



Design and implementation of a photovoltaic powered moving message display system

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Abstract

The focus of the research was the design of a stand-alone PV powered moving message display system for implementation at the main gate of ATA Polytechnic. The display system circuitry was designed and drawn using the proteus software. The total load profile of the display system and other electrical loads at the main gate where the system would be installed were computed and the value obtained was used to select and size the major components of the PV system needed to power the LED dot matrix display system. The 24 pieces of 4" 5 x 7 Acrylic LED dot matrix modules used as the display panel were horizontally arranged and cascaded together to produce a panel of 120 columns and 7 rows to display the text in one line. An aluminium casing was fabricated with internal dimensions to house the LED array. The display system was then interfaced to the Atmega8515 microcontroller, while one piece of UNL2003 Darlington sink driver, a 74HC295 buffer and 15 pieces of 74HC595 shift registers were connected to form the intermediate section. A program code in Assembly Language was written and burn in to the microcontroller to output control signals for the drivers to sink current to the dots and scan the rows and columns of the LEDs in quick succession using multiplexing technique. On completion of the construction and testing, the display system was test run and observed to display the text "Welcome to Atapoly Bauchi" which scrolls from left to right. The components of the photovoltaic power system required to supply power to the moving message display were sized. The framework to support the components parts were fabricated and fixed. The two PV modules were rigidly fixed on the supporting structure inclined at an optimum tilt angle of 30⁰, and connected to the other component parts of the system at the gate. Tests were conducted and the system was found to be working as designed.

Keywords: design; display system, implementation, moving message, photovoltaic powered

Introduction

The display systems developed and used for versatile applications have evolved over the years. In the early times, manual display media such as billboards, signposts, noticeboards, cardboards etc. were the commonly used means for advertisement and information display. However, with the advent of technology, electronic display systems have been developed which are widely used today in the advertisement industry and information display. The digital display systems are gradually replacing the manually display devices because of its efficiency; reliability and effectiveness [3].

The main component of an electronic display system is the either the Liquid Crystal Display (LCD) or Light Emitting Diodes (LEDs). The latter is widely used in advertising, traffic light and many more display applications because of (i) its ability to generate different pattern of displays e.g. scrolling; (ii) it has more brightness, (iii) easily available and its low power consumption amongst other advantages it has over LCDs [3].

LED matrix display operates on what is known as persistence of vision (POV). An LED is displayed at every point in time and the human eye combine the lit LEDs to perceive an illusion of an image. The technique employed to scan the LEDs dot matrix is referred to as multiplexing in which rows and columns of the LED array are scanned in sequence and in quick succession e.g. at a rate of not less than 50 times per second. Such fast scanning of the dot matrix causes a phenomenon known as the persistence or permanency of vision (POV) to come to play. This happens when the eyes sees images that changes at a very fast rate of 10 scans per second [8]. In today's rapidly advancing

technological market, most conventional digital display system is now being implemented using individual logic gates and integrated circuits such as microprocessor and microcontroller chips which contain the circuitry necessary to create logic functions are being used to implement digital systems. Moving message display systems, like other electronic systems require reliable source of power to operate efficiently and uninterruptedly. The power can be obtained from photovoltaic system, a renewable energy source. Exploiting solar energy from the sun to power electrical appliances starts by transforming energy to electricity [4] Photovoltaic is the direct conversion of sunlight to electricity. It is increasingly preferred as alternative to traditional sources of electrical energy for a number of reasons: it is harmless, silent, renewable, environmentally friendly, unexhausted and unlike fossil fuels, it is available everywhere on earth and this source of energy is free [2]. The photovoltaic modules charges the battery during the day and the battery in turn continuously feeds the display system.

1. Statement of problem

The manual sign display boards are characterized by limitations, which include lack of its flexibility, inability to handle large information, less attractive form of display, as well as its inability to display clearly at night.

2. Aim and objectives

The aim of this project is to design and implement photovoltaic powered moving message display system. Specifically, the research work sought to achieve the followings:

1. Design and draw the circuit the moving message display system using the proteus software
2. To fabricate an aluminum frame and transparent casing for the housing of LED dot Matrix array and structures to support the PV array and the batteries bank.
3. To assembly the components of moving message display system and the stand-alone PV system and install system at the main gate of Abubakari Tatari Ali Polytechnic, Bauchi.

Materials and research methodology

1. The design procedure of the major components of the PV powered moving message display were described as follows

The moving message display system consists essentially of the following major components:

- 24 modules of 5x7 LED dot-matrix display
- One Atmega8515 microprocessor
- One UNL2003 driver.
- One 74HC595 IC
- 15 Pieces of 74HC295

- Power supply unit (SMPS)

1.1 Sizing the power consuming elements of the LED display system

1.2 Sizing the major components of the stand-alone PV array system.

The first step to size the major components of the stand-alone PV system is to determine the load profile of the moving message system as well as other load at the main gate of Abubakar Tatari Ali Polytechnic, (ATAP), Bauchi, where the system will be installed.

1.2.1 Abubakar Tatari Ali Polytechnic’s (ATAP) main gate load profile

The main gate load profile was determined by considering the moving message display system as well the power ratings of other loads and hours which they are expected to be operational to obtain the total average energy demand in watt-hours per days as illustrated in Table 1.

Table 1: Daily load profile of display system / Other load at The main gate of ATAP

S/N	Appliance	X ₁ Quantity	X ₂ Power rating (Watt)	X ₃ = X ₁ * X ₂ Power (Watt)	X ₄ Hours of use per day	X ₅ = (X ₃ * X ₄) Energy per day
1	Moving message display system	1	27.01	27.01	14	378.14
2	Compact fluorescent lamp	6	13	78	6	468
3	Ceiling fan	2	75	150	16	2400
	Total load profile					3,246.14 Wh /day

Table 2: Summary of PV array sizing

S/N	Parameter to be calculated	Formula used	Computed parameter value
1	Required Daily Energy Demand (E _{rd})	$E_{rd} = \frac{E_d}{\eta_b \eta_i \eta_c}$	4.71KWh. Day ⁻¹
2	Average Peak Power (P _{ave,peak})	$P_{ave, peak} = \frac{E_{rd}}{T_{sh}}$	1,178kW
3	Total dc Current (I _{dc})	$I_{dc} = \frac{P_{ave, peak}}{V_{dc}}$	48.84A
4	Number of Series Modules (N _{sm})	$N_{sm} = \frac{V_{dc}}{V_{rm}}$	1
5	Number of Parallel Modules (N _{pm})	$N_{pm} = \frac{I_{dc}}{I_{rm}}$	2
6	Total number of Modules (N _{tm})	$N_{tm} = N_{sm} \times N_{pm}$	2

Table 3: Summary of battery bank sizing

Number of Days in Autonomy (D _{aut}) = 3 Days			
S/N	Parameter being Computed	Formula used	Parameter computed value
1	Estimated energy storage (E _{est})	$E_{est} = E_d \times D_{aut}$	9. 684kWh
2	Safe energy storage (E _{safe})	(E_{safe})	$E_{safe} = \frac{E_{est}}{D_{disch}}$
3	Total capacity of batteries in bank (C _{tb})	$C_{tb} = \frac{E_{safe}}{V_b}$	645.6 Ah
4	Total number of batteries in bank (N _{tb})	$N_{tb} = \frac{C_{tb}}{C_b}$	2
5	Number of batteries in series (N _{sb})	$N_{sb} = \frac{V_{dc}}{V_b}$	2
6	Number of batteries in parallel (N _{pb})	$N_{pb} = \frac{N_{tb}}{N_{sb}}$	2

Table 4: Summary of charge controller sizing

S/N	Quantity being measured	Formula	Value of quantity calculated
1	Required charge controller current (I _{rec})	$I_{rec} = I_{sc}^M \times N_{pm} \times F_{safe}$	20A
2	Number of charge controller (N _{cc})	$N_{cc} = \frac{I_{rec}}{I_{cc}}$	2

Table 5: Summary of inverter sizing

Parameter being computed	Formula	Parameter computed
Power of non- inductive appliances (P_{nia})	$P_{nia} = \sum_{i=1}^n P_{niai}$	1954 W
Power of Inductive Appliances scale by $3(3P_{ia})$	$3 P_{ia} = 3 \sum_{k=1}^k P_{iak}$	879 W
Total inverter power (P_i)	$P_i = 1.25(P_{nia} + 3P_{ai})$	3541.25W

Table 6: Summarized procedure for selecting cable size

PV system cable	Current rating of cable (I_{cab})	Copper cable	
		Length	Cross- sectional area
Cable to link PV array to battery bank via charge controller	$I_{cab} = I_{max} = I_{sc}^M \times N_{pm} \times F_{safe} = 20A$	1.5m	1.44mm ²
Cable to link battery bank and inverter	$I_{io} = \frac{P_i}{V_{io} \times pf} = \frac{5000}{230 \times 0.8} = 27.15A$	6.0m	1.66mm ²
Cable to link inverter and load	$I_{phase} = \frac{P_i}{V_o \sqrt{3}} = \frac{5000}{230 \sqrt{3}} = 12.55A$	15m	7.1mm ²

1.3 Installation site and inclination of PV array

The average solar irradiance of Bauchi town where ATA Polytechnic is situated during clear sunny, cloudy and harmattan season is 950.8W/m² 600 W/m² and 586.7 Wm² respectively. The town can be said to possess adequate solar energy resources that should be tapped, and being on latitude and longitude of 10.313⁰ and 9.843⁰ respectively, entails that the two PV array should be inclined at an optimal angle of 30⁰ in the direction of southeast for fixed orientation [13].

1.4 Framework of the LED matrix array

The casing comprised three major parts namely (i) The framework made of aluminum, (ii) the transparent plastic covering and the ACO Board. The internal dimension of the framework required to accommodate the 24 pieces of LEDs is 19.96 x 27.80 x 8.0mm The transparent plastic covers the

LED modules, protecting the LEDs from direct exposure to the environmental hazards such as rain, humidity, dust and heats etc.

1.5 Implementation of the PV powered moving message display system

The moving message display system was implemented as shown in the circuit in Fig.9. The components were tested using millimeter after it was arranged and cascaded on the fabricated frame. The 24 pieces of the LED modules were placed and firmly fixed next to each other on the fabricated frame so that no space was left between them, and the modules were then daisy chained i.e. the data output (D_{out}) of the first module was connected to data input (D_{in}) of the next module and so on until all the 24 pieces of the modules were so cascaded horizontally to

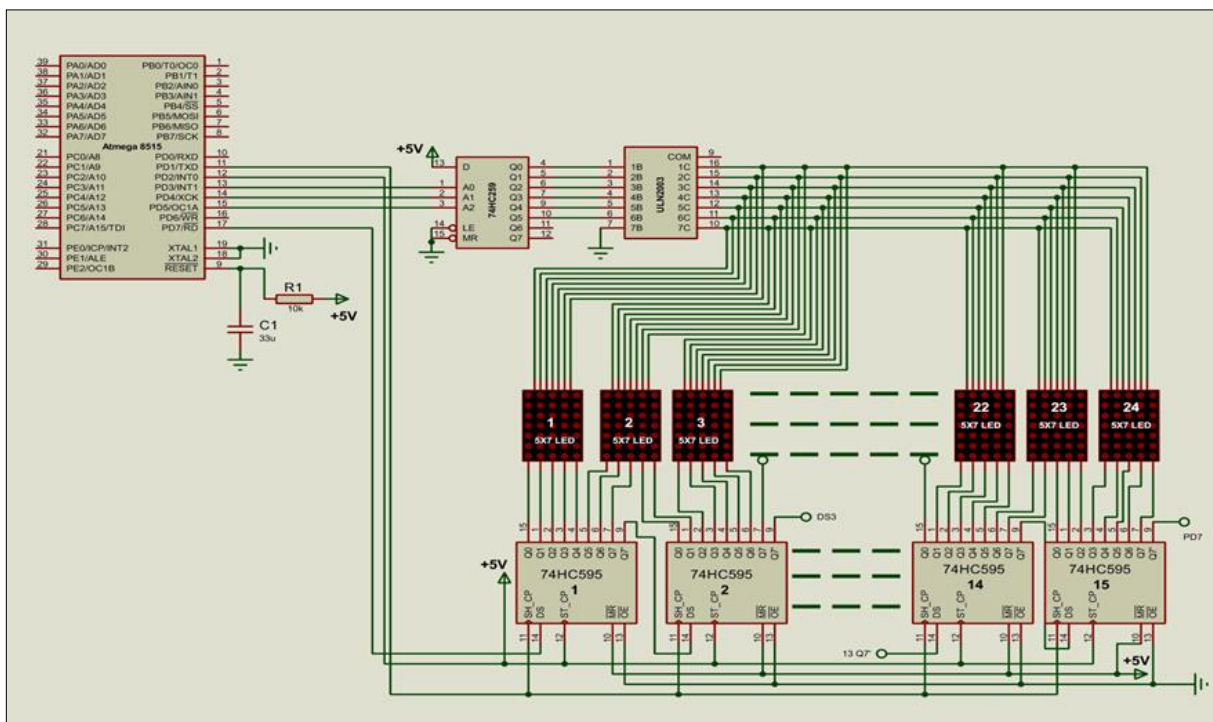


Fig 1: Circuit diagram of the display panel elements used for debugging software

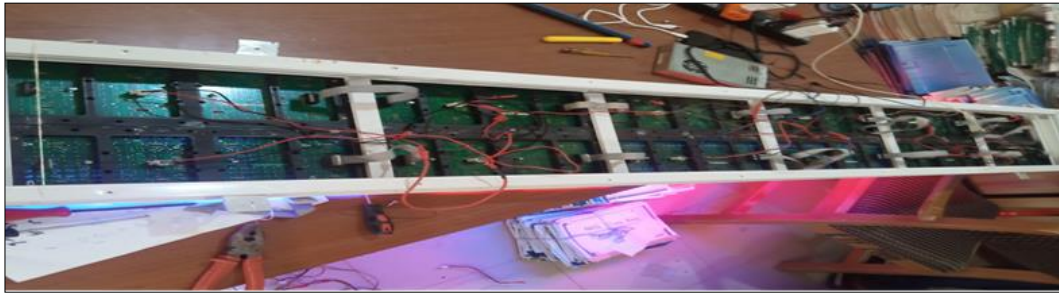


Fig 2: 5 X 7 dot matrices on a fabricated framework



Fig 3: 5 x 7 LED panel displaying the word welcome without spacing



Fig 4: 5 x 7: LED array displaying the word “to ATAPOLY



Fig 5: Panel displaying the word “BAUCHI”

produce a display of 120 columns and 7 rows to display the text in one line. The drivers which form the intermediate section between the microcontroller and the output display LEDs, consist of 15 pieces of 74HC595 shift registers, one piece of ULN2003 Darlington sink driver and one piece of 74HC259 buffer. The program in Assembly Language was written using mikro C software and the burn into the microcontroller. Display control signals from the microcontroller are serially transmitted to the dot matrix display element via the driver circuits. The current for each dot is delivered by 74HC595 output, while the current for the Row(s) are sinked by the ULN2003A. The 74HC259 scan the rows one after the other in accordance to a set of instructions input to the ATmega8515. The procedure of the scanning is achieved as follows: Set data ready on the 74HC595 stage, then activate the first row (Q₀ of 74HC259 active), then store the data at the outputs of the 74HC595s. Stop for a few msecs, and then switch the outputs of the 74HC595s off again. This is followed by switching the 74HC259 to the next row (3-bit up count). The sequence is repeated 7 times (7 rows). This is one frame which must be set on the display faster than one can observe^[5]. The 24 pcs of 5X7 LED modules were carefully tested one after another to ascertain their functionalities. The modules were firmly arranged and screwed to an aluminum framework which was fabricated with an internal dimensions of 667.2 x 19.96 x 8.00mm to provide just the

space to accommodate modules. The LEDs matrices were then daisy chained together as shown in Fig. 10 to create the desired display. The 15 shift registers were progressively cascaded on a breadboard with the input of the first one wired to the microcontroller. The 120 input lines of the 24 display modules were progressively wired to the 15 cascaded 74HC595 shift register. Tests were steadily performed as the circuit was progressively being built. The board containing the cascaded shift registers was firmly secured inside the framework. This was followed by covering the frame with transparent plastic as shown in Fig. 4 to protect it against environmental hazards such as humidity, dust, and rain precipitation. The casing was coupled by screws and riveting, and the drilling of holes was done at a uniform distance^[8]. The 15 pieces of 74HC595 shift register, one piece of ULN 2003 Darlington sink driver and one piece of 74HC 259 buffer who together make up the intermediate sections are connected to the Atmega 8515 microcontroller and the display system^[13]. Display control signals are serially transmitted to the dot matrix display element driver circuits as shown in Fig. 8. Firstly a single shift register was wired to the microcontroller and tested, and then two shift registers were cascaded on the breadboard to trial the cascading process. The circuit was progressively tested as it was being built^[11].

1.6 Installation of the photovoltaic system

The metallic mounting framework was fabricated and then rigidly fixed to the ground. The two solar panels were then placed on the mounting system at an optimal angle of 30° facing southwest for fix orientation. Similarly, a supporting framework was also constructed which houses the batteries and the inverter. The sized copper cables were used to link the various components of the stand-alone PV system.

Results and discussion

Results

The sequence of program instructions in Assembly Language was developed to display one word, 7 characters that uses 7 dot matrix units without spacing. Fig. 3 shows one word output results that is "WELCOME".

The sub-routine is then modified for displaying a text of two words of 9 characters " TO ATAPOLY " with spacing as shown in Fig.3, and another one to display the word "BAUCHI" with spacing preceding it as shown in Fig. 5.

Another sub-routine is developed for creating a scrolling text which reads "WELCOME TO ATAPOLY, BAUCHI" through the display panel. The first letter is displayed for a certain period of time and this is followed by shifting the next letter into the display and so on from left to right.

Discussions

The computed percentage error above indicates that there were some deviations from the time designed for the moving message to appear and re-appear and the observed time that the message re-appears on the implemented message display. Therefore, the display system can be said to have attained 95.4% accuracy. The error margin may be attributed to the losses which may occur when data is being transmitted from the main control to the display system.

The daily electrical energy demand (load) for the display system and other load at the main gate of ATA Polytechnic was estimated based on their watt-hour ratings. Table 1 showed the estimated daily demand for the display system to be 3246.14Wh/day. The major components of the stand-alone PV system was sized and implemented based on the estimated daily load profile. The results from the Table 1- 4 indicated that the display system / electrical appliances require Two PV modules type SUNTECH STP390S ...C54/Umhb, 24V to generating 730W of electrical energy for the system. To store energy for use on demand, the display system / appliances require Two DEKA8A8D batteries of battery bank capacity of 245Ah, and to safely charge the batteries and to ensure their longer lifespan, the display system / electrical load at the gate require a voltage regulator of 150A. The capacity of the inverter model PV1800VPM Series selected for use to convert its DC current to AC current is 5000W.

Recommendation

The moving message display system can be expanded to display more characters. This can be achieved through the addition of more 5 x 7 dot matrices. This will require more expansion of the circuitry and in effect additional components. Similarly, 16 x 32 LED array can be used instead of the 5x7 dot matrix in the design of the display system. This LED display configuration will display larger and bolder characters which will make the moving message more visible and attractive to the observer.

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