A

PROJECT REPORT ON

"LIQUID SOLAR ARRAY PV CONCENTRATOR"

Submitted in partial fulfillment of the requirements of the degree for

Bachelor of Engineering

IN

ELECTRICAL

BY

Chaudhary Israr Ali (11EE14)
Khan Tanveer Aalam (11EE56)
Ziyaul Haque (11EE34)
Shaikh Junaid Shakil (11EE41)

Supervisor (s):
Prof. AnkurUpadhyay

Anjuman-I-Islam's
Kalsekar Technical Campus

ANJUMAN-I-ISLAM'S KALSEKAR TECHNICAL CAMPUS, NEW PANVEL

DEPARTMENT OF ELECTRICAL ENGINEERING

YEAR 2015-2016

CERTIFICATE

Certified that the project report entitled, "**LIQUID SOLAR ARRAY PV CONCENTRATOR**" is a bonafide work done under my guidance by

- CHAUDHARY ISRAR ALI
- KHAN TANVEER AALAM
- ZIYAUL HAQUE
- SHAIKH JUNAID SHAKIL

During the academic year 2015-2016 in partial fulfillment of the requirements for the award of degree of Bachelor of Engineering in Electrical Engineering from University of Mumbai.

Date-

Approved-

(Prof. ANKUR UPADHYAY)

Project Guide

(Prof. SYED KALEEM)

Head of Department

(Dr. ABDUL RAZAK HONNUTAGI)

Principal

ANJUMAN-I-ISLAM'S KALSEKAR TECHNICAL CAMPUS, NEW PANVEL

SESSION 2015-2016

CERTIFICATE OF APPROVAL

The foregoing dissertation entitled, "**LIQUID SOLAR ARRAY PV CONCENTRATOR"** is hereby approved as a creditable study of Electrical Engineering presented by

- ChaudharyIsrar Ali
- Khan TanveerAalam
- ZiyaulHaque
- ShaikhJunaidShakil

In a manner satisfactory to warrant is acceptance as a pre-requisite to their Degree in Bachelor of Electrical Engineering.

Internal Examiner External Examiner

(Prof .Ankur Upadhyay)

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CHAUDHARY ISRAR ALI

KHAN TANVEER AALAM

ZIYAUL HAQUE

SHAIKH JUNAID SHAKIL

Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

PV concentrators appear to offer significant potential saving cost. However, to date the potential saving have not yet realized due to complexities arising mainly from the mass of the physical structure needed to provide adequate support from the concentrator, cells and tracking mechanism in adverse weather condition.

This report shows a mean whereby all major limitations, and cost, may be considered reduced by adopting a configuration, termed the "Liquid Solar Array" (LSA) where each element of floating array comprises a raft supporting solar tracking lens in partially-submerged water cooled PV cell assembly. An important feature of LSA is that lens can be submerged in windy conditions thereby reducing structural requirements in comparison to PV concentrator cell arrays. The paper shows that the LSA structural cost saving outweigh the cost any associated complications and lead to a projected capital cost of under US$1 per watt.

The LSA mimics techniques employed by some plants that lie down to accommodate the wind, and others such as the Lotus flower that emerge from the water completely dry.

Table of Content

List of Figures

List of Tables

List of Symbols

$	:	Dollar
kg	:	Kilogram
m	:	Metre
hr	:	Hour
W	:	Watts
Vdc	:	DC Voltage
Vac	:	AC Voltage
mW	:	Milli watts
GW	:	Giga Watts
V	:	Voltage
µs	:	Microsecond
Vcc	:	Common Collector Voltage
Vdd	:	Drain Supply Voltage
Vss	:	Source Supply Voltage
Vref	:	Reference Voltage
kb	:	Kilobytes
Hz	:	Hertz
MHz	:	Megahertz
Ta	:	Actual Temperature
A	:	Ampere
mA	:	Milli Ampere
g	:	Gram
<	:	Less Than
>	:	Greater Than
=	:	Equals to
+	:	Plus
_	:	Minus
kΩ	:	Kilo Ohms

f	:	Farad
rpm	:	Rotations Per minute
°C	:	Temperature in Degree Celsius

List of Abbreviations

PV	:	Photovoltaic
LSA	:	Liquid Solar Array
US	:	United States
ADC	:	Analog to Digital Converter
LDR	:	Light Dependent Resistor
LCD	:	Liquid Crystal Display
IC	:	Integrated Circuit
LSB	:	Least Significant Bit
MSB	:	Most Significant Bit
SAR	:	Specific Absorption Rate
ISP	:	In System Programmable
RAM	:	Random Access Memory
CMOS	:	Complementary Metal Oxide Semiconductor
CPU	:	Central Processing Unit
LED	:	Light Emitting Diode
EEPROM	:	Electrically Erasable Programmable Read Only Memory
PCB	:	Printed Circuit Board
DC	:	Direct Current
USB	:	Universal Serial Bus
DIM	:	Dimension
ADDR	:	Address
AC	:	Alternating Current
CAD	:	Computer Aided Design
UV	:	Ultraviolet

CHAPTER 1

INTRODUCTION

1.1 PV Concentrator

PV concentrators appear to offer significant potential savings in cost over flat plate semiconductor PV systems. This potential advantage derives from the trading of large areas of high grade semiconductor and glass (silicon) for similar areas of cheap acrylic plastic in the form of a thin Fresnel lens or a thin glass mirror, plus a small area of PV cells (typically silicon) and a tracking mechanism. However, to date the potential savings have not yet been realized due to complexities arising mainly from the mass of the physical structure needed to provide adequate support for the concentrator, cells and tracking mechanism in adverse weather conditions.

This report shows a means whereby all major limitations, and costs, may be considerably reduced by adopting a configuration, termed the “Liquid Solar Array” (LSA) where each element of a floating array comprises a raft supporting a solar tracking lens and partially-submerged water-cooled PV cell assembly. An important feature of the LSA is that the lens can be submerged in windy conditions thereby reducing structural requirements in comparison to PV (land-based) concentrator cell arrays. The paper shows that the LSA structural cost savings outweigh the cost any associated complications and lead to a projected capital cost of under US$1 per watt.

The LSA mimics techniques employed by some plants that lie down to accommodate the wind, and others such as the Lotus flower that emerge from the water completely dry.
The main potential advantage of PV concentrators over one-sun flat plate PV derives from reducing costs by trading large areas of high grade semiconductor-under-glass (silicon) for similar areas of cheaper materials, such as acrylic plastic in the form of a thin Fresnel lens or a thin glass mirror, needing only a small area of PV cells.

CHAPTER 2

LITERATURE SURVEY

2.1 Previous Types of PV Concentrator

Silicon cells in concentrator systems are quoted as low as US$0.20 per watt; however, difficulties arise from the lens or mirror structure that focuses the light onto these economical cells as the structure needs to be substantial. Added to this is the cost of the tracker that, along with the structureThus it may be seen that the structure must withstand pressure of 120 kg/m^2 if exposed to winds of 150 km/hr. If exposed to wind forces at only 60 km/hr, the peak forces per square meter acting on the structure are reduced to 20 kg/m^2 , thus if the effective pressure could be reduced, there would be less need for such a substantial structure and tracking mechanism. Around one sixth of the strength and mass should be possible without compromising performance.

The substantial structure of the present PV concentrators is keeping their cost in the $2 to $4/W range, only a little better than flat plate PV, which is currently about $4-5/W. Very high efficiency PV cells are advantageous for these exposed heavyweight systems despite the considerable extra cost of such cells relative to the standard silicon variety (as the higher output per square meter helps offset the structural cost). A lighter structure would be a big cost saving, both directly and in a reduction in the size of tracking drive required.Renewables must be economicallyattractive, especially in developing countries, if they are to be globally effective.A ‘Moral Imperative’ is not sufficient renewables cannot be imposed.Prosperity in the developed countries is based on cheap but polluting energy sources.

2.2 Real World Issues

There are a few issues that need to be addressed in a practical implementation:

- Waves need to sufficiently sub dued so that they not affect power output.
- There needs to be a means to prevent salt or solids residue build-up on the lens after immersion.
- All components that are exposed must withstand saltwater and direct sunlight.
- Algae must not foul the critical components.

The possible build up of residues on the lens has been addressed by a number of experiments to determine salt residue after many cycles of dipping of the hydrophobic lens cover material – a fluoro polymer similar to Teflon. These showed that residues did develop after around a dozen dips in saltwater (sea-water equivalent). This seemed related to gradual accumulation of dust which reduced the hydrophobic nature of the surface. A strategy was determined to wipe the dust from the surface with a thin rubber vane while the lens cover is underwater. This was tested and found to keep the lens cover dry and salt-free for over 500 immersion cycles. Hence it is expected that similar wipers will be required on production models.

The need to withstand saltwater and sunlight is a matter of materials selection and good design.Both are often quoted suitable for 20 years in sunlight. The PV container would typically be thin pressed stainless steel with a glass entrance window (or lens).

Algae can potentially create a bio-film on all wetted components. For some sections this is not a problem. The raft and anchor chains are not likely to be adversely affected by algae. The lens is also unlikely to be fouled by algae as it is not wetted for long periods (only during extreme weather). The component most vulnerable to algae is the PV container, whose rear is almost permanently immersed.

CHAPTER 3

BLOCK DIAGRAM

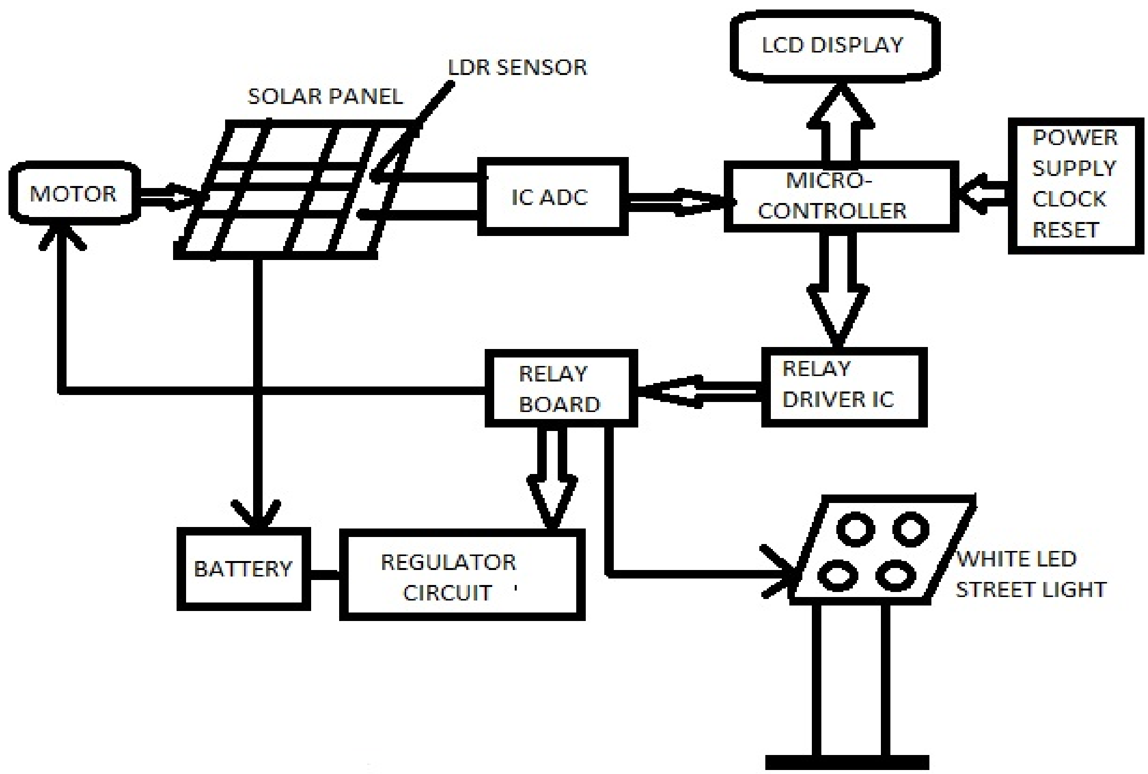


Fig. 3.1 Block diagram of Liquid solar array PV concentrator

Fig. 3.1 shows block diagram of liquid solar array PV concentrator in which a stepper driven motor is connected to solar panel which takes analog signal from solar panel and convert it to digital signal and then this digitized signal is sent to microcontroller. Power supply is given to the microcontroller and LCD is connected which shows performance of device.

Microcontroller send signal to Relay IC on the basis of which relay board is operated. The relay switches ON & OFF depending upon the signal received so as the motor rotates following relay board condition. Battery used is connected to solar panel for storing power consumed by the panel which can be further used in certain ways.

CHAPTER 4

COMPONENTS USED

4.1 ADC0808/ADC0809 8-Bit µP Compatible A/D Converters with 8-Channel Multiplexer

4.1.1 Features

- Easy interface to all microprocessors
- Operates ratio metrically or with 5 V_{DC} or analog span adjusted voltage reference
- No zero or full-scale adjust required
- 8-channel multiplexer with address logic
- 0V to 5V input range with single 5V power supply
- Outputs meet TTL voltage level specifications
- Standard hermetic or molded 28-pin DIP package
- 28-pin molded chip carrier package
- ADC0808 equivalent to MM74C949
- ADC0809 equivalent to MM74C949-1

4.1.2 Key Specifications

Table No. 4.1 Specifications of ADC0808/ADC0809 8-Bit µP

Resolution	8 Bits
Total Unadjusted Error	±^{1}¤2 LSB and ±1 LSB
Single Supply	5 V_{DC}
Low Power	15 mW
Conversion Time	100 µs

4.1.3 Block Diagram

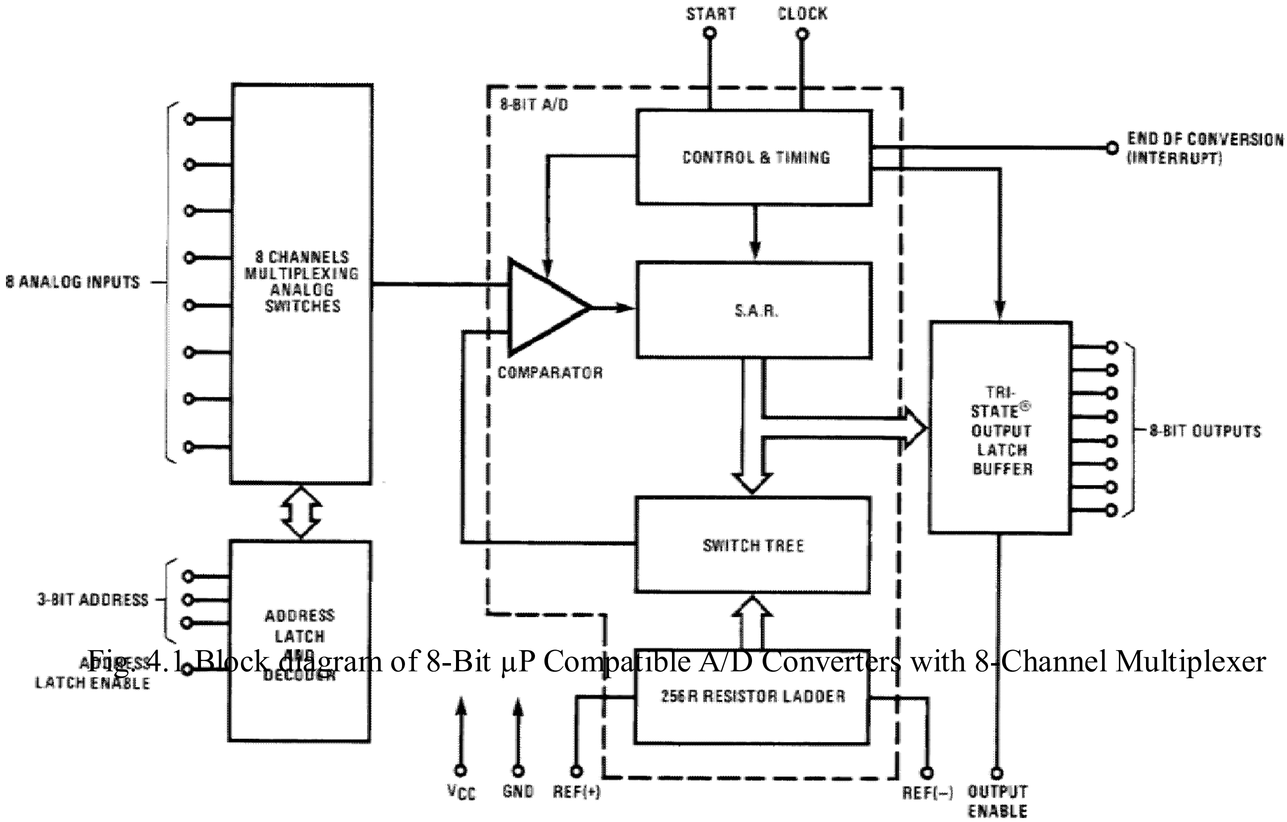
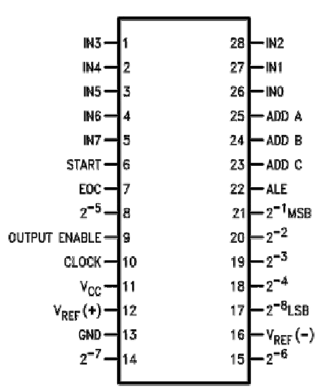


Fig. 4.1 Block diagram of 8-Bit µP Compatible A/D Converters with 8-Channel Multiplexer

4.1.4 Connection Diagrams



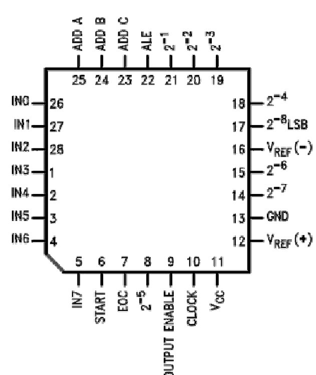


Fig. 4.2 Dual-In-Line Package Fig 4.3 Modeled chip carrier package

4.2 AT89S51*8-bit Microcontroller with 4K Bytes in System Programmable Flash

4.2.1 Features

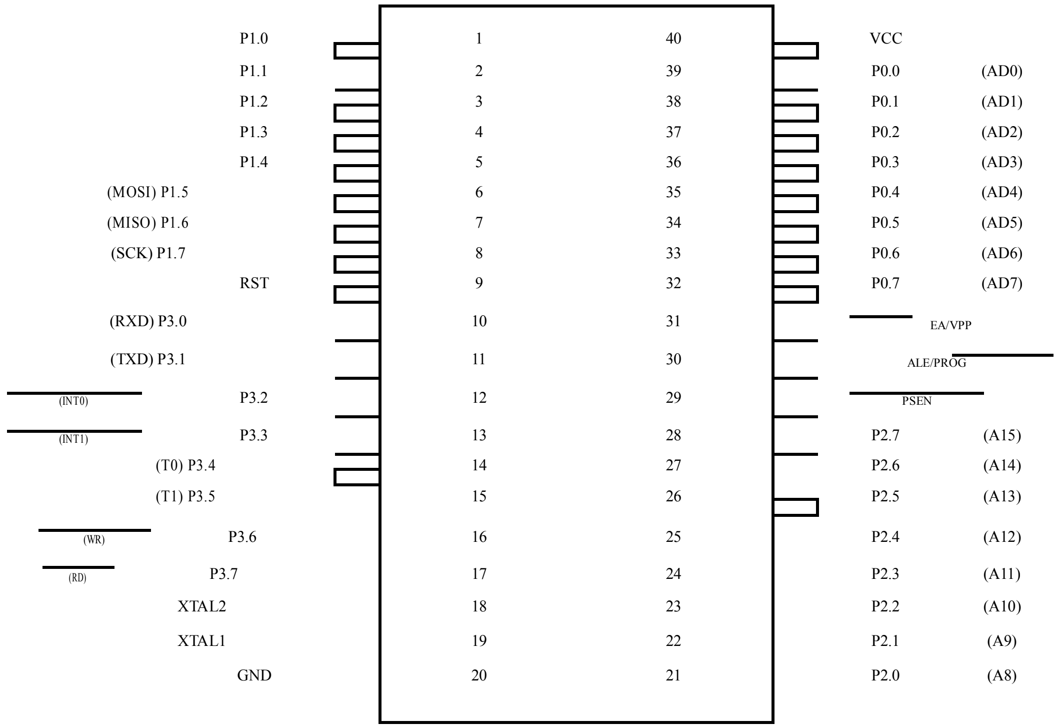
- Compatible with MCS®-51 Products

- 4K Bytes of In-System Programmable (ISP) Flash Memory
- Three-level Program Memory Lock
- 128 x 8-bit Internal RAM
- 32 Programmable I/O Lines
- Two 16-bit Timer/Counters
- Six Interrupt Sources
- Full Duplex Serial Channel
- Low-power Idle and Power-down Modes
- Interrupt Recovery from Power-down Mode
- Watchdog Timer
- Dual Data Pointer
- Power-off Flag
- Fast Programming Time
- Flexible ISP Programming (Byte and Page Mode)
- 4.0V to 5.5V Operating Range
- Fully Static Operation: 0 Hz to 33 MHz

4.2.2 Description

The AT89S51 is a low-power, high-performance CMOS 8-bit microcontroller with 4K bytes of In-System Programmable Flash memory. The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard 80C51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with In-System Programmable Flash on a monolithic chip, the Atmel AT89S51 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications.

4.2.3 Pin Configuration



4.3 LCD Display JHD162A SERIES

- DRIVING MODE：1/16D
- EL/100VAC，400HZ LED/4.2VDC
- PARAMETER (VDD=5.0V±10%,VSS=0V,Ta=25℃)

Table No. 4.2 Specifications of LCD Display

Parameter	Symbol	**Testing Criteria**	**Standard Values**			Unit
			Min.	Typ.	Max	
Supply voltage	VDD-VSS	-	4.5	5.0	5.5	V
Input high voltage	VIH	-	2.2	-	VDD	V
Input low voltage	VIL	-	-0.3	-	0.6	V

Output high voltage	VOH	-IOH=02mA	2.4	-	-	V
Output low voltage	VOL	IOL=1.2mA	-	-	0.4	V
Operating voltage	IDD	VDD=5.0V	-	1.5	3.0	mA

4.3.1 Application Circuit

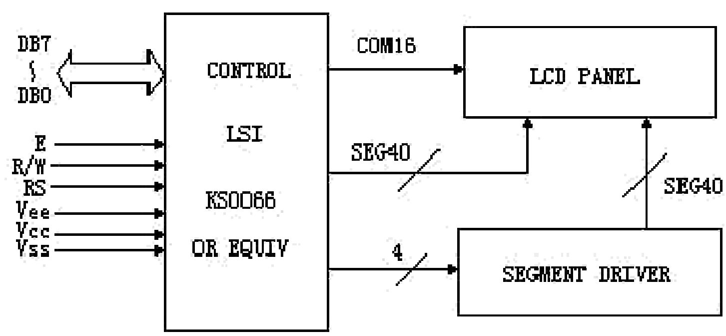


Fig. 4.5 Application circuit of LCD

4.3.2 Dimensions display & Content

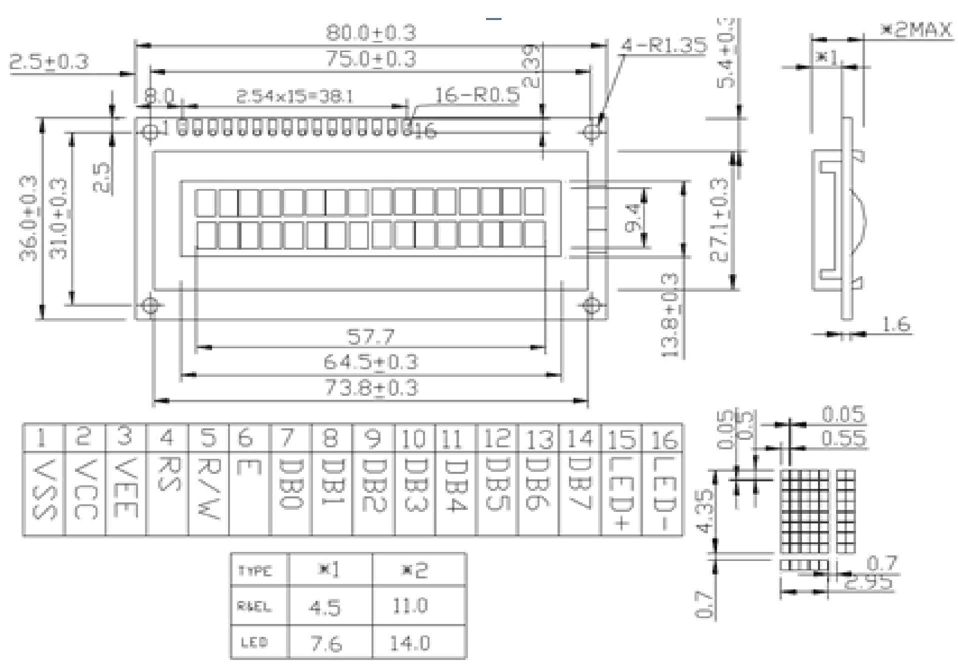


Fig. 4.6 Dimensions display & Content

4.3.3 Pin Configuration

Table No. 4.3 Pin Configuration of LCD Displays

4.3.4 Circuit Diagram

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
VSS	VCC	VEE	RS	R/W	E	DB0	DB1	DB2	DB3	DB4	DB5	DB6	DB7	LED +	LED-

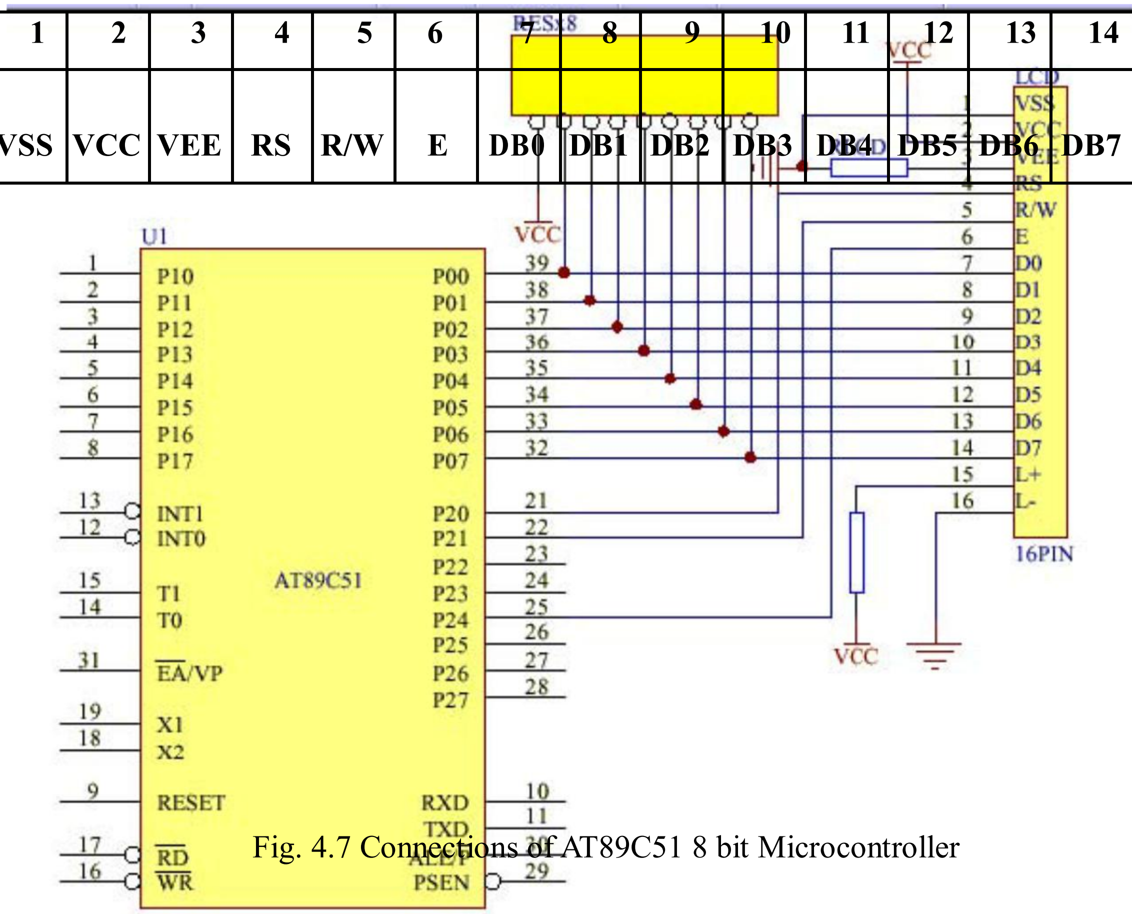


Fig. 4.7 Connections of AT89C51 8 bit Microcontroller

CGROM

4.4 Voltage Regulator

MC78XX/LM78XX/MC78XXA

3-Terminal 1A Positive Voltage Regulator

4.4.1 Features

- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V

4.5 Relay

Fig. 4.8 NT73 (JQC-3FC)

4.5.2 Dimensions & Wiring Diagrams

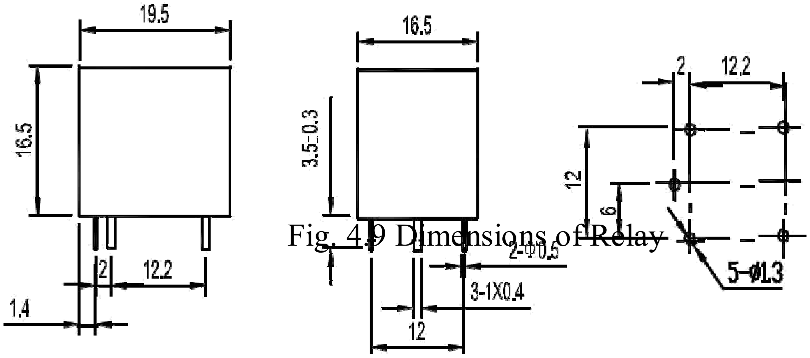


Fig. 4.9 Dimensions of Relay

4.5.3 Reference Data

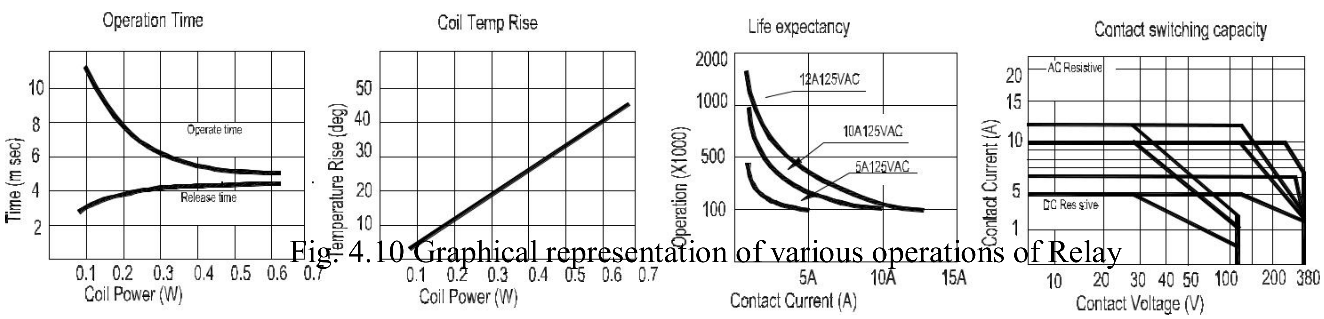


Fig. 4.10 Graphical representation of various operations of Relay

4.6 Hex Schmitt Trigger

4.6.1 Features

- Operation for very low slow edges.
- Improved Line Receiving Characteristics.
- High Noise Immunity.

4.6.2 Description

- Each circuit function as an inverter.
- Because of Schmitt action it has different input threshold levels for positive or negative going signals.
- This circuit are temperature compensated and can be triggered from the slowest of input ramps and still give clean output signals.
- The SN74LS14 are characterized for operation from 0-70 degrees.

4.7 Arduino Microcontroller

The Arduino microcontroller is an easy to use yet powerful single board computer that has gained considerable traction in the hobby and professional market. The Arduino is open- source, which means hardware is reasonably priced and development software is free. With the Arduino board, you can write programs and create interface circuits to read switches and other sensors, and to control motors and lights with very little effort.

The Arduino programming language is a simplified version of C/C++. If you know C, programming the Arduino will be familiar. If you do not know C, no need to worry as only a few commands are needed to perform useful functions.

The board features an Atmel ATmega328 microcontroller operating at 5 V with 2Kb of RAM, 32 Kb of flash memory for storing programs and 1 Kb of EEPROM for storing parameters. The clock speed is 16 MHz, which translates to about executing about 300,000 lines of C source code per second. The board has 14 digital I/O pins and 6 analog input pins.

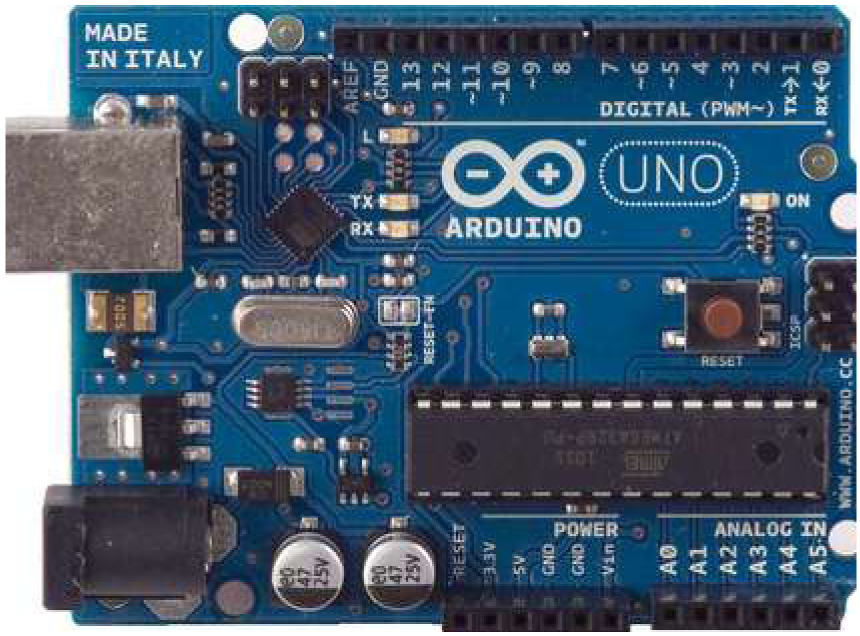


Fig. 4.11 Arduino circuit

There is a USB connector for talking to the host computer and a DC power jack for connecting an external 6-20 V power source, for example a 9 V battery, when running a program while not connected to the host computer. Headers are provided for interfacing to the I/O pins using 22 g solid wire or header connectors.

An important feature of the Arduino is that you can create a control program on the host PC, download it to the Arduino and it will run automatically. Remove the USB cable connection to the PC, and the program will still run from the top each time you push the reset button. Remove the battery and put the Arduino board in a closet for six months. When you reconnect the battery, the last program you stored will run. This means that you connect the board to the host PC to develop and debug your program, but once that is done, you no longer need the PC to run the program.

4.8 Developing PCBs Using ExpressPCB

- Design the PCB layout in ExpressPCB software.
- Print the PCB design through a laser printer & get PCB etched using FeCl3 Solution.
- Material Of PCB is Phenolic, which generally brown in color
- PCB hole drill Size is normally 0.8mm to 1mm.
- Take the impression of the circuit on a copper-clad board.
- Remove the excess copper by etching.
- Soldering wire material is lead and tin, ratio is 60:40%.
- Soldering iron wattage is 25 or 30 w.

4.9 BASCOM PROGRAMMING

```
Dim Addr As Byte
Dim Result As Byte
Dim S As Integer
Dim S1 As Integer
Dim S2 As Integer
Cursor Off
P2 = 255
P3 = 0
Cls
Lcd " Liquid Solar "
Lowerline
Lcd "   Array "
Wait 2
Cls
Lcd "  A.I.K.T.C   "
Lowerline
Lcd " "
Wait 2

Cls
Lcd "Guided By:Prof."
Lowerline
Lcd "Ankur Upadhyay"
Wait 2
Do
For Addr = 0 To 1
P1 = Addr
Waitms 1
P1.3 = 1
Waitms 1
```

```
P1.3 = 0
Waitms 1
Result = 0
If P2.0 = 1 Then
Result = Result + 128
End If
If P2.1 = 1 Then
Result = Result + 64
End If
If P2.2 = 1 Then
Result = Result + 32
End If
If P2.3 = 1 Then
Result = Result + 16
End If
If P2.4 = 1 Then
Result = Result + 8
End If
If P2.5 = 1 Then
Result = Result + 4
End If
If P2.6 = 1 Then
Result = Result + 2
End If
If P2.7 = 1 Then
Result = Result + 1
End If
If Addr = 0 Then
S1 = Result
End If
If Addr = 1 Then
```

```
S2 = Result
End If
Next
S = S1 - S2
Cls
Lcd "S1:" ; S1 ; "  S2:" ; S2
Lowerline
Lcd "Sensor Diff.:" ; S
If S > 10 Then
P3.7 = 1
Waitms 100
P3.7 = 0
Else
P3.7 = 0
End If
If S < -10 Then
P3.6 = 1
Waitms 100
P3.6 = 0
Else
P3.6 = 0
End If
Waitms 250
Loop
```

CHAPTER 5

CIRCUIT ESTIMATION

5.1 CIRCUIT DIAGRAM

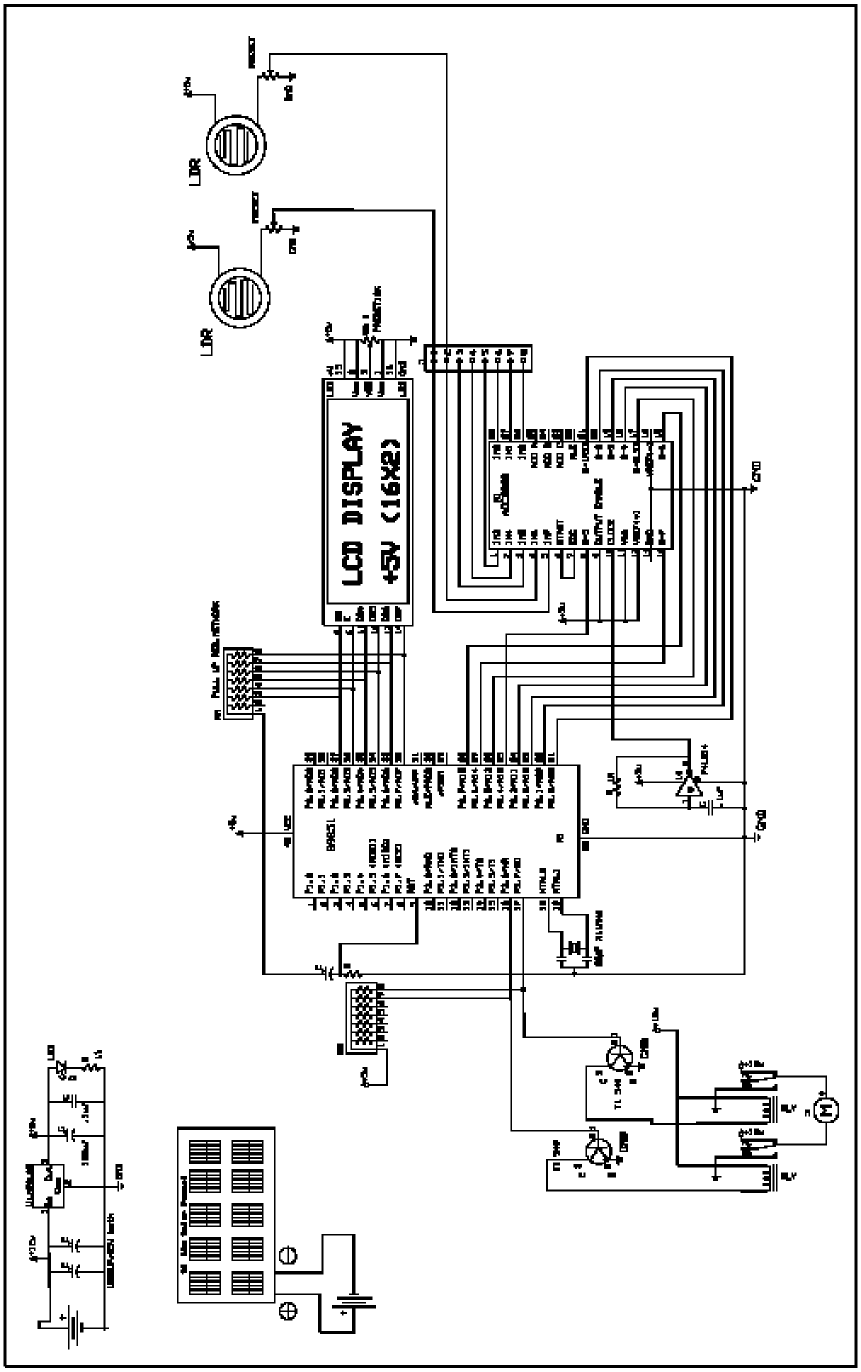


Fig 5.1 Circuit diagram of LSA

5.2 Working of Model

DC reduction gear motor is connected to solar panel through pulley. There will be 2 LDR sensors in between this sensors partition is done. So when equal sunlight is incident on both the sensors at that time the panel will be in horizontal position. Panel will be of LDR and aside the panel there will be a control room.

The panel will rotate according to the sunlight for which we require LDR sensor which will be dependent on light. Resistance varies as the light varies. LDR is of 10kohm. We require charged voltage for which we made potential divider at the junction if pd is given to output ADC. Both will be of 10kohm, because of which we will get half o supply i.e. 2.5V. As light increase LDR resistance decrease.

To convert the output into digital ADC is used. ADC0808 6-bit input & output i.e. total 28-bit IC, 5Vcc ground, negative voltage reference ground connected to input 0-7 from input 0-7, output of which sensor is to selected and change, that input address line i.e. Address A,B,C & latch is given with sequence pulse and is latched after which sensor will be selected and after this start and end of conversion will take place . If we short this then it will be continuous in free running mode. Clock signal will brought NOT gate and will give the feedback and capacitor noise is grounded.

From IC 7414 NOT gate whose value is around 500kohm as will get LSB-MSB digital output. To rotate the motor and to give address microcontroller is used (i.e. microcontroller 8951). In this microcontroller 4kw of flash memory is present because of which we can reprogram it 1000 times. To run this microcontroller pin 20 is grounded 18-19 pin is oscillator pin to crystal oscillator of 22f. Crystal value is 11.0.592 MHz. Microcontroller consist of 4 parts, part 0-3 are all bidirectional part , address or latch is to be done then address is given to part 1. After giving address it is latched, after which sensor will be selected and free running mode will take place and its data will be given to part 2, so that all the data will come in input. After giving address input will come in less than 100 microseconds, sensors data when comes in input that will be displayed on port 0 of LCD display. LCD display is of 16x2, Vcc 5 V, ground pin will be grounded after which is contrast pin in between which is resistor which will control the brightness. Except which there are 3 control pin Rl drive, enable, control pin are connected to port zero. After this is d-0 to d-7 bus is present, from which 4 bit i.e. d4, d5, d6, d7 are used because of which it is called as 4 bit mode. Output from port 3 is triggered on its base and then current limiting resistor. Relay is used which is of 12 V single pole double through relay. There are normally two operations normally open and normally closed. The normally closed is grounded and normally open is given with supply and at the centre pole motor will be connected. Motor will be of DC motor, 12V, permanent reduction gear motor, 10 rpm speed. Output of the panel will be positive or negative, output will be grounded and positive output will be connected to rechargeable battery. To run the circuit we require 5V, but we are getting 12V at output. So the output voltage is given to voltage regulator 7805 in which input is given as 12V and output will be of 5V. Middle pin will be grounded.

CHAPTER 6

RESULTS & DISCUSSIONS

6.1 Results

By arranging the PV concentrators in an array that is placed on water rather than on land, a simple solution has been released that gives efficient cooling of the PV cells and allows a lighter structure to be used, resulting in major cost savings. A buoyant raft comprising molded plastic members supports a tracking mechanism and light weight lens as shown below in fig. 6.1. The lens system can be rotated into the water at any time that wind-speeds exceed some threshold, or according to weather predictions and thereby obviate the need for the large area components to withstand high winds. An array of such rafts and immiscible collectors might be termed a liquid solar array (LSA).

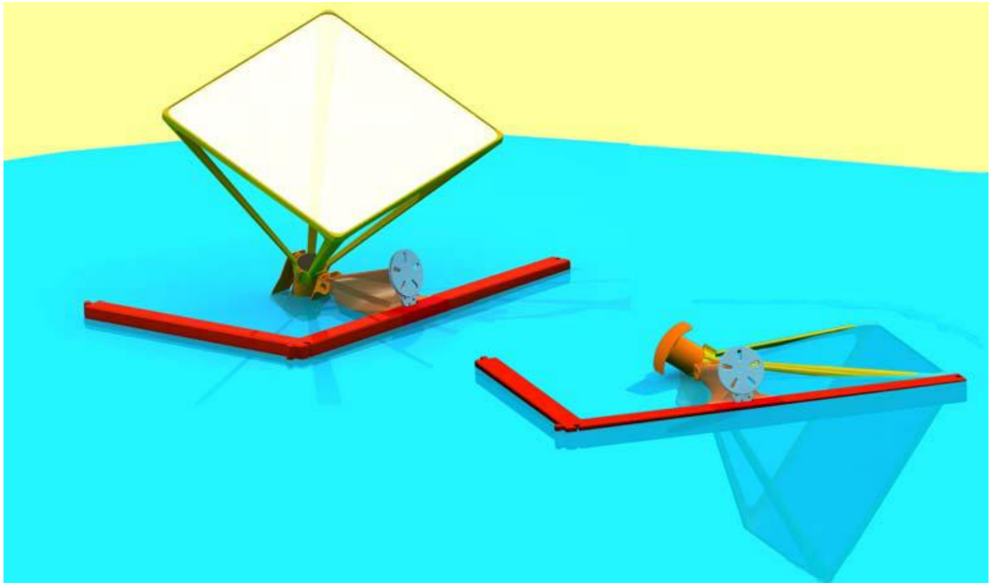


Fig 6.1 Collector in operating and protected positions

So the mass of the moving components is greatly reduced. Hence the tracking motor drive is also reduced in size and power. An extra and substantial benefit of the LSA situation is free cooling from the surrounding water, creating a very low operating temperature at the PV cells (resulting in longer life and better efficiency). In comparison, the equivalent land-based 1

m^2 concentrator must be provided with 1 m^2 of convection cooled aluminum fin area to dissipate the 700 W of radiation absorbed by the PV cells and not converted into electricity just to achieve 80° C cell temperature. (To achieve a smaller heat sink or lower working temperatures would require forced cooling or liquid cooled heat sinks and the consumption of additional electrical power to drive the cooling system). Note that the water is not heated above its normal equilibrium temperature in the sun by the LSA system and there is no effect on the water composition.

Another significant advantage of this approach is that the system is likely to survive coastal cyclonic conditions that are expensive to manage with existing solar collectors and wind farms, leading to lower insurance costs for the LSA. With this method, it is possible to get nearly the same output as a more traditional concentrator or present one-sun PV systems for about one third to one sixth the cost.

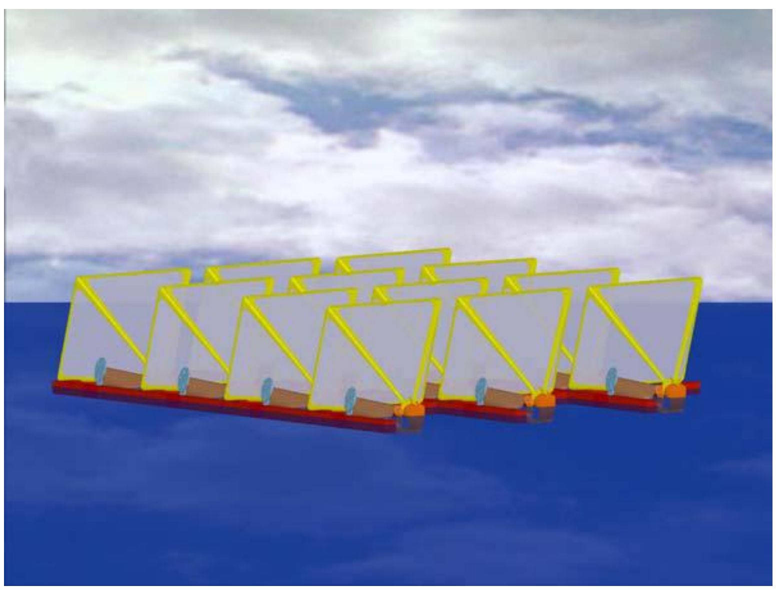


Fig 6.2 A small array of LSA collectors in operation (CAD Model)

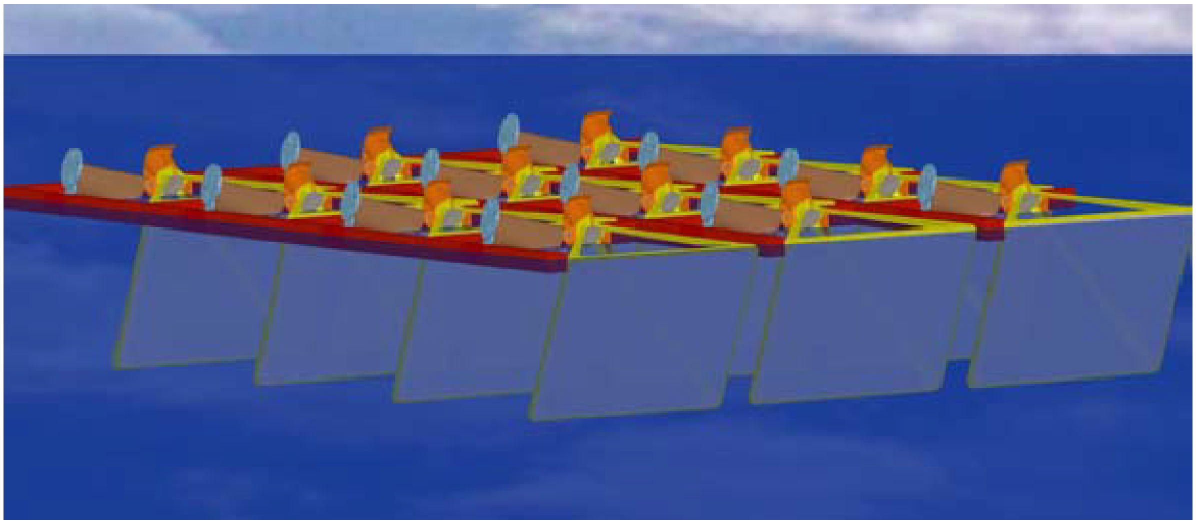


Fig 6.3 The array in protected position

6.2 Advantages

- Photovoltaic cells used are naturally cooled by
- convection of the water to give top silicon efficiency.
- Structure & Concentrator lens can be made from very
- light-weight, low cost plastics as they are protected from extreme weather forces.
- Technologies used are all ‘off the shelf’.
- Minimal land & setup cost (dual use of water).
- Modular: any scale from 1kW to Giga-watts.
- Small quantity of silicon means rapid deployment
- of large capacity possible (to 40 GW p.a. with
- current Silicon refining capacity).
- Minimal mass ~ 10-14 kg per sq. m of collector.
- Long life (20 yrs should be achievable).
- Gives near constant output all day.

CHAPTER 7

CONCLUSIONS

The lifetime due to UV effects is very long but there could be abrasion issues. Several suitable cover materials are being considered. Partial tests have been done on a cleaning wiper that is likely to be used. These tests show a reasonable life for the cover is likely when wiped every few days at least five years. A well-sealed and durable tracking drive is necessary. Such drives have been in use for many years in related applications (especially marine systems).LSA reduces each of these limitations and, in particular, avoids the problem of weather in a way that reduces both complexity and mass.

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