit disconnected through the relay action. At the same time, an alarm is activated to attract quick attention of users. As long as the unit exceeds the preset value, the unit remains cut off and only restored when the load is reduced to fall within the allowable level.

Design calculation

The source power is shared among the loads in percentage.

$$P_{L1} + P_{L2} + P_{L3} = P_S \quad (1)$$

Where P_{L1} – power consumed by load 1

P_{L2} – power consumed by load 2

P_{L3} – power consumed by load 3

P_S – safe rated power of the renewable power source

$$P_S = 90/100 * P_T \quad (2)$$

$$P_{L1} = I_{L1}V \quad (3)$$

$$P_{L2} = I_{L2}V \quad (4)$$

$$P_{L3} = I_{L3}V \quad (5)$$

Where I_{Li} – current measured by current sensor i

V – voltage of the AC supplied to the load

$$P_{L1} = 33/100 * P_S \quad (6)$$

$$P_{L2} = 33/100 * P_S \quad (7)$$

$$P_{L3} = 33/100 * P_S \quad (8)$$

For the purpose of this stud, a 1KW power source is used as P_T . So,

$$P_S = 90/100 * 1000 = 900W$$

$$P_{L1} = P_{L2} = P_{L3} = 33/100 * 900 = 297W$$

With this design, any attempt by any load to go beyond the allowable preset power level, the microcontroller sends signal to the appropriate relay to open the circuit thereby switching off the particular load. At this instance, a message is displayed on the LCD indicating overload condition for the particular unit. Also, the alarm is activated temporarily to draw the attention of user to reduce the load on the source. The relay is restored to power the load only if the load is reduced within the safe limit and a time delay response has elapsed.

RESULTS AND DISCUSSION

Figure 3. showed that each unit was powered up by the source. The system initially checked for overload in each of the power units. All the units were powered as soon as the source was energized. For the fact that a 100W lamp which was within safe limits of the system was connected to each unit, the Arduino sent signal to the relay module to switch on the loads.



Figure. 3. System response when connected loads are within acceptable limits.

The load in each unit was displayed on the LCD with no alarm activated.

While the system was still active, the 100W lamp was removed and replaced with 200W lamp for all the units. No alarm was activated and each unit stayed switched on. This was expected as the connected load of 200W to each unit were within the safe limits. Meanwhile, one of the units was tested by connecting a 100W and 200W lamps to it while leaving other units as earlier connected. As soon as the load was connected, the unit got disconnected but other units stayed on. The alarm was activated attracting the attention of people within the premises. The alarm went off after 30 seconds as the overload in the unit was not reduced. After the elapsed time, the alarm was automatically deactivated but the unit stayed disconnected. When 100W was eventually removed from the overloaded unit, the unit was consequently switched on after five seconds. The test was carried out for each of the power units and the results remained the same.

Afterwards, the system was switched off. Each unit had 300W load connected to it. Then, the system was switched on. With this load condition, no unit received power from the source as the loads were above the safe limit programmed for the system. The LCD indicated overload for all the units. Each unit received power after 5 minutes from the source only when the load was reduced to stay within the safe limits for the system.

CONCLUSION AND RECOMMENDATION

The design and development of dynamic power distribution system using Arduino for solar powerable inverter system was carried out and successfully tested for the purpose of automatically sharing and shedding of power from a limited power resource. The results of the test aligned with the intended purpose not only to share and shed load but also to provide additional protection for the power source against overload situations. This system could be useful where renewable energy sources are installed.

Although the system achieved its intended purpose, it is worth of note that the design shared the loads equally among the sub power units. This system would not be efficient where demands by users varied. The system could be modified to allow for such a situation. As a result of the fact that Arduino has limited input/output pins, the number of units achievable is limited and other means may be required to achieve multiple sub power units.

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